REDISCOVERING THE ARCANE SCIENCE OF GROUND HANDLING LARGE AIRSHIPS:

an investigation into ways of reducing the risks inherent in the development of a new generation of very large airships and of establishing guidelines for their ground handling procedures based upon a study of historical records

by
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Doctor of Philosophy

I certify that this thesis is wholly my own work and material
that has been extracted from others has been clearly referenced.

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DECLARATION

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ABSTRACT

This research, which was begun as part of the now defunct CargoLifter project, concerns the ground handling and support systems of the large rigid airships (commonly known as "Zeppelins") that were built between 1900 and 1940. The intention was to assess the value of such historical information as has survived from the previous generation of very large airships in order to minimise the physical and financial risks inherent in the development of any future generations of such aircraft.

The idea was to isolate and understand the fundamental issues that were actually encountered by the ground based personnel responsible for looking after the various British, German, American and Italian airships of the previous generation, and to gather as much information as possible about the techniques and operational procedures that were devised, tried and tested in the field. This information would then be used to establish guidelines for future projects that are based on real experience rather than on prediction, assumption or theory. Sadly, the CargoLifter project foundered in 2002; however the author had by then amassed sufficient research material for him to complete the study independently and to present it as a guide for the ground handling of hitherto unrealised concepts such as the proposed new "Transport category" or "CargoLifter" type large airships.

Such practical skills as those required by airship ground crew personnel are normally passed on by first-hand instruction from one experienced practitioner to the trainee. This option is not available for the next generation of very large airships because there are no personnel alive today with any operational experience of the previous generation of really large airships. The problem therefore is to examine the historical records and to evaluate the written information in order to interpret it and pass on knowledge that will reduce the risk of future generations wasting their time in "re-inventing the wheel."

In the course of the study it was found that historical research (HR) enabled the results of the pre-war prototype projects to be usefully assessed despite the fact that very little of the material was written with that end in view. More specifically the analysis of historical airship activities (AHAA) revealed that it was possible to retrieve a considerable amount of lost or forgotten knowledge concerning the ground handling of very large airships; also to unearth ideas that were ahead of their time, which might be applicable today or in the future; and in addition to identify several areas worthy of further investigation (e.g. ideas that were rejected at the time but which may now be feasible due to technological progress). The research and analysis also uncovered some ideas and suggested solutions which are fundamentally flawed and that should be avoided by designers of large airships and their support systems.

The work includes a detailed analysis of the tasks involved in the ground handling of very large airships and concludes with a suggested strategy for all those intent upon the design and planning of ground support infrastructures for any further large airship development projects either today or in the future.

DEDICATION

To my parents, who encouraged my curiosity in the world and allowed me to go my own way in life.

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KEY TO SYMBOLS OR ABBREVIATIONS

AEW - Airborne Early Warning
AFS - Advanced Flight Simulator
AGHS - Advanced Ground Handling Simulator
AGL - Above Ground Level
AHAA - Analysis of Historical Airship Activities
AHT - Airship Heritage Trust
AMSL - Above Mean Sea Level
AMSR – Air Minister for Supply and Research (at the Air Ministry)
APU – Auxiliary Power Unit
ARDD - Automatic Rapid Deflation Device
ATA - Air Transport Association
AV - Code number for US Navy surface ship fitted out as aircraft tender. The "*Patoka*" was *AV-6*
BBAC - British Balloon and Airship Club
BFA - Balloon Federation of America
BTU - British Thermal Unit; A measurement of heat
BuAe or BuAer - US Navy Bureau of Aeronautics
CAA - Civil Aviation Authority
CFIT – Controlled Flight Into Terrain
CL – CargoLifter
CL160 P1– CargoLifter prototype transport category airship intended to lift a 160 tonne payload
CLOSHRP - CargoLifter Operational Support Historical Research Project
DAD – Director of Airship Development (Royal Airship Works, Cardington)
DELAG - Deutsche Luftschiffahrt Aktien-Gessellschaft (German Airship Transportation Company)
DZR - Deutsche Zeppelin Reederei (German Zeppelin Shipping Company)
EASA - European Aviation Safety Agency
EQ – Equilibrium, i.e. held in a stasis by equally balanced opposing forces
FAA - Federal Aviation Authority (American Aviation Regulatory Authority)
FSF - Flight Safety Foundation
GAC – Goodyear Aircraft Corporation
GH – Ground Handling
GHE – Ground Handling Equipment
GHO - Ground Handling Officer
GS – Ground Support
GSE - Ground Support Equipment
HR - Historical Research
HTA – Heavier-Than-Air
ICAO - International Civil Aviation Organisation
I.S.A. - The International Standard Atmosphere
LAGH – Large Airship Ground Handling
LBA - Luftfahrt-Bundesamt (German Aviation Regulatory Authority)
LEP - Load Exchange Procedure
LES - Load Exchange System
LTA – Lighter-Than-Air
MRO - Maintenance Repair Overhaul supplier
MRU – Meteorological Research Unit
NAA - National Aviation Authority (USA)
NACA - National Advisory Committee for Aeronautics (USA)
NAS - Naval Air Station (US Navy)
NASA – National Aviation and Space Administration (USA)
NATA - National Air Transportation Association (USA)
NGVLA - Next (or New) Generation Very Large Airship
NT-07 - The Zeppelin Company's New Technology Airship
NTSB - National Transportation Safety Board
OCIMF - Oil Companies International Marine Forum of Bermuda
ODM - Operational Development Model
PGVLA - Previous (or Past) Generation Very Large Airship
PRO - Public Record Office (British Archives)
RAeS - Royal Aeronautical Society
RAW - Royal Airship Works, Cardington
RDD - Rapid deflation device
RNAS – Royal Naval Air Service
TAR – Transport Airship Requirements (Regulations governing the NGVLAs)
USAF – United States Air Force
VLA - Very Large Airship
VLCC - Very Large Crude Carrier (Marine "supertanker" with deadweight of 150,000 to 500,000 tonnes)
W/T - Wireless Telegraphy equipment (i.e. radio)

PREFACE

In view of the fact that airships today are not in the mainstream of aviation development, and, that in the past they were only briefly so, it is anticipated that many readers, and especially researchers approaching the subject for the first time, will have a limited understanding of the fundamental principles by which these rare aircraft operate.

> "Only a few hundred airships have been built in the world, as against hundreds of thousands of airplanes, for as Charles G. Grey, the British aviation writer once observed, "Airplanes breed like rabbits, airships like elephants." ..." (Litchfield & Allen, 1945/1976: 79)

As a consequence, airships remain relatively scarce in the skies of the world today, and the further consequence of this is that misconceptions, as to both their capabilities, and their limitations, are widespread within the sphere of Heavier-Than-Air (HTA) aviation. It is therefore deemed appropriate at the outset of this investigation to say something of airships in general and of the true nature of their characteristics.

So, first, what exactly is an "airship"? The answer, officially, according to the British regulatory authorities,[1] is that an airship is "A power-driven, lighter-than-air aircraft." However, in view of the fact that the most obvious thing which distinguishes an airship from a simple balloon is its ability to be steered, then it would perhaps be more illuminating to define an airship as "A powered aerostat with dirigibility,"[2] or "A dirigible motor-driven balloon, usually of an elongated cigar-shaped form."[3] But while these definitions may be simple, and succinct, their brevity and use of unusual words once again, tends to hide the meaning from readers unfamiliar with the subject. Thus, a slightly more descriptive definition is needed:

> "The non-rigid airship is ... a balloon specially shaped to facilitate its passage in a definite direction, having suspended from it a car or cars containing engines and propellers, and fitted with tail planes, rudders and elevators, which serve to direct its course." (Spanner, 1929:5)

> "AIRSHIP - A term applied loosely to any powered aircraft incorporating a significant element of aerostatic lift. Other terms used from time to time include dirigible, Lighter-Than-Air Vehicle (LTAV) and Air-Buoyant Vehicle (ABV). An airship with a substantial aerodynamic or powered lift contribution becomes a hybrid airship." (Mowforth, 1991:101)

Having thus established in essence what the word 'airship' means, it then becomes pertinent to ask by what means such aircraft actually work, and in what manner they differ from conventional HTA aircraft? In order to do so it is necessary to understand some of the fundamentals of the science of "Aerostatics." Obviously a detailed analysis of this complex science lies beyond the scope of this work, but a brief outline and sources of information available for further, deeper study can be found in: **Appendix A – The Fundamental Principles Of Aerostatics.**

From this it can thus be seen that one of the major fundamental differences between HTA and LTA craft is simply that:

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[1] (CAA: CAP 471, 1979 : Chap. Q1-2 Definitions : 4)

[2] (Recks, 1977)

[3] (Stubelius, 1958 : 98)

"An aeroplane or helicopter spends its life on the ground, punctuated by flights, but an airship is 'flying' throughout its life, just as a seaship is always afloat even when in port." (Netherclift, 1993:13)

Therefore, it is evident that airships are far closer to free-flying balloons than they are to any other type of flying machine. Consequently, the piloting skills required are thus totally different from those usually associated with the "piloting" of an HTA aircraft:

"... Free balloons were extremely delicate to control and exquisitely sensitive to changes in weight, temperature, humidity, and pressure. An expenditure of only a handful of sand, for example, had an immediate effect on the altimeter, which probably surprised most novices. To descend, the cord to the valve atop the bag was pulled and the seconds counted off. Students found to their frustration that a balloon was seldom in an absolutely stable condition. It therefore was emphasised, repeatedly, that a balloon (and airship) pilot had to recognize the true aerostatic condition of his aircraft at all times, anticipate changes, and apply the proper control at the proper time – not wait for the ship to gather momentum or "run away." The inattentive pilot found that his in-flight corrections demanded a greater application of control, thereby wasting gas and ballast." (Althoff, 1990:62/63)

So, its ballooning ancestry gives the airship a capriciousness that is seldom found elsewhere in modern aviation. And the truth of this is confirmed by the pilot of one of today's modern blimps:

"Take a procedure from an aeroplane flight manual, apply it during operations and if correctly exercised the aeroplane will respond in a predetermined manner. Apply a similar item from an airship manual and it might respond how you hoped, or not at all, or in a totally different manner." (Adams, 2001a:29) [1]

However, aerostatics are only one part of the story because, unlike a balloon, an airship, when in flight, is subject not only to aerostatics but also to aerodynamic forces. Indeed the unique operational abilities possessed by airships, and many of their advantages over HTA craft, depend upon the controlled interplay of both these forces.

"When an airship is flown either light or heavy, use is made of aerodynamic force to balance the excess of buoyancy or of weight, as the case may be. The required positive or negative aerodynamic lift is obtained by flying with the longitudinal axis at an angle of pitch to the flight path; and the elevators are manipulated as necessary to maintain this angle." (Burgess, 1927:88)

This is familiar territory to HTA aviators. The behaviour and control of an aircraft in aerodynamic flight is well understood. However, it is from this apparent similarity between airships and aeroplanes that most of the misconceptions arise, because the introduction and superimposition of this second, completely independent but equally powerful, lift-generating force, into the one flying machine, does have some surprising and counter-intuitive results. For example:

"A streamlined airship, if travelling through the air at a small angle to the axis of the ship, instead of tending to return to the direction with its centreline parallel to the line of motion, tends to increase this angle. This has a remarkable effect upon the controllability when the ship is being flown [aerostatically] light or heavy. Thus when a ship becomes light she appears to be nose-heavy and conversely when she becomes heavy she appears to be nose-light. This effect acts in favour of the pilot at certain speeds, but at high speeds ... the effect becomes so great that the elevators cannot cope with it **and the ship, if heavy, will continue to climb or if light will continue to dive.** The correction in such case, should it occur, is to slow down the engines." (Johnston, 1994:44-45) **[GC emphasis]**

Moreover:

[1] Edited for brevity

"The ship [*Graf Zeppelin*] was almost always operated in trim ... Paradoxically ... this was not the most stable condition in which the ship could be flown. When flown statically heavy, the ship always tends to nose up and climb, while when light, she puts her nose down and tries to descend. The reason is that with the hull acting as an airfoil, and meeting the air stream at an angle, *the center of pressure on the hull moves forward*, creating a pitching moment either upward or downward. To the elevator man, however, it *appears* that the center of gravity has shifted ... " (Dick & Robinson, 1985:69)

While this, as the saying goes, is not rocket science, it is exceedingly strange behaviour from the point of view of newcomers to the LTA field. And it serves to illustrate the fact that in many instances there really is no valid comparison between LTA and HTA vehicles.

Thus, notwithstanding that many readers of this work can be expected to be familiar with the Aerodynamics of HTA craft, it is deemed appropriate to include some brief information concerning the topic with regard to LTA craft, and more specifically how this impacts on the Ground Handling (GH) of them. This material can be found in: **Appendix B – Airship Aerodynamics.**

As can be seen, both "Aerostatics" and "Aerodynamics" have profound influences on, and implications for, the ground handling of very large airships. However, for those unfamiliar with LTA flight, it is also instructive to bear in mind that there are actually far more similarities between airships and a completely different, and seemingly unrelated, form of transport, altogether.

"The airship at rest supports the majority of its weight by buoyancy and achieves aerostatic stability in both roll and pitch by keeping its centre of gravity below its centre of buoyancy and in the same vertical; once under way it needs to achieve aerodynamic stability, which it does through after stabiliser surfaces, and flight controllability, which it does through rudders and ailerons; also when it is under way there is a need to minimise its aerodynamic drag, which it does by adopting an elongated tear-drop shape shown by research to be optimum for the purpose. Practically all these considerations and the research and development findings read across to the submerged submarine..." (Burcher & Rydill, 1994:34/5)

Strangely, this simple fact is regarded as a virtual heresy in most aviation circles, and indeed today, there are many even within the modern LTA world itself who find such comparison both uncomfortable and "old-fashioned." Nevertheless, the link was widely accepted by some of the most knowledgeable and skilled airship designers in the past, (Upson & Klikoff, 1931),[1] and, when considering the development of the Next Generation of Very Large Airships (NGVLAs), and endeavouring to understand the peculiarities of airship flight behaviour, it is illuminating to take note of the way a submarine behaves under water; also of the way in which nautical designers and theoreticians, (Burcher & Rydell, 1994),[2] have dealt with, and produced equations of motion for, their almost identical problems encountered in a parallel universe - the maritime environment – albeit in a medium that is 800 times denser than air.

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[1] NACA Report 405 – Application of practical hydrodynamics to airship design

[2] "Concepts in submarine design"

1 INTRODUCTION

Large airships are being proposed as solutions to some of the World's transportation, communication and other problems.[1] Some of these airships will have to be very big indeed; many times larger than anything currently flying and far bigger than the previous generation of large airships - the giant rigid "Zeppelins" - which flourished briefly in the 1930s.

As yet, none of these new aircraft actually exist; nor, it seems, (following the collapse of the German based CargoLifter [2] project in 2002), are any getting close to completion. However, it is already clear that all such schemes have one thing in common. Their success will be entirely dependent upon an extremely high level of operational performance. In addition, many of the tasks for which these aircraft are being proposed, are going to require as standard practice, operational procedures that have seldom (or never) been previously attempted by airships. These include:

- Precision hovering - i.e. the accurate holding of position for prolonged periods of time
- Lifting single indivisible loads that are too large or heavy for ground-based transportation
- Picking up payloads or cargo directly from the ground whilst in flight [3]
- Placing carried objects exactly on defined locations with the correct orientation
- Operating within the stratosphere

Irrespective of how, in physical terms, such envisioned procedures will eventually be accomplished, and regardless of the actual mechanical systems involved, one thing is immediately obvious. If these tasks are to be accomplished safely, then they are going to require to be overseen by highly trained personnel who will need to possess some exceptional and very specialised skills. Thus it is evident that no matter what configuration is finally chosen for the Next Generation of Very Large Airships (NGVLAs), nor what structural solutions eventuate, it is an unavoidable fact that unless there are reliable and competent crews on-board from the very beginning, (individuals who simply know how to fly these gigantic aircraft "straight and level"), then there will be enormous risks, either of the airships themselves sustaining ruinously expensive physical damage, or of them endangering the safety of the public at large.

This fundamental requirement for highly skilled personnel, both in the air and on the ground, creates some extremely serious and complex problems that are all too easily overlooked. Nowhere is this more evident than in the difficulties that will be encountered in the ground handling of the NGVLAs. However, such is the complexity and the obscure nature of these Ground Handling (GH) problems, that considerable explanation is required by the uninitiated in order to fully appreciate the seriousness of them.

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[1] See: Von Gablenz, 1996; Peeters, Tensen & Sleurink, 1997; Santistevan, 1997; Walker, 2000; Harris, 2001; Hochstetler, 2001; Valera, 2001; Chadburn & Stewart, 2002; Hodge, 2002; Scherbakov & Yakovleva, 2002; Tabo, Mori, Maruhashi & Oikawa, 2002; Kim, 2003; Prentice & Thomson, 2003; Warwick, 2006;

[2] The CargoLifter project attracted some 70,000 shareholders between 1996 and 2002. An enormous hangar was built at Brand, (south of Berlin) in eastern Germany but sadly their promised airship, the *CargoLifter CL160*, (intended to lift 160 tonne payloads), had not progressed beyond the conceptual design stage when the company went into voluntary liquidation in July 2002.

[3] Despite rumours of secret and/or military trials, the only airships known by the author to date, which are publicly recorded as having successfully picked-up, carried and put-down again, suspended loads, on anything approaching a reliable commercial basis, are the Hot Air Airships built for the "Radeau de Cimes" project. (See Lowman, 1999 : 144 & 146; and Hallè, F. 1990 : 129/138).

Thus an initial brief look at some of the effects which untrained flight crew personnel will inevitably have on the NGVLAs is deemed to be a better starting off point for a largely HTA experienced readership.

1.1 The Knowledge Gap

The last very large airship of the previous generation (the German Zeppelin *LZ130* [1]) was dismantled in 1940 and nothing even approaching the size of the proposed NGVLAs has flown since that date. Anyone old enough at the time to have gained personal hands-on experience of these airships must today be in their nineties. Thus:

> "We now find ourselves at a point where we have lost the final generation that knew first hand how to fly these giants." (Adams, 2001b:22)

So there is no one around today with any actual operational experience of the Previous Generation of Very Large Airships (PGVLAs) who knows how big ships really behave in flight, nor has any practical knowledge of how they were handled on the ground. There is thus no one who can pass on their "tips and tricks" to the new trainee crews. Yesterday's hard-learnt lessons have quietly been forgotten.

A parallel loss of expertise has recently been recognised within the world of Heavier-Than-Air (HTA) aviation and the serious consequences of this have been noted:

> "There is clear evidence in the analysis of accidents and incidents that mistakes made in maintenance, design and operation of aircraft are continually being repeated, resulting in further incidents. This is despite the fact that the initial action taken at the time of the first accident or incident was thought to have been preventative for all time. ... A contributory factor is undoubtedly the decline of inherent knowledge and know-how that comes with the early retirement of experienced staff causing a reduction in the overall industry knowledge and skill." (Ratcliffe, 2001)

But, in the case of very large airships there is not simply a reduction of experience and know-how, there is a complete absence of it. The entire large airship industry is now defunct and has been so since 1940. Therefore, the first 'Big Question,' and the one that offers a common threat to all plans to build any very large airships in the future, is this:

Q.1 - How will the flight crew of the first prototype NGVLA learn the skills necessary to operate it?

The seriousness of this lack of skilled flight personnel must not be underestimated:

> "The Federal Aviation Commission of the United States summarized its findings on their airship losses, in these words: "While the record of the airship has been marked by a number of disasters as a matter of common knowledge, each of them appears to have been due either to errors in navigation or airmanship, which were in no way inevitable, or to a serious miscomprehension of the capacities of the airship. **The operation of airships is a highly specialized art, requiring long experience and the highest order of skill."...**" [2] (Williams, 1974:194/5) **[GC emphasis]**

Statements from knowledgeable sources in Britain also endorse this conclusion:

> Lord Ventry: "It is no good having modern airships flown by inexperienced crews. Experience has shown that a good crew can do wonders with a "dud" ship, but there is no case on record of a bad crew making an efficient airship do anything worthwhile." (Ventry, 1939)

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[1] LZ130 (*Graf Zeppelin II*), shares with its much more famous (or infamous) sibling - LZ129 (*Hindenburg*) - the record of being the largest human-made object ever to have flown. They were 245 m (804 ft) in length and 41.1 m (135 ft) in diameter.

[2] Edited for brevity

However, there will initially be no way of knowing whether the first prototype NGVLA is perhaps performing badly because it just happens to be a "dud ship" or simply because its crew is inexperienced. At the outset all the crewmembers will be inexperienced and all the machinery will be untested. Furthermore, the problem is going to be aggravated by the simple fact that airships, which are large enough to carry out many of the tasks envisaged for the next generation of proposed "transport solutions," are themselves absolutely unprecedented. Nothing with the dimensions and all-up mass of these monstrous aircraft has ever flown before.[1] Even with a very experienced and completely competent flight-crew on-board there would still be enormous risks in getting them safely through a test flying programme. But, with a partially skilled or novice crew on-board a prototype airship it is going to be extremely difficult merely to obtain the certification for the first NGVLA to even begin to operate today in the exact same way its forebears did in the past. The incorporation into this process of additional complex procedures that have never ever been achieved, nor even previously attempted, by any Lighter-Than-Air (LTA) craft in history, makes the whole enterprise into a formidable challenge.

Obviously, the risks associated with putting unskilled personnel onto any type of untested aircraft are very great. But, more importantly for the NGVLAs, the historical records reveal that when it comes to airships, even with tried and tested ones, the performance of their crew members was in the past of critical importance. This has been confirmed by responsible people who had a great deal of first-hand experience with the PGVLAs. Here is Lord Ventry, one year earlier than his previously quoted "dud ship" comment, once again hammering home the point:

> "It cannot be too often remembered that to get the best results out of airships they must have well-trained crews. A good crew can do wonders with an inefficient ship, but an untrained crew will soon smash up the best airship ever constructed." (Ventry, 1938:20)

And there is further confirmation from the German cognoscenti, who had far more experience than anyone else with the PGVLAs, but who also came to the same conclusion:

> "... his [Scherzer's] work and success offer a fine example of how much can be done with a relatively poor ship [*LZ85*] in the hands of a good commander and crew. There are many other examples of how little a poor commander can do with a good ship." (Lehmann & Mingos, 1927:215/216)

Indeed the Germans' experience with their First World War Zeppelin programme offers ample evidence that these aircraft have a unique vulnerability when compared to all other flying machines, simply because their enormous physical size, combined with their inherent structural fragility, makes them exceptionally sensitive to errors of judgement by personnel.

> "On the morning of September 5th [1916] while returning from Ploesti the *LZ86* was completely wrecked in landing. The commander and a number of her crew were killed instantly. I cannot recall all the details, but this accident resulted from an error in judgement." (Lehmann & Mingos, 1927:221)

> "In airship operations slight mistakes can easily lead to serious consequences." (Korvettenkapitän Peter Strasser,[2] quoted in Robinson, 1994:236)

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[1] According to published figures the *CargoLifter CL160* would have had an overall length of 260 m, a diameter of 65 m and a gas volume of 550,000 m^3. (Everding & Reich, 2000, Table 5 : 234)

[2] Leader of German First World War Naval Airship Operations. Comment made in February 1917 on receipt of news that the "height climber" Zeppelin *LZ82* (German Navy No. *L36*) had been wrecked while attempting a forced landing.

The consequences of a novice flight crew making a "slight mistake" with the first prototype NGVLA, (which will inevitably have cost a fortune just to design and build), and inflicting irreparable damage to it on its first flight, would indeed be "serious." Worse still, there can be little doubt that the wreckage of one of "tomorrow's transport solutions" appearing in the media, ignominiously wrapped around its mooring mast, as the result of a ground handling mistake before it has even tried its first take-off, will certainly reinforce the disastrous reputation of its forebears.

Yet if the trainee flight crews for the NGVLAs are simply going to learn as they go, then an occasional mistake would appear to be unavoidable. After all novices learn by making mistakes.

> "Experience is the sum of many mistakes." (quoted in Thompson, 1999)
>
> "The lamentable fact that experience is the best teacher, though often a most costly teacher, held true in the case of the Zeppelins." (Lehmann & Mingos, 1927:254)

It is therefore quite unrealistic to expect that the novice crew of the first prototype NGVLA will be able to learn their trade without making any mistakes at all. On the contrary, the early flight crews will inevitably make some mistakes, and, furthermore some of their small mistakes will become big accidents, and just as inevitably, some of these will turn into full-scale disasters. In addition, a high proportion of all accidents, be they small or large, are costly in financial terms - and some of them are also physically dangerous, both to those personnel actively involved (crewmembers) and/or to innocent bystanders (the public at large). It is also inconceivable today, that the crash of any brand new, enormously large airship could be hidden from the gaze of the media or kept a secret for very long. Such an event, would undoubtedly be linked on world-wide television to repeated airings of the unfortunate *LZ129 Hindenburg* (famously filmed crashing in flames in 1937,) thereby further undermining public confidence in airship projects in general. The airship industry has been here before:

> "The Doctor [Eckener] had been very successful in training operating personnel, first for the DELAG [1] and later for the German Navy. ... The basic premise for Dr. Eckener was that one could not *assume* that a situation was satisfactory; one had to *know* that it was satisfactory and then one could go on. If an assumption was incorrect, and a disaster occurred, the whole airship industry could be destroyed." (Dick & Robinson, 1985:57)

Thus it is evident that the success or failure of the NGVLAs really does hinge upon the knowledge and skills that will have to be possessed by, what may very well be, only a handful of exceptionally talented, and very highly trained, specialists. In other words, there is a real danger that one relatively small error, or even a minor misjudgement by a single person, could literally put an end to the whole NGVLA industry almost before it has really got going. This is another fact that has already been noted:

> "The [crashing of] *R-101* in the UK and the *Hindenburg* on the world-wide stage during the inter-war years, drove a stake into the heart of an industry. Crew induced accidents in giants like the big CargoLifters and the big SkyCats could repeat the experience. Someone else's accident can damage everyone's business." (Walker, 2001:25)

[1] "DELAG - Deutsche Luftschiffahrt Aktien-Gesellschaft, was the commercial airship transportation company founded by Count Zeppelin in 1909. Its personnel played an important role in training German Army and flight crews before and during World War I." (Dick & Robinson, 1985) – "Deutsche Luftschiffahrt Aktien-Gessellschaft (German Aerial Transportation Company), the pre-WW1 German passenger Zeppelin service. Between 1909 and 1914, the hydrogen-inflated vehicles of this airline flew a total of 107,180 miles carrying 34,288 persons without so much as a scratch." (Topping & Brothers, 2001)

So, the "knowledge gap" clearly poses a very serious threat indeed to all future NGVLA projects, because the skill of an airship crew really is paramount. Consequently, the weight of responsibility on the shoulders of the individual flight crew members of the first NGVLA is going to be enormous.

Nevertheless, regardless of what the very first NGVLA prototype actually looks like, and no matter what its intended purpose is, it will inescapably have to run this risk. Even if it were to be Lord Ventry's "best airship ever constructed" there is no escape from the fact that at some point, it will have to make its very first test flight, and when it does so, then someone will have to operate it. Obviously, whoever these people are, they must be adequately trained. However, one thing is absolutely certain, the Knowledge Gap means that it is not going to be possible for them to be prepared for their tasks today in the same tried and tested way that their predecessors were in the past.

> "... Eckener, an original thinker much experienced with wind and weather, insisted on thorough training for all [Zeppelin] flight personnel in theoretical aerostatics and meteorology, **and constant practice in ship handling in all weather conditions ...**" (Dick & Robinson, 1985:15) **[GC emphasis]**

But large airships are now extinct, so the initial training of the NGVLA crews, and the maintenance of their skills by such practical means, is currently impossible. Thus, while in the normal course of events, it is undeniably true that "Most learning is not the result of instruction. It is rather the result of unhampered participation in a meaningful setting." (Illich, 1973:44) In the specific case of learning how to operate the NGVLAs, the fact is that there is no "meaningful setting" within which the first crew can practise. Neither will there be any such place, at least until the first NGVLA is almost ready to fly. The only learning process that is proven to be effective is simply not going to be available for the first flight crew.

Furthermore, whereas: "Education in the exploratory and creative use of skills ... relies on the relationship between partners who already have some of the keys which give access to memories stored in and by the community" (Illich, 1973:24) if, as now seems to be the case, all memory (i.e. first hand knowledge) of how to operate very large airships has faded away, then there are not even any potential candidates to become partners (instructors) available. As a consequence, the whole question of crew training for the NGVLAs becomes extremely serious and difficult to solve, especially as it is also now apparent that it is rather urgent too:

> "Part of the difficulty here is that training by its nature is an up-front activity. The trained crews need to be there, ready to go, as the new equipment is delivered. For that to be achieved not only have the training aircraft and the training organisation to be in place but the vital element on which the quality and style of the new-era force will fundamentally depend also has to be there, the Instructor Pilots. They themselves need to be trained before student training can commence. All that up-front capability equates to cost - up-front cost!" (Walker, 2001:24)

Such recognition that flight crew training is of fundamental importance, and the realisation that the lack of suitably trained pilots is going to have a big impact on the budgets and construction schedules of all future NGVLA projects, is indeed welcome. However, the starting point for this thesis lies in what this seminally important article by Sir John Walker[1] does <u>not</u> say. There is no mention at all, anywhere within it, of the threat that is posed by the even further "up-front costs" that will unavoidably be incurred by the equally vital need to provide adequately trained ground crews. Yet all of the points raised thus far,

[1] "Training - overcoming the airship pilot shortage." In <u>Airship 131</u>, 2001: 24/5

concerning the risks, the costs and the consequences of an inept or incompetent flight crew for the NGVLAs are just as valid for their ground based personnel.

No one has any doubts that the pilots will need to be exceptionally talented people. Indeed, it is a fact that has long been recognised:

> "The smoothness of a [large rigid airship] landing depends on the sensitiveness of the pilot to kinetic energy. How great the difference in this sensitiveness may be is illustrated by the two following cases. One submarine commander brought his craft smoothly alongside the dock with three manoeuvres, while another commander gave 84 orders to accomplish the same result." (Krell, 1928)

And yet the equally vital need for similarly skilled ground crew goes unremarked. Nevertheless, if the NGVLAs are going to attempt procedures that are unprecedented in the history of airship flight then clearly they are going to need "three manoeuvre" people at every level of their command hierarchy - and this must include their ground handlers too.

1.2 The fundamental importance of Ground Handling (GH)

It is an inescapable and unavoidable fact that some time before the first untested and untried prototype NGVLA sets off on its very first test flight, (with its novice flight crew nervously pushing buttons to see what happens), it will first have to be brought safely out of the hangar in which it was built.

This is a procedure that has caused serious problems for large airships in the past.

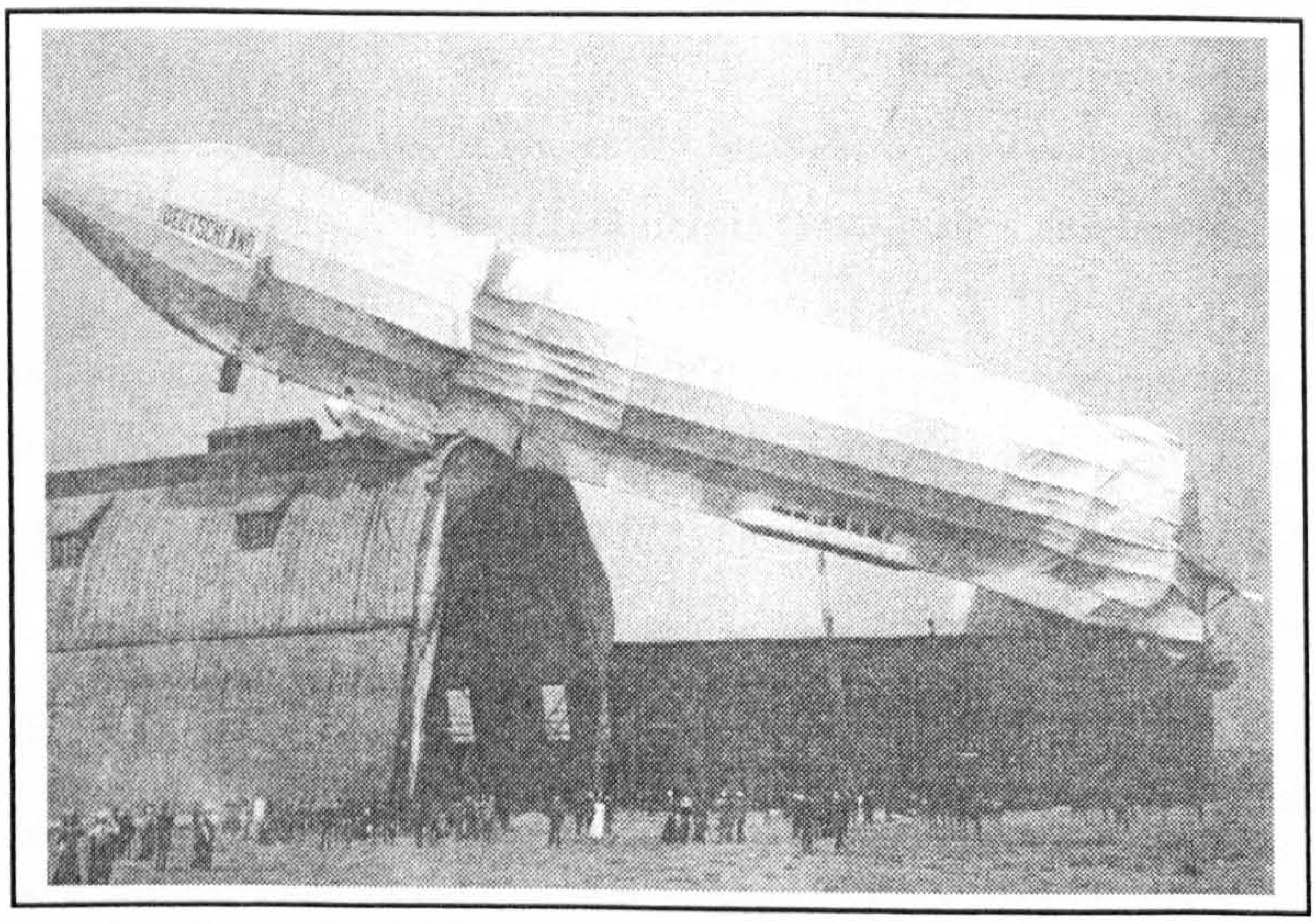

Figure 1.1 ***LZ8 "Ersatz - Deutschland"*** **at Düsseldorf in 1911 (Gütschow, 1985)**

Figure 1 shows Dr Hugo Eckener, the man universally acknowledged as the greatest-ever expert on large airships, learning the hard way, in his early years, that a GH error can be just as disastrous as any other "small mistake." This accident occurred while Eckener was bringing the airship out of the hangar on a windy day. His passengers escaped unscathed, thanks to the fire-brigade's ladders, but the airship was totally wrecked.

Of course the consequences of a GH error may be more annoying than disastrous but nonetheless the risks are real and the results can still be enormously costly. Even the most modern airship has had its development schedule disrupted by a small GH mistake:

> "*Zeppelin NT-07* was damaged in March [1999] when part of her tail fin struck the hangar door as she was being drawn out prior to further instrument testing … she has spent a month 'grounded'…" (Airship, 1999a:3)

Scaling up such an incident, in terms of time and costs, to a development plan for something the size of the notional *CargoLifter CL160* is a sobering thought. Furthermore, it also underlines the reality that in today's safety conscious world it is extremely unlikely that, upon completion of its assembly, the first NGVLA will come straight out of its construction hangar and immediately fly off on a test flight. Such a large and complex machine will inevitably require a considerable number of ground tests before it is ready to fly.

This was also foreseen to be the case prior to the very first flight of its earliest ancestor, more than 100 years ago:

> "Of course, for such an experiment as the first ascent, [of Count Zeppelin's first "Air-Ship" *LZ1*] it will be necessary to await for the most favourable weather, as without doubt many trials will be necessary before the craft is in a really workable condition." (Aeronautical Journal, 1899:78)

In the event, as history records, eight months later on 1st July 1900 *LZ1* did actually come straight out of its hangar and immediately fly off on a test flight. Although it reportedly did not work very well, both it and its novice crew survived the experience and the airship was put back into its floating hangar on Lake Constance that same evening without incident. However the world view of what is an acceptable risk has changed considerably in the last hundred years and it is certain that on completion of the first NGVLA, a protracted period of structural and systems testing will initially ensue, in order to reassure the regulatory authorities and others that a test flying programme, under the control of what, at best, can only be a partially skilled flight crew, is really safe to allow.

It is thus logical to assume that at least some parts of such a pre-flight test programme (possibly the engine tests for example) [1] will need to be done out of doors. But whatever happens, at some point, someone, somehow, will have to move the newly built airship out into the open air. It therefore follows that if a new generation of very large airships is ever going to be built, then some group of people who really know what they are doing, are going to be required right from the very start, simply in order to manoeuvre the first prototype NGVLA on the ground long before any attempt is made to fly it.

Furthermore, no matter what type of airship the first prototype turns out to be, nor for what purpose it is finally built, if it is to be a success then someone is going to have to prepare it for its first test flight, and someone will also have to take charge of it when it touches down again .

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[1] Notwithstanding that at least one of the previous generation of large airships had its engines tested inside its construction hangar, it would seem inconceivable that present day health and safety regulations would allow a re-enactment of R100 engine run-up inside the Howden shed on 25th September 1929: (see Meager, 1970 : 149)

Thus, unless the first NGVLA prototype is going to be fitted with some exceedingly sophisticated systems which allow its pilots themselves, single-handedly to:

a) top-up the lifting gas within it, and
b) refuel it; and
c) establish an equilibrium by adjusting its static-lift to ballast-weight ratio; and
d) taxi it out of the hangar under its own power, (or otherwise move it by some remotely-controlled, mechanised means); then,

there is no escaping the conclusion that it must have a fully trained, competent and reliable 'Ground Crew' long before there is anything very much for its 'Flight Crew' to do.

It therefore becomes apparent that there is, in truth, a second fundamental "Big Question," which, although it lies hidden beneath the first one, actually precedes it and is consequently even more "up-front" and urgently in need of a solution. Simply stated, it is this:

> **Q.2 - How are the *ground* crew for the first prototype NGVLA going to learn the skills they will need in order to *handle* it safely when they prepare it for its first flight?**

This second "Big Question" is obviously going to be just as difficult to answer as the first one, but in the author's opinion it is far more of a threat to all future NGVLA development programmes simply because it lies buried so deeply beneath the first question, that is almost completely obscured by it. Indeed, the whole topic of Ground Handling (GH) is so apparently dull and unexciting in comparison to Flight Ops, that it is commonly taken for granted, and in the author's experience it is difficult to get even confirmed airship enthusiasts to take the subject seriously. As a consequence, the danger of an unskilled groundcrew handling an NGVLA is generally ignored, and the true magnitude and real extent of the effects of the Knowledge Gap are entirely overlooked.

Perhaps it is simply because this second "Big Question" appears at first glance to be both obvious and innocuous, that the implications of it are so frequently underestimated? Whatever the reason, an answer to this question, or at least some way around it, will have to be found if the NGVLAs are going to survive and succeed.

Therefore the primary objectives of this thesis are

- To raise the profile of GH generally and to explain the risks of neglecting or ignoring it.
- To make the case that Historical Research (HR) is vitally important to future NGVLA developers as it offers a practical way to minimise the impact and ramifications of Q2 and permits them to identify real PGVLA GH problems that remain as a serious threat today. Moreover, despite the fact that little archived material was written to that end, Analysis of Historical Airship Activities, (AHAA) can prevent NGVLA developers from "re-inventing the wheel" and enable a better understanding of the extent and proper context of the many obscure GH problems that stem from the "Knowledge Gap"

However, before starting the investigation it is necessary to understand something of the true magnitude and complexity of the GH problems that the NGVLA development teams will have to face.

2 UNDERSTANDING THE PROBLEMS

The repercussions of the "Knowledge Gap" and the serious nature of this unrecognised "Second Big Question" (Q2) first came to the author's attention in June 1998 when he was employed by the German-based CargoLifter (CL) company to assist with the design of the GH systems for the *CargoLifter CL-160* - the first of their planned cargo-carrying NGVLAs. However, it quickly became apparent that this question was itself only the tip of an iceberg. It was just one small part of a much more complex and far-reaching collection of inter-related, but essentially unanswerable, questions which started to accumulate within the company as CargoLifter began the task of recruiting a team to design and develop their prototype airship.

These difficult questions centred on such things as what Ground Handling Equipment (GHE) was going to be "absolutely and vitally necessary" for the safe operation of the *CL-160* (as opposed to being merely "useful") and, how long it was going to take to design and construct it all? Here are some examples of the difficult questions that were put to the author shortly after he joined the CL project:

- Is a mooring mast really necessary for the *CL-160*?
- If so, then should the first *CL-160* mooring mast be mobile or a fixed structure?
- If mobile, then should the mast move on railway-lines or crawler-tracks?
- What would be the load on the wheels of a railway-based mobile mast large enough to handle the *CL-160*?
- Why can't the *CL-160* pilots just "fly" the airship directly onto the mooring mast without any groundcrew assistance?
- What other ground-based infrastructure will be required for the *CL-160* in addition to a mooring mast?
- How long will it take to physically move the *CL-160* into or out-of its hangar?
- How many times each year will the *CL-160* need to go into its hangar?
- What will be the operational limits imposed by the weather for:
    a) Getting the *CL-160* into and out of its hangar?
    b) Connecting and disconnecting the airship to its mooring mast (if used)?
    c) Taking-off and landing?
    d) Loading and unloading the payloads?
- Considering that the agreed norm for monitoring low-level wind and weather world-wide is via 10 m high masts, and that the top fin of the *CL-160* when it is moored on the ground will be some 80 m high, how can meaningful, and locally accurate, short-term weather data be provided, at all potential operational sites?
- How can the reliability of weather forecasts be guaranteed so as to ensure that the complex, unprecedented and untried procedures can be planned, organised and carried out in safety?
- How long will it take for the *CL-160* payload to be:
    a) Loaded, and
    b) Unloaded, or
    c) Exchanged for another payload or for some sort of ballast weight?

These initial questions quickly spiralled into further ever more complicated and detailed ones. Many of these concerned the people who would be needed to carry out the GH procedures. They included:

- How will the operators of the brand new Ground Handling Equipment (GHE) practise or rehearse their untried procedures, so that they can safely move the very first prototype *CL-160* out of its hangar for the very first time?
- How can the ground crew subsequently try a "walk-through" of any improvements to, or theoretically advantageous variants of, any GH procedures without the risk of damaging, or perhaps destroying, enormously expensive equipment or even the airship itself?
- How many people will be needed to operate the separate component parts of the GHE?
- Who is in command of each GH phase?
- What is the minimum number of groundcrew that will be required for each procedure?
- What skills will be required by each of them?
- What qualifications will be required by applicants wishing to join the *CL-160* ground crew?

This last revealed the need for some sort of licensing system for the groundcrew personnel, and that led in turn to yet further questions concerning the certification and testing of the GHE itself (regardless of what it or the airship using it might eventually turn out to be). And the unanswerable questions continued, ever further into the "up-front" problem areas that were to be publicly pointed out some two years later by Sir John Walker in his article on flight crew training (Walker, 2001). How long was it going to take to train the ground crew initially? Who was going to do it? And how? And to whose syllabus? And to what standard? And when? And where? And over-riding everything else – what was all this training and equipment going to cost?

Obviously, getting the answers even slightly wrong, to some of the questions in this complex web, was going to have enormous financial implications. Again, this was a point which had previously been noted:

> "The trade-off between the number of handling personnel required and the technological sophistication of the installation they use is always a critical factor, conditioned predominantly by the type of operation envisaged and the number of airships involved. **The significance of ground handling costs in the overall economics of airship operation is not always appreciated.**" (Mowforth, 1991: 37) **[GC emphasis]**

However, the author found that, at CargoLifter, shortly after he joined the project in 1998, it was not only the costs of GH for the *CL-160* that were being overlooked – in many instances the whole topic was either taken for granted or simply ignored. Moreover, the longer the project ran, the worse this attitude became.

One of the main reasons for this oversight was that, throughout the autumn of 1998, new team members were being enlisted to join the company in ever increasing numbers. While these new recruits brought with them much needed specialist knowledge from a wide range of disciplines, they also brought many preconceived ideas and prejudices from their various fields of expertise - and the majority of them had no previous experience of LTA aircraft. The result was that each influx of new personnel served only to add ever more difficult questions to the mixture. By the early part of 1999, these essentially unanswerable but urgently necessary questions were being passed round and round within the company, from department to department, and as they proliferated so the misunderstandings multiplied and the frustration increased.

There were no answers. There were simply too many unknowns, and in many departments, out of sheer necessity, design decisions for the *CL-160* began to be made on the basis of unfounded assumptions. In particular, the author became acutely aware that the lack of sensible answers to the difficult GH questions also led to a general tendency at meetings for the whole subject to be dismissed as merely a detail, or for GH to be put on hold to be solved later. Through the following year, 2000, matters concerned with the airship's structure and the flight operations began increasingly to take precedence over the GH systems, and progress in the development of the GHE for the *CL-160* came to a virtual standstill. As time passed so despondency within the GH Department grew, culminating in the memorable comment that the company seemed so intent upon flying the airship first and solving the GH afterwards that "perhaps the strategy is for a fly-and-forget airship?" (Girard, 2001)

However, this same attitude to the problems of GH had been noted elsewhere, ten years previously.

> "Half the solution to any problem, however lies in knowing exactly what the problem is, and the modern airship groups are repeatedly seen to be rediscovering - usually by falling over them - technological and operational obstacles that were well known and documented many years ago. Nowhere is this tendency more evident than in the all-pervading indifference, already mentioned, to the importance of ground handling procedures in the assessment of operational economics." (Mowforth, 1991:41)

These events at CL, led the author to the realisation that the "Knowledge Gap," although it had not previously been publicly recognised as such, was actually an extremely serious problem. Not only would it offer precisely the same obstacle to all attempts to establish further large airship development programmes, but it would do so regardless of the purpose for which any future very large airship was intended. Furthermore, the tide of unanswerable questions which resulted from the lack of experienced or suitably trained personnel, would unavoidably reappear, and in particular those questions related to GH would effectively sabotage every new attempt at NGVLA development. The subsequent collapse of the CargoLifter company in 2002, after some 300 million Euros of investment, merely served to underline the reality of this threat and to confirm the author in his suspicions.

It was also apparent however, that there was an even bigger, much more immediate and far more insidious danger to the NGVLAs. It centred around the "all-pervading indifference" which seemed to the author at CL, to have spread to encompass all matters concerning GH - particularly towards the end of the project when one had only to mention the subject for the room to fill with groans, yawns and rolling or glazed eyes. To a large extent this attitude appeared to be based on, and compounded by, several popular misconceptions. These, in some cases, amounted to quite deeply held convictions, and in meetings at CL, arguments approaching the intensity of religious schism occasionally erupted, notwithstanding that many of these widely held beliefs were plainly wrong and did not stand up to scrutiny.

Because of the depth and strength of these dogmatic views, and the fact that the disinterest which is engendered by some of the erroneous beliefs is of itself an obstacle, which, in the author's belief, is a dangerous and unrecognised threat to all future NGVLA development, it is deemed necessary, before embarking on a possible way of answering the Second Big Question (Q2), to pay some attention to understanding why some of these ideas are wrong, and why they also promote an attitude whereby the problems associated with GH are so frequently underestimated or even deliberately ignored.

2.1 The problem of the Cinderella profession

To support the views held by the author, it must first be shown that there is genuinely a widespread lack of interest in airship GH. These, however, are deep waters because it is notoriously difficult to prove the lack of something merely by its absence. Nevertheless, the case can be made that the whole subject has been neglected in the past by the simple fact that it is hard to find one single airship history book that lists either "ground handling" or "ground crew" in either its glossary, or its index.

Moreover, there is some evidence to support the case, and these quotes confirm, if nothing else, that a disinterested attitude was prevalent in France in the early 1900s and also in America in the late 1960s:

> "As these early airships [*La France*, *Le Jaune*, *La Patrie*, et al] were being built, [1902 - 1909] little thought was spent on the means of mooring them, or on their housing when not in the air. For these reasons many ships that structurally were perfectly correct were disastrously wrecked when on earth." (Hylander, 1931:181)

> "20 Nov 69: Goodyear made their pitch. It involves marrying two *ZPG-2* bags together side by side ... It gives them the lift they need but the problems it creates in flight control, ground handling and mooring boggles the mind. As usual, its GAC [The Goodyear Aircraft Corporation] doing the talking and proposing and ... there's no pilot or ground handling input." (Moore, 2004:202)

There are however two aspects to consider here. There are the personnel who carry out the tasks and then there is the actual work that they do. Of the former, it is a fact that the profession of ground-crew has never been treated with the respect it deserves. Indeed, there is a long tradition whereby ground-based personnel have generally been held in such low regard as to be scarcely worth a mention. Here is one example. It comes from the US Navy's report on their *"Airship Accidents, World War II"* in which there is to be found this damning statement

> "During the entire course of the War accidents occurred to fifty-six airships of all types, attached to both fleet and shore units ... Seventy-seven lives were lost during the War, **(excluding fatal accidents to ground handlers)** ..." (US Navy, 1946) **[GC emphasis]**.

There is no further mention of them!

Naturally, many reference books do make some mention in their text of the ground crew personnel and of their duties. However, this tends, in the main to be fairly dismissive, and, many airship history books actually neglect to make any reference at all of what must have become highly sophisticated and complex GH routines - procedures that were devised, refined and polished over some forty years of trial and error and which culminated in the great successes of the PGVLAs. This is a classic case of a Cinderella Syndrome, whereby the work that is acknowledged to be of vital importance is also taken for granted, while the people who do it are denigrated and treated with little respect, or even ignored.

However, recognition that there is a problem does not solve a problem, and as far as the NGVLAs are concerned, it is important at this point to distinguish between the recognition that there is going to be a GH problem for them and taking a serious interest in finding a solution to it. As Mowforth [1] has pointed out: "Half the solution to any problem, however lies in knowing exactly what the problem is ..." But this

[1] (Mowforth, 1991 : 41)

is only *half* the solution. The other half is actually doing something about it and here again there is an evident lack of interest - notwithstanding the occasional dismissive mention of the GH of large airships as being "an unsolved problem" -

> "... ground handling was an operational problem that was never entirely resolved." (Althoff, 1990:68/9)
>
> "Although many ground handling techniques have been developed over the years, the problem of handling an airship with safety, rapidity and economy in the context of a commercial operating programme has not yet been solved." (Mowforth, 1991: 37)
>
> "... while the principles and behaviour of airships in flight are now well understood and cause relatively few design problems, *all weather* ground handling remains a major concern On this the airships' future will stand or fall." (Netherclift, 1993:13)
>
> "Ground Handling of airships has always presented problems; it is almost certainly true to say that a fully satisfactory solution has never been achieved for larger craft. ... There can be little doubt that the whole area of **ground handling remains as the outstanding difficulty** in airship design and operation." (Howe, 1999:298/9) **[GC emphasis]**

This begs the question "why, in that case, is so little written about it?" Even the book in which this last statement appears devotes a mere 22 pages to the combined topics of "Ground Handling and Mooring." This is compared to the flight-related topics of "Aerodynamics" (45 pages), "Stability and Control" (33 pages), and "Propulsion" (32 pages), all of which:

a) are held to be not nearly so problematical,
b) are far better understood,
c) already have cost-effective solutions that are tried and tested in the field, and,
d) are self-evidently of greater general interest.

This is not to be taken as a criticism of the book, but merely as a demonstration of the low priority that is commonly given to GH in general. Doubtless it can be argued that this apparent lack of interest is perceived rather than real, and that the reason for the disparity is actually due to an absence of substantially new material to write about. It is undeniably true that:

> "In recent years the bulk of resources for research and development has been absorbed by redesign and upgrading of the airships themselves, ground handling being left largely to traditional 'bodies holding lines' methods." (Netherclift, 1993:29)

However, this has echoes of the "fly first and solve the GH problems afterwards" philosophy that reared its head at CL, and it only serves to confirm the point that flight has been consistently given a higher priority than GH in many people's minds. Nevertheless this disparity is surprising, considering that lip-service has been paid to this same problem for such a long time, viz. :

> "It must be borne in mind also, that in the compromise between weight and strength, all rigid airships at present in existence, as well as those of the past, were designed and constructed with flying qualities and considerations predominant, whereas handling was left a secondary matter. We are certain that future design can and must yield more to handling considerations." (Rosendahl, 1927)
>
> "The greatest problems of airship operation in the past have been those due to undeveloped methods and equipment for handling airships on the ground – in other words, terminal facilities for airships have been inadequate." (Rosendahl, 1928)
>
> "The problem of handling is admittedly the vital key point of the whole development, and the future of the airship largely, if not entirely, depends upon its successful solution." (Burney, 1929:214)

"The non-availability of satisfactory handling equipment is today a big handicap to airships and one that must be overcome." (Fulton, 1929:63)

"The success of airship transport or any form of airship operation depends to a very large extent upon the efficiency of the ground organisations and equipment. In the past the lack of appreciation of this fundamental fact, has been the cause of the troubles encountered and to a large extent the reason for the comparatively slow development of the airships." (Richmond & Scott, et al, 1930)

"... the major task facing the airship industry now ... is to moor and handle airships on the ground reliably in all weathers, and economically in capital cost, maintenance, and manpower." (Netherclift, 1993:7)

Clearly the problem is identified but where is the interest in doing something about it? It is plainly not in the aforementioned article by Sir John Walker, which is far from isolated in its failure to even acknowledge the existence of the ground crews; let alone to recognise the vital role that they will inevitably have to play in the development of the NGVLAs.

Quite why, the specialised skills and knowledge of the ground crew should be seen as of less worth than the different skills and knowledge of the flight crew, is somewhat puzzling, especially as, it might be argued, that in order to be efficient at their job, the flight crew only really need to know how to use airship flight control systems, whereas, in order to save the airship in extreme circumstances, and in extremes of weather, the ground crew must have a thorough understanding of both flight and GH systems. For example, drooping the horizontal control surfaces to shed accumulating snow could save the ship, or, following the failure of an APU, it might be possible to use the flight engines to maintain ballonet pressure through a storm. But to do so requires those involved to understand both the normal functions of these systems and what their limitations are, as well as the consequences of going beyond them. Relying on flight crew to carry out all emergency GH procedures which involve flight controls, as is commonly done by today's small blimps, does not remove the need for the ground crew personnel to understand all the systems that are available. Thus the GH team must be familiar with the intricacies of both systems, whereas, the flight crew only need to be competent in the use of the flight controls. In other words, there are GH systems that are never used by flight crew to help fly the airship, but there are flight systems which can be used by ground crew personnel to help with GH. Therefore, it follows that in general terms the leadership of the groundcrew must have at least as extensive a knowledge as the flight crew.

Plainly GH is an important and skilled occupation, and those who do the work are dedicated souls. Yet it is seldom acknowledged that every single one of the famous achievements of the PGVLAs, in terms of passenger carrying, and ocean crossing, and even their short-duration military missions, must each have been preceded by many hours of laborious preparation in the hands of highly skilled specialists.

"Airships spent but a small part of their lives in the air, and for every man who flew there were perhaps a score who never left the ground but whose work was just as vital." (Abbott, 1989)

These were the multi-talented individuals who maintained, provisioned, weighed-off and launched, what were for their day, operationally complex and technologically advanced flying machines, and which still today remain the largest objects ever to have flown. These specialists, were the same dedicated souls who, while the airship was away from its base, turned their attention to cleaning, checking and testing a bewildering array of machinery and equipment, all of which was necessary for them to do their job.

It included, on occasion, everything from cavernous hangars and gigantic towers to massive mobile mooring masts pulled by specialised locomotive engines along hundreds of metres of purpose-built railway track. These people were responsible for the provision and smooth running of everything from winches and cables, to pumps and hoses; from the clips and clamps and couplings that joined them all together, down to the tiniest of nuts, bolts, washers and rivets, not forgetting the loo rolls and light bulbs. It all had to be kept ready, and in working order, for without it the airships could not function.

Equally, at the end of every flight, regardless of the success or failure of its mission, there was inevitably a landing (of some sort) for every one of these enormous aircraft. And, for those that made it successfully back to base, the outcome of this "touch-down" depended to a large extent on the skill of the groundcrew. And again, afterwards, when the flight crews had gone off to celebrate, (or home to quietly try and forget,) then these same specialist custodians were still hard at work. Behind the scenes they were repairing, replenishing, and re-designing, or perhaps manoeuvring, or even simply hanging-on to their physically enormous "babies" until some storm winds abated. If they got it right, the airship survived to fly again, but if they got it wrong, the airship was lost. Furthermore, if the flight crew got things wrong and the airship crashed, or if the designers erred in calculation and the airship broke away from its moorings, then it was always the ground crew who were left to clear up the mess.

A further small point, but a very important one, is that everyone who has anything to do with aviation today is so used to seeing things from the conventional HTA viewpoint that their ways of seeing have now become entrenched. Consequently, the popular view of what constitute the main problems for GH airships and where the real difficulties lie has also become firmly fixed. An example of this can be seen in the Contents List of the first draft of the Transport Airship Requirements [1] (TAR) (**Appendix C**). This valiant attempt in the late 1990s, by the combined Dutch and German aviation authorities, to provide at extremely short notice, regulations to govern all aspects of the NGVLAs, revealingly lists "Take-off" at paragraph number §51 and "Landing" at §75, but makes no mention at all of "Ground Handling" until §255. Even more revealingly there is no reference anywhere within the entire document of moving the airship into or out of a hangar – a procedure which has repeatedly been proven to be one of the most risky for airships of all sizes and types.

Finally, this mention of regulation, brings up the interesting point that all the so-called "Ground Handling Manuals" for the airships currently flying are actually written as part of, and in compliance with, the *flight* certification process of the airship that each refers to. The purpose of these official documents therefore, is to satisfy a certification requirement of the individual aircraft type. They are thus written for the benefit of the aircraft they belong to, and not specifically to pass on techniques to ground crew personnel, nor to preserve knowledge of ground handling *per se*. The fact that they appear to fulfil this role, serves only to add further confusion to the blind spot.

[1] (LBA, 1999)

2.2 The problem of the Ground Handling blind spot

It has been the author's experience in conducting this research that one of the main reasons why the magnitude and the complexity of GH is neither recognised nor treated with the respect, and indeed the caution, that it deserves, is because there are several separate groups of people who each downplay, disregard or dismiss the seriousness of the GH problems for completely different reasons.

Firstly there are those who genuinely do not know that there are any GH problems. These include the public at large who generally have no idea how LTA craft work, but who are used to a diet of television advertisements showing hot air balloons equipped with sand-bags, and images of the *Hindenburg* crashing in flames every time the word "airship" is mentioned. They are truly naïve and, indeed, are genuinely puzzled by the whole concept of LTA flight. As a consequence, they usually take the GH of airships for granted and if asked about it, are apt to declare that they "never really thought about it." However, such people "know that they do not know" and are consequently quite open-minded and ready to accept information, provided it is "interesting" and comes from an authoritative source.

Then there are those who know that there are problems but are unaware of the magnitude, complexity and extent of them. They include administrators, engineers and other aviation experts, who come fresh to the subject of airships, often with extensive experience of other branches of aviation. They cannot see that there is much of a problem largely because a dozen or so "advertising blimps" are currently in operation [1] around the world today, and although these are few in number, they have a great visual impact. Their role as an 'eye-in-the-sky' at sporting events attracts much attention. The result is that those familiar with HTA, see "aircraft" that are flown by licensed pilots, maintained by certified engineers and supported by a fully-functioning, up-to-date, quality control system - as is standard practice throughout the world of HTA aviation. This reinforces the erroneous belief that all airships of whatever size would like to behave as if they were to all intents and purposes "normal" (i.e. fixed wing) aircraft - taking-off and landing horizontally by "taxiing" along a runway using an "undercarriage." However those who have first-hand experience of LTA flight know how very different airships really are. Airship pilot Paul Adams explains:

> "...aircraft fly by the book, airships do not. The way an airship behaves, on the ground and in the air, depends on many variables that have a small, inconsequential effect on most other types of aircraft. Minor changes in wind direction, speed or ... variances in temperature, the lightest, shortest shower or even the passing of a cloud will change the condition of an airship and the way it handles." (Adams, 2001a:29) [2]

Thus airships really are very different from HTA craft and the NGVLAs are going to be even more different from them than the modern blimps are.

Some further idea of the effects of this difference can be seen by making a comparison between the two sorts of aircraft and examining the percentage of accidents (where data exists) for different phases of HTA and LTA flight. It is immediately apparent that airships are far more vulnerable on the ground:

[1] Nayler, 2003, "Airship activity and development world wide – 2003" AIAA 6727

[2] Edited for brevity

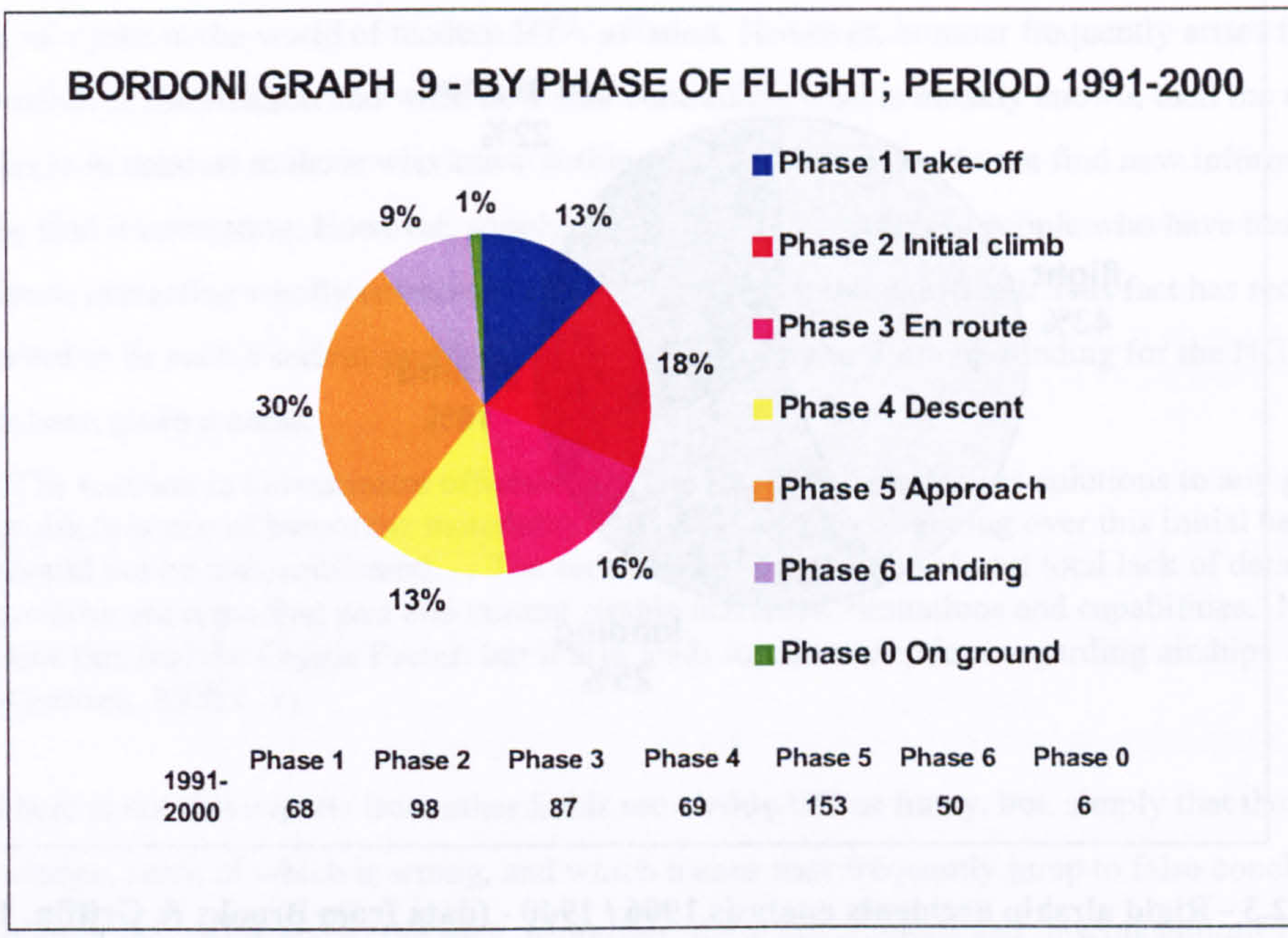

Figure 2.1 - Percentage of HTA accidents by phase of flight, 1991 – 2000

(Bordoni, 2001: Aircraft Accidents Register)

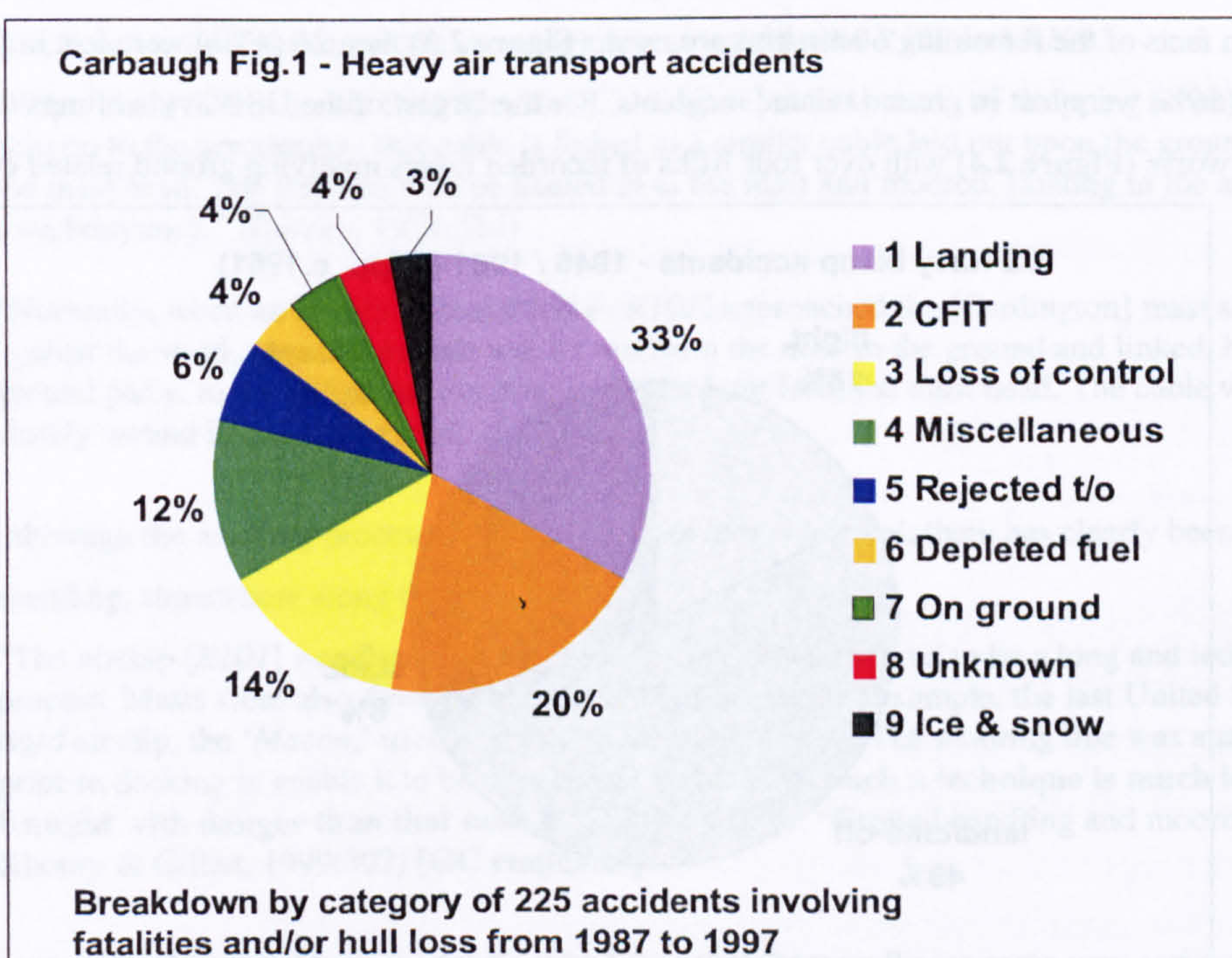

Figure 2.2 - Heavy air transport accidents involving fatalities / hull loss

(Carbaugh et al, 2003 : Boeing Commercial Airplanes)

From these charts it can be seen that despite the obvious disparities in their data handling the ground related categories for HTA "take-off," "landing," and "on ground" accidents add up to 23% in the first case and to 43% in the second. The picture for airships is rather different:

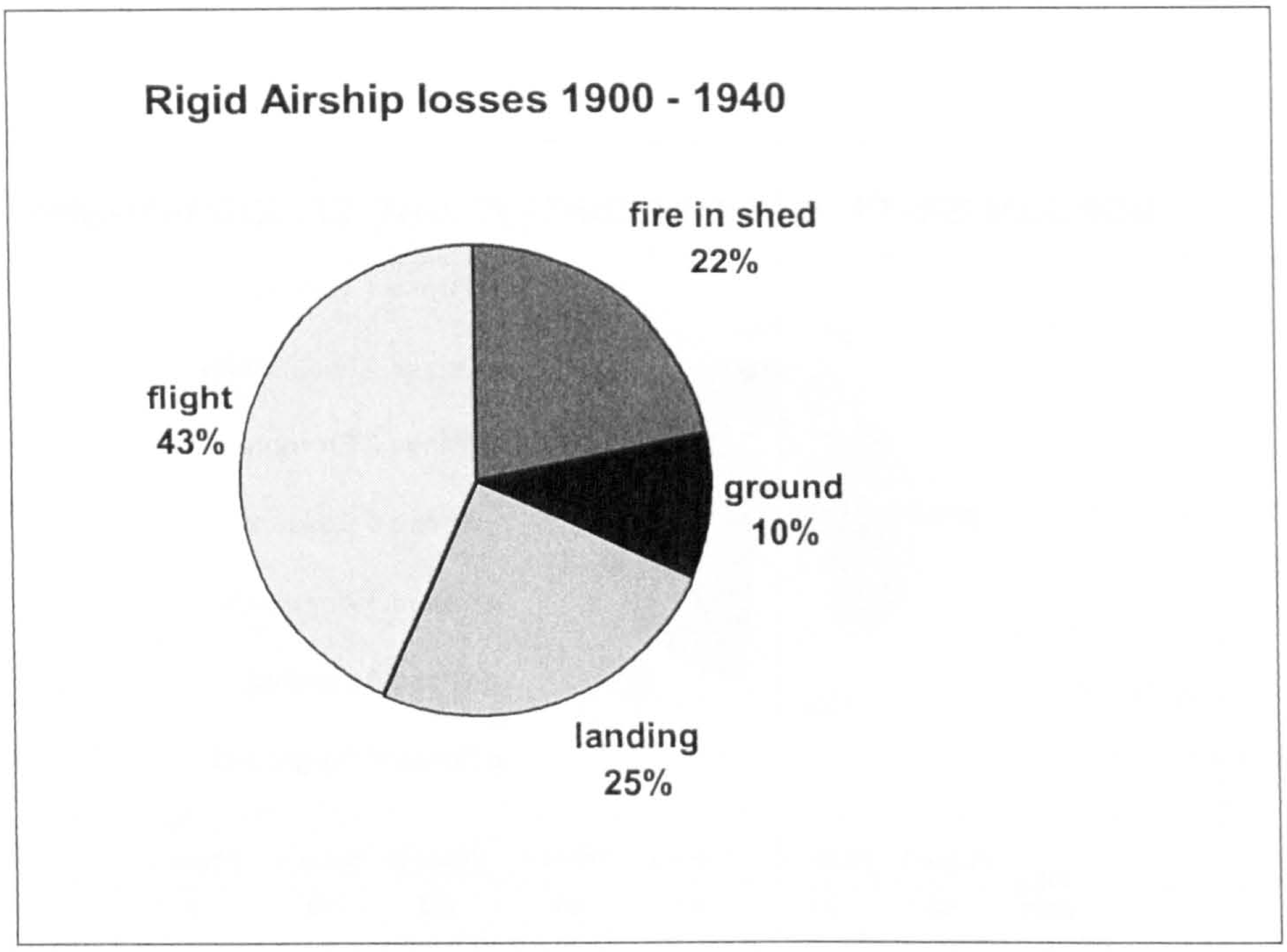

Figure 2.3 - Rigid airship accidents analysis 1906 / 1940 - (data from Brooks & Griffin, 1973:50)

Although data on very large airships is harder to find than for HTA aircraft, one study reveals that out of a total of 99 PGVLA rigid airships that met violent ends, 39 can be attributed directly to acts of war. If these are discounted, (on the grounds that any projected figures for them must be conjectural), and only the known facts of the remaining 60 airships are used, (**Figure 2.3**) then 26 (43%) were lost in flight, while 34 (56%) were lost in ground related incidents. For the largest of the US Navy's blimps the picture was even worse (**Figure 2.4**) with over four fifths of recorded losses involving ground related events:

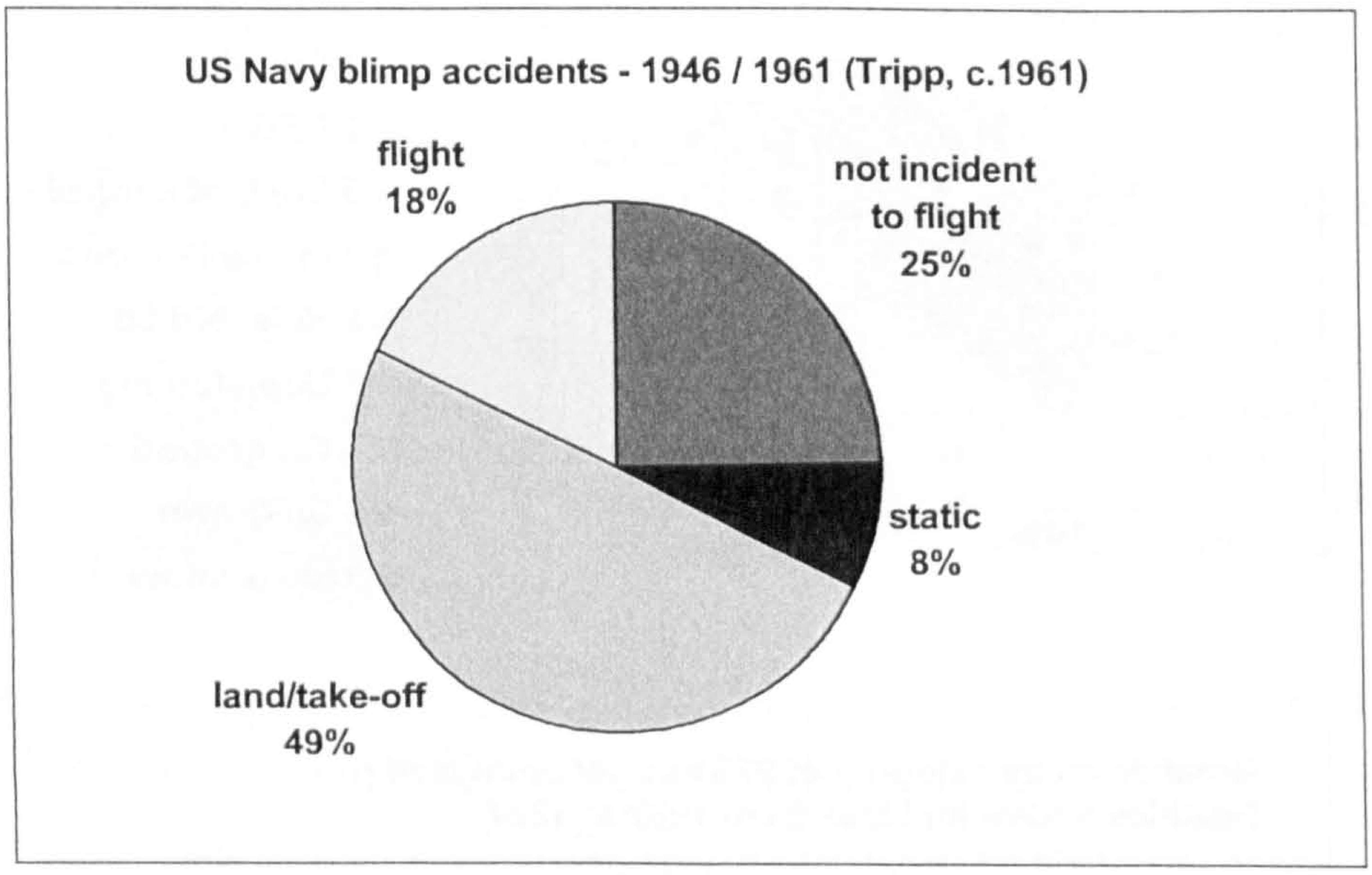

Figure 2.4 - US Navy Post war blimp losses (data from Tripp, c.1961 - US Coastguard)

It is therefore clear that ground-handling was of far greater importance to both the large rigid airships of the 1930s, and to the big blimps in the 1940s and 50s, than it is to the more familiar HTA aircraft flying today. Thus any misunderstanding by the designers of the NGVLAs as to the vulnerability of large LTA aircraft when on the ground could prove to be very expensive indeed.

To a large extent this misunderstanding is exacerbated by the fact that airships generally are seen as something of a joke in the world of modern HTA aviation. However, humour frequently arises from an internal conflict of information and when new data contradicts what is already known, then the recipient laughs. This is in contrast to those who know nothing to start with. They do not find new information funny, they find it interesting. However, supplying accurate information to people who have none, is one thing, whereas correcting wholly erroneous convictions is much more difficult. This fact has recently been observed to be such a serious problem for those attempting to drum up funding for the NGVLAs that it has even been given a name:

> "The reaction in Government officials first presented with airships as solutions to any given problem is one of humorous incredulity... The difficulties of getting over this initial barrier should not be underestimated.... The serious side of this is the almost total lack of data within government regarding past and current airship activities, limitations and capabilities. Not only does this fuel the Giggle Factor, but it also leads to misconceptions regarding airships ... ." (Gottlieb, 2000:L-1)

The point here is not that experts from other fields see airship GH as funny, but, simply that they have prior knowledge, some of which is wrong, and which means they frequently jump to false conclusions. They get hold of the wrong end of the stick. Moreover, these assumptions and misconceptions make the second group, in many ways the most difficult to deal with, especially when some of them are eminent in their own fields of knowledge.

For example, here are descriptions of the mooring process used by the *R100* and *R101*.

> "Attachment of the airship [*R100*] to the [Cardington] mast is made by dropping a cable from the ship on to the aerodrome ; this cable is linked to a similar cable laid out upon the ground from the mast head. The ship can then be hauled in to the mast and moored, floating in the air with her own buoyancy." (Burney, 1929:214)

> "Normally, when an airship [either *R100* or *R101*] approached the [Cardington] mast slowly against the wind, a mooring cable was let out from the nose to the ground and linked, by a ground party, to the end of the mooring cable paid out from the mast head. The cable was then slowly wound in ..." (Masefield, 1982:490)

But here, although the mooring process described appears to be identical, there has clearly been some misunderstanding, somewhere along the line:

> "The airship [*R101*] was **flown onto the mast** which often proved to be a long and tedious process. Masts were also developed in the United States. For example, the last United States rigid airship, the '*Macon*,' used a large and substantial mast. The mooring line was attached prior to docking to enable it to be winched onto the mast. **Such a technique is much less fraught with danger than that used by R101**." (Howe, "Ground handling and mooring" in Khoury & Gillett, 1999:307) **[GC emphasis]**

Then there are a third group. These are people who know that there really are some very serious problems but who deliberately deny or downplay them. In this category are frequently to be found those who have vested interests to protect.

> "Every new weapon has at least two enemies in addition to official conservatism: its rabid opponents and its violent enthusiasts. Both have vested interests to protect. The former ridicule it as expensive and useless, the latter see it as an almost universal panacea. Neither is of course, right." (Higham, 1961:9)

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In this instance, it is the latter group, the rabid enthusiasts, who are the problem. This is because they are so convinced that airships are the solution to all the world's ills that they try desperately to minimise any obstacle to their development. Naturally this includes GH problems, which are perceived as a boring topic that will hopefully go away if ignored Adherents to this philosophy certainly do not wish to take GH difficulties seriously and will frequently deny that any exist at all.

> "It is to be regretted that a rabid few paint airships only with the free unrestricted superlative and seem to have forgotten, if they ever, knew, that there are any difficulties in airship operation." (Rosendahl, 1927)

This group includes a sub-group composed of those who are intent on drumming up finance for airship projects. They are motivated to deny the problem or to hush-it-up for political reasons and are apt to make such statements as "we don't want to frighten off potential investors."

The fourth group might be termed " the disinterested." They may acknowledge that there are some serious GH problems but in general they are not really interested in anything to do with airships. On the contrary, many in this group actively try to ignore the whole field of LTA and perceive airships as at least a waste of time; if not something of a nuisance. In the past, this group has included some, but certainly not all, of the regulatory authorities and there remain many within these ranks who would much prefer it if airships in general just went away forever. Latterly this attitude has mellowed somewhat; however, the old prejudice still surfaces occasionally - especially with regard to GH:

> "Ground personnel [for the NGVLAs] will definitely not be licensed by the state. For their training the [operating] company has to accept the full responsibility." (Krüger, 2000:4)

This statement comes from an LBA presentation which was given at a conference organised by the LBA in their hometown of Braunschweig, Germany. It can thus be taken as an officially sanctioned, if not actually declared, policy. However, it is the author's opinion that this policy will change, either when the regulatory authorities themselves start to think seriously about the consequences of a NGVLA GH accident, or, sad to say, more probably, when some government department throws the problem at them following a major head-line-grabbing incident.

Lastly, there are the over confident. These include experts from within the LTA field who think they can easily cope with the size increase. Some are convinced that they already know all the answers and as a consequence usually underestimate the scale, the time, the cost and the complexity of the NGVLA GH problems, which they perceive as having a fairly low priority. Many of this persuasion are well aware that GH is indeed a big problem for all airships and would argue that there is a widespread acknowledgement of its importance within the industry, as evidenced by statements such as these:

> "All airships require a ground support team. It is impossible to safely operate an airship without such a team and the job of the ground crew is as important as flight crew - neither can operate without the other." (Flying Pictures (Airships) Ltd., c1988:3)

However, there are those among this group who refuse to admit that the size difference and the unprecedented procedures are going to make things any worse for the NGVLAs than they are for today's blimps. This deliberate denial is occasionally founded on professional pride, which adds further complexity, because there is no doubt in the minds of some insiders that the necessary skills to operate the NGVLAs already currently exist within the modern blimp industry. Thus anyone who asserts otherwise is seen to be attacking the competence or abilities of those who run what has plainly become a perfectly viable system for the operation of small blimps within a world dominated by HTA flight.

Consequently, there is a widespread failure by many people, and not only those inside the LTA industry, to appreciate the enormous difference in size between the small modern blimps and the NGVLAs, and the difficulties that this can cause showed itself at CL - as can be seen from the following.

2.2.1 Defining the Spatial Reference Point

There is a problem with the Spatial Reference Point (also known as the Datum Point) viz. – if a report concerning a large airship states that "the airship was 100 feet above the ground" then the question needs to be asked "where exactly on a very large airship is this being measured from?"

In the course of this investigation, the author discovered that different departments within *CL Development* all answered this simple question rather differently, and at one time there were at least five different datum points in simultaneous use. These were :–

- The tip of the airship's nose,
- The centre of gravity (C of G) within the gas envelope,
- The pilot's head,
- The bottom of the gondola (i.e. the interface between under-carriage and ground,) and
- The lowest point on the airship structure (which changes as the airship pitch angle alters).

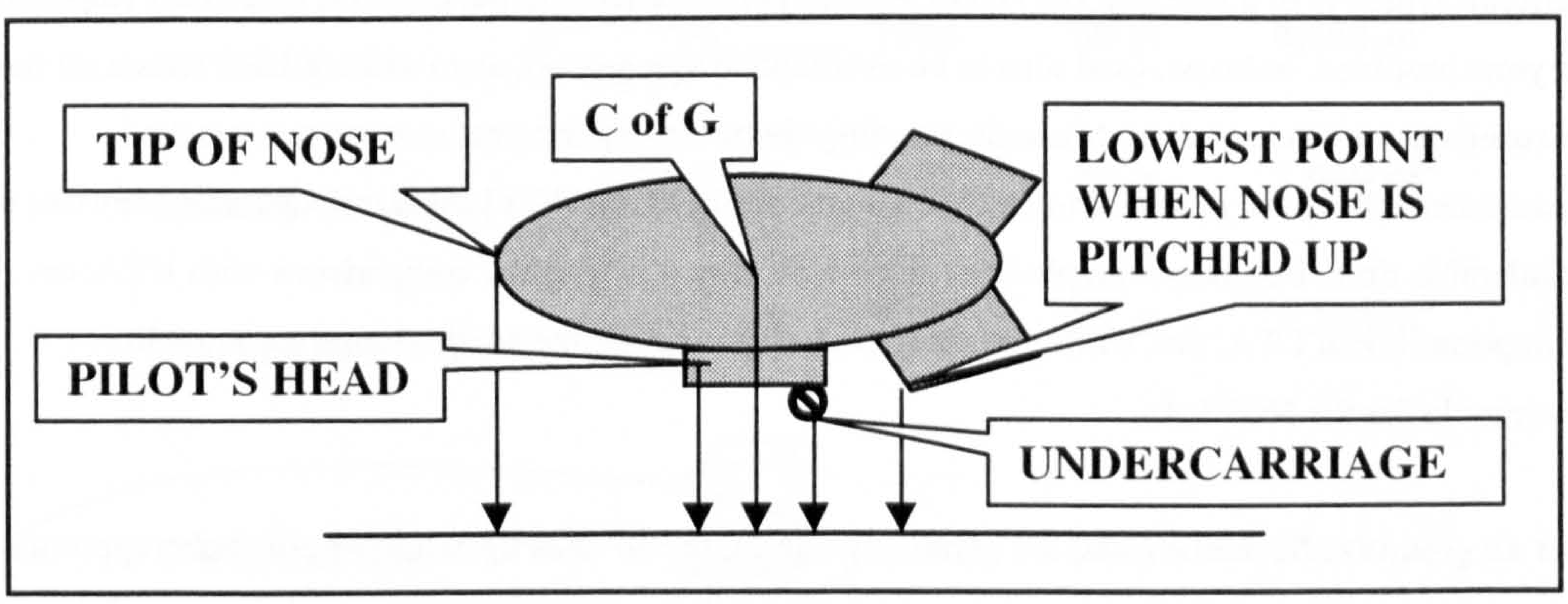

Figure 2.5 - The different Datum Points

For small blimps, perhaps this difference does not matter very much, but with really large airships there can be more serious consequences - although sometimes these may be more amusing than problematical. As for instance, when Draft 1 (January 1999) of the Transport Airship Requirements (TAR) appeared for review, boldly stating that:

> "**§ 51 Take-off**
> Upon reaching a height of 50 ft above the takeoff surface, the airship must have reached the recommended climb speed; and …

§ 75 Landing
The horizontal distance necessary to land and come to a complete stop from a point 50 ft above the landing surface must be determined, ..." (LBA, 1999)

This, of course, quite overlooked the fact that, were the datum point from which the measurement is taken,[1] to be defined as either the nose, or the C of G, (or for that matter the pilot's head, in the three-deck-gondola version), then an airship the size of the notional *CL-160*,[2] would at all times be considerably above a height of 50 feet - even when it was securely attached to its mooring mast or safely parked inside the hangar.

However, for the GH team the datum point question does have real relevance. For instance, if an NGVLA which is itself more than 200 metres in length, were to arrive at its landing place, with its safe capture dependent upon the ground crew connecting up one or more mooring lines dangling from its nose, and the length of these lines had been measured so as to reach the ground when the airship was flying straight and level, then a large nose-up pitch angle would mean that the ropes might not reach the ground before the tail-fin did. Alternatively, if the airship were pitched steeply nose-down it would drag many meters, (or perhaps many tens of meters,) of slack rope over the ground, and this would need to be wound onto the cable drum of a winch before the tensioning process necessary for the landing proper could even start to happen. If the winch drum had been not been sized to accommodate this extra slack (resulting from the altered pitch angle), then again, the consequences could be very serious, especially if the airship was not actually able to complete a safe landing in these circumstances.

This is only one, perhaps extreme, example, but it demonstrates that, when dealing with a brand new type of aircraft which is of a size that the NGVLAs will per force have to be, then it is extremely important for everyone involved, to know, (and also to be in complete agreement), as to exactly from where all the measurements are being taken. Misunderstandings between departments or even mismatched measurements have the potential to be exceedingly costly to the NGVLAs if only because they can waste considerable time. But, this example does show how easy it is to make comparisons with HTA, or assumptions about LTA, that while they may perfectly valid for the small blimps are in reality unworkable for the NGVLAs.

Thus all groups – the public (who are genuinely naïve); the novices from other fields (who approach the topic with deeply ingrained misconceptions); the enthusiasts and entrepreneurs (who try to minimise it or deny the problem exists); the regulatory authorities (who simply want it to go away), and, most particularly, the LTA experts (who think they can easily cope with the size increase) – are inclined to downplay the importance of the ground handling and the crew training problems and to arrive at the same frequently asked question.

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1 At that time undefined in the TAR

2 A hull diameter of 65 m (i.e. 213 ft) would put the tip of the nose at least 100 feet a.g.l.

2.3 The problem of scaling up existing procedures

When considering ways in which the NGVLAs might be handled on the ground, the most frequently asked question is: "Why not take the tried and tested procedures that are already certificated and fully licensed for current use by the modern blimps and simply scale up them to suit the NGVLAs?"

The answer is twofold.

Firstly, because the difference in size is quite simply too great. The largest modern airship currently flying, the *Zeppelin NT-07,* is 75 metres (246 ft) long. This is many times smaller than either the last, and largest, of the old Zeppelins - *LZ130,* which was 245 metres (803 ft) long,- or the first, and smallest, of the unbuilt *CargoLifter* prototypes, the *CL160,* which promised to be at least 260 metres (853 ft) long.

However the length of an airship gives no real idea of the inertial forces that its pilot has to deal with. A far better guide to this can be gained from a comparison of the internal volumes, and thus of the weight of air, that each airship displaces.[1]

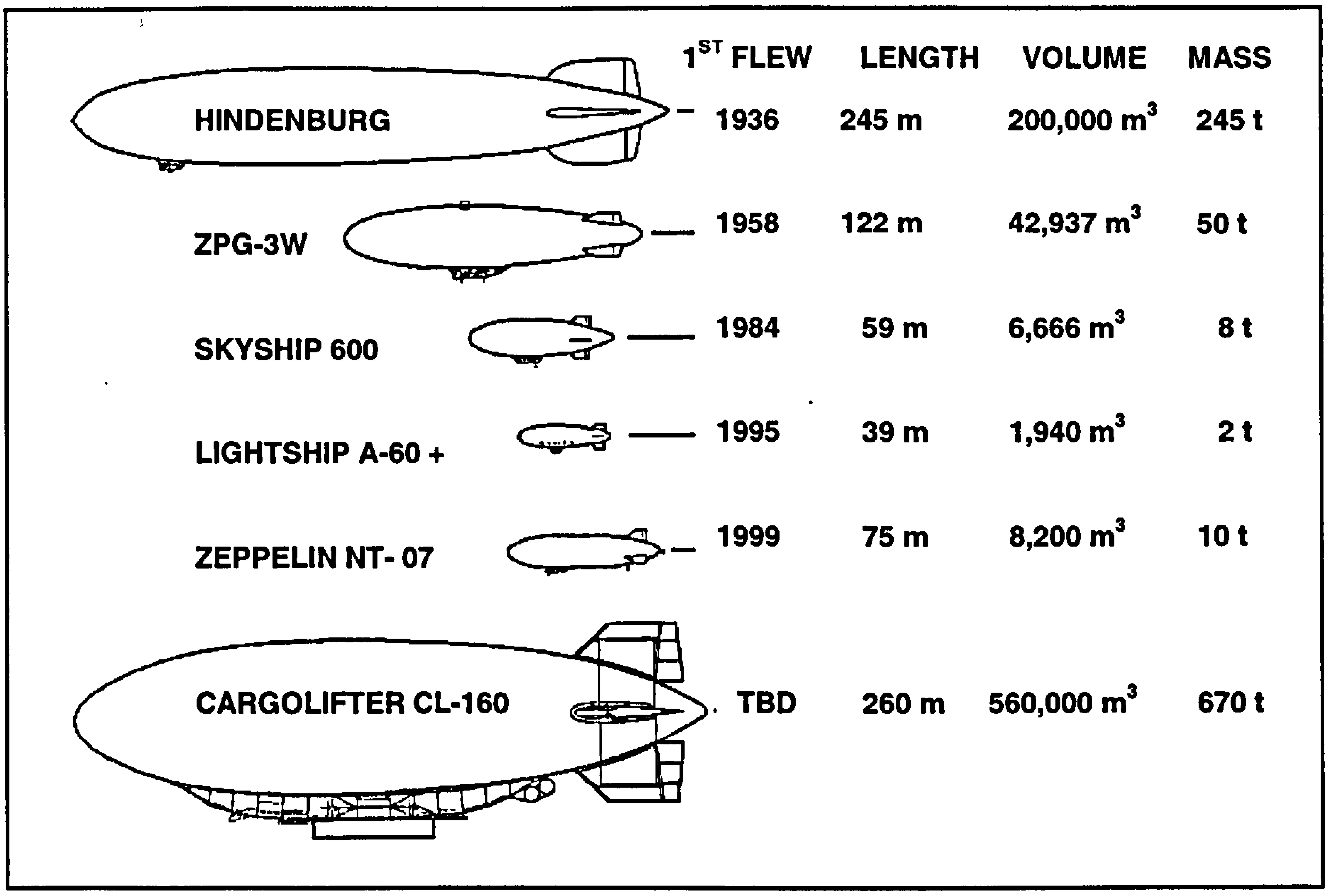

Figure 2.6 - Comparison of NGVLA physical dimensions with PGVLAs and modern blimps
Adapted from CargoLifter scale drawing DE 550018 by Ferris (30 April 1999)

[1] It is not commonly understood that despite their apparent "weightlessness", all LTA craft, still do have "mass" and that, for example, a relatively small 4-seater hot air balloon, (which typically has hardware and internal gas with a mass of some 3 tonnes, and which also displaces some 3 tonnes of air), when gently drifting along at walking pace, would need the same amount of effort to stop it, as a 6 tonne truck free-wheeling, un-powered, along flat ground at the same speed. (See also Foot note 1 on page 40)

Thus, in terms of the weight of air displaced, the modern *Zeppelin NT- 07*, with a volume of 8,200 cu m has a mass of gas and hardware of less than 10 tonnes. This compares with 245 tonnes for both the *LZ130* and its sister ship *LZ129 "Hindenburg"* (each of which had a volume of 200,000 cu m) and, just for the record, had the *CL160* (volume 550,000 cu m) got off the drawing board it would have weighed in with a displaced mass of more than 670 tonnes. In HTA terms this is worse than putting the flight crew of a small twin business jet (10 tonnes) straight onto a Boeing jumbo airliner (350 tonnes) with no intermediate steps. It is therefore quite unreasonable to expect that the NGVLA flight crews will be able to make such a large skill-jump in both the size and the complexity of their aircraft in one go.

The second reason why the modern blimp operational systems currently in use cannot simply be scaled up for super-large airships is because many of the procedures are actually inappropriate. This fact is readily acknowledged by those few who have seriously thought about the problem:

> "Whilst adequate techniques have been devised for use with smaller, non-rigid, craft, these are unlikely to be satisfactory for application to large, heavy lift airships should these become a reality." (Howe, 1999:299)

Nevertheless, the popular misconception persists that the safest, quickest, cheapest way to develop the NGVLA operational systems is to base them on "modern airship operating procedures." To see why this will not work, and why attempting to use even modified versions of these widely accepted, standard, modern blimp procedures is really not going to be a practical solution for the NGVLAs, it is necessary to examine some of these procedures in a little detail, and also to look briefly at their origins.

The modern blimp operating procedures are derived from, but essentially the same as, those devised by Goodyear for the US Navy's blimps in the 1940s. These procedures are often collectively referred to as "heavy operations" and their original purpose was to minimise the need for the US Navy pilots to "valve off" or vent their lifting gas (the rare and expensive helium). This system was introduced as an alternative to the method previously used by earlier blimps, and the giant rigid "Zeppelins," whereby cheap, and readily-available, hydrogen was vented with impunity.

> "The high cost of helium (at that time[1] about 70 times that of hydrogen), and the consequent undesirability of valving off gas to reduce excess buoyancy in flight, led in the Goodyear blimps to the technique of "heavy" operation, in which the ship is kept at all times slightly heavier than its aerostatic lift. It then takes off, flies and lands on dynamic lift like an aeroplane ..." (Mowforth, 1991:9)

However, operating in the Goodyear manner did require that the blimps be fitted with certain specialised equipment that no HTA aeroplane would ever carry:

> "Dangling from the bow [of the *K-ships*] were two sets of ground-handling ropes, a pair of short lines and a pair of long lines. The former, because they were too short to whip into the propellers, were allowed to trail and blow about in flight. The latter, long enough to entangle themselves with the blades, were stowed before takeoff in boxes, port and starboard, at the front of the car." (Vaeth, 1992:41)

Modern blimps have dispensed entirely with the "long lines" and all current GH procedures are conducted using only the "short lines", (nowadays known as "Main Handling Lines") but the operational system they employ remains essentially the same. Here, by way of comparison, is the manner in which the US

[1] c.1940

Navy *K-ships* (vol. 12,036 cu m = mass 14.7 tonnes) were made ready for flight using the Goodyear "heavy operations" system in the Second World War.

> "The ground party used the short lines to hold the ship and keep it pointed into the wind after de-masting and just prior to takeoff." (Vaeth, 1992:41)

And here is what the GH manual for the modern *Skyship 600* series (vol. 6,600 cu m = mass 8 tonnes), says regarding the same procedure:

> "Once released [from the mast] the Crew Chief will move the airship rearwards using every means to keep it under control and facing into the wind. At the take-off site the Crew Chief will re-ballast the ship taking into account the pilot's static weight instructions." (Airship Operations Inc. 1998:5-11)

Thus it can be seen that there are actually two separate problems to be solved at this point. Firstly, the airship must be disconnected and moved a safe distance from its mooring mast, and then, secondly, it must be held with its nose facing constantly into wind, so that it can be "weighed off." This latter procedure is necessary in order to accurately determine two things:

a) the amount of static lift the airship has, and
b) the trim angle it will adopt when released from its mooring restraints.

Both these standard pre-flight procedures, of maintaining constant nose-into-wind position and of adding/removing trim ballast, are done manually, by teams of people, for all the modern blimps that are currently operating. Few would argue that this system would be either safe or sensible for the NGVLAs - even the smallest of which will be many tens of metres high and contain ballast weighing tens of tons.

For example it is inconceivable that the Ground Crew Chief for the NGVLAs will stand under the nose rope and make hand signals to the ground crew in order to weigh off the airship prior to a flight, as is depicted in a *Skyship 600* Ground Handling Manual,[1] (See **Figure 2.7** - Skyship Hand Signals overleaf.) To begin with, the physical distance from nose rope to the gondola looks likely to be in excess of 100 metres so the NGVLA pilots and gondola crews will hardly be able to see if the Crew Chief has an arm raised, let alone how many fingers he/she is holding out.

The idea that these procedures can simply be "modernised" and replaced by some alternative communication method, such as a radio-link or by CCTV, needs to be viewed against the question of why, if this is so, the small advertising blimps which are currently operating have not already done this? The truth is that visual signals, which are non-electrically dependent, are at the heart of the modern blimp GH systems, and it would be foolhardy to assume that these tested means can simply be dispensed with, at least until an alternative has been satisfactorily demonstrated to work safely and reliably in the field.

This is not to say it is impossible, only that it has not been done yet, and the current operators and regulators seem convinced that the system they are using for weighing-off the blimps prior to flight, is both the safest and the most cost-effective.[2]

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[1] Airship Operations Inc. 1998

[2] It should also be noted that the majority of the world's highly sophisticated aircraft at even the most modern airports continue to be directed visually onto their loading ramps by hand signals from ground crew personnel waving "paddles" and "illuminated wands."

BEFORE FLIGHT, CREW CHIEF PERFORMS THE GROUND WEIGH OFF AND BALLASTING:

9) Arm extended, palm flat, facing upwards, the hand is moved up and down, then rotated palm downwards, and moved from side to side.

Means: PICK THE SHIP UP FOR THE WEIGH OFF

This is followed by the "Hold" signal (8) to steady the ship

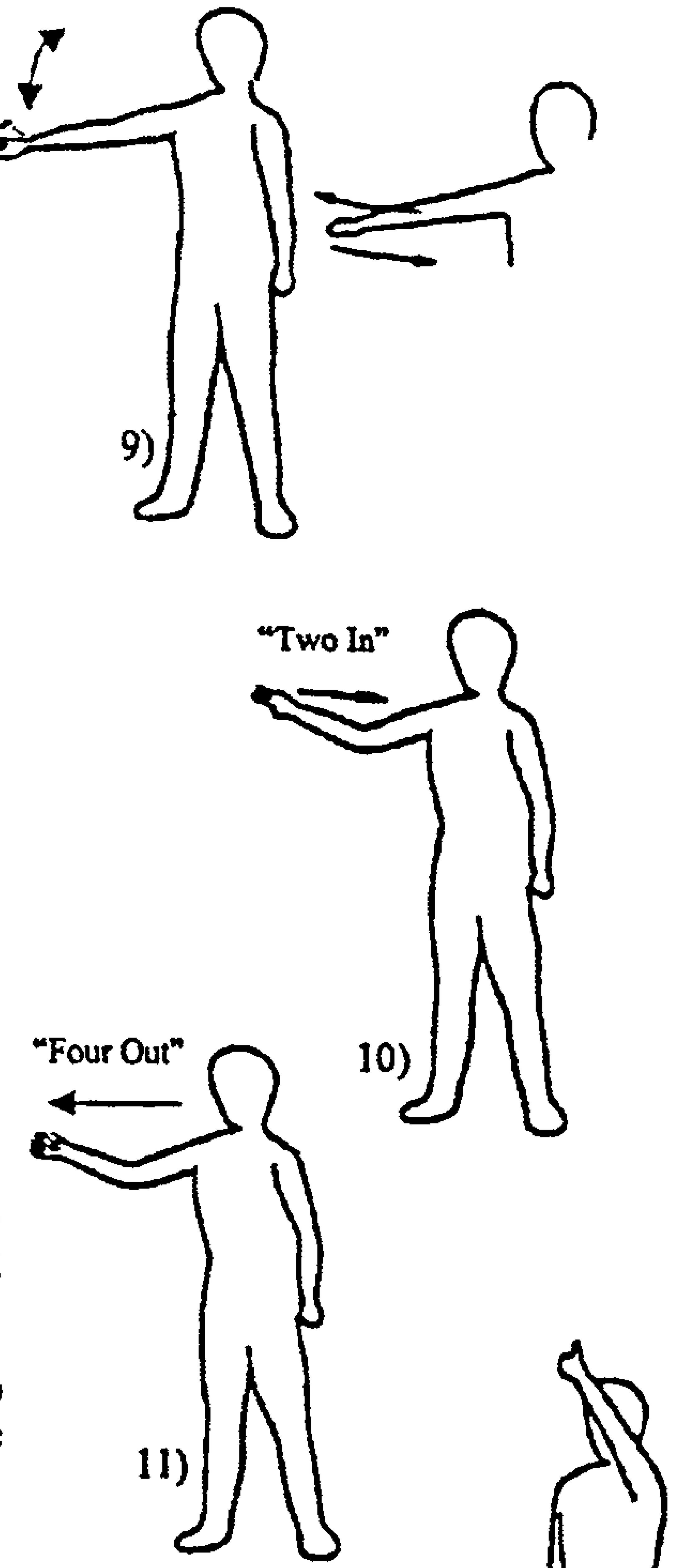
CREW CHIEF REQUIRES BALLAST TO BE ADDED TO THE SHIP:

10) Arm at shoulder level, fingers extended to indicate the number of bags or weight to be added, the hand is moved as shown by the arrow.

CREW CHIEF REQUIRES BALLAST TO BE REMOVED FROM THE SHIP:

11) Arm at shoulder level, palm towards the crew, the hand is moved outwards with the palm still facing the crew.

Means: REMOVED THIS NUMBER OF BAGS.



CREW CHIEF HAS COMPLETED ALL CHECKS AND BALLASTING, AND IS READY FOR TAKE-OFF. HE ASKS THE PILOT IF HE IS READY:

12) Arm extended and towards the pilot. Thumb up as shown. The whole arm and hand above the head.

Means: ARE YOU READY FOR TAKE-OFF?

PILOT IS READY FOR TAKE-OFF:

13) Pilot's hand extended towards the Crew Chief in the "Thumbs Up" sign, the hand is then moved upward sharply or the vectors are raised to 45°.

Means: I AM READY FOR TAKE-OFF.
It also is an instruction to the Crew Chief to allow the ship to lift off in the event of the pilot wishing to take control and clear the ground.

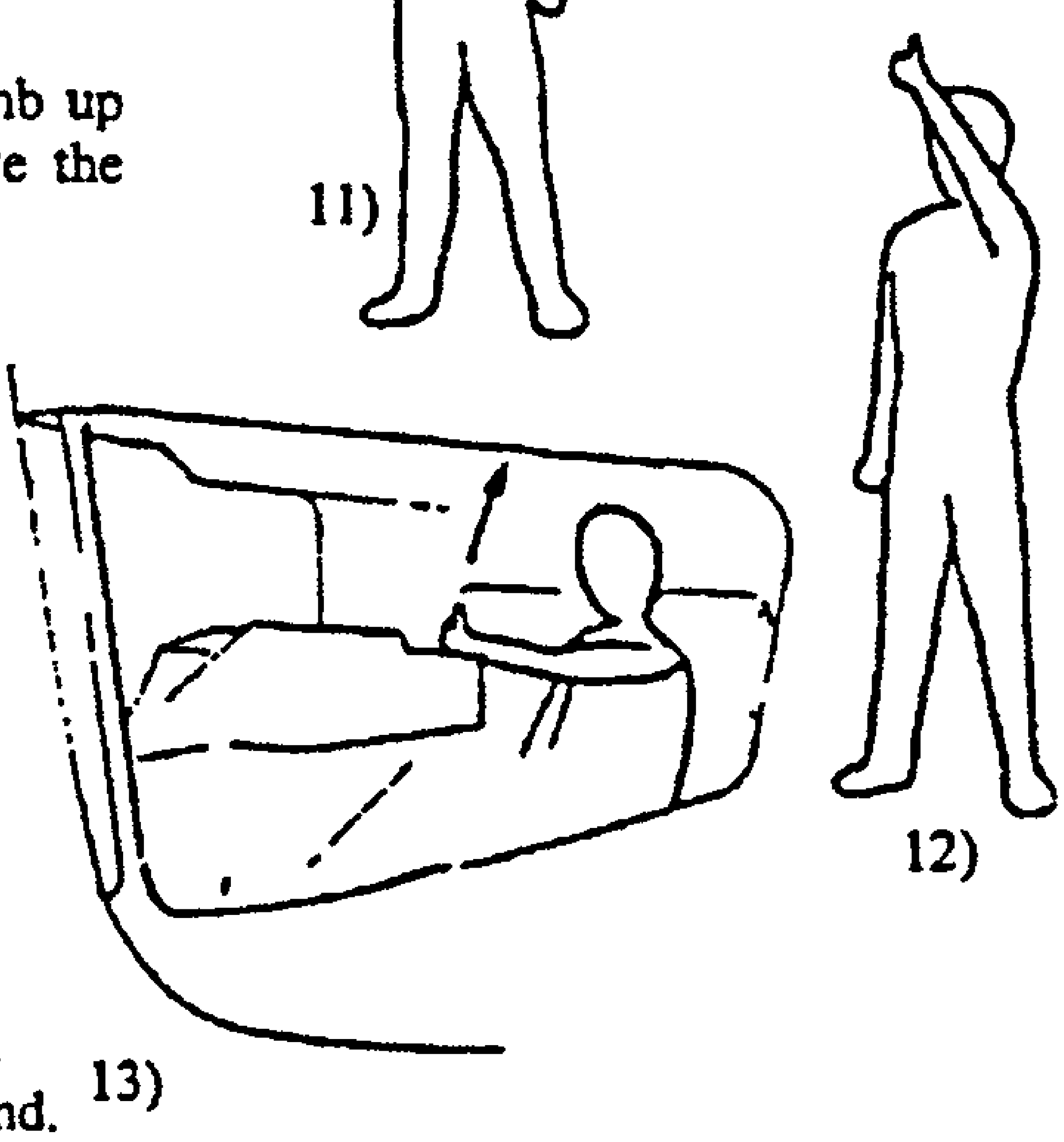


Figure 2.7 – Skyship Hand Signals (Airship Operations Inc., 1998:5/19)

However, after having separated the modern blimp from its mooring equipment, and established that it is correctly trimmed and loaded, the next problem is to get it airborne. There are essentially two ways in which this has been achieved

- horizontally (also known as the rolling take-off), and
- vertically (also known as an up-ship take off).

The Goodyear system is based upon the former method and here is how the US Navy did things horizontally in 1942-44:

> "... *K-ships* customarily took off "heavy," their total or gross weight exceeding what their gas alone could lift. To overcome this heaviness, they made a take-off run on their wheel, becoming airborne when the aerodynamic lift generated by airspeed, angle of attack, and hull form overcame the heaviness. ... *ZNP-Ks*, although designed for a maximum "heavy" take-off of 1,500 pounds [680 kg], were commonly flown much heavier, 1800, 2,000, even 3,000 pounds [816 - 1360 kg] heavier than the lift that their helium alone would permit." (Vaeth, 1992:39)

But there are some fundamental laws of physics that make such a system unattractive for very large airships. To whit:

> "Scaling effects are disadvantageous at this point ... the relative amount of heaviness, which can be taken dynamically, **decreases** with size. An A60+ [1] when taking off 10% heavy needs the same lift coefficient and speed as a CargoLifter *CL 160* [2] taking off 1.5% heavy. This effectively cancels out one major advantage of utilising "aerostatic" lift. ... and ... If large airships, which displace 500 tons of air and entrain the same amount more ... (resulting in an inertial mass in excess of 1,000 tons) [3] are going to take-off and land **horizontally,** then they are going to require some enormously long runways." (Camplin & Schaefer, 2002)

Moreover, in contrast to their HTA competitors, the inherent inability of all airships to take-off, or make a landing, with any sort of cross-wind, will mean that the NGVLAs are also going to need their very long runways to point into every conceivable wind direction. Not only would this result in a formidable civil engineering project but it would also seem to undermine the very reason for building very large airships in the first place.

> "... dependence upon aerodynamic control is in direct contravention of the primary advantage of aerostatic lift in conferring vertical take-off and landing. Some amelioration is possible by resorting to short take-off and landing, but any significant compromise in this respect removes one of the major operational advantages of the airship." (Howe, 1999:299)

Thus STOL or VTOL procedures look far more attractive for the NGVLAs, rather than trying to scale up the Goodyear "heavy" operational methods for taking-off - or, indeed, for landing.

> "A normal landing [for the US Navy blimps] was made about two hundred to four hundred pounds [90–180 kg] heavy, the aircraft touching down and rolling out toward the ground crew with power just ample for control. Once well in hand, the ship was hauled in to the mobile mooring mast, then shunted to a mooring circle or towed to a hanger berth." (Althoff, 1990: 215)

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1 [*Lightship A60+* has a volume of 1,940 cu m = mass of 2 tonnes]

2 [estimated volume 550,000 cu m = mass of 670+ tonnes]

3 "The development of the equations of motion follows standard aircraft practice where derivative notation is used to describe aerodynamic effects. The major differences are due to the fact that the vehicle is buoyant and displaces a large volume. The buoyancy force B and virtual mass and inertia terms are significant additions to the familiar aircraft equations of motion. ... The virtual mass and inertia effects are described by the derivatives of aerodynamic force and moment with respect to linear and angular acceleration perturbations. For this reason it is arguable whether these effects should be regarded as part of the aerodynamic description of the model or whether they should be regarded literally as additional mass or inertia terms. In the present context the latter description is preferred since in a practical situation it is impossible to distinguish between physical mass and inertia and added mass and inertia." (Cook, 1999 : 76-77)

However, if the NGVLAs are going to land horizontally then their enormous inertial mass will mean that the airships themselves are going to require some very substantial (i.e. heavy) landing gear. This was foreseen to be a problem prior even to the first ever successful large airship ascent and was acknowledged again in the golden age of the large rigid airships:

> "Landing [Count Zeppelin's first Air-Ship *LZ1*,] will also be a very ticklish manoeuvre, as anything like a bump might cause the whole framework, and especially the propeller connections, to be bent." (Aeronautical Journal, 1899:77)
>
> "It is impossible to conceive a large airship running at high speed along the flying field before taking the air; and still less would it be possible to construct an airship capable of sustaining the shock of striking the ground at high speed when landing." (Burgess, 1927:289)
>
> "The chief thing in landing is to expose neither the craft nor its occupants to harm. This applies to both air and water craft. The danger of the landing shock increases with the size of the craft, and still more with its speed at the moment it comes in contact with fixed objects on the earth's surface." (Krell, 1928)

Indeed, it should be noted that, whereas, the landing gear fitted to the majority of the small First War blimps was a simple "skid", the large rigid ships used a "bumper bag" (with the exception of *LZ129 Hindenburg* and its sister ship *LZ130 Graf Zeppelin II* which were unique among the PGVLAs in that they were equipped with retractable wheels). This was in contrast to the "Goodyear" three-wheeled, shock-absorbing, "tricycle undercarriage" that was used by all the US Navy's Second War blimps, which allowed them to behave more like normal aeroplanes.

While the adoption of this system was fine in theory, and things undoubtedly worked well when conditions were "normal", in practice, the determination to cling onto the lifting gas at all costs often meant that when it came to a "light" landing in the heat of the day, the Goodyear system actually had little, if any, advantage over that previously used by the First World War airships. For example, here is the enormously experienced First War blimp pilot Capt. George Meager recalling his landing in the hydrogen-filled, Italian-built semi-rigid *SR.1* (vol. 12,489 cu m = mass 15.2 tonnes), at Aubagne Airship Station, near Marseilles, at 3 p.m. in the afternoon on 28th October 1918.

> "Although I valved a large amount of gas, the sun was still heating us up ... and I had to go round again. We made a very wide circle under the lee of the mountains; I remember valving practically the whole way round; even then, when we turned in to make our landing we were still light, so I went very low, having to keep up a fairly high speed to do so. I had a good length of trail rope on the ground; one brave matelot, ahead of the main party, grabbed hold of it and was dragged some distance along the ground, but wouldn't let go until the main party manned the rope and hauled us down." (Meager, 1970:110)

Compare this with the experiences of the helium-filled Goodyear/US Navy *K-ships* using the "heavy operations", some twenty five years later, during the Second World War.

> "Getting down by valving helium was strongly disapproved of ... So landing approaches had to be made and repeated until, flying nose down to generate negative aerodynamic lift, the ship eventually came low enough to the ground to place its handling lines, car rail, and drag rope into the hands of the awaiting and long-suffering ground crew. When forcing itself down, it had to have a fair amount of airspeed, but to permit the ground party to grab the lines, it had to slow down. When it did, it began to rise again. One exhausted ground-handling officer reportedly broke down on the field and cried, frustrated beyond all understanding by the airship's unwillingness to come down. It was said at Lakehurst that one K-ship had made thirteen attempts before getting down. A South Weymouth airship was reputed to have made something like nineteen!" (Vaeth, 1992:43/44)

Sixty years still further on, and the light landing remains a problem for small blimps today. Although operational techniques have developed in the meantime that ameliorate things for the smallest of them:

> "Landing when light - Another option, and a very effective one, is the "hooked" landing. This entails approaching the crew low to the ground at an acute angle and turning sharply into the 'V' at the last moment. The turn rapidly absorbs much of the airship's energy and momentum [*Lightship A60+* volume 1,940 cu m = mass of 2 tonnes] and, if judged correctly, can bring the ship into the crew at a very slow speed, even if quite light. The crew must be quick to react as the airship will soon begin to rise, as speed is lost." (Adams, 1999)

However, no one could seriously consider scaling-up this particular manoeuvre for the super large airships of the future. Nevertheless it underlines the value of technique in overcoming some of these intractable problems, and it also demonstrates that there has been a steady evolution of blimp procedures since the advent of the Goodyear system. This is an important point, for it emphasises that, while modern procedures are "derived" from "heavy" operations, they actually differ from them in significant ways.

Of these, perhaps the most obvious, and most influential, is the capability of some modern blimps to produce "vectored" or vertical thrust to counteract their excess lift. This is a system that was originally trialled and then abandoned by the British, in the very earliest days of their airship development programme,[1] before the First World War. It was then re-invented, with some success by the Americans for the largest and most sophisticated of their helium-filled rigid airships (*ZRS-4 "Akron"* and *ZRS-5 "Macon"*) both of which used it as standard practice until their respective untimely demises in the early 1930s. The idea was then ignored by Goodyear for the US Navy blimps of the Second World War, only to reappear at the start of the modern blimp revival with the British built *Skyships* in the 1970's.

However, even these modern airships, which now regard their vectored thrust capability as a vital part of normal operational procedures, still find the light landing problematical - although far less so than the large rigid airships of the past, which also suffered from, and had their own ways of dealing with, the same problems of superheating:

> "Today, [25th November 1924] Commissioning Day, [for *Los Angeles*] there are thirty-nine officers and men on board ... The airship tries to land. ... she cannot reach the ground - the ship is too "light." The navy is operating its lighter-than-air program on a budgetary shoestring ... if possible the captain wants to land without valving the precious gas. But the ground crew ... cannot pull her down. The wind is gusty. A handling line snaps. Reluctantly, ... seventy thousand cubic feet of helium are released ... After several failed attempts, *ZR-3* lands into the anxious hands of the ground crew. Navy men scramble aboard as ballast to help keep the ship heavy; the rest hold her down. The ceremony can finally proceed." (Althoff, 1990:xi/xii)

What this highlights, is that despite all their differences, the one thing that all these systems have in common is their total reliance upon the ground crew personnel to effect a safe landing - and the Goodyear system, throughout and beyond the Second World War, did need a lot of people.

> "The long lines were essentially landing ropes. Released and dropped as the blimp reached the handling party, they were caught hold of and used to slow the ship and, in the case of a "light" landing, to haul it down. For unusually light landings or those being made in high winds, a drag rope was also carried, stowed under the deck, to be dropped to the ground handlers if an additional line was needed. In good weather, ground handling required about forty men, more, of course, if it was bad, particularly if it was gusty." (Vaeth, 1992:41)

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[1] Swivelling or directional propellers were patented in England by Capt. W. Beedle whose unsuccessful blimp made its only flight with them in 1903. They were subsequently fitted to all four of the "Willows' blimps" and also to Army Airship *"Gamma"* (*HMA No.18*) in 1913. An extensively modified version of them was also fitted by Vickers to the British rigid airship *"HMA No. 9r."*

It was a similar story when it came to landing the British blimps in the First World War:

> "When the flight ended, it was sometimes possible for the pilot to "ballast up" and adjust the trim before flying the airship very slowly upwind at a low height towards the landing party, who would attach their lines to the handling guys, take hold of the car and walk the craft back into the hangar. In difficult conditions or in gusty weather, however, such a simple procedure was not possible and it became necessary to drop a long and heavy trail rope, which was grabbed by the handling party, who then pulled the still-buoyant airship down within reach. Sometimes a loop of the trail rope was passed under the wheel of a "snatch block" - a form of swivelling pulley open at one side and set in concrete - in order to prevent the handlers from being lifted off their feet and to enable them to use their strength more efficiently." (Abbott, 1989:9/10)

Of even greater concern to those intent on development of systems for the NGVLAs, is the fact that even with their vectored thrust capability, the modern *Skyship 600* blimps, which are arguably the most successful of the modern blimp generation, but which are tiny[1] in comparison with the large rigid ships, still typically require a ground crew complement of some 15 or so people[2] to grab hold of their ropes and bring them to a standstill a the end of their flights.

Indeed, it is interesting to note that, despite the fact that the US Navy spent a great deal of time and money in the 1950s, developing "motorised mules" for GH the largest blimps ever to have flown,[3] that such vehicles are not used by any modern blimps today, apart from Goodyear - who only use them at their Wingfoot Lake home base. Furthermore, when given the opportunity to start with a clean slate, the largest modern airship currently flying has proudly become the single exception in the modern fleet and reverted to a vertical landing method. The *Zeppelin NT07*, (roughly half the length and one-fifth the volume/mass of the *ZPG-3W*) claims a vastly reduced number of groundcrew as a result of its use of vectored thrust from swivelling engines - just as the giant rigids *Akron* and *Macon* did in the 1930s.

Nevertheless the fact that all, except one, of the 20 or so airships currently operating world wide still rely on "people power" serves only to underline that even in today's hi-tech world there is nothing better for all-weather, all-terrain work than the human runner. No wheeled vehicle can accelerate or decelerate, and simultaneously change direction as quickly, on such a wide variety of different surfaces, as a person on two legs. Thus, notwithstanding that there have been some promising trials using "hover-cushions" with unmanned model airships,[4] and that airship ground crew personnel are commonly derided as little more than 'voice-activated, self-propelled sandbags,' it is still the case in the modern world, that their replacement by mechanised (presumably robotic?) means would seem to be a very long way off.

However in today's highly regulated and safety conscious world, the idea of hundreds of people running around after dangling ropes, as a primary braking system for the NGVLAs, is laughably impracticable. Nevertheless some way of bringing the NGVLAs safely to a halt, unharmed, whenever they need to make a light landing will have to be found, if for no other reason than this:

> "Reliable mechanised ground handling systems will be essential with larger airships as they will be too big to be handled safely by any ground crew small enough to be economic." (Netherclift, 1993:29)

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[1] Skyship 600 volume 6,600 cu m = mass 8 tonnes.

[2] 1 ground crew chief, 2 licensed engineers, 13 general purpose crew (Netherclift, 1993 : 67)

[3] The *ZPG-3W* was 122m (406 ft) long, displaced 42,000 cu m of air = mass of some 50 tonnes

[4] E.g. The Advanced Technologies Group "*Skykitten*" which first flew at Cardington in 2000

And, whatever this system is, it will have to include the development of a less frantic and much more reliable braking system, to replace the "aerodynamically" based methods currently in use after the modern blimp has touched down.

As can be seen from the following (**Figure 2.8/3**) the problem for all airships is that the inherently high centre of gravity always results in the ship's nose pitching sharply downwards.

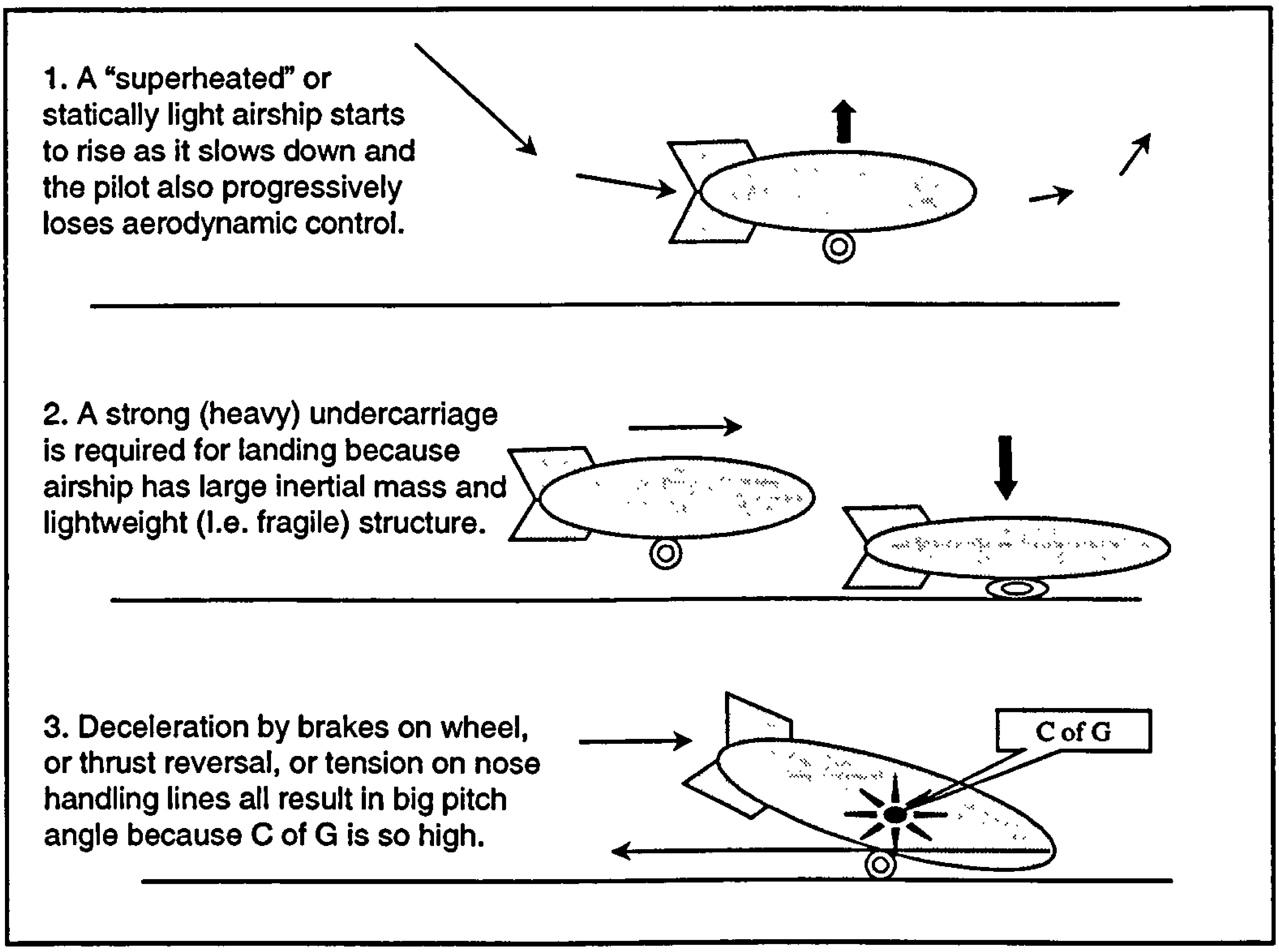

Figure 2.8 - The problems of deceleration when landing horizontally

The faster the deceleration is, the greater the tendency to pitch forward, which puts greater loads upon the structure and increases reliance on the shock-absorbing capabilities of the undercarriage. This is regardless of whether the decelerating force is applied by means of brakes on the wheels (the First War blimps gave up and used a simple wooden "skid"), or by reversal of thrust from the engines (which are traditionally low-slung for ease of access/maintenance), or by teams of people pulling on the nose mooring lines - as is currently done by the blimps today.

Deceleration in general will thus be quite a problem for the NGVLAs, even when making a normal landing, and this is especially so for those intended as cargo-carrying ships, where the stability will be strongly influenced by the "pendulum" effect of the many (100's?) tons of payload (or ballast) on board.

Clearly there are serious problems with using this horizontal method for very large airships and indeed better, and potentially more useful systems have been devised for, and were used by the PGVLAs. These "forgotten" methods centre on the vertical rather than the horizontal approach, which has so dominated all airship development ever since it was adopted by Goodyear for the blimps of the Second World War.

For example, at the conclusion of their development programmes in the 1930s, the big rigid airships, when they took-off, used either their passive "aerostatic lift" or, in the case of the US Navy giants *ZR-4 Akron* and *ZR-5 Macon*, their active "vectored thrust" to climb vertically from their "moorings." They were subsequently "winched" vertically back down again when they "moored."

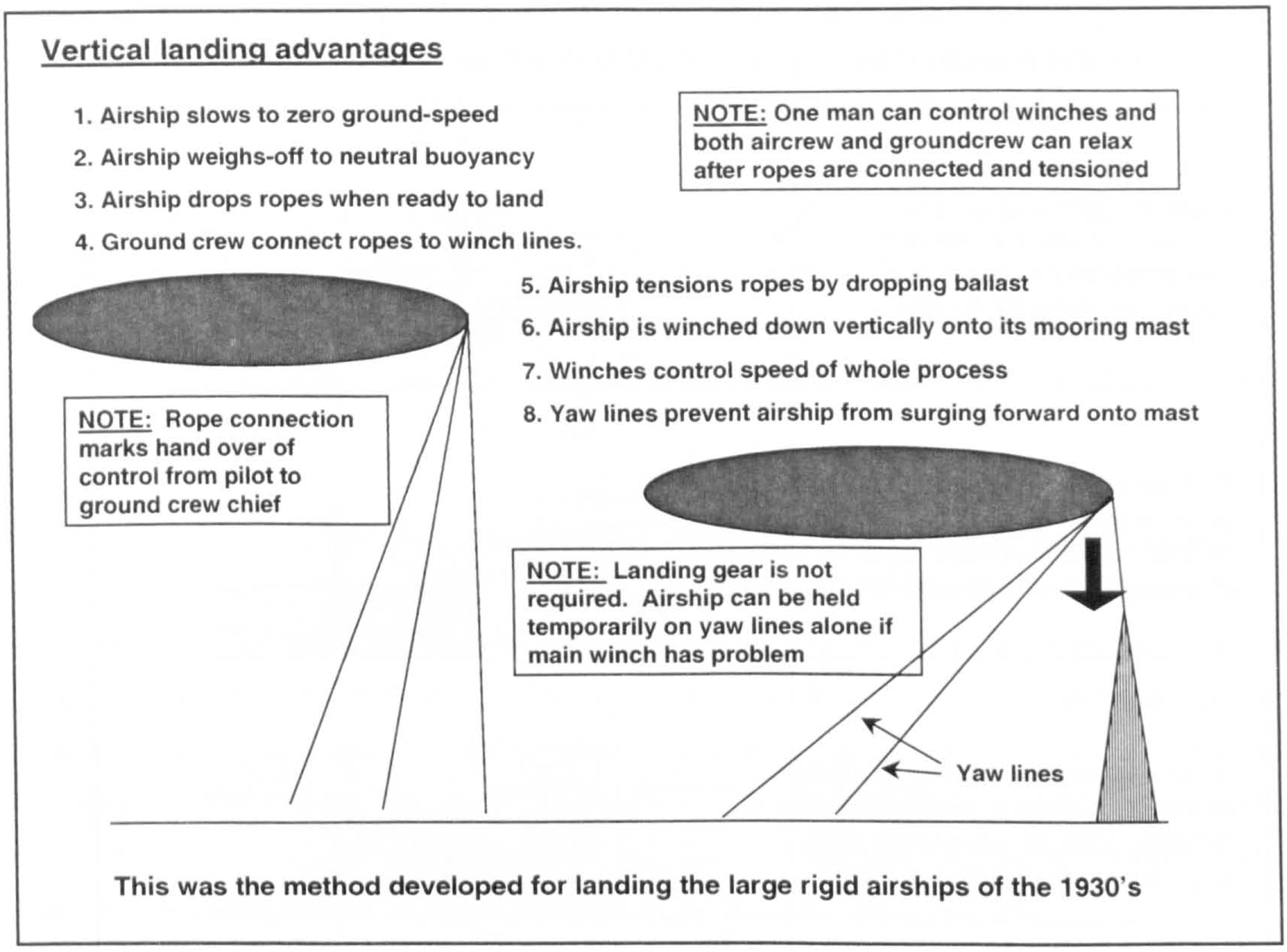

Figure 2.9 - Vertical landing advantages

Figure 2.9 shows some of the advantages for very large airships of using the vertical mooring method. Although this process was occasionally assisted by vectored thrust, it should be noted that very few of the PGVLAs were fitted with, or seemed to feel the need for, swivelling propellers.

Indeed, a little closer examination of the next step in the mooring process, after deceleration, reveals a further serious problem for the NGVLAs. Irrespective of whatever method is used to slow them down, even after a normal landing in standard operating conditions, there is still the problem of what to do with them after they have stopped – i.e. the actual "Ground Handling." **Figure 2.10** (overleaf) shows in diagrammatic form some of the fundamental difficulties of attaching airships to mooring masts. It also incidentally demonstrates the point that the airship and the mast are two parts of one system because the flexibility built into the mast is reflected in the loads generated in the airship structure.

However, this passive, aerostatic method is a completely different principle more akin to sea-going ships coming alongside a jetty than to any landing system currently in use by anything flying under the present rules of aviation.[1] But the vertical approach is obviously a far more realistic starting point when considering potentially suitable landing systems for the even larger NGVLAs envisaged for the future.

[1] Helicopters do not rely on ropes and winches to pull them down!

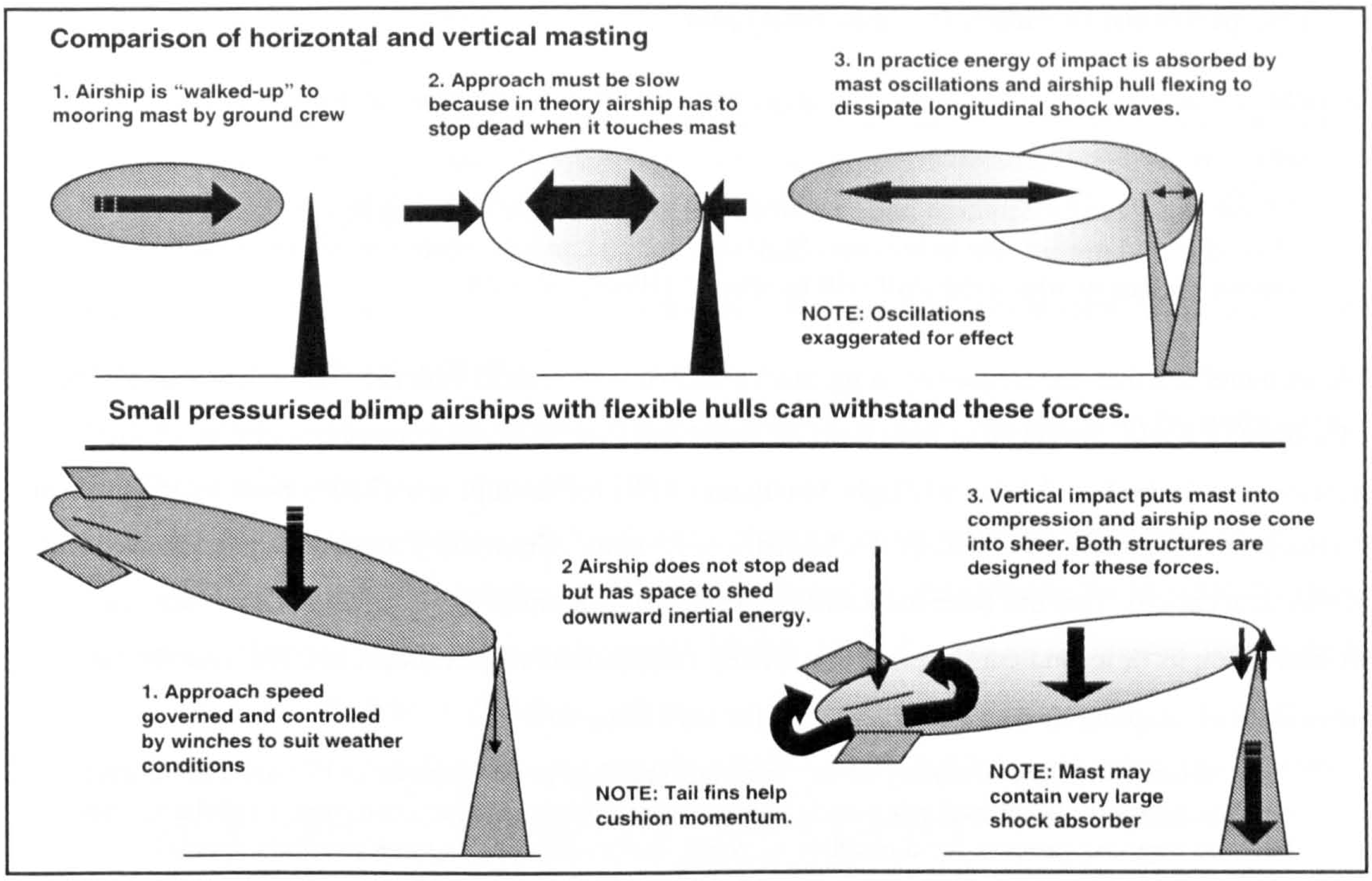

Figure 2.10 – Comparison of horizontal and vertical mast operations

Such thinking is alien to many of those who come fresh to the subject of airships from other branches of aviation today. They see the modern blimps simply as rather peculiar aircraft that are the "successful" end-product of a continuous development process, which essentially evolved after the old, "failed," rigid airships had become extinct. They see no reason why this evolutionary process should not continue and the procedures be adapted to the NGVLAs. What they fail to appreciate, and what this brief analysis has shown, is that the Goodyear "heavy" or horizontal operational system is not so very different from the operational systems that were commonly used by the small blimps during the First World War.

Consequently many of these so-called "modern" methods were indeed contemporary with the large rigid airships, and the reason that such systems were not used by the PGVLAs is therefore rather different from that which is commonly pre-supposed. - and it is directly related to size. An additional disadvantage of operating an aerostat as if it were an aerodyne is that it also significantly increases drag and this will both upset scheduled flight arrival times and increase fuel consumption for the NGVLAs – however these issues lie beyond the scope of this work.

It is therefore evident that although the small modern blimps may outwardly resemble their extinct cousins, (and indeed are widely regarded by many people as merely smaller versions of the large rigid airships), they are actually completely different aircraft, and they possess very different capabilities and requirements. Consequently the GH procedures that are widely accepted, and most commonly used, by the "small" modern blimps are not going to be suitable for the comparatively "enormous" NGVLAs. Thus, the current operational techniques cannot simply be "scaled up to plug the Knowledge Gap" and some other way will have to be found to train the NGVLA ground crews.

2.4 The problem of simulating prototypes

In the field of education, it is commonly accepted, when it comes to job-training and the acquisition of skills, that:

> "Most skills can be acquired and improved by drills, because skill implies the mastery of definable and predictable behaviour. Skill instruction can rely, therefore, on the simulation of circumstances in which the skill will be used. " (Illich, 1973:24)

It follows therefore, that one frequently suggested, possible way around both the "Knowledge Gap" and the "Problem of Scale" would be to train both the flight and ground-based personnel using an airship flight simulator. Indeed an Advanced Flight Simulator (AFS) for airships has already been established (in 1995) thanks to the combined efforts of the Ministry of Defence, Cranfield University and DRA Bedford (as it was then called). This has been used with some success for small blimp airships. However, the paper describing its development, given at the Airship Association's Convention in 1996, reveals the Achilles Heel of adapting this, or any other AFS, for very large airships:

> "The validation of the accuracy of any simulation is key to confidence in the simulation trial results. Again, unlike fixed wing and rotorcraft simulations, where core model validation has been an ongoing process for a number of years, the airship programme presents special challenges in this area." (Martyn & Brown, 1996)

And here is one example of just such a 'special challenge':

> "Dedicated flight trials on the DTEO Boscombe Down S600 [*Skyship 600*] were planned to gather validation data, but when the vehicle was involved in an accident in Spring 1995 the validation flight test programme was lost." (Martyn & Brown, 1996) [1]

Fortunately, for the team at DRA Bedford, the *Skyship 600* was already a fully certified aircraft, with a proven and successful track-record and a long, well documented, operational history:

> "One mitigating factor was that it was understood that the core Cranfield model had been validated against flight test data." (Martyn & Brown, 1996)

However, this cannot be the case for the NGVLAs. They have no previous flight history and thus there is no validation data available. There are only 'virtual' airships – and, while some may argue that some theoretical work could be some of assistance, the fact remains that accurate data of NGVLA performance and of their behaviour in the 'real' world cannot be collected until at least one, real, very large airship actually makes (preferably more than one) real test flights. Thus there is a circular argument wherein a large airship is needed to make test flights, in order to gather the data, to validate a simulator, to train the crew so that they are adequately skilled to fly the first test flight!

In the meantime, simulation programmes for NGVLAs can only be based on unvalidated and unverifiable theories. And relying on theory alone, when building new flying machines, carries significant risks - as was previously noted in the early days of fixed wing aviation:

> "Both men [the pioneer aircraft builders M. Clément and Wilbur Wright] much prefer what <u>is</u> to what <u>may be</u>, and ... they are deeply imbued with the deceptiveness of theory and the foolishness of counting upon anything which has not withstood the test of time and experience." (G.A.R. 1909)

[1] [Authors note: It would be interesting to know how close theoretical pre-test-flight predictions were to actual performance.]

And in similar vein, the French architect of the then revolutionary design for the long-standing corrugated concrete hangars at Orly, Paris, wrote:

> "It is only natural that intuition should be controlled in the light of experience, but when it turns out to be in direct opposition to some calculated result ... it is almost always the answer determined by calculation that turns out to be wrong." (Eugene Freyssinet (1879-1962), quoted in Dean, 1989:13)

This remains true today and some recent prime examples of over-confidence in modern computer-based design and calculation methods include:

- The Boeing *Osprey* VTOL aircraft which has recently suffered severely from the unforeseen effects of flying into its own wake vortex.
- London's famous "wobbly footbridge" where the most advanced software analysis in the late 1990's failed to predict a potential performance failure; notwithstanding the fact that the same design of bridge had been rejected for the Messina Straits for reasons of dynamic instability in 1971. (D.E.J. Walshe via Wootton, 2001).
- The Met. Office weather forecast computer which failed to predict the October 1987 "London hurricane" because it could not accept the existence of radically extreme conditions.

This last example highlights a further problem for simulations in general and with the development of an AFS for large airships in particular.

> "Although simulators can replicate normal manoeuvres, they cannot replicate every eventuality that might be experienced in real flight. Physical limitations on the movements of a motion platform make it impossible to replicate extreme manoeuvres." (Read, 2001)

In fact most current simulations are of operations where the mathematical relationships are linear, or can be defined by a simple functional relationship. This imposes limits on their use, as has been noted:

> "The use of modern simulators in the current [military] flying training system is somewhat limited and where they are used they are generally relatively simple. They provide only a limited capability beyond the instruction of basic aircraft systems, basic emergency handling, and instrument flying." (Field, 2001)

Thus, simulators for HTA craft are seldom actually operated in highly non-linear modes such as a stalled condition for example. However, an airship when it is moored is subject to an airflow (the wind) which has a comparatively low speed and which may approach from almost any angle. The hull and the fins are thus technically "stalled " for much of the time. Consequently it is only simulations of the highly non-linear relationships that are of any real interest.

Moreover, it must not be forgotten, that in order to simply take-off and land vertically from the hover, the NGVLAs will inevitably be using, as normal, operating procedures that are completely different from those currently in use by conventional HTA aircraft. Furthermore, while any large airship's behaviour during approach to a landing, and climb-out from take-off, would, superficially, appear to be akin to the 'vertical' methods used by today's helicopters, or by Harrier jump-jets, (and therefore ought to be amenable to their similar extant regulations and training programmes) in fact, the NGVLAs will, in reality, have very little in common with HTA craft. The difference stems from the airship's inherent buoyancy, which means that, for example, an engine failure during take-off would be far from critical. Indeed, some of the PGVLAs habitually "took-off" without using their engines at all.

"With the controls in neutral *Shenandoah* [1] [US Navy's *ZR-1*] was carefully weighed off, the officers noting any rise or fall of the stern. Ballast (water, fuel, or men) was shifted as needed, and at 15.00 [on 31st May 1924], the ship cast off [for her 24th flight] a trifle light by the bow. She was allowed to free-balloon to a safe height above the mast, where, finally, her Packard engines barked to life." (Althoff, 1990:41)

Thus there is no doubt that, whatever their eventual chosen preferred procedures turn out to be, any NGVLAs will perforce clearly be quite unlike any aircraft currently flying and will consequently operate using methods and systems that are similarly unparalleled in modern aviation. Herein lies a further acknowledged problem for any attempts to construct computer simulations of them.

"The aim of the first trial was to assess the simulation subjective [ly] in a known configuration. This was done by configuring the simulation as an *S1000* [*Sentinel 1000* [2]] and conducting general handling, stability and control testing. This precluded an acknowledged problem with the NASA Ames Airship trial – that the simulation was not configured as a vehicle which the subject pilots had flown." (Martyn & Brown, 1996)

Even where cockpit configurations are well established there are still severe limitations as to what may be achieved in terms of crew training with simulations.

"The speaker [Air Vice Marshall Corbitt] accepted that the Services were some way behind the civil community in the use of simulators ... Research had shown that the anticipated level of simulation would still not represent the physical stresses or psychological aspects of military flying; nor would simulators be able to reproduce the unpredictable nature of live flying which was essential to the development of sound operational captaincy and airmanship." (Field, 2001)

Furthermore, it would seem to be a great mistake to assume that old flying machines were easier to fly (and therefore required lesser skills) just because they were less sophisticated and of simpler construction. In fact the reverse would seem to be case.

"Test pilots from Edwards Air Force base flying a simulator fitted with the flying characteristics of the original 1903 Wright Flyer were all unable to keep the craft airborne for one second without crashing. The pilots practised on a Learjet 24 simulator adapted by the American Institute of Aeronautics and Astronautics." (RAeS, A. I., 2001:13)

It is thus evident that computer simulations, far from providing a solution to the crew training problems for the NGVLAs, are themselves also subject to the very same "Knowledge Gap" that has arisen as a result of the inconvenient date-expiry of all experienced personnel. Without either data to validate the computer programmes on which they are based, or personnel with experience of very large airships, who can comment on the approximation to reality, and give some comparison with the behaviour actually observed in the past, it is difficult to see how the results of any immediate present-day attempts to create NGVLA simulations can produce anything that is much more than guesswork.

However, misunderstandings and confusion are widespread in the public mind, as to the problem-solving capabilities of computer-controlled simulations - and indeed, of the absolute necessity of training with them. As an example, one serious suggestion, which was made to help solve some of the problems foreseen with the training of GH personnel for the gigantic CargoLifter airships, was that a mock-up of

[1] *ZR-1 Shenandoah* was 207 m (680 ft) long and had a volume of 60,800 cu m (2,148,000 cu ft) giving a displaced mass of approximately 75 tonnes

[2] The Sentinel 1000 (S1000) was conceived in 1987 as a half-linear scale, proof of concept for the US Navy's YEZ-2A Operational Development Model (ODM) airborne early warning (AEW) airship. The YEZ-2A was never built but the prototype S1000 flew many hours of trials until it was destroyed in a hangar fire at Weeksville on 2nd August 1995. The Sentinel 1000 was 65m (213ft) long and contained 10,000 m3 of gas giving it a displaced mass of some 12 tonnes.

the "Load-Exchange System" (LES) could be suspended from the hangar roof and that "computer controlled cranes" could then be used to mimic the behaviour of the airship. This of course completely overlooked the annoying little fact that there is currently no verified data available upon which to base the computer programme needed to control the cranes. And, unfortunately:

> "Simulators rely on input from mathematical models based on data provided by aircraft manufacturers from flight test programmes. If any of this information is wrong, then pilots could be relying on inaccurate information." (Read, 2001)

And, what is true for the pilots inside the airship is equally true for those on the ground who are endeavouring to take control of the same aircraft when it wants to stop flying. Thus, unless the airship behaves accurately in the simulation, then procedures may easily be devised and rehearsed which will prove, in reality, to be either unworkable, or perhaps unnecessary, or just plain dangerous.

This is a serious problem for all prototypes, not just for the NGVLAs. In today's world of computer animation, it is extremely easy to get carried away with the technology and to lose sight of exactly what the aim is.

> "The most seductive tool of all [for management] is computers. Of course, computers are important and necessary in many applications ... But they are not 'solutions'. A computer is a tool, like a hammer, and the only strategy a company needs for it is to use where appropriate." (Caulkin, 2005)

The danger of falling into this trap has recently been further increased by the dramatic development of the computer's abilities to spawn virtual realities, including visual graphic models, which give the appearance of coming ever closer to the real world. But, the old saying still holds good - "appearances can be deceptive" - and without some basis in the real world, (i.e. a reality check), then attempting to rely on un-validated computer simulations to train novice personnel to conduct unprecedented GH procedures for the untested prototype NGVLAs seems almost certain to cause more problems than it solves.

2.5 The problem of simulating Ground Handling

If the foregoing focus on "flight" simulation, would seem to have little to do directly with the problems associated with the GH of airships, then it should be borne in mind that any Advanced Ground Handling Simulators (AGHS), intended to assist with the training of ground crews for the NGVLAs, can only be derived from an AFS for a specific airship and not the other way around. The AFS must exist before the AGHS because GH does not exist for its own sake. The procedures involved are a response to the actual needs of the airship and consequently, the training of its ground crew must depend upon any specific airship's real requirements. Until these requirements are clearly defined and the GH procedures agreed, then the planning of the training systems to guarantee the competency of the personnel involved, cannot seriously begin in detail.

Furthermore, it must be emphasised that all of the problems so far identified above, with regard to the Knowledge Gap, and the problem of scaling-up, and the simulation of prototypes, that were foreseen to be problematic for the NGVLA flight crews, are going to be even more difficult to overcome with regard to the training of their ground crews.

For example, a realistically useful AGHS for any size of airship is going to require far more than just an accurate data model of the airship's behaviour in flight. Simply to remove it from its assembly shed in the first place, there is the airflow around the complex bluff-body shape of the hangar to consider. Then what happens to that airflow when the hangar doors are opened and the airship is manoeuvred through them into the open air? There will also be some aerodynamic interaction between the airship hull and the ground, which will be in close proximity. Then there are the relative motions of the attached vehicles, or whatever is moving the airship, (which machinery incidentally, will also first have to be defined, designed and proven fit for purpose, before it too can be mathematically modelled). And finally there are a whole range of unquantifiable variables such as the effects of wind, and sun, and rain, and snow and ice; and the tension in ropes; and how much they will stretch; and how this will change over a lifetime of abrasion and use. So while a flight simulator for the pilots of the NGVLAs might just be possible within a reasonable time-frame - assuming sufficient funds and resources - there is no hope at all of anything similar for the ground crew because GH is far too complex.

There is also the financial aspect to consider:

> "...full flight simulators have the disadvantage that they are expensive to buy, maintain and operate. In some cases, the cost of a simulator is higher than the actual aircraft." (Read, 2001)

And this was written concerning currently flying HTA aircraft, which already exist in their thousands, and for which there is a vast wealth of knowledge and plenty of operational experience available on which to base the programmes. Starting from scratch for the NGVLAs is going to be enormously more expensive and it should be noted that corners had to be cut even for the flight simulator of a well-established airship such as the *Skyship 600*:

> "Although initial discussions suggested that an airship cockpit might be developed specially for the programme, it was decided that a **more cost effective approach** would be to adapt the generic AFS helicopter cockpit for the airship flight trials ... Details of the layout were achieved through **interaction with the airship pilots ...**" (Martyn & Brown, 1996) **[GC emphasis]**

This is not to say that simulators will have no part to play in the development of the NGVLAs, nor that crew training, (and even ground crew training) for very large airships will not one day be possible with them. Computer based simulations are obviously extremely useful tools and much time and money can be saved by the careful use of them. However, establishing a reliable simulator for the first of the NGVLA prototypes is clearly going to be an enormous development task in its own right. It will be a large and complex research project and initially it will require a great deal of both time and financial investment.

Fingers have already been burnt in other areas of aviation and these lessons are unlikely to be quickly forgotten:

> "The first British Apache pilots, from 656 Squadron 9 Regiment Army Air Corps, are training at a new centre at Middle Wallop, which includes two giant simulators for practising helicopter attack missions. ... Although the simulators are acknowledged as world-beating training facilities, **they were the main cause of the delay** in the programme. The MoD ordered them late and there followed a delay of 18 months because of software problems." (Evans, 2004) **[GC emphasis]**

Bearing in mind, that any projects to develop the NGVLAs are likely to be faced with tight schedules and limited budgets, and that the airships themselves, when complete are intended to be used for tasks that will involve currently unprecedented procedures, it is hard to escape the conclusion that there is really very little to be gained by embarking on a complex simulation development programme in parallel with the real hardware. As was noted nearly a century ago by the German aeronautical pioneer Otto Lillienthal:

> "In flying machines conception is nothing, construction is little, experiment is everything." (Lillienthal, 1909)

Thus, when forced to choose between spending hard won funds on building and testing a flyable prototype or on an, at best unreliable simulation (with a high probability of producing unrealistic results), it would seem wise for the future NGVLA project leaders to choose the former empirical route rather than the latter theoretical one. Their decision will also undoubtedly be influenced by the fact that the certification authorities already acknowledge the risks of relying on unverifiable calculation. This can be seen in an excerpt from the British Civil Airworthiness Requirements (BCAR) for Non-rigid Airships (CAP 471 - Section Q):

> "Sub-section Q3-Structures:...
> Ground loads:... 2 Energy Absorption ...
> 2.2 Proof of Compliance. The energy absorption characteristics of the landing gear **shall be determined by dynamic tests ...**
> 2.3 Design Velocity of Descent. The design velocity of descent **shall be substantiated by data from development flying ...**
> 2.4 Ultimate Velocity of Descent. It **shall be demonstrated by test** that the shock absorption capacity is sufficient to withstand landing ..." (CAA: CAP 471, 1979:41) **[GC emphasis]**

No question of simulation or mathematical analysis being allowed to take the place of testing in these cases. However, perhaps, more importantly for the future, the draft regulations that will govern the NGVLAs (the Transport Airship Requirements or TAR) tell a similar story:

> "GENERAL ...
> **TAR 21 Proof of compliance**
> Each requirement of these regulations must be met at each appropriate combination of total mass, static heaviness and lightness and centre of gravity within the range of loading conditions that may occur during the operations for which certification is requested. **This must be shown by tests upon an airship** of the type for which certification is requested, **or by calculations based on and equal in accuracy to the results of testing** or a combination of each. ..." (LBA, 2000:19) **[GC emphasis]**
>
> **"TAR 307 Proof of structure**
> (a) Compliance with the strength and deformation requirements must be shown for each critical load condition. Structural analysis may be used only if the structure conforms to those for which experience has shown this method to be reliable. In other cases, **substantiating load tests must be made.**" (LBA, 2000:25) **[GC emphasis]**
>
> **"TAR 481 Mooring and handling conditions**
> ... (b) ... All static and dynamic loads must be determined considering the wind conditions to be expected during mooring and handling. These values must be listed in the Airship Flight Manual. **The determination by analytical means is only acceptable if a procedure is used warranting reliable results. Otherwise appropriate ground tests have to be performed."** (LBA, 2000:29/30) **[GC emphasis]**

In other words - from the regulatory authorities' viewpoint, analysis is optional but testing is mandatory. Thus, while there is a strong possibility that computer based simulations may well offer designers and structural engineers a shortcut, when it comes to the NGVLA certification process, (provided that proven aviation methods and materials are used), it is also clear that this is not going to be the case when it comes to the GH operations. Therefore, analytical models (be they virtual realities or whatever), which at the outset of the NGVLA programmes can only be derived exclusively from unverified data, are certainly not going to be able to plug the "knowledge gap" that lies at the heart of this investigation.

> "Useful lift can be *estimated* only as a (relatively) small difference between two large quantities : when the hull is air-borne it can be *measured* with certainty. Estimates, it is safe to say, have been the curse of airships : so hard to check, when airship flights are as infrequent as solar eclipses ; so easily modified to suit the thesis of the moment, whether sanguine or condemnatory." (Southwell, 1929 :4)

And finally, to conclude this section on the inability of mathematically based models to provide a solution to the NGVLA crew training problem, it should perhaps be strongly emphasised, in view of the widespread misunderstandings concerning many aspects of airship operations in general, that the term "ground handling theory" is in itself something of an oxymoron. By its very nature the science of GH has to be based upon practical skills. The sole purpose of GH is to keep the airship from harm and this requires action - and sometimes quick action - in the real world. For example, the groundcrew of a modern blimp cannot just stop loading ballast into an excessively light airship simply because a calculated number written on a piece of paper tells them that they should do so. Their job is to stop the airship from blowing away. If the airship is "too light" then it needs "more" ballast and the ground crew, struggling in the wind and the weather, have no option other than to go on loading weight onboard until there is "enough" and the airship is safe.

Naturally, after the emergency situation is under control, someone will calculate how much extra weight was actually put on-board, and the number thus generated will indeed be "useful" (if nothing other than to know how much ballast to hold in reserve in case it happens again). It may even be that the calculated number is "important" (for instance, indicating that something has fallen off the airship). However, the calculation in itself is an afterthought and it cannot be said to be "vital" to the airship's immediate survival. It alone cannot protect the airship from imminent danger and neither can it, in this example, say what exactly has fallen off, nor where it is. Only physical action in the real world, both to put sufficient ballast on-board, and then to go look for any missing component and put it back in place, will save the airship from damage and possible destruction. Therefore, although experienced groundcrew may well find the calculated number "interesting" or "useful" they will still be hard to convince that it is really "necessary" for them to know in order to carry out their duties.

Thus, an empirical approach to NGVLA groundcrew training would seem to be the only way forward.

2.6 The problem of crew training with real equipment

It would therefore seem that there really is no credible alternative for the GH team of the first NGVLA, other than to learn to use their brand new Ground Handling Equipment (GHE) as they go. However, there are obviously very big risks in this process and it would also appear that there would be a significant advantage if the novice groundcrew were at least to familiarise themselves with the GHE controls, preferably by running it through a few test cycles, before the airship was attached to it. If nothing else this would minimise the risks posed to the project by mechanical failures.

> "The history of technology indicates that most major engineering enterprises which are undertaken in fields where almost all of the factors are unknowns are bound to have some failures." (Higham, 1961:132)

Furthermore, allowing the groundcrew a "shake-down" period to test and train with the brand new GHE would also get the bugs out it. More importantly it would give the crew themselves some confidence and not make the front pages of the world's newspapers if they got things slightly wrong.

> "In every new model of any machine we build "bugs" arise, which must be caught and corrected, for progress comes **only through experiment, and the long cycle of trial and error.**" (Litchfield & Allen, 1945/1976: 79) **[GC emphasis]**

As head of the Goodyear/Zeppelin Company, and one of the driving forces behind the American Rigid Airship Program, Litchfield certainly spoke from experience. But, this "de-bugging" and familiarisation process poses a further problem for the prototype NGVLA, for while such a ground crew training period would obviously minimise the risk of Kapitan Strasser's aforementioned [1] "slight mistake that leads to serious consequences," it presupposes that the GHE will be completed and ready for use some time in advance of the airship. Unfortunately, for the prototype NGVLA, this is unlikely to be the case.

In order to understand why this will be so, it is necessary to look briefly at the sequence of events likely to occur in the initial phases of design and construction of any future large airship development projects. However, this needs to be only a very superficial examination in order to reveal that there is a fundamental and inescapable conflict within any such schedule, and that, regardless of the size or the type of airship, (or even of the GH systems selected for it,) the GHE is almost certain to be unavailable for ground crew training.

In an ideal world, **(Figure 2.11 – Generic NGVLA Development Schedules - Scenario #1)** the two major component parts - the airship and the GHE - could simply be treated as two inter-linked but essentially separate projects. Each would then have their own design and construction teams working alongside each other. This would seem sensible, as the skills required to build the light-weight aircraft look likely to be rather different from those required to build the heavy-weight mobile mooring mast (and any associated machinery that will be needed to move the airship about when it is on the ground).

Thus, regardless of whether the airship and the GHE are actually assembled in the same physical building, or merely in close proximity, they could, in this ideal world, both be designed, built and tested simultaneously, before being brought together as finished items to begin operations. There would then be scope for both flight and ground crews to learn to use their own component parts as the separate construction phases came to an end and while the testing and certification phases were in progress. The subsequent integration of the two differently complex parts of the system, airship and GHE, would therefore be conducted by personnel who were familiar with, and also skilled in the use of their own equipment. A further advantage would be that both component parts would also have had many of their major bugs removed by the time they came to be joined together.

However, this 'concurrent scenario' – i.e. running the two separate projects side by side at the same time - will only work where the requirements for both the airship and GHE are clear and already well established at the outset of the programme. In the real world of today this cannot be the case.

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[1] See page 15

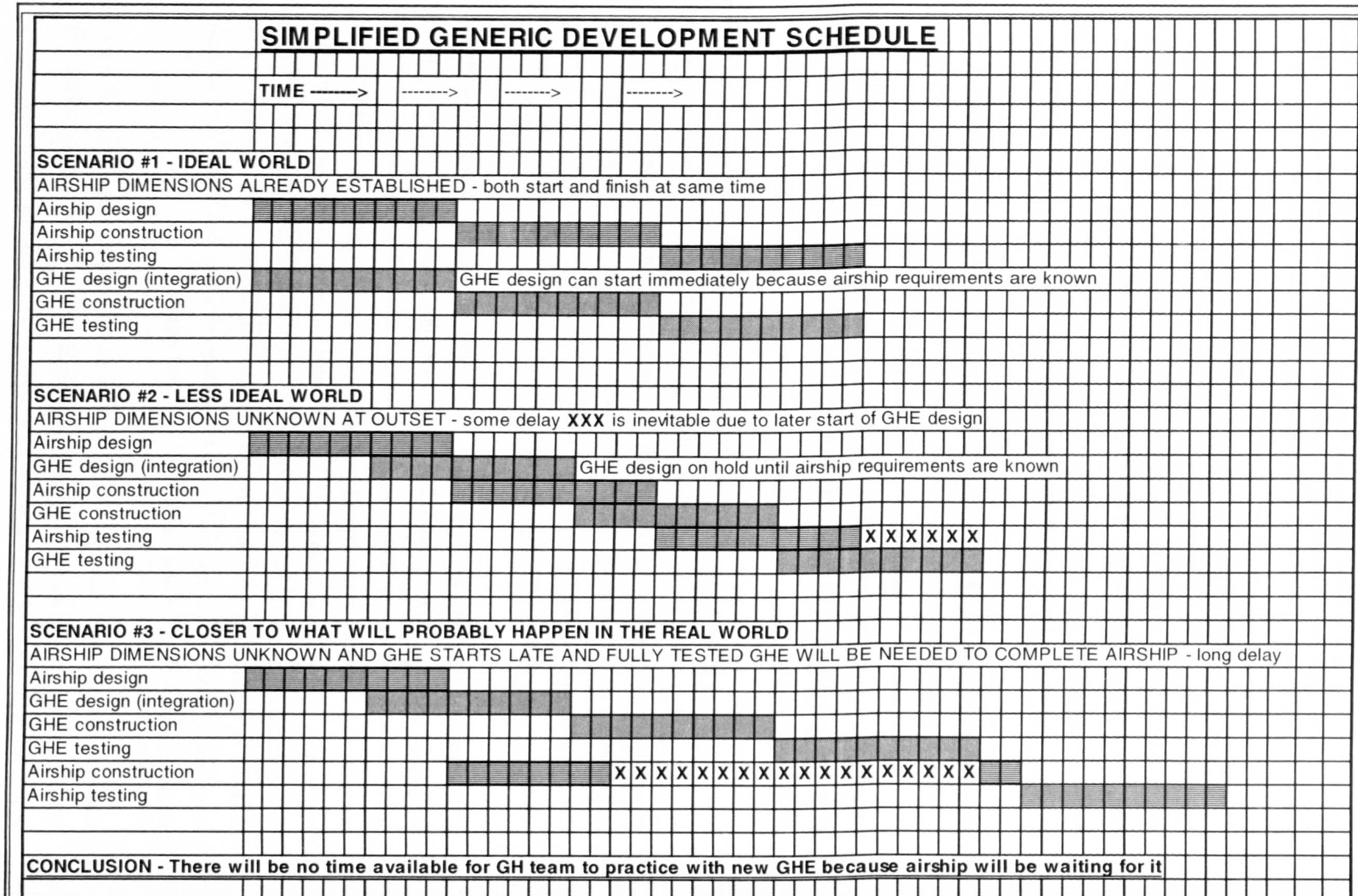

Figure 2.11 – Generic NGVLA Development Schedules

In the real world super-large airships do not exist. The first NGVLA will be a prototype without precedent. Thus, at the start of its design, many of its requirements will be unclear and undecided. The structural configuration and the layout of its cockpit, along with whatever monitoring and control systems are vitally necessary, (as opposed to merely desirable), will inevitably be the topic of much heated debate. Moreover, while it is obvious that the airship design cannot be completed until these issues have been resolved, (with trade-off studies and the like), what is less obvious, but equally true, is that the GHE design cannot seriously even <u>begin</u> until after some basic decisions have been made as to what precisely is going to be built and how exactly it is going to need to be handled. After all the only purpose of the GHE is to serve the airship. By definition, it only exists because the airship has need of it If, this is not the case, and the airship could for instance be undocked without any GHE, then why waste money on it? Obviously there is no point in building GHE for its own sake. The whole purpose of the project is to build a new type of airship.

Therefore, it follows, that while it is true, from the airship design team's point of view, that: "The **philosophy** adopted for recovery and mooring [i.e. a major part of GH] **dictates the design concept** and other aspects are then most likely to be adequately covered." (Howe, 1999:302) (**GC emphasis**) - it is also the case that, it is only <u>after</u> the precise position of suitable anchorage and attachment points have been identified on the airship structure, that the GHE design team can seriously begin to determine the true dimensions of their own project. It is only when they know exactly where they can take hold of the airship structure, that they can start to calculate the forces that their equipment will have to deal with. Thus, while some of the general principles for the GH systems may be agreed early on, the actual detailed GHE design cannot really proceed until after the airship's dimensions, at the very least, have been established and agreed.

Therefore, in a more realistic world, (**Figure 2.11 - Scenario #2**) it is evident that the integration of the two structures (NGVLA and GHE) cannot sensibly start until <u>after</u> the airship's actual size and shape have been finally frozen. Furthermore, this integration, which is in truth the final design of the GHE, must be an iterative process. It will involve compromises and uncomfortable trade-offs on both sides of the interface. This is necessary in order to minimise the flown weight, while ensuring that the anchorage points, and the like, have sufficient strength for all eventualities. Indeed, the defining loads on some parts of the airship structure may well be the loads imposed by the intended GH procedures. For example, when re-docking, the lower tail fin might be used to pull the airship sideways against the wind and into alignment with the hangar axis - as was done with *Akron* and *Macon*. Here again it can be seen that many of these decisions are totally dependent upon what the structure of the airship actually comprises – i.e. the nature of the component parts and exact location of any strong points that are potentially capable of serving as GH attachment points.

Consequently, while the design integration of the two structures has to be an iterative process it cannot be led by the GHE design. Neither can the GHE, for reasons of cost saving, nor for convenience in its own construction, dictate any changes to the airship, which will materially alter the shape, nor add any significant weight, to the airship. It has to be emphasised that the airship always wins in the end - and rightly so - its performance and its survival are paramount.

Therefore, in the event of a really serious problem at the interface between the two structures it is always the GHE that will be modified in order to suit the airship. If changes to the airship requirements arise, which call for a drastic alteration of the designed structure halfway through construction, (such as inserting an extra section into the hull so as to increase the volume and consequently the amount of lift - as has happened more than once in the past) then the GHE cannot deny them. Neither can it ignore them. It can only follow-on with its own redesign to accommodate the effects of these changes. Thus the GHE which started its design later than the airship, is also condemned to follow behind the airship as it passes through the construction phase of development. Allowing the GHE construction to get too far ahead of a prototype airship could be very costly in the event of any major, late, structural changes.

To some extent this inherent delay can be expected to be mitigated by the fact that the GHE does not have to fly. It can thus be generally more robust and this, in theory at least, should make it easier and quicker to build. In addition, the airship will also have to conform to a rigorous and time-consuming quality control process in order to achieve certification whereas, that for the GHE is currently less clearly defined. However the GHE will obviously have to be tested in some way. It may also have to be certified; if not by the aviation authorities then almost certainly under the rules of the airport whereon it is based - and quite possibly by both. This will take time.

There are already today health and safety regulations, that are applicable to all workplaces and these include airfields[1]. The GHE will need to conform to at least some of these regulations, and it is more than likely that in the future there may be further constraints imposed by increasingly severe conservation and/or environmental protection rules. Worse still, these regulations are likely to be administered and enforced by a whole range of government departments (and/or international organisations) none of whom will have had any previous experience whatsoever with large airships. Satisfying these bodies and complying with all of their edicts, in order to prove that the prototype GHE machinery is safe and "fit for purpose" looks certain to have a serious effect on both cost and time budgets. However, in reality there is a further twist and the situation is almost certain to be even more complicated by what appears to be a fairly obvious simplification:

> "... operation is simplified if the airship can be moved with the device which is used to moor it." (Howe, 1999:301)

This simple statement has enormous hidden consequences. It is the tip of another iceberg and it goes unchallenged simply because there are no large airships in operation today, and there is so little knowledge of them within a world that is dominated by HTA practices. However, the fallacy behind this apparent simplification becomes clearer if the concept is applied to fixed-wing aircraft. For example, following this logic, it would "simplify" the operation of today's jumbo jets if the fuel bowser, and a passenger-carrying bus, were to be combined with, and incorporated into, the tug that moves the aircraft around. In theory this would save considerable time by allowing an aircraft to be refuelled and disembarked while it was being towed along. In practice, everyone with any knowledge at all of HTA aircraft systems can immediately see that such "multi-tasking" would cause enormous problems.

[1] For example ICAO (1987) "Airport Planning Manual" & ICAO (1999) "Annex 14 – Aerodromes"

Thus, while the simplification statement is undoubtedly, absolutely true for the small blimps, which are operating today, (and it may well become so from the perspective of the fully developed NGVL airships of tomorrow,) from the point of view of developing the prototype GHE, then adding or "piggy-backing" systems is really going to be a false economy. A problem with any one system will *force majeur* hold up development of all the others. The more systems that are required to be incorporated into a single prototype device, the longer it is going to take to design, and then to build, to test, to certify and, subsequently to train the personnel who will operate it.

Nevertheless, it does seem more than likely that the prototype GHE will be required to carry-out at least some multiple tasks. An obvious example being that it will be needed to help complete the construction of the first NGVLA (**Figure 2.11 - Scenario #3**), or, at least it will be found to be the best way to hold the airship down securely during the inflation and final assembly process. (Bearing in mind that if the GHE is not used for this purpose then further large and expensive equipment will be needed in it's stead.) But, if this proves to be the case, and the GHE becomes part of the airship assembly process, then some loads that will have to be carried by the GHE structure during inflation, may easily be greater than if it were only ever to be used to handle the "flight ready" airship.

For example, if the gondola was not attached to the envelope at the start of the gas fill then the GHE would have to cope with the total possible lift load that could be generated by the maximum volume of 100% pure gas within the unballasted envelope. This would mean a second, separate set of attachment points to join the envelope directly to the GHE, and space would have to be provided within the GHE structure to allow the gondola to be moved into position for its attachment to, and subsequent removal from the envelope. Furthermore, if the GHE becomes a completely integrated part of the airship production equipment then it might need additional fixtures to facilitate the removal and exchange of other major components for maintenance and repair, such as the fins, the nose cone and the engines.

On the face of it, these are all straightforward engineering problems and they are most likely to be fairly easily solved. Whether they will prove to be cost effective is difficult to say at the start. But the point is that either using the GHE to aid airship assembly, or adding complexity to the prototype GHE machinery by incorporating Ground Support Systems (GSS) within it, can now be seen to be considerably less attractive as ideas, simply because they can only further reduce any flexibility in the NGVLA schedule. Moreover, there is an additional disadvantage with the latter scheme because multi-purpose equipment will also dramatically increase the risk that a single point failure may hold up or even ruin the whole programme. For instance if an untested mobile mooring mast were to de-rail during its first attempt to move along its new railway track from hangar to mooring circle then, without the airship attached to it, this would probably result in an expensive delay, but with the airship in tow, such an event could easily turn into a major, news-worthy and project-wrecking disaster.

Thus a very rudimentary analysis of a generic NGVLA development programme reveals that because the GHE design is completely dependent upon the airship dimensions there is automatically created an initial delay, which means that the airship will almost certainly start its construction before the GHE does. Furthermore, the GHE, which appears condemned to follow the airship into the design phase of its existence, has to lead the way out of construction - especially if it is to be incorporated into the production process - for the airship cannot be completed without it. The GHE must logically therefore overtake the airship during construction or it will delay the programme. Indeed any delay in the development and building of the GHE will seemingly add significant delay to the whole project, and the longer the design decisions take to make at the start, the longer the delay in availability is likely to be at the end.

It should, however, be noted that most of these problems are only applicable to the prototypes, and to a certain extant, they will go away after the basic system functions of the two components have been successfully proven in the field. The very first NGVLA and the first GHE are almost certain to be subject to some drastic alterations, in the early days, before they are considered fit to carry out their unprecedented procedures. Keeping the two systems separate initially, will thus allow them to be modified independently and in the quickest and most cost-effective manner, each according to its own needs and respective regulations. Once each is established and the systems are proven, then the integration and amalgamation of some GSS into the GHE may become an attractive option, but if all the answers are known at the start of the project then there is no need to build a prototype.

There is, however, yet another vicious circle at this point, because just as a frozen design of the airship was shown to be fundamental to establishing the composition and configuration of GHE, so a frozen design of the GHE is now seen to be essential before the training of its operatives can begin. How can people be trained when no one knows what the tasks are and what equipment they will be using? And, as stated above, computer simulation training devices can do little to assist here simply because they are hamstrung by the same lack of dimensional and operational data, which is needed to construct their virtual reality models.

So, just as it has already been established that the ground crew are going to be needed well in advance of the flight crew, it can now be seen that if the GHE is used as a part of the assembly process then it too will also be needed well in advance of the airship – possibly many months beforehand. Moreover, this will always be so, for, whereas the airship design may have an end date that is tied to the calendar, the end date for the GHE cannot be other than "whenever the airship needs it." Thus, while the end date for the airship construction phase of the project might quite reasonably be the first test flight, the end date for the GHE must inevitably be earlier - if nothing else because, in all scenarios, it will be needed to move the airship out of hangar prior to its first flight. But, if the GHE becomes an integral part of the inflation process, then it must be ready for action earlier still, roughly halfway through the airship build process.

Either way, there will be tremendous pressure to finish the prototype GHE and then to use it immediately. However, the GHE cannot be used for training when it is in use. Plainly the crew cannot drive it around and test the brakes and other systems when there is an airship attached to it. Thus there is no room whatsoever in this grossly simplified generic NGVLA schedule for the ground crew to practice with it prior to its first use. The only possible time in this programme for crew to train with the GHE would be during the test phase of the GHE (i.e. immediately following completion of the GHE assembly), but this phase too will have to be seriously curtailed if the half-finished airship is already waiting to use it.

It must also not be forgotten that there is plenty of scope for damaging the airship in the process of simply joining these two enormous structures together for the first time. This is irrespective of whether the GHE is used as an integral part of the initial NGVLA inflation and assembly process, or not. Even with fully trained crews there is always going to be enormous potential for expensive errors whenever the two component parts of the system are separated or re-united again.

Thus there appears to be no room at all in this simplified generic schedule for the ground crew to gain proficiency in using the GHE by initially running it through a few test cycles, nor even to simply familiarise themselves with the controls, by driving it around before the airship is attached to it. On the contrary it can now be seen that, even from this simplistic and superficial study, time for ground crew training with the real equipment is going to be extremely unlikely and it is most probable that the airship will be waiting to use the GHE as soon as the latter's construction is complete.

Obviously the prototype GHE will have to be fully tested somehow, before attempts are made to move the new airship around with it. The only question is: "When, in the NGVLA development schedule, is this testing going to take place"? And this of course then begs "who is going to do it?" which takes us right back to where we started. So the original GH question (Q2) remains to be answered: "How are the *ground* crew for the first prototype NGVLA going to learn the skills they will need in order to *handle* it safely and prepare it for its first flight?"

2.7 The problem of hierarchy and responsibility

There are however, some further problems with personnel which the NGVLA developers will also have to address. On the face of it many of these are not directly associated with GH, but the author's experience at CL revealed that the lack of experienced personnel at all levels, who were able to make reliable decisions, meant that the ground crew inevitably got drawn into these discussions. Yet again, assumptions and misunderstandings frequently led everyone back into the wilderness of indecision.

However, some of these problems are fundamental to everything that the NGVLAs are trying to achieve, and they add a whole new dimension to the developers' task because solving them is going to require a paradigm shift in thinking among regulators and the aviation authorities - and possibly even changes to international law! A good example of one such problem is the command hierarchy for any future very large airships and such questions as who will issue the orders and who will bear the ultimate responsibility for each and every operational decision when the airship is on the ground.

Indeed, the seriousness and intractable nature of these hierarchical "who-has-command" type of questions has already been recognised by several interested parties. These include potential NGVLA operators (The UK MOD) and the regulatory authorities (The German Luftfahrt-Bundesamt or LBA):

> "During the visit to Cardington [at the end of the Airship Association's 1st International Airship Conference at Bedford, England in 1996], a panel of experts was convened in an open forum, at the request of UK MOD (PE), to answer questions on airship ground handling and command and control." (Nayler, 1996:19/20)

> **"TAR AC255 Ground handling characteristics**
> The ground handling of airships is a classical problem area that needs to be notified with high importance.[*sic*] ... Further issues, that should be considered, are: Ground crew co-ordination: ground crew chief and responsibility sharing / hand-over between ground crew chief and pilot ... and ... on-mast / off-mast responsibility, ..." (LBA, 2000:25)

The problem here is that the GH of very large airships is so very different from modern aviation practice that the current rule books, whether they be for small blimps, or for HTA craft, cease to have much meaning. As shown above (in **Section 2.3**) the captain of one of today's blimps may be able to sit in the pilot seat and hold up his/her fingers to indicate to the ground crew chief how many sand/lead shot ballast bags need to be added (or removed) to establish the required take-off weight. However, this is not going to work when the two individuals are several hundred metres apart and the ballast is ten tons of water. Also, whereas it is logical for the captain of a jumbo jet to be in complete charge of the aircraft whenever the engines are running, things become a unclear when a large airship can lift off vertically and start its engines in mid-air afterwards - as was normal in the case of the *Shenandoah* (see **Section 2.4**)

Equally there seems little to be gained by the driver of the GHE winches, who is actually controlling the movements of a partially captured airship, to await the arrival of orders from an airship captain, who is strapped into a seat several hundred meters away, with his engines idling. Or, indeed, from a ground crew chief-cum-mooring officer who is standing, perhaps on the ground, or on top of the mooring mast, and who is nearly as far away, is equally as powerless to influence events, and in many instances cannot even see what is really happening. This will be all the more so, if, as seems likely, the GHE driver and the airship pilot are not only equally highly skilled to operate their very different machines, but are also both equally qualified and licensed to carry out their respective tasks.[1]

Thus, despite the fact that a well-disciplined, hierarchical structure is universally recognised as being absolutely essential for the safe working of the NGVLAs, at many stages of their foreseeable GH operations, the answer to the question "who is in command?" is currently ill-defined. Establishing who passes responsibility to whom, exactly when, and in a manner that all are immediately clear about, will be no easy matter. Convincing the regulatory authorities, that irrespective of its final form, this chain of command is safe enough to allow the NGVLAs to be integrated into today's overcrowded and heavily regulated skies, will also clearly be a challenge - but thankfully it lies beyond the scope of this study.

It must however be recalled that the previous generation of very large airships (PGVLAs) encountered these exact same problems and that their solution was a "Mooring Officer." It is a moot point where such an individual would fit into today's world, where the universally agreed rules of international aviation have successfully, and safely, shared the responsibilities, and all decision making and monitoring of flight preparations for HTA craft, between, the captain (on board the aircraft), the dispatch engineer (on the ground outside the aircraft) and the air-traffic controller (at a remote location).

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[1] The need for a licensing system for ground crew was discussed at CargoLifter after early rough estimates suggested that the driver of a mobile mooring mast large enough to handle an airship the size of the *CL160* would be in sole charge of a vehicle that weighed at least 600 tons.

Here again, those familiar with modern HTA aviation are apt to make sweeping assumptions, and it may well be that the answer for the NGVLAs is simply to modify the role of the dispatch engineer. Nevertheless actually carrying this out and getting universal agreement at international level for a reliable, tried and tested hierarchical structure that governs the transfer of responsibility between the flight and ground crews, and putting it into place prior to the first attempted test flights of the first prototype airship, is going to present a formidable obstacle which cannot simply be ignored. But, at least this problem has begun to be recognised, unlike a hitherto unacknowledged second facet of the hierarchy problem, which, in common with the aforementioned problems inherent in ground crew training, will also have to be faced by the first prototype NGVLA, and which will be at least as difficult to solve.

2.7.1 The conflict between pragmatists and theoreticians

The second facet of the hierarchy problem into which ground handlers are dragged is even more obscure. It stems from the fact that quite apart from their personal skills, the effectiveness of the ground handlers, in dealing with both the day to day operations of the NGVLAs, and with any crises that may arise, will also depend to a very large extent upon the actual physical configuration and properties of the GHE machinery they are given to work with – or more precisely, on the capabilities that are built into it. This in turn will be determined and governed by the knowledge of those who design and build it.

It is an obvious truth that the quality of work that can be done by any machinery, (even in the hands of the most highly trained, competent and quick-thinking operator), in terms of the flexibility of its use, and for example, of the possibilities of multitasking with it under a variety of perhaps unforeseen conditions, or in unpredicted circumstances, and of bypassing functions, or of substituting certain procedures and thereby permitting alternative ways of achieving its intended purpose to be employed, is governed by the requirements that are originally foreseen and provided for, by the aforesaid designers of that machinery. Thus the cost-effectiveness and safety of the NGVLA programmes really hinges on the designers of the GHE being fully aware, before they even start to design the prototype GHE, not only of all the GH problems liable to arise, but also where the deviations from the norm will most frequently occur. This, of course, they currently are not, and neither can they be in the foreseeable future.

However, in circumstances where the designers of both the NGVLA and its GHE are only too well aware of their lack of knowledge, as was the case at CL, one obvious solution is for them to turn for advice to those who have at least some experience of how airships behave in the real world – namely the personnel who operate the small blimps which are currently flying.

There is however, a serious philosophical point which needs to be noted here. It stems from one very fundamental difference between the designers and the end users of any piece of equipment. Design is inherently a creative process. If something is found not to work because the numbers "do not stack up" then a new idea can simply be conjured out of thin air and quickly substituted for the failed, theoretical concept without penalty. Moreover, a new device, which is not quite working yet is of far greater interest than something old that continues to work perfectly.

Operations, on the other hand, are quite different. The ground crew of an airship, for example, (and to a large extent also the pilots) have to deal with the real equipment in the real world – i.e. with those items which are actually available at any given instant, no matter whether they are in working order or not. The operators are thus forced to be pragmatists. If some component does not work when it is needed to then the groundcrew cannot wait around until a new bit of idealised equipment appears out of thin air. If they delay taking action when it is necessary, then almost certainly something will break, and someone may get hurt, and the airship could be damaged beyond repair or even lost altogether. Reliability is therefore a must. Defects and weaknesses in equipment are actively dangerous; as is delay caused by unfamiliarity. New devices are consequently treated with some suspicion and operators are generally keen to test new things until they break, preferably under controlled circumstances, simply so that they know where the failures are likely to occur when things begin to get out of control, (as their enduring experience with the perversity of inanimate objects has shown is always eventually going to be the case). Thus old and "inefficient" equipment, (even objects which are damaged or broken but which can still be trusted and relied upon to do a specific task), are not only looked on with affection, but are regarded as worth far more than something new and "more efficient" that is unknown and untested.

One way to differentiate between the two groups is to observe their very different instinctive reactions when confronted with an emergency situation. The operators will take anything that is to hand and try to adapt it to their immediate needs whereas the designers reach for their drawing boards and create a new tool specifically for the task that has arisen. In other words, there are those whose first reaction is to modify the "technique," and there are those whose instinct is to rely on changing the "technology," and as a result there is a fundamental conflict and a deep mistrust between the two groups.

Moreover, the conflict between these diametrically opposed world views is exacerbated by a further philosophical point that again is often overlooked. The ground handlers are the first real "users" of any newly designed airship. In other words, they start to break it. All design and production up to the time of their arrival is creative and constructive, but the very act of taking the airship out of its shed starts to wear it out. Indeed, it has the potential to destroy it. Consequently, many prototype airships, which have been lovingly built, have never made it out through the shed door. They have stayed safely in the hands of their designers, undergoing an unending series of improvements and modifications. There is thus a mental barrier that has to be overcome in order to accomplish this first usage of a prototype airship and the builders are naturally loath to let "their baby" out into the dangerous world of operations - especially in the hands of the "mad bad" groundcrew. Conversely, the ground crew need courage, determination and a thick skin in order to wrench the prototype away from the perfectionist protection of its creators and to start to test it and discover which bits wear out, break or fall off it, when it is first put to work.

Therefore, from the designers view, the operators are a bunch of bodgers and clumsy, mindless thugs who either ruin, or refuse to use, every new thing they are given. Whereas, from the ground crew perspective, the designers are a bunch of heartless and dangerous dreamers, who have little grasp of reality. They are forever solving non-existent problems with new-fangled gizmos that plainly won't work, while ignoring, or wanting to throw away, perfectly useable kit. Thus in general terms designers love problems and operators fear them.

Neither view is of course wholly correct but both of them do have a point, and of course both the over-optimistic theoreticians and the pessimistic pragmatists will have their vital parts to play in the evolution of the NGVLAs. However, this uneasy marriage between these two philosophically opposed outlooks is further compounded by the fact that, in this instance, there are really two completely separate teams of designers to contend with. Those who will produce the prototype Airship, and those responsible for the prototype GHE.

> "We are well supplied with designers of airships themselves and this needs to be paralleled by designers of robust and economic mooring systems." (Netherclift, 1993:7)

CL did attempt to fulfil this need, and what their efforts to provide both groups with the necessary information to design the *CL160* eventually revealed, is that the two design groups actually have rather different requirements. They also have separate agendas (as shown above in **Section 2.6**) and they ask different questions of those who have real experience of blimp ground handling. More to the point, there is no natural hierarchy to govern the interaction of the three groups. On the contrary there is a classic three-way split, which creates a vicious and time-wasting circle. This arises because, whereas, the airship designers can, and do dictate their wishes to the GHE designers, they can also be wrong-footed by "evidence" from the operators. The result is that the designers of the GHE get caught in the middle. They are forced to accept the decisions of the airship designers but cannot use this authority to dictate their own decisions to the operators, because, if the operators don't like what they are presented with, then they can go over the GHE designers heads and take their case back to the airship designers. Being ill-equipped to contradict the voice of experience, the airship designers will tend to accede to the operators' wishes thereby creating a situation where no-one can ever have the final say.

At CL people from all three teams were going around this loop in both directions with everyone blaming someone else for not giving them the information they needed or for not listening to what was being said. Thus the difficulty of establishing a hierarchy, to settle the arguments and differences of opinion which naturally arise when these conflicting groups are brought together to attempt the design of the first prototype NGVLA, should not be underestimated. Especially when other groups, who have further different ways of seeing how things ought to be done in an ideal world, are bound to get involved too.

For example, there are the accountants, whose natural instinctive tendency is to prefer the cheapest (and thus usually the quickest) possible solution to every question. This frequently brings them into conflict with the operators (who tend to place quality and performance above cost) and the designers (whose creative processes and calculations cannot always be hurried). Then there are the production/construction team, whose practical knowledge of assembly methods allies them naturally with the pragmatists, but whose specific lack of experience with the construction of very large airships leaves them vulnerable to the whims of the theoreticians and the diktats of the accountants.

All this adds up to a morass of constantly shifting alliances with the different groups circling around the unpalatable but historically proven fact that it is perfectly possible to design an object on paper which will not work in reality, (1-0 to the pragmatists). Plenty of airships that cannot be either assembled or inflated have been designed in the past.[1] This of course has the potential to waste very large amounts of time and money. Equally, it is also often overlooked that on occasion, it is quite possible to save a significant amount of time and money later on, by using equipment in a way that was never intended, and for a purpose never originally envisaged nor even conceived of, by its designer, (2-0 to the pragmatists).

So, clearly, for the NGVLA development projects, design must come first, but it must be recognised that it cannot be successfully completed without feedback from the operators. Furthermore both groups need information from each other and obviously will need input from many other groups of specialists. However, without a hierarchy in the design authority and someone to call a halt to the design process then it becomes prey to a series of interlocked feedback loops, which can continue forever – or at least until the money runs out.

2.8 The problem of substituting automation for skill

One final problem centres on the fact that the NGVLAs will be forced to use equipment for which there is no precedent.

> "In the early days of airships large teams of ground handlers were relied on to hold the craft steady as it was 'walked' into and out of its hangar, or when it took off and landed. Anyone who has seen an old film of an airship near the ground will have noticed these often vast teams of men swarming around like ants as they handled the lines from the ship, but in the 1990s wages are no longer reckoned in shillings per week and – certainly for a large airship – such labour intensive methods are no longer economic. Mechanised handling will be essential." (Netherclift, 1993:13)

Here again, we have a perfectly sensible statement, which, on the face of it, few could find reason to disagree with. And yet, as with the statement by Howe, (previously quoted in **Section 2.5** above), concerning the advantages of using the mooring masts to move the airships around, the assumptions and implications are far-reaching. For instance, the old saying "the higher the fewer" inverts and comes home with a vengeance, because plainly the fewer groundcrew members there are going to be, the higher the level of individual competence, and the greater the number of diverse tasks each will need to be capable of carrying out. Thus, here is a case where quantity and quality are directly, inversely proportional. Furthermore, reducing the numbers of personnel must not only increase their level of necessary skill, but it must also involve the use of more, (and of more complex), equipment as well. However, if any piece of machinery is increased in size, or in speed, or in the number and variety of simultaneous tasks it can carry out, so then the need also increases for the driver/operator of it, not only to have a greater understanding of, and capability to, monitor what is actually going on at any one time, but also, to posses the foresight, and the abilities, (along with the quick reactions, the communication skills and the manual dexterity), to take effective mitigating action whenever operations start to deviate from the norm.

This means that the driver (or operators) of the NGVLA ground handling equipment (GHE) will indeed have to be the very highly trained and multitalented individual(s) who were shown to be necessary in **Section 1.2** above. But it also means that the degree of training they will need in order to become proficient, prior to the first operations of the prototypes, must be directly proportional to the sophistication and complexity of the machinery they are given.

[1] There are numerous examples among the designs registered at the Patent Office. (See Appendix G)

Therefore, the more the GHE is capable of doing, the longer it will take to design, and the more expensive it is going to be, both to build it and thereafter to train its operators. It would therefore seem most sensible for the NGVLA project managers, who will perforce be dealing with inexperienced personnel at all levels of design and operation, when faced with an untested prototype airship, which is totally dependent for its survival upon unproven prototype GHE, to keep things as simple as possible to start with. Initially they would be well advised to restrict "multitasking" and to utilise instead a diversity of specialist expertise in a multitude of separately trained and easily interchangeable people.

2.8.1 The difference between knowledge and ability

A second facet of this same problem was also manifest at CL, where there was, in many instances, a failure to truly appreciate the vitally important difference between knowledge and ability. Again this may appear to be a rather trivial point, but in the author's experience, the fact that entire departments were apparently unable to grasp it led to a considerable waste of time and effort.

Perhaps it is an easy mistake to make? For example compare the apparently subtle distinctions between:

a) knowing how an airship works in principle, and
b) knowing how to design, build and operate a specific airship.

Now consider the rather more obvious differences between:

c) knowing how to design a proven, tried and tested airship,
d) having a workforce with the necessary skills to construct a proven, tried and tested airship, and
e) having trained crew who are licensed to operate a fully-certified, modern small blimp safely and reliably in all weathers.

Then see how in reality the subtle distinctions add up by small steps to a yawning chasm when it comes to the difference between an enterprise that is capable of c) and d) and e), and one that:

f) owns a detailed design [1] for something that although it look may look like an airship, has never actually ever been assembled, (let alone flown), and
g) has a workforce able first to build, and then to operate a gigantic, unproven, prototype airship in perfect weather conditions, and
h) has trained staff who are competent to carry out unprecedented manoeuvres with the largest flying object ever built, in a cost effective manner, without endangering the public or interfering with other users of airspace – as is fundamental to the success of the NGVLAs.

What this emphasises is that knowing *how* to do something, does not guarantee proficiency at it. Only "practice makes perfect." Similarly, knowing how to use an object, or how it should be used, is a very different thing from knowing how to design it, or how to assemble it, and, these are different again from having hands-on previous experience of, and of being really adept at, actually *doing* any of them. This is the difference between being virtuoso or a novice. Thus, for the first prototype NGVLA, it has to be borne in mind that even if we knew what to do with it, and how things should be done, it still might not be possible to actually do them.

[1] N.B. This includes old-fashioned two-dimensional blueprints, ultra-modern three-dimensional CAD drawings, and any future possible fully-orchestrated, computer-generated "virtual reality" images.

So, although it is true that skill in general is based on knowledge, and knowledge can be increased by the acquisition of a skill, it is also important to realise that knowledge can, and frequently does, exist independently, without there necessarily being any skill or proficiency at all. Furthermore, this is in contrast to the reverse case, where skill without knowledge is an exceedingly rare thing.[1] In addition, it should not be overlooked that there is a great deal of difference between ignorance and incompetence- even though the results may often be the same. Nevertheless, it is equally possible for an ignorant, inexperienced and unseasoned, beginner to be both competent and well-trained, while an acknowledged master, or a veteran practitioner, may on occasion be both clumsy and inept, and thus incompetent, perhaps by reason of being out of practice and thus "a little rusty."

This harks back to the point previously made above (**Section 2.7.1**) concerning the conflict in outlook between the theoreticians and the pragmatists, and the fact that it is perfectly possible to design on paper an object which will not work in reality. However, what seems not to be appreciated by many NGVLA enthusiasts, and what seemed often to be overlooked at CL, is that it is also perfectly possible for the inexperienced NGVLA development teams to inadvertently make this same mistake at every step along the way. Thus they may unwittingly:

i) design an airship that cannot be assembled, or
j) assemble an airship that cannot fly (or does not fly very well),[2] or
k) design, build and fly a thoroughly good airship that cannot carry a worthwhile payload, or
l) do all the above, and carry a worthwhile payload in perfect safety, only to find they require an infrastructure with a capital outlay and GH overheads that are not cost effective.

All these have been done in the past. Moreover, returning to GH, it is perfectly possible, at the outset of a project, for planners and managers who are lacking in large airship experience, to decide, for example, to the best of their abilities, the numbers of personnel needed for an idealised (or affordable) NGVLA ground-crew, only to find in reality that the members of it will either be totally over-loaded with work, and thus physically exhausted, or under-used and bored mischievous, or misplaced at key times.

The vital difference in all these things is the skill of the personnel doing the work and making the decisions. This collective skill can only come from a mixture of the team members' long term, past experiences and their recent currency in rehearsing, or in practising, their specific tasks. Thus, whereas the NGVLA designers need skill at designing similar equipment, (and a thorough knowledge of NGVLA systems,) in order to create their designs, the operators need knowledge of the precise NGVLA GH procedures, in order to become skilled at doing them. Evidently, the two groups are facing in very different directions, and proud of it, as exemplified by this:

> "[Barnes] Wallis saw creative engineering as an art and ... and accepted without reservation Einstein's observation that 'imagination is more important than knowledge' ..." (Morpurgo, 1972:xv)

Tell that to an airship ground crew who are wrestling with a flailing rope on a dark night in a wet and windy field. Obviously the knowledge of how, and the ability to quickly tie, without being able to see it, a knot that will not slip, and which can be untied again easily on the morrow, is far more important.

[1] An exception perhaps being child prodigies and autistic savants - neither of which groups sadly seem to have produced individuals who are able to work reliably as team members within a disciplined workforce.
[2] As per the "dud" ship pre-supposed by Lord Ventry (see Section 1.1)

Thus the set of problems facing the NGVLA designers is different from that concerning the operators and much of the misunderstanding between them, and the failure to distinguish between knowledge and ability probably stems from the simple fact that the NGVLA prototype designers are lacking knowledge, but the operators are lacking skill.

A further misunderstanding arises because, contrary to the designers' "technology based" view, the "technique-practising" ground crew are essentially flexible in outlook. They have to be in order to cope with such everyday, real-time events as the vagaries of the weather. Consequently, they will quickly "adapt, adopt and improve" new procedures, provided three things can be assured:

a) it is proven to be safe to do so, and
b) there is adequate and reliable equipment to do the job, and
c) the personnel are allowed sufficient time to become proficient and confident.

However, as already stated above (see **Section 2.5**) "GH does not exist for its own sake. The procedures involved are a response to the actual needs of the airship and consequently, the training of its ground crew must depend upon any specific airship's real requirements." Thus it is only after a frozen design exists that it is possible to work out exactly where to hold an airship, and how to move it, and what materials, (i.e. fluids, gases, consumables, etc.,) need to be delivered, to which locations, in what quantities, and at what speed. Furthermore, it is only when these facts have been established that it is possible to work out how many people are going to be needed to carry out the GH tasks, and what skills they will require individually, in order to guarantee their own safety, and to ensure both the physical and commercial survivability of the airship. And finally, it is only after all of this detail is known that it is going to be possible to devise a system for training the prototype NGVLA personnel to carry out their tasks, reliably, safely and cost-effectively.

Therefore, it can now be seen that there is also a quite separate "Skill Gap" to add to the "Knowledge Gap," and that both of these must somehow be bridged if the NGVLAs are ever to fulfil their suggested roles as solutions to some of the world's most pressing transportation and communications problems. In other words, the airship's potential to carry cargo in the future, while utilising minimal amounts of fuel and comparatively small areas of land, and thereby allowing the continued expansion of world trade, without creating a lot of noise, or significantly adding further damage to the Earth's atmosphere, actually hinges upon the urgent need to come up with a reliable, safe and cost-effective answer for both of the "Big Questions" (**Q1** and **Q2**) which were identified at the start of this work.

2.9 Summary of the problems

It can now be seen that all future attempts to develop the NGVLAs will be faced with, and put at risk by, the same set of inter-woven, intractable, insidious, and frequently ignored problems. Namely:

- Many of the NGVLAs' normal operating systems are unparalleled in modern aviation practice
- Some procedures envisioned for the NGVLAs are unprecedented in the history of airships
- GH accidents have been a very serious threat to all airships in the past
- The GH of all types and sizes of airship is totally dependent upon highly skilled personnel
- There are no experienced personnel to pass on the required skills to the NGVLA ground crews
- GH is a neglected "Cinderella" profession and the importance of it is commonly underestimated
- Current procedures for GH small, modern blimps cannot be scaled up because they are inappropriate
- Simulations cannot solve the NGVLA GH problems because there is no data to base them on
- The GH of any airship is too complex and unquantifiable to be accurately or usefully simulated
- The NGVLA prototype GHE will not be available for groundcrew training
- The hierarchy and the hand over of responsibility between personnel groupings is ill defined
- Conflicting views of designers and operators confound prototype GHE design decisions
- Skill cannot simply be replaced by automation and this has a big impact on crew training

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3 THE SEARCH FOR SOLUTIONS

The problems described in detail in the previous section were not clear to the author, nor, indeed, to anyone else at CargoLifter, in the early days of the airship development project. The full scope and the complexity of them, along with the reality of the threat that they will inevitably pose to any future NGVLA projects, were only fully realised after the company collapsed in the summer of 2002. All that anyone was aware of at the time was that trying to design the GHE for the prototype *CL160* was extremely frustrating because there were innumerable, unanswerable questions (see **Section 2**), and the absence of reliable answers to them kept leading everyone round in circles.

3.1 CargoLifter and the circular arguments

From the author's perspective, inside what was most commonly known[1] as the "Operational Support" department, these complex and well-worn circular arguments went something along these lines:

- The Ground Handling Equipment, (GHE) which will be required for the *CL160* is entirely dependent upon the actual needs of the airship.
- The needs of any airship are themselves dictated by two things - the type of airship it is (i.e. the physical structure) and its purpose (i.e. the job it is built to do).
- The *CL160* airship type, has still to be defined, but its intended purpose is known - it will pick-up and transport large and/or heavy weights.
- However, any airship's ability to carry out its intended purpose in a cost effective way is also dependent on two things - the actual equipment with which the airship is fitted, and the skill of the personnel who operate that equipment.
- To some extent these two things are mutually exclusive in that the more experienced and highly skilled the crew become, the more ingenious and flexible they will be at adapting, and making up for, any lack of, or deficiencies in, the equipment they are provided with. Thus, perversely, the more highly skilled the crew are, the less sophisticated or specialised the airship and its associated equipment needs to be.
- But, both air and ground-based equipment for the *CL160* have yet to be decided. Therefore everything rests on the skills and abilities of the ground crews, and the flight personnel, and on their collective capability to operate the technology safely and efficiently.
- However, the efficiency of any group of individuals can only depend on their level of personal experience and/or training. But, the first of the *CL160* crews will inevitably be in-experienced at the outset for two reasons. 1. There are no large airships for them to have experience of, and 2. There is no one available for them to learn the necessary skills from. Thus the individual crew members will have to rely exclusively on their training.
- All training, however, depends on repeated rehearsals of known procedures, and these in turn are composed of an agreed sequence of tasks which have been demonstrated to be absolutely necessary.

[1] During the company's existence the name of the department responsible for ground handling the *CL160* changed several times.

- But the actual tasks that will make up *CL160* GH procedures will depend largely on the operational systems that the airship will use and have therefore still to be decided.
- Nevertheless, the operational GH systems for all airships must consist of three items: the infrastructure that is available on the ground; plus the equipment on board the airship; and personnel with the necessary skills to use them both.
- However, the GH equipment onboard the *CL160* is TBD, and both flight and ground crews are unskilled, and furthermore they cannot be trained until their tasks are defined. Therefore everything must rest on deciding and designing the GH infrastructure on the ground.
- But this infrastructure, whatever it is, must be limited by cost, and this can only be kept within reasonable limits by providing the minimum amount of basic machinery that is absolutely necessary to handle and support the airship.
- This, however, is dependent on the airship's specific requirements, and the *CL160* requirements will depend on the type of airship it is, and on the tasks it is designed to perform, ... and so on, *ad nauseum*.

What this, and similar discussions with colleagues, revealed to the author, in numerous vain attempts to progress the GHE design of the *CL160*, is that there are essentially three necessary elements that are intrinsic to any GH systems for all airships. There is the hardware, there is the software and there are the people (sometimes rather inelegantly, but usefully, termed the "wetware").

- <u>The hardware</u> is the actual machinery, the bits and pieces of GH equipment. This is divided into two physically separate component parts, which must meet at a common interface. These are:
  a) the GHE which flies on-board the airship, and
  b) the GHE and infrastructure which remains on the ground.
- <u>The software</u> is the sequence of procedures, which comprise the system, or systems, that use the hardware to accommodate the airship's needs - i.e. whether it makes a horizontal or a vertical landing; whether, after landing it is moored to a mast or is "walked" directly into a hangar; whether entry into that hangar is done by manual or mechanically assisted means. These systems, or alternative methods, consist of one, or more, sets of instructions for sequential and concurrent tasks. They are largely governed and constrained by the physical limitations, and the designed capabilities, of the hardware, but their effectiveness and the efficiency of them are wholly dependent upon the third component -
- <u>The wetware.</u> These are the highly skilled practitioners who use the hardware to run the software, and upon whose individual abilities, and levels of competence, the whole enterprise rests. The important point is that differently skilled personnel, given identical hardware and the same instructions, are capable of manipulating it differently – i.e. more or less effectively, efficiently, safely etc., - in order to achieve the same goal.

The problem for CargoLifter was that they did not have any of these three components. There was no GH infrastructure, there was no consensus on a reliable GH system, and neither were there any skilled personnel with the necessary knowledge to carry out the *CL160* GH operations safely and cost-effectively. Had the company had only one of the three components it would doubtless have been possible, using a combination of modern techniques (such as reverse-engineering, programme planning, targeted training, etc), to either, adapt things to fit, or to work out a way to use, or to learn the necessary skills with which to reconstruct, the other two. However, without any of them there was (and still is) a closed circle, and notwithstanding their aggressive policy of head-hunting some exceedingly talented personnel, (plus a more than adequate supply of financial back-up), CargoLifter could find no evident way to break through this circle - despite more than five years of effort.

During this time, it became clear to the author, that at CL, two groups – the "hardware" designers and the "wetware" operators - were each blaming the other for not supplying them with the vitally necessary "software" information. Both groups needed it but neither they, nor anyone else in the company, possessed it, and to the mutual frustration of all, this was ultimately to the detriment of the entire project. Furthermore, it is hard to see how any future NGVLA projects are going to avoid this same trap or indeed how they can ever hope to succeed ultimately without all three of these elements.

3.2 The CargoLifter Operational Support Historical Research Project

Although the full impact of the "Knowledge Gap" and the complexity of the problems that stem from it, were not fully appreciated in the early days of the CL project, nevertheless a suggestion was made, in 1998, that did have the potential to break through the closed circle. This idea was put forward in an attempt to speed up the *CL160* development process and it was based on the fact that, although the US Navy blimp programme had long been terminated, some airships did actually continue in operation until the mid-1960's. Consequently, in 1998, there were still people living in America, who had first hand experience of the large Navy blimps. Although by this time they were quite elderly, many of them were more than willing, and perfectly capable of passing on some of their tips and tricks to the next generation.

Thus the availability of the three vital components that had survived from past airship development projects, at the start of the CL development project, could have been be summarised in this way:

Types of Airship	Date of operations	Hardware	Software	Wetware
British WWI blimps	1910 – 1919	No	Yes*	No
PGVLA rigids	1900 – 1939	No	Yes*	No
US Navy WWII blimps	1940 – 1965	No	Yes*	Yes**
Small modern blimps	1970 – today	Yes	Yes	Yes
NGVLAs	?	No	No	No

No = Non-existent : Yes = Extant : * = Information held in archives
** = Hands-on knowledge fading fast

TABLE 1 - AVAILABILITY OF SURVIVING COMPONENTS IN 1998

While this table did not exist until drawn by the author specifically for this thesis, nevertheless, there was at the time an appreciation of the situation by the core group of CL personnel who were charged with solving the *CL-160* GH problems. The suggestion was therefore made that, instead of embarking on the construction of an entirely new, and completely unproven, type of airship (as a proof-of-concept for shareholders, and a learning device for the workforce,) the company would be better advised to start by building a revised, or "updated" version, of the last, and the largest of the highly successful US Navy blimp series – the *ZPG-3W*.

This idea, which came from one of the company's influx of new employees who did have previous LTA experience, was presented to CL management as a study paper, (Hochstetler, 1998).[1] In it Hochstetler argued that such an airship, which would have been much bigger than anything currently flying, then or now, having approximately one tenth of the disposable lift of the *CL-160*, could rather conveniently be used as a scaleable test airship. This would permit the testing and development of some of the novel component parts, and also of the unprecedented procedures intended for utilisation on the *CL-160*, at far less cost and risk than the real thing, with the additional benefit of potentially saving a lot of time in the long-term development schedule.

What Hochstetler did not say, and, what seems subsequently to have been missed by those who evaluated the idea, was that, if used in conjunction with the co-operation of the US Navy's surviving, blimp-experienced personnel, the updating of a proven design of airship would have provided, not only a short cut to the acquisition of real knowledge, which derived from tried and tested "large airship" techniques (for both the CL design and assembly teams,) but would also have allowed the transfer, under personal tuition, of operational skills to both the flight and the ground crews.

Unfortunately, and somewhat naively from the author's perspective, Hochstetler's plan was summarily dismissed, even as a subsidiary project, and CL opted instead to continue with their own experimental prototype blimp, (the highly innovative, but diminutive, "*Joey*") and to rely on a combination of modern analytical techniques - in conjunction with a considerable investment in computer simulations. This course of action cost a lot of money and, as was foreseen, did little to enhance the company's knowledge of the behaviour of very large airships in reality. Nor, indeed, did it add anything much to the skills of the personnel and their hands-on experience with the construction, handling and operation of large airships..

However, the rejection of the Hochstetler plan was not the end of the matter because the discussions within the Operational Support department, that had led up to its submission, had derived from a previous report written by the author, and a group of like-minded colleagues,[2] in which it had been demonstrated that a further possible way of progressing the project, and of perhaps attacking the tide of GH related unanswerable questions, was to use Historical Research (HR) to investigate how some of these same (or certainly very similar,) problems must already have been solved by the previous generation of very large airship (PGVLA) development projects in the 1930s.

The original intention, in suggesting Hochstetler's plan, had been that it would be run in conjunction with a properly funded, professionally handled HR study project. This 'three-pronged attack' of searching out written material lying forgotten in PGVLA archives, and combining it with remembered hints and tips from the survivors of the US Navy blimp programme, to help build and fly a "modernised" large blimp of a proven design, and thereby to collect reliable first-hand information, would have maximised the company's chances of quickly retrieving as much as possible of the aforementioned three vital knowledge components (see **Table 1**) as had survived from previous attempts to develop large airships.

[1] Hochstetler, 1998 : Questions regarding a ZPG-3W rebuild
[2] Camplin, Bischet & Watson, 1998 : Preliminary outline for ground handling CL-160

Behind the suggestion of an HR project lay the premise that there is every reason to believe that any new very large airships will work quite satisfactorily today, (and at any time in the future,) simply because such aircraft are known to have worked perfectly well in the past. In fact, one of the previous generation giants [*LZ127 "Graf Zeppelin"*] flew around the world in the 1929, and clocked up more than a million air-miles in its 590 lifetime flights. So the airships themselves are unlikely to be a problem. The problem for the NGVLAs is that there are no GH facilities for Large Airships (LAGH). Indeed the author made the point that were the *LZ127* to magically reappear in the sky today, it would almost certainly come to grief, as there was (and is) no place on earth to which it could be directed, where there were either any facilities, nor the expertise, to enable it to land safely. Furthermore, the GH infrastructure that had supported the triumphs of the 1930s had been built up incrementally over a 30 year period of experimentation, whereas CL would have to develop the GH infrastructure for their *CL160* in its entirety, from scratch.

In support of the argument that HR might offer a possible way of assisting in this formidable task, or at least give CL some insight into the GH problems they were facing, the Operational Support team, in their report, turned the idea of a time-travelling *LZ127* around:

> "If, for example, we actually had a prototype *CL160* in flight, where, in history would we choose to go with it? Where could we expect to make the safest, quickest, cheapest and most trouble-free landing? In other words, who in history has come closest to our currently envisaged plans? How many men did they use in the mooring process? Where did they stand? What hand tools did they use? What were the limitations of wind speed? What was their emergency fall back procedure if a major component broke at a critical moment? How did they really get the airships in and out of their hangars?" (Camplin, Bischet & Watson, 1998)

Here can be seen in embryo some of the difficult questions which were already starting to preoccupy the department at the time. Moreover, the preliminary report, for what was to become the CargoLifter Operational Support Historical Research Project, (CLOSHRP) incorporated a further hope that it might be possible, by means of such an investigation, to find ready-made solutions – at least to some of them:

> "If we could unearth their actual hand books, or better still the orders and instructions that both the air and ground crews were working to, at several potential historical "safe havens," then we would have in our possession tried and tested procedures that we know actually worked. Not just some best guess theories but the end result of many years of hard learned experience. Men were actually killed and injured getting this knowledge. Their rule books would give us at the very least a solid basis for compiling our own landing sequence and maybe even provide us with ready written complete procedures for problems we have not yet thought of when it comes to servicing and ground handling the *CL160*. The value to us of this information in terms of cost and time saved would obviously be enormous." (Camplin, Bischet & Watson, 1998)

This latter hope proved to be somewhat over-optimistic, and it later came to be regretted by the author as, within the minds of some people, it caused much misunderstanding as to the actual purpose, and potential scope, of the HR project (see **Section 4.1**). Nevertheless, the weight of the argument was sufficient to convince some decision-makers within the company that an historical research project was worthy of pursuit, and notwithstanding their complete lack of previous experience with, or indeed qualification for, conducting such an investigation, the Ground Support team was instructed to continue the collection of such historical material on LAGH as could be found.

In view of the fact that this thesis is based on much of the early work from what came to be called the CargoLifter Operational Support Historical Research Project (CLOSHRP) it is deemed appropriate to pay brief attention here to some of the problems and processes involved in it.

3.3 The feasibility of an Historical Research (HR) project

In seeking to persuade CargoLifter of the feasibility of an HR study of large airship GH it was necessary to establish two things. Firstly, that in general, by such means, there was a precedent for the retrieval of lost knowledge (and/or the resurrection of extinct skills) and secondly that there was likely to be a sufficient quantity of pertinent information that could be retrieved within a reasonable time-frame.

3.3.1 Is there a precedent for the retrieval of lost skills?

It has been argued that the true wealth of the world is the continuing acquisition of know-how:

> "Energy cannot decrease. Know-how can only increase. It is therefore scientifically clear that wealth which combines energy and intellect can only increase ..." (Buckminster Fuller, 1969:288)

Furthermore, it has been declared by the same author that such knowledge/wealth is indestructible:

> "The physicists make it very clear that energy can neither be created nor destroyed. You cannot exhaust that kind of wealth. ... Even when we only learn that something we thought might work won't work, that's learning more! Every time we make an experiment we learn more, we can't learn less." (Buckminster Fuller, 1969:109)

But, we can forget - and collectively, the whole of humanity loses when know-how is forgotten or a rare technique is lost. The death of the last surviving practitioner of any "difficult," "arduous," "complex" and/or "obscure" discipline, in which proficiency can only be acquired by way of a long-lasting, or physically demanding apprenticeship that involves non-intuitive or non-logical processes, has consequences for all succeeding generations.[1]

However, in terms of the knowledge and skills acquired in the past, for the operation of old or out-dated vehicles, nearly all the forms of transport that have ever been devised, are still being operated, somewhere in the world today. Furthermore, where a system has been superseded, the old know-how usually [2] survives because adherents like to "keep their eye in." Thus coal-fired railway engines still pull trains, wooden-hulled "tall ships" still sail the seas under canvas and wooden airplanes are still flown for fun by experienced enthusiasts. There are also numerous events and rallies where horses pull carts, and veteran cars and steam traction engines are put through their paces; but all of this is only possible because the expert skills to operate these vehicles have survived - and here again there is a feedback loop. The very existence of these machines, in working condition, allows old hands to "have some fun" and keep their operational skills alive, while the fact that there are people with these necessary skills means that the machines can be kept in working order and thus new personnel can be trained to perpetuate the cycle.

Nevertheless, keeping in mind the NGVLAs, the task of building a completely "new generation" of bigger and better steam trains, or of even taller tall-ships, would not be quite so easy without the experts; also because many of the original manufacturing techniques have now died out, or become rather rare.

Here again, however, the continued existence of the machines themselves, in full working order, would be of some considerable assistance to new age designers, and in this respect, all airships, and particularly the

[1] "Take our 20 best people and virtually overnight we become a mediocre company." (Bill Gates, Microsoft)

[2] This is not invariable and notable exceptions include, for example, the Greek and Roman galley-ships rowed by slaves.

VLAs, are peculiarly disadvantaged. Their sheer physical size and the unavoidable cost of keeping them buoyant – helium costs a lot more than pumping dry a watertight hull – makes the use of airships, for fun-flying by groups of amateur enthusiasts, all but impossible. If left to their own devices for any length of time, airships lose their lifting gas, simply because it either percolates away or loses its purity due to pollution from the ingress of air and/or moisture.[1] But even if the lift could be guaranteed, the cost of keeping such necessarily gigantic and intricate structures in fully-certified, flyable condition would be prohibitive. Consequently, with large airships there is a gap; there are none in existence, and the skills to operate them have died out.

It should however be noted, that airships are not unique in this [2] and that other skills in completely different areas of human endeavour have previously died out altogether. Moreover, in the recent past, some skills have also successfully been re-captured from the edge of extinction. Dry stone walling and the thatching of cottage roofs are good examples of revitalised skills that have been brought back from the brink. Lost languages are probably an even better-known example, but there are many others, and a brief excursion into the realms of archaeology reveals, not only that the vital part played by "know-how" when putting knowledge into practice, has now been widely accepted within the discipline, but also that HR has previously been used successfully as a method of retrieving lost skills.

One or two specific examples will illustrate the point while also revealing the magnitude of the difficulties encountered, and offering some caveats for future attempts to recover knowledge and skills of VLA GH by similar means. Thus:

- In agriculture:- "The methods used ... to reproduce ancient materials should not exceed those presumed to have been within the competence of the contemporary society. This presupposes a detailed knowledge of ancient technology ... because sometimes ... experimental work is conducted with 'primitive' tools handled in an inexperienced and therefore inefficient way, and this can reduce the value of the work ...Digging with antler picks and chopping trees with stone axes are both unaccustomed exercises for modern man ... and the need for practice before recording efficiency tests is clear." (Coles, 1973:15/16)

- In cooking:- "We must conclude that cooking in a skin or paunch is possible, but that it requires some experience on the part of the cook, and it is likely that there are several small tricks of the trade that are necessary to ensure success." (Coles, 1973:52)

- In the playing of musical instruments:- "These instruments [Mayan ocarinas] ...are fortunately limited in their potential range of notes, and through experiment we can say with some confidence that the sounds, or some of them, that we hear were heard by ancient man; more than this we cannot say. ... The recent recording of a Rumanian peasant playing on two barley stalks must surely point to the irretrievable loss of evidence for music that must have existed in the Balkans for perhaps 5 or 6 thousand years." (Coles, 1973:161)

- And finally, in engineering:- "Throughout both Old and New Worlds the traces of ancient man include evidence of his skill as an engineer ... The statues on Easter Island in the Pacific are up to 60 tonnes ... [they were] fashioned from the solid rock, and man-handled into place ... an experiment ... to see how difficult it would be to actually raise the largest fallen statue ... occupied 12 men for 18 days ... [and] required very considerable expertise and judgement." (Coles, 1973:82-94)

[1] Jones, & Thach, 1995 : The transmission of water vapor through aerostat hull material and the effect on buoyant lift

[2] For example - only a hand-full of pilots still retain the ability to fly aircraft that are powered by rotary engines.

In this latter enterprise, the Norwegian archaeologist/adventurer Thor Heyerdahl, (who famously wrote several best-selling books detailing his attempts to reclaim lost knowledge from ancient civilisations), [1] was greatly assisted by the fact that, at the time of his statue-raising experiment, the necessary know-how lay just within the range of living memory of the local people. Thus information concerning the techniques needed to complete the work could be passed by word of mouth. However, of greater relevance to this thesis, Heyerdahl's subsequent work on the possibility of prehistoric ocean crossings using balsa-wood rafts and reed boats, proved to be the most successful of all his attempts to regain the lost skills necessary for the operation of an extinct transportation system. Here is his problem:

> "When a pharaoh wanted a boat built he had no special problem. His skilled boat builders knew everything about papyrus and papyrus boats, after generations of experience. His labour force was unlimited and the building materials grew in boundless numbers just outside the palace gates ... But that was long ago. ... When the papyrus disappeared from the banks of the Nile the last Egyptian master of the art of building papyrus boats also faded away for ever." (Heyerdahl, 1970:87)

The results of Heyerdahl's empirical experiments are well-known. His first reed boat, *Ra I* failed and sank in the Atlantic, but *Ra II*, built with greater knowledge by more experienced reed-boat builders, reached the Bahamas. However, the proof that Heyerdahl's success in these projects was founded on his prior application of a thorough, wide-ranging and in-depth study of the historical records can be found near the start of one of his earliest books - "The *Kon Tiki* expedition."

> "Useless as it is to try to interpret the thoughts and actions of a primitive people by reading books and visiting museums, it is just as useless for an explorer of our time to try to reach the horizons which can be contained in a single bookshelf. Scientific works, journals from the time of the earliest explorations, and endless collections in museums in Europe and America offered a wealth of material for use in the puzzle I wanted to try to put together." (Heyerdahl, 1956:15)

> "In the library I dug out records left by the first Europeans who had reached the Pacific coast of South America. There was no lack of sketches and descriptions ..." (Heyerdahl, 1956:26)

Therefore, it would seem that there is a successful precedent for the resurrection of extinct knowledge by means of an HR project and that skills too may be re-acquired when the information retrieved is used in conjunction with empirical trials. Giving further cause for optimism is the fact that Heyerdahl was attempting to retrieve knowledge that was lost thousands of years ago whereas the skills that appear most useful for the NGVLAs have disappeared in the last 75 years. Furthermore, there is evidence that careful study of recent past endeavours in the field of LTA has previously borne fruit:

> "...Renard and Krebs had studied all the contributions of their predecessors, and had adopted any ideas that seemed to have merit. Theirs was not a vague idea, translated into reality without any reference to previous successes or failures in the same field. Most carefully had they studied and planned; and the results showed the value of all this care. ... in *La France*, for the first time in history ... a true dirigible balloon followed a fixed course and returned to earth at the point from which it had departed." (Hylander, 1931:112)

3.3.2 Is there sufficient information for a viable HR project?

The second thing to consider, prior to embarking on an HR project, was whether sufficient information was likely to be available. Obviously, in the specific case of large airships, having too much information to sort through, would be as much of a problem as there not being enough. Recourse to one or two books revealed that there was unlikely to be a problem with too much information.

[1] E.g. "Kon Tiki," "Aku Aku," "Ra" and "Tigris."

"It appears that about 850 pressure airships [blimps] were built between 1900 and 1970. ... The figures for rigid airships between 1900 and 1940 are predictably smaller and rather better defined ... The total appears to be 162." (Mowforth, 1991:14)

While, not all sources were in absolute agreement with these numbers, and for example, Mowforth's total number of rigid airships is somewhat less than those listed by Robinson (1973) in his Appendix A, or by Brooks & Griffin (1973:50) (who give a "total number of configurations launched = 178") nevertheless, regardless of how the calculation was done,[1] it was apparent that the number of airships ever to have previously existed was not very great. Something over 1000 would seem to be a reasonable approximation and of these, fewer than 180 [2] could properly be said to be "large" airships (see Definitions in **Section 5.3.1**). Thus it was decided that there was likely to be sufficient information available for study without the project being either overwhelmed with data or unduly protracted. However, in both cases, this anticipation subsequently proved to be somewhat over-optimistic.

3.3.3 Identifying potential sources of historical information

Having established that sufficient information probably existed, the next problem was where to begin to look for it? Returning to the same historical reference books wherein were found the numbers of previously extant airships, there were also to be found further statements as to their origins:

"... 27 of these [rigid airships] were built before World War I (1 French, the rest German), 115 during that war, (8 British, the rest German), and the remainder between the Wars (3 US, 8 British, 7 German) The figures show that almost 90% of all rigid airships were built before 1919, and that a similar percentage of the total originated in Germany - mostly as Zeppelins." (Mowforth, 1991:14)

From this, and similar reports, it was possible to establish a fairly clear picture of where the main PGVLA projects had been centred, and thus to identify those countries where the greatest experience of GH was most likely to have accrued. Taking firstly the blimps and then the rigids the following pictures emerged.

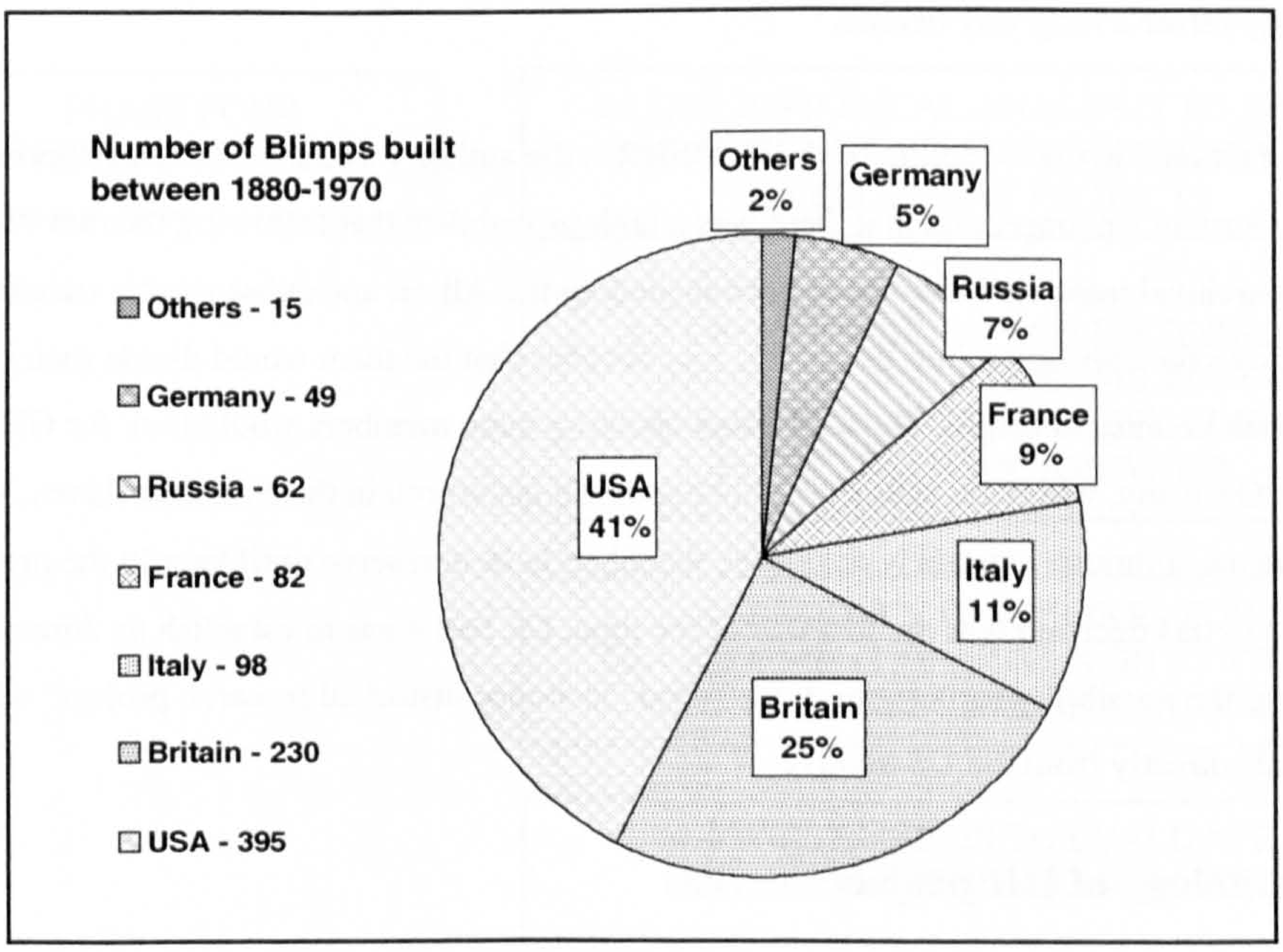

Figure 3.1 - Countries that built blimps

[1] Part of the problem centres on such complications as to whether airships that were cut in half, and lengthened, are to be counted as one or two separate aircraft, and whether putting a new gas bag onto an old gondola makes for a completely new blimp.

[2] For this investigation a more conservative estimate of 160 will be used

Clearly the bulk of the knowledge, as far as the operation of blimps is concerned, was likely to be found in the USA, with Britain looking like a promising alternative second source, and it would appear there was little advantage to be gained from spreading the search for GH information on this type of airship anywhere much further afield. However for rigid airships the picture was very different:

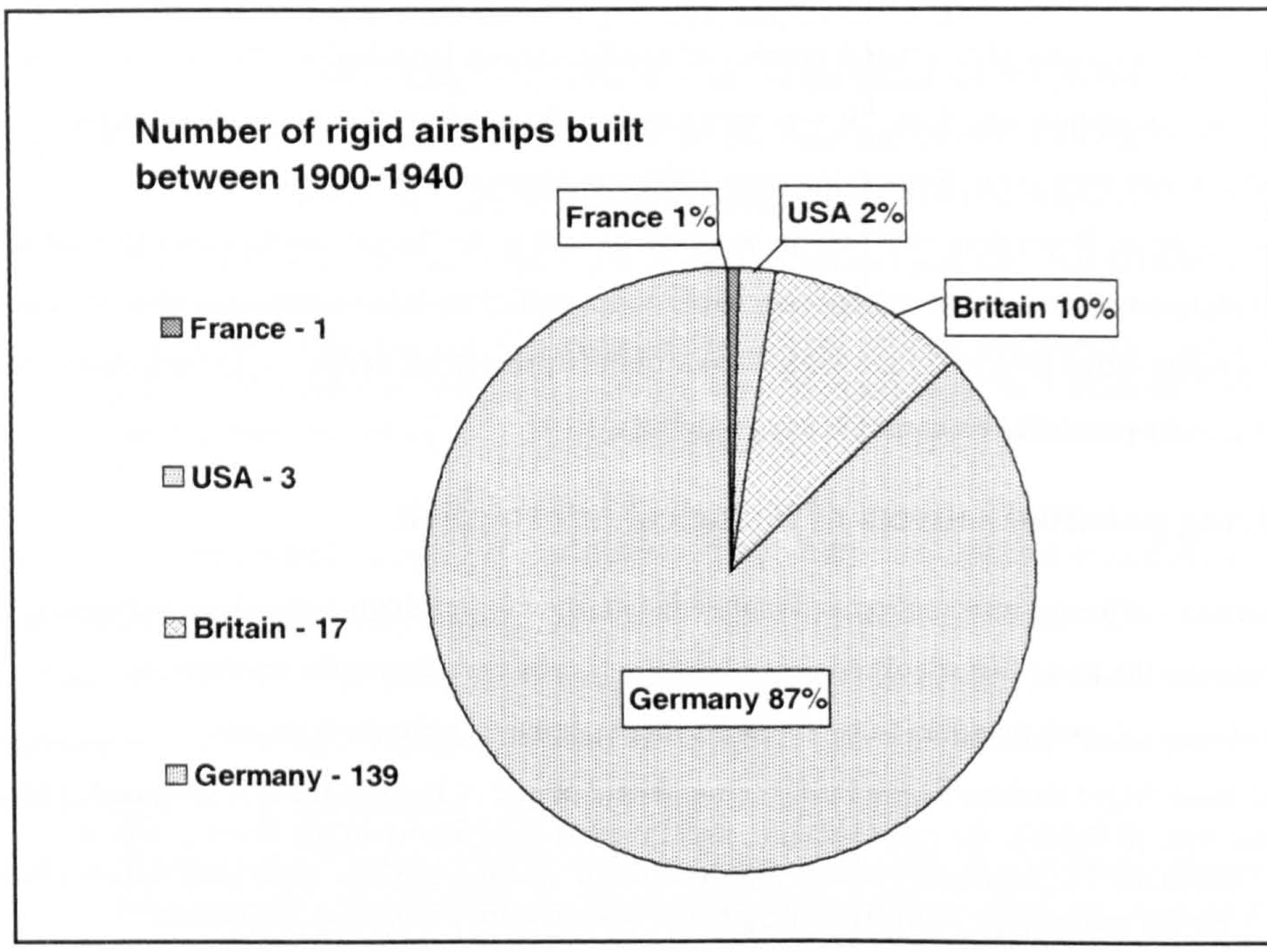

Figure 3.2 - Countries that built rigid airships

Here there could be no doubt that any surviving records concerning the GH procedures for the rigid PGVLAs were going to be concentrated in the German archives, with Britain once again in second place - albeit seemingly rather a long way behind.

In view of the fact that, at the inception of the CLOSHRP, the author was unable to read documents written in the German language, and that there was a high probability that following the two World Wars, much German archival material would have been copied by the Allies, and subsequently transferred to their own archives for translation into English, it was decided that the team would divide their efforts according to their country of origin. Thus, German-speaking team members would look for GH information in Germany, while the author would commence his search in the British archives. Visits to American archives, although extremely desirable, would be held in reserve until later in the project. Adding weight to this decision was the fact that at the time, CL had plans to establish an American office, thereby offering the possibility for a future USA based "in-house historical research project" which could collect materials directly from the US archives.

3.4 Methodology of HR project

Hindsight reveals that the HR project was actually composed of four separate phases, and from the diagram (See **Figure 3.3** overleaf) it can be seen that the investigation which the author and the GH team had been tasked with, was essentially that contained within Phases Three and Four of the project, as it had been originally conceived.

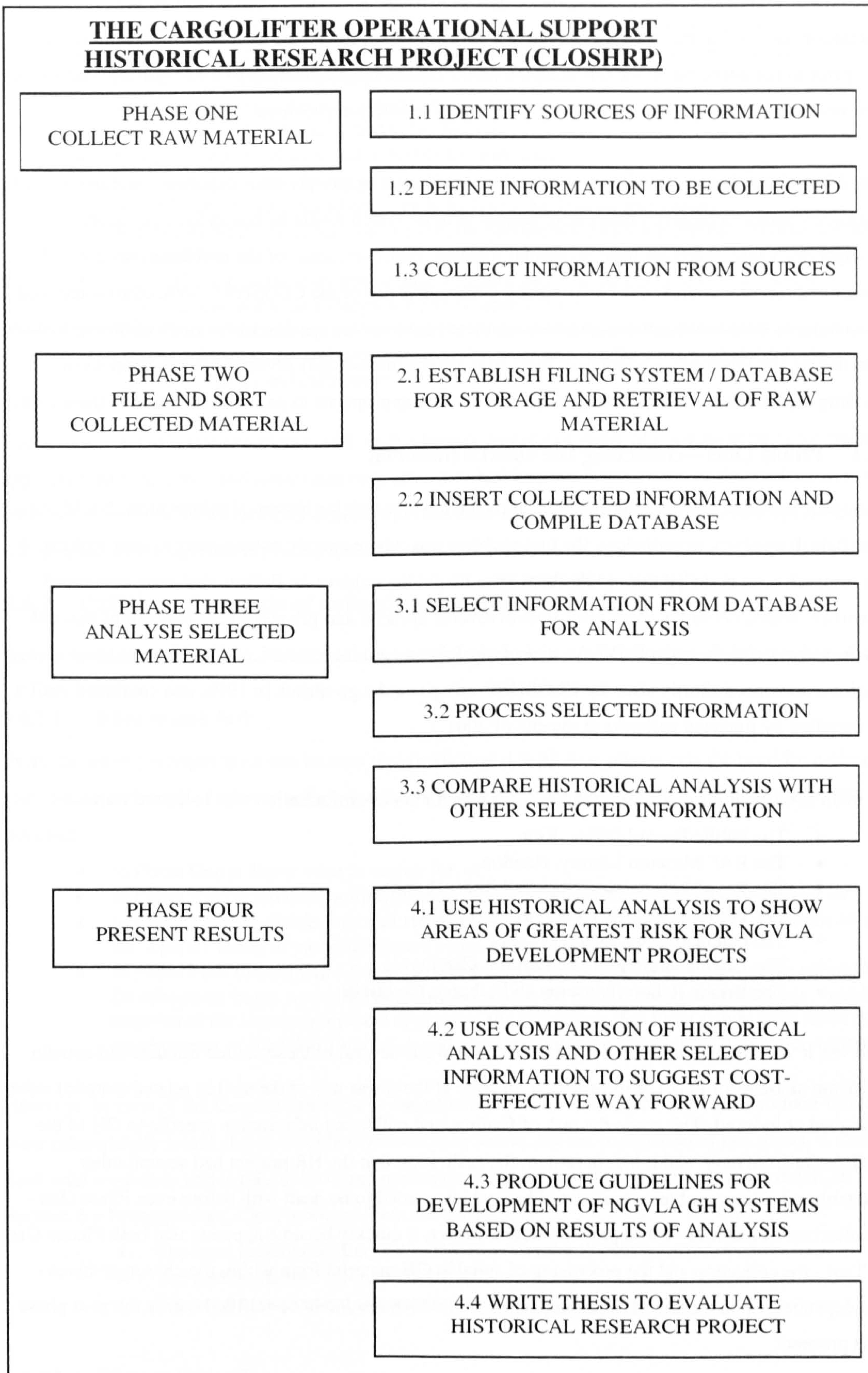

Figure 3.3 – Methodology of the CargoLifter Operational Support Historical Research Project

However, the fact that the newly emergent CargoLifter company, in 1999, had no library of historical information, meant that the team was effectively forced to back-track, and to conduct Phases One and Two, prior to commencing on the GH analysis work. This added enormously to the length and complexity of the project and embedded a whole range of new and unforeseen problems.

Some of these problems arose simply because of the author's lack of previous experience in running such an historical research project. Others were similar to those which would be common to any such investigation. These, therefore need no special mention. However, some of the problems encountered during the three-year course of the information gathering phase of the CLOSHRP, were convoluted, and far-reaching in their consequences, and because these problems are specific to the study of airship history, (even though the relationship of some of them to it are not immediately obvious,) in the interests of providing assistance to future investigations, it is deemed appropriate to pay brief attention to them here.

3.4.1 Phase One – collecting the source material

Although it had been agreed, in principle, that the author's search for historical information should begin in the British archives, nevertheless, the first problem was where exactly among them to start looking. A little research soon revealed that, while there were no public archives, in Britain, that were concerned exclusively with LTA flight, there were several diverse libraries and privately-held collections that did contain information from the PGVLAs, and most of them were in, or near London. Visits to these source libraries commenced shortly after the CLOSHRP was given the go-ahead, in 1998, and continued until it was curtailed by financial cutbacks at the end of 2001.

The main sources of historical information from which PGVLA information was collected were:

- The Public Record Office, Kew
- The RAF Museum Library, Hendon
- The Royal Aeronautical Society Library, London
- The Imperial War Museum Library, London
- The Patent Office Library, London
- The Airship Heritage Trust Library, Cardington
- The British Balloon Museum and Library, Cranfield

However, it was almost immediately discovered that while several of these source libraries did contain significant amounts of PGVLA information, in none of them was any of the airship related material either catalogued or indexed. This made the task of finding, and collecting information specific to GH of the PGVLAs far from easy, and it led, in turn, to the realisation that the HR project had several other intractable subsidiary problems buried within it which needed to be dealt with before even Phase One - the collection of material - could properly begin. In fact, it quickly became apparent that both Phases One and Two - the collection and the processing of suitable GH material from within the chosen archives - were dependent upon a chain of requirements each of which needed to be fulfilled before the next phase could proceed.

Viewed with hindsight, the chain of "prerequisite requirements" looked like this:

- Before conclusions regarding NGVLA GH could be reached, historical material containing the PGVLA information had to be analysed

- Before such analysis could begin, information specific to the PGVLA GH had to be held somewhere and filed accessibly so that it could be retrieved to order for study
- Before the information could be filed, it had to be sorted, categorised and indexed
- Before the information could be sorted, it had to be collected
- Before it could be collected, it had to be copied
- Before it could be copied, it had to be discovered
- Before it could be discovered, it had to be searched for
- Before a search could begin, potentially suitable archives where information relevant to the GH of large airships was likely to be held, had to be located and visited
- But, before likely archives were visited, the precise information required for collection had to be defined
- And definition of the information that was potentially of interest and thus needed to be collected required a list of keywords, or of search terms,
- This, in turn, dictated the further need for an understanding of the, sometimes obscure and often out-dated, terms and terminologies that were used in the documents held in the PGVLA archives and collections.

The author's lack of prior experience with such a project meant that many of these problems only became apparent with hindsight - and sometimes only after they had become acute. Much of the work to rectify these deficiencies in the CargoLifter project was thus done in a piecemeal fashion and retrospectively, which again added significantly to the duration of the project.

3.4.2 Pitfalls and caveats of collecting uncatalogued information

Having decided where to look for information, the next problem was to decide precisely what to look for.

3.4.2.1 What to look for?

From the list of prerequisites it can be seen that fundamental to all four phases was the need for a clear and concise definition of what exactly was meant by the term "Ground Handling." Without this it was not possible:

- in Phase One to know what to search for, or
- in Phase Two to structure a filing system or repository for the collected information, or
- in Phase Three to divide, rule and analyse the complex and intertwined GH problems so that the separate facets of particular topics could be isolated and investigated, or
- in Phase Four to establish a framework in which to present the results so that the various CL Development teams, and other departments within the rapidly expanding company, could understand the lessons learnt and appreciate the full effects that these would have upon the requirements of the GHE for a VLA and of its innumerable interactions with other systems.

However, in view of the fact that this topic is one of several of the links in the prerequisite chain which were subsequently found also to be either necessary, or useful, for the completion of this thesis, it will be dealt with separately and is thus to be found included among others which are examined in detail, in **Section 5 – Prerequisites.** Chief amongst them are these:

- The need to define a "Large Airship"?
- The need to define "Ground Handling"?
- The need to understand the terminology

3.4.2.2 What to Collect?

The original aim had been to collect as wide a range of GH related material as possible and it was anticipated that useful information concerning the PGVLA GH would most likely be found in two forms:

a) In large, concentrated volumes - where GH specific documents, such as manuals, log books, etc., were unearthed, and
b) Piecemeal - when gleaned from writings about topics other than GH which mentioned it in passing.

Furthermore, it was recognised in advance that the material found could be expected to have very different levels of usefulness, e.g.

- Actual descriptions in detail of relevant procedures, or of GHE and infrastructure.
- Material that gives some insight into specific GH procedures or how they were conducted.
- Material that leads to other potential reservoirs or repositories of knowledge
- Material that poses questions or opens further avenues of research.

All this proved to be so, however the reality also proved to be far more complex, largely because:

> "Libraries have conventionally been concerned with books, but 'the collection' in most libraries goes beyond the book. Very few libraries would not also collect conference proceedings, reports, microfilms, serials and maps. Small collections of videos, slides, film strips and computer software are held by many libraries, whilst others, often described as resource centres, actually specialize in such media. Organizations also keep extensive collections of documents in the form of records or files which may contain letters, invoices, leaflets, personnel documents and a host of other items." (Rowley, 1992:4/5).

Thus, whereas the original intention had been to seek out from the PGVLA archives, documentation that contained first hand accounts of matters relating to GH, it actually transpired that there was a huge reservoir of exceedingly useful information to be found elsewhere. The list of possible sources therefore had to be extended to include these, and anyone considering similar research should also bear these in mind. Other sources of potentially valuable airship GH information (in alphabetical order) include:

- Archive documents
- Books and booklets
- Conference Proceedings
- Films and videos
- Internet web-pages and chat rooms
- Journals containing peer-reviewed Technical Papers
- Magazine features
- Manuals
- Newspaper articles
- Official enquiries and reports (most frequently into accidents and incidents)
- Patents
- Photographs (a lot can be learned with careful use of a magnifying glass)
- Rules and regulations

However, all this diversity only increases the need for a clearly defined set of search terms, or keywords, at the start of the collection process. As stated, the author's analysis of this part of the problem, and his attempt at a solution to it, can be found below under "Definition of Ground Handling" in Section 5. The problem of what to do with the information after it has been collected still remains to be dealt with.

3.4.2.3 Unknown quantity of material

During the course of the CLOSHRP the author was constantly asked how much the historical research project was going to cost and how long it would take to complete. Both of these are virtually impossible to answer because without an index of keywords, searching can only be random, and unless there is a catalogue there is no way of knowing how much useful information there is to collect from any one repository. Thus there is no way of knowing what lies buried in the archives or when it will come to light.

Consequently, there is no way of estimating the length of time it will take to collect. Furthermore, in the context of acquiring lost knowledge, even if there is a catalogue of the documents, then how much is enough? How will a researcher know when there is no more useful information to be found?

Thus a budget cannot be determined with any accuracy at the start, or even part way through, such a project. Therefore, it would seem that until the English language PGVLA records are catalogued and indexed, it would be best to treat future historical research within them very much as an archaeological dig and to finance research accordingly. For instance one way to deal with the problem would be to copy the "Time-team" method (as demonstrated to good effect on television,) and to designate a length of time and sufficient funds for a pilot research and collection project, and then, at the end of it, evaluate the material gathered and either stop, or do it again.

3.4.2.4 Missing archives

It must also be kept in mind that many archives have been destroyed in the past, by bombing, (in London) and looting, (in Germany) so there is a high probability that much which was once recorded has now been lost, damaged or misplaced. Also it is evident that an unquantifiable amount of material has simply been thrown away or deliberately destroyed, due, either to competition for storage space and the cost of preservation, or to a plain lack of either interest or foresight. For example:

> "Footnote ...the material contained in the Handbook [on *Rigid Airship No.1*] is probably the only complete and reliable account extant. The Air Ministry Archives unfortunately had destroyed the contracts and correspondence just before I arrived, and the other papers including the Court of Inquiry Report have been lost." (Higham, 1961:41)

Furthermore, in the course of his own research, the author frequently came across references to potentially interesting documents of which no trace could be found throughout the duration of the CLOSHRP. For example:

- "In March 1930 the Royal Airship Works **produced designs** for an 8,300,000-c.f. ship with gaseous-fuel engines. *R-102* would have been of 226 tons gross lift and 88 tons disposable ..." (Higham, 1961:320) **[GC emphasis]**
- "**...plans were drawn** at the time for an R102 ... R 102 remained a paper scheme of course ..." (Robinson, 1973:318) **[GC emphasis]**
- "In March 1930 the Royal Airship Works at Cardington **had produced designs** for an 8,300,000 cubic feet airship to be called *R-102,* but no further action was taken." (Williams, 1974:162) **[GC emphasis]**
- "Early in August [1930] ... two important decisions were made: first that **design work should be started immediately** on two stretched versions of *R101* ... to be designated *R102* and *R103* ..." (Johnston, 1994:136) **[GC emphasis]**

Notwithstanding that following CL's demise, subsequent reading by the author did reveal a probable location for the example given,[1] it still reinforces the point first made in this section, as to the difficulty of estimating the cost of research and its likely financial return. On any given day (or within any allotted time period) a researcher may find many items that will yield big savings or nothing at all of value.

[1] "They left behind in two neat files* [Footnote: * Public Records Office (A/M) Files : AIR 5/987/3069 and AIR 5/988/3069] ... the designs and estimates for R.102 and R.103, new airships to embody all they knew; all they had learned." (Masefield, 1982 : 4)

3.4.2.5 Multiple copies

A further complication is that one may find identical copies of the same document in different archives, or even, many slightly different versions, or variants, of the same document in several different places within one, or more archives. For instance, one may find an author's hand-written notes for a technical paper, and then, one or more drafts of the typewritten versions of it, which were perhaps circulated to his or her colleagues, and some of these copies may have exceedingly valuable or insightful comments on them – perhaps penned directly by eminent, or knowledgeable, or even anonymous, people. Then there may be a printed draft or a proof copy of the same work, perhaps with the author's notes and corrections, and then a copy of the actual finished paper as it appeared in some conference proceedings, or in a publication. And finally there may be further edited, or abridged, versions of the finished work that may have been printed elsewhere, such as in technical journals devoted to other related fields, or even to totally unrelated, topics.

In addition, the same author may later re-vamp and expand an already published paper, and use what is essentially the same text, or at least the same ideas, or perhaps one specific section of it, to form the basis of a later, larger and more detailed work. All these various versions may have different dates on them – or none at all. Some may have the author's name on them, and others may not, in which case the authorship may only become apparent after the document has been collected and processed and the similarities noted. Sometimes authors meet and collaborate, and a name is added – sometimes they dispute, or fall out, and a name is dropped. The title may change and may very well be different on different versions, and early versions may have no title at all. The first line or the first page or even whole sections may be missing in some versions.

While the opportunity of watching a particular author's ideas develop may be useful for biographers, for the general researcher, collecting multiple copies of exactly the same (or almost identical) documents is a waste of time and money. Although, collecting different versions, may have benefits, especially if they show how an author's ideas changed in the face of input from, or exposure to, other fields of knowledge, or, more importantly following the realisation of a concept and the results of some empirical experiments.

However this duplicate copy problem is really only part of a greater one that is generally acknowledged to be inherent in all research projects, and when deciding which pieces of information to collect for any library, it is just as true as in the context given here:

> "The researcher begins by taking notes of everything that he thinks might be useful; some will prove to be, quite simply, not as useful or relevant as was first thought likely; some will have to be pruned, or excised, in the interests of space. **Waste is inseparable from research.**" (Berry, 1966:24) **[GC emphasis]**

Try telling that to the bean counters!

3.4.2.6 False witnesses with "axes to grind"

One further problem to be borne in mind when searching for information in the PGVLA archives, or when attempting to analyse it, is that some of the material may not be true. Among the reasons for this:

> "Most writers have a "thesis" – a point of view which they seek to advance. Put more bluntly, they have an axe to grind." (Berry, 1966:20)

This is especially so when it comes to the history of airships and indeed, many books [1] and biographies have been written revealing the way in which the various conflicting personalities drove their own agendas and influenced the development of the PGVLAs. To quote but one historian on this problem:

> "... the airship business in particular was full of petty jealousies and the survivors still hold strong opinions. The task of the historian has been made no easier by the dearth of vital materials in certain areas and the plethora of remembrances offered to fill these gaps." (Higham, 1961:XX)

Thus there may be contradictory reports of some events that are due simply to the writers' own particular prejudices, or perhaps because of their need to justify decisions taken at the time of writing, or even in order to attract financial support for their future plans. A prime example of this latter, where the capabilities of the American mechanised GH system are shown to have been falsely over-stated, appears in a revealing Memorandum from The University of Akron Archives, that turned up in the CargoLifter library. Dated 13th June 1930 and signed by W.T. van Orman, the Memo concludes that "*Unquestionably the present Lakehurst mechanical handling gear represents a tremendous step forward.*" However, prior to this, it clearly accuses the officer i/c Lakehurst, (the highly regarded and influential Commander Charles Rosendahl), of massaging the numbers to prove his case:

> "As set forth by Commander Rosendahl, the '*Los Angeles*' has been docked and undocked in cross hangar winds of 17 to 20 m.p.h., and further that gusts momentarily increased this to 25 m.p.h. Existing aerological records show the maximum cross hangar velocities for docking and undocking with present equipment to be 10 knots for the '*Los Angeles*'." (Van Orman, 1930)

Similarly in Britain, it is well-known, and frequently repeated, that there was considerable friction between the two developmental teams of the "private-enterprise" *R100* and the "state-owned" *R101*. For example statements by witnesses describing the first ever connection of *R100* to the "opposition's" High Mast at The Royal Airship Works, Cardington were clearly coloured by the respective positions of the writers. Thus the view expressed by an experienced ground handler, who had narrowly missed being appointed as Mooring Officer at Cardington, is somewhat rueful and focussed in his criticism:

> "*R-100* made her first flight on 16th December 1929 and after trials in the vicinity of Howden flew to Cardington to join *R-101*. There was great disappointment here, apparently due to the lack of experience of the landing officer. Three circuits had to be made before a connection with the ship's mooring wire was made ..." (Williams, 1974:156)

Whereas, Nevil Shute Norway, a leading light within *R100*'s design team, when commenting on the same event, uses it to pour scorn more generally on his competitors and on their abilities:

> "We had assumed that there would be little difficulty in landing the ship on the Air Ministry mooring mast; so much had been written about this method of handling airships that it came as rather a surprise to us to find that the experts on this matter were inexpert in the use of their rather complicated apparatus. On this first flight it took three hours to land *R100* to the mast, no less than three attempts being made to establish connection between the ship's rope and the mast rope." (Norway, 1933)

However, only 8 flights later, for the first ever connection of *R100* to an identical high mast at St Hubert, near Montreal in Canada, Norway seems to have acquired a slightly less jaundiced view of the system:

> "... we came up to the mast just as dawn was breaking, and made connection at the first shot; the ship was moored without incident." (Norway, 1933)

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[1] E.g. Johnston, 1994; Meyer, 1991; Dick & Robinson, 1985; Masefield, 1982; Knausel, 1981; Cochran, 1980; Morpurgo, 1972; Higham, 1961; Eckener, 1958; Spanner, 1929; Lehmann & Mingos, 1927;

This brings him more into line with Wing Commander R.S. Booth, (Captain of *R100*) who seems to have had a more balanced, less partisan view of that first mooring at Cardington, as demonstrated by this latter-day exchange:

> "... he [Nevil Shute Norway] says [in his memoir "Slide Rule"] "It came to us as a surprise to find that the experts ...were inexpert in the use of their ... apparatus", as though to castigate by implication the rival gang. It looks to me [E.A. Johnston, son of the navigator of *R101*] rather more like inexpert handling of the new ship by its own crew. [Wing Commander R.S. Booth answers] *Agree entirely. Scott did this landing and quite rightly took his time about it. The ship had never landed before on that tower and the crew had been trained using a kite balloon! We went through the motions by approaching three times, and who is to say that he* [Scott] *was unduly cautions? At our best we never got much below one hour, though we were working out simpler methods.*" (Johnston, 2001:24)

So, it is important when researching into the history of past airships to know, not only who an author was, - in terms of his (and almost never her) standing, or rank, within the various competing development teams, - but also, when the item was written – not only with regard to the maturity of the individual's personal career, but also of the context, (politically, financially and historically,) within which the particular project or event is being spoken of.

3.4.2.7 Secrecy

And finally, it must be kept in mind when digging into the historical records that many, if not most, past airship development programmes were run by the military in times of war. Thus much information was classified as secret. In general, as few copies as was possible, were made of 'sensitive' reports, with access to all severely restricted on a "need to know" basis. Espionage was seen as a serious threat during the Second World War and in many areas even the taking photographs was forbidden on pain of death. It is therefore to be expected that unofficial pictures will be hard to find, and in some cases information that was originally scarce may have been destroyed simply in order to keep it secret.

> "Precisely what happened [to *HMA No. "Mayfly"*] may never be known, for evidence that might settle the point is not available. Winston Churchill, First Sea Lord of the Admiralty when the causes of the accident were investigated, refused to allow the minutes and proceedings of the Court of Inquiry to be published, and the report was afterwards described as 'lost'." (Andrews, 1969, cited in Collier, 1974:65/67)

Some documents may also not exist today because when de-classified they were judged to be of very little interest and were destroyed immediately - again to save archive space. Conversely, it is also possible that some very secret material may still be classified as sensitive, or potentially of future value, and may still be lying, safely hidden in the archives awaiting public release at such time as its usefulness will have been deemed to have expired. It is not inconceivable that some material was adjudged so valuable and useful that it was sealed away for one hundred years. Whatever the case, the need for secrecy means that there is a high probability that for today's researchers there will be some unquantifiable holes in the picture.

A further problem is that 'disinformation' was sometimes actively spread in wartime to confuse enemies. The German Army, for example, deliberately chose a confusing numbering system for their First World War Zeppelins. By adding a number "1" to the front of the manufacturer's production number they increased the perceived size of the Army's fleet, literally at a stroke. It is not clear if, at the time, this did deceive their opponents, but it certainly has potential to confuse historians and researchers in the future. Thus "*Caveat Lector*" is a good thing to keep in mind when searching archives.

3.4.3 Phase Two – filing and sorting collected material

Soon after the author started to collect information from the British archives, in Phase One of the CLOSHRP, it became evident that Phase Two, establishing a repository for the discovered documents and organising a system for finding material within it, was going to be an enormous task. Yet again the author's lack of previous experience exacerbated the problem, as the pursuit of this goal led him into the deep waters of Information Science. While much of this work has no relevance to this investigation, some does, and because, again lessons were learnt, and some useful pointers discovered that may be of assistance to any future attempts to establish an archive dedicated to the history of LTA flight, it is thus thought appropriate to include here some of the most serious difficulties that were encountered.

3.4.3.1 Inherent complexity of the subject

First and foremost, as stated above (in previous section) it was found that a fundamental prerequisite for all four Phases of the CLOSHRP, and subsequently for this thesis, was the need to establish some system of dividing up into recognisable and useful categories the material held in the airship archives. The difficulties in doing this had been previously noted and one suggested solution had also been made:

> "The innumerable facets of an airship's peculiarities are interlinked to an extent that defeats categorisation but for convenience a survey may at least begin under the separate headings:
> - the mechanics of the airship
> - the airship in the air
> - the airship on the ground" (Mowforth, 1991:16)

At the outset of the project the author's intention was to concentrate solely on the last of these divisions, however, as time passed, more and more interest was shown by other CL departments in learning how the PGVLAs had dealt with a whole range of diverse problems, in many spheres, and in disciplines other than GH. This further complicated and extended both the time and costs of Phase One - not least because the lack of a coherent collection policy frequently meant the author returning to collect previously noted items, on subsequent visits, instead of continuing the search for new material. Anyone contemplating a future investigation along the same lines would be well advised to clarify this and define the scope of their search prior to starting their project. The use of experienced researchers is also highly recommended.

However, there is evidence that the difficulty of organising the information concerning fully-immersed, buoyant vehicles may be endemic in the type; submarine experts have had the same problem:

> "We encountered some difficulty in structuring the contents of the book ["*Concepts in Submarine Design*"] ... because each aspect is so closely interrelated to the others that it is difficult to treat any one in isolation." (Burcher & Rydill, 1994:xii)

3.4.3.2 How to categorise the findings?

A further dimension of complexity is added to an already difficult problem by the previously identified, plethora of different types of potential source material that is held in the PGVLA archives. This is because they combine with the interrelated nature of the material to make it virtually impossible, in this case, to use what is commonly regarded as a normal basis for a straightforward classification system of historical archives. "Historians especially like to distinguish between Primary and Secondary sources." (Berry, 1966:48). However, accepting the definition of these two terms, as given by the same author, thus:

> "Primary materials are first hand accounts, reflections and statements. They are not based on other written works. They are in the original form, without having been arranged or interpreted

> by anyone else.... Secondary sources - by far the larger group - discuss primary sources. They consist of works which select, edit, and interpret this raw material." (Berry, 1966:14)

... this author found that, in the airship archives, it was often extremely difficult to decide which is which. This was partly because there are seemingly examples of both categories in nearly all sections of the list of potential information sources identified above. But mostly it was because, in the document collections, (where the PGVLA primary sources were predominant,) actually sorting them into categories which would allow a third person to search them, by reference to any normal means, was rendered virtually impossible by the fact that many exceedingly interesting papers were either, untitled, or undated, or unsigned - and on occasion, all three.

In trying to sort these, it was often considerably easier to subdivide the research findings loosely into three rather different parts - contemporary accounts, retrospective memoirs and modern reviews – but it was frequently the "Provenance" or the context in which particular papers were found that actually gave the information contained within them its value. For example, undated and unsigned memos, or hand-written notes, that were discovered amongst the official papers taken from the offices of the Royal Airship Works at Cardington, had obviously been adjudged of some interest, to those unfortunate individuals who had lost their lives in the crash of the *R101*. Obviously the thoughts, writings and intentions, of these exceedingly experienced men can reveal a great deal of interest, and whatever was left on the desks to which they intended to return, represents a snapshot of their immediate concerns, prior to the unexpectedly abrupt, and tragic ending of their project. As a consequence, these fragments are again more like the findings from an archaeological dig where the context in which items are found is vital to an understanding of their importance. Thus, in trying to organise, and to categorise, the results of an airship based historical research project this would seem to be a very useful suggestion:

> "Ancient archives were almost never catalogued alphabetically because so many authors were unknown. Titles didn't work either because many historical documents were untitled letters or parchment fragments. Most cataloguing was done chronologically." (Brown, 2000:223)

However, the value of this nugget is perhaps questionable, if for no other reason than that the quote actually comes from a work of fiction. Nevertheless, this author also found that there was seemingly equally useful advice hidden away elsewhere in popular literature:

> "A complex assembly is best described first in terms of its substances: its subassemblies and parts. Then, next, it is described in terms of its methods: its functions as they occur in sequence. If you confuse physical and functional description, substance and method, you get all tangled up and so does the reader." (Pirsig, 1979:332)

Regardless of the fictional source of such wisdom, it is nevertheless apparent that trying to untangle and define the requirements for the physical "hardware" of the NGVLA GH systems, and of then specifying exactly what a particular prototype will *actually need*, in terms of its GHE, and of then further defining and describing not only the method, (i.e. the "software" or how this equipment will be used,) but also its functions, (i.e. what skills the "wetware" who are going to use it will need to be trained in so as to operate it cost effectively and safely,) is a formidable set of tasks. Providing a reference library to encompass all that looks likely to be required in order to facilitate this process, and which allows inexperienced personnel to complete the work before the prototype airship has been built, appears even more daunting.

Yet, despite the complex nature of the subject it is useful to remind ourselves that in this we are not entirely pioneering new ground. To some extent today's researchers are merely retracing the almost obliterated tracks of the previous generation of airship authors who were faced with finding solutions to these very same problems. They also had to solve the problem of how to categorise and how to present this interwoven complex of information. It is therefore pertinent to ask how these problems were solved in the past? How for example did the authors of airship manuals for the PGVLAs break down the complex subject? How have others previously dealt with the interdependent nature of the GH processes?

It would be instructive to compare the layout of PGVLA operations manuals and perhaps to use their contents lists as the basis for a classification system? However, this lies beyond the scope of this present investigation.

3.4.3.3 Retrieving stored information

To a large extent the structure of any reference library of historical information that is focussed on LAGH will depend on what is found from other archives to put into it, and what, from the diverse sources mentioned above, is also deemed worthy of inclusion. However, there are other considerations. The purpose of any and all information storage is essentially to facilitate its subsequent retrieval on demand. This is confirmed in specialist literature devoted to the subject of information processing. For example:

> "The organization of knowledge is a process that has been recognized as necessary for thousands of years. As the quantity of knowledge expands, the need to organize it becomes more pressing. ... the organization of knowledge is an essential preliminary to the effective exploitation of that information." (Rowley, 1992:3)
>
> "Any attempt to organize knowledge must, in order to justify the effort involved, have an objective. ... In general terms, the objective ... is to permit that information or knowledge to be found again on a later occasion. Thus the organization of knowledge and ... information retrieval, are very much part of the same process. Poor organization makes it difficult to find something later ..." (Rowley, 1992:3)

Furthermore, there may still be problems even when things are perfectly well "organised":

> "If someone else puts your things away but is unfamiliar with your usual system, then the objects may be organized, but that does not mean that you can find things. ... Organization in itself has limited value. The organization must be sensible, according to some criterion, and preferably familiar to, or at least expected by, the user. Thus ... it is not possible to divorce the organization of knowledge from information retrieval." (Rowley, 1992:3)

Here is confirmation that the three facets of this problem – what to collect, where to keep it and how to make it easily accessible - are united by the common need for a universally agreed categorisation system. Moreover, in the situation, which it seems will inevitably face the NGVLA developers, where the majority of their incumbent personnel – i.e. those who will be most in need of a reference library – will have little or no experience of the vagaries of airships, and/or of LTA matters, then the requirement for speed and clarity in an information retrieval system should perhaps take precedence. The requirements for such an accessible filing and information storage system would seem to be twofold:

a) that it affords easy and quick categorisation to facilitate insertion of new material,
b) that it is easy for the uninitiated to find filed information that is contained within the system.

The key to this would appear to this author to be the founding of a database, or a databank of sorted source material; one that is easy to understand, and regardless of the fact that it will almost certainly be computer-based, one that is based on the simple indexing, and cross referencing principles of an old-fashioned card index would seem to be a good place to start:

> "Essentially, each card contains three items of information : a descriptive label, or some identifying phrase ; the main body of the note itself ; and the reference to the source." (Berry, 1966:25)

In view of the complex nature of this problem, and of its fundamental importance, it is the author's belief that a very considerable investment of time and money, along with specialist advice from the world of Information Science, will be required to solve it. Nevertheless, in attempting to establish a reference library of historical information specific to the construction and operation of large, or very large, airships for CL the author did attempt his own inexpert, preliminary analysis of some of the advantages and disadvantages of different information storage systems. This is given overleaf in **Table 2.**

A further possible starting point for anyone contemplating taking on this categorisation problem would be to base it upon the Air Transport Association (ATA) classification system,[1] as is commonly used in the HTA world. This would however have to be extensively modified to allow for such additional airship parts as ballonets and other LTA peculiarities, including, for example, disposable ballast for discharge during flight. The author is aware that CL did at least start to carry out this exercise but the abrupt closure of the company in 2002 has left the fate of this, and many other potentially useful documents, uncertain. A modified ATA system would however only categorise the aircraft itself and further additions to the system would be required to cater for the GHE – masts, dollies, rail tracks, etc. Much further work on this topic remains to be done.

3.4.3.4 Presentation of results

A final difficulty in conducting this investigation has been the three-dimensional nature of the subject. If, for arguments sake, there are 100 different airships, and each has a life of ten years, and there are a dozen different GH procedures that each airship is subject to, and moreover, each of these procedures evolves into a definably separate variant every year, then, in order to contain this information, a matrix is required that will contain 100 x 12 x 10 = 12,000 fields. However, the fact that the procedures interact with each other as they evolve, and can be passed through the matrix in both time and space directions, (i.e. reappearing later in the same airship's lifetime, or transferring to a different airship of the same age,) means that this is a "Rubic Cube" of mammoth proportions. Furthermore, in order to produce a written report that traces the evolution of these procedures through time it is thus necessary to attempt to trace a linear narrative through a three-dimensional space.

In reality, of course, there are far fewer fields and the shape is far from being a cube, simply because the lifetimes of the world's airships ranged from a few days to a decade, and many procedures found to be effective, continued in use until a problem occurred or a new idea supplanted them. Nevertheless, the problem of how to present the information collected during the CLOSHRP is one that occupied a great deal of the author's time and NGVLA developers would be well advised to consider carefully how they will deal with this three-dimensional problem.

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[1] ATA Spec 100 contains format and content guidelines for technical manuals written by aviation manufacturers and suppliers and is used by airlines and other segments of the industry in the maintenance of their respective products. This document provides the industry-wide standard for aircraft systems numbering, often referred to as ATA system or chapter numbers.

Method	Advantage	Disadvantages
By author	Logical, used in Libraries, Only 26 alphabetical categories	Need to know names and who is important. Some documents are anonymous.
By title	Easy to search by keyword	Confusing words like "The" and "An", Some documents have no title only number, Infinite number of categories
By date Chronologically, in date order Example – (previous section on History) 1920 Jan, British R33 did xxx, British R34 did yyy, German Zeppelin Co resumed construction, USA closed project X but continued with Y. .	Logical framework, Easy to find stuff by date, Can trace evolution of ideas, Easy to write up	Lots of repetition (3 countries), Some items are undated, Date of writing may not correspond to date of event, Cannot find items without date, lose continuity of individual experimental programmes, jumping back and forth between countries and projects, need to know when something happened to find it. Must assume that readers and future researchers will not know dates.
By airship, Example – Zeppelin 1 did this, Schutte-Lanz 1 did this, British No 1 did this…	Can see experiments evolve to results, Very thorough so nothing missed out.	Enormous files, hugely detailed. Hard to find specific result if you don't know the airships history. Nowhere to put generic material, Very repetitious,
By country Example - The German system started like this and ended like this; The British System started like this and ended like this; The American system etc.	Can trace evolution of ideas through experiments to conclusions	Repetitious, Confusing, Cannot find things without prior knowledge
By task definition, Procedures. Example – List tasks and break down – In hangar, on field, remote site	Can follow evolution of ideas, easy to find information on specific topic	Confusing overlay of airships and countries, No continuity of projects, Terminology is problem for novice researchers,
By component parts of system – modified ATA numbers for GH equipt - or GH topics Example – Hangars evolved thus, mooring masts thus, dollies thus, mules etc..	Simple system, Easy to put in and to find, Well understood by aviation engineers	Airship ATA is different from aeroplane, Some findings won't fit e.g. sheds and masts, We are looking for procedures as well as hardware or parts
By solutions to the major problems, Example – The major problems one by one	Can follow thread of topic, Easy to search for subject,	Confusing overlay of successful and failed experiments

TABLE 2 - Advantages and disadvantages of filing methods

4 ORIGINS AND AIMS OF THE THESIS

4.1 The origins of the thesis

This investigation stems from the unpublished internal CL Technical Report,[1] (previously mentioned in **Section 3.2**) that was submitted to the company by the author and his colleagues in September 1998. This report outlined the preliminary findings of a brief search through archives in Britain and Germany for historical material concerning the PGVLAs, and it indicated that continued research along these lines would be of large potential benefit to the company. As a consequence of this report the author was tasked with collecting further historical material from British archives and this led in the following year - 1999 - to the founding of **The CargoLifter Operational Support Historical Research Project (CLOSHRP).**

In addition, in this same year, a "risk" was registered by the author on CargoLifter's newly established Risk Management Database. It voiced the concern that unless the company were to conduct a thorough study of the PGVLA GH there was a high probability that designers would inadvertently "re-invent the wheel" and waste both time and effort devising GH systems already proven in the past to be ineffective for large airships. This would have potentially serious financial consequences for the company.

Shortly after submission, the original report was re-formatted, and incorporated into the embryonic CL document database as "ref. DE 01 00001." This document then served throughout 1999 as the basis for a majority of the formative decisions regarding the early evolutions of the *CL160* GH systems. The seminal nature and importance of the CLOSHRP was thus recognised internally, by many within the company. In the year 2000, on the basis that HR and analysis could be seen as having a wider application externally, with potential benefits to other organisations within the LTA community, (which would thereby enhance CargoLifter's image,) the author was encouraged to expand and promulgate the work. Initially this was done by embarking upon an academic qualification (this thesis in 2001) and latterly by the presentation of a conference paper given by the author at the Airship Association's 4th Conference, held in Cambridge in 2002. Both of these projects were initially funded by CL, however, the delivery of the paper,[2] (hereinafter "the Cambridge paper") which was intended merely as a step in the evolution of the thesis, also unhappily coincided with the financial collapse of the entire company, which threw everyone's plans awry.

Originally, as can be seen from **Figure 3.3**, this thesis was foreseen as an end product of Phase Four of the CLOSHRP, but, the premature termination of CL in July 2002 meant that, although Phases One and Two (Historical Research - HR) were under way, work on Phases Three and Four (Analysis of Historical Airship Activities - AHAA) had barely begun. The company's demise thus left all four phases incomplete with the thesis in limbo. In response to appeals, encouragement and some financial support, from within the LTA community, the author determined to complete the work independently, and to turn the focus away from the specifics of heavy-lift airships towards the GH of very large airships in general.

[1] Camplin, Bischet & Watson, 1998 : *Preliminary outline for ground handling CL-160*
[2] Camplin & Schaefer, 2002 : *Learning from the past*

Central to the reasoning behind the whole idea of an historical research project had been what appeared to be a very great danger for the emergent large airship industry in the 21st century. It was one that had been noted some ten years prior to the start of the CLOSHRP, and it was quoted by the author in his conclusion to the Cambridge Paper in 2002:

> "More than one modern designer, intoxicated by the perceived omnipotence of today's technology, has turned his back on history and marched upon the airship with the confident intention of programming the concept into instant and final submission. The subsequent process of rediscovering the problems, and reinventing the solutions, already well documented in the archives can become terminally expensive. Computers don't read history." (Mowforth, 1991:16)

With hindsight, this can perhaps be seen as something of a timely warning. What was certainly true at CL was that not all departments were cognisant of the finer points and possibilities of an historical research project and, particularly in the later stages of the company's rapid expansion, when a large influx of "LTA novices" were enlisted, there was in some cases, (as mentioned in **Section 3.3**) considerable misunderstanding as to the investigation's true nature and purpose. Moreover, as the current dormant state of the LTA industry (particularly in Britain) would seem to make it unavoidable that most of the personnel joining any future NGVLA development projects will perforce also be comparative newcomers to the subject, and thus prey to similar misunderstandings, it is deemed appropriate here to explain briefly some of the less obvious aspects and advantages of conducting such an investigation, before laying out the aims of the thesis itself.

Firstly, in recognition of the reality of the "perceived omnipotence of today's technology," the point was put to the author on occasion that modern airship designers have available to them today, infinitely better calculation methods, greatly improved materials, and a whole range of processes that were not available to those who built the PGVLAs. These include computer simulations, systems monitoring, cost estimating, finite element modelling, and project management, to name but a few. Consequently things today are plainly very different from the way they were in the 1930s. Thus, it was argued, that the experiences of the PGVLA teams, along with the problems they encountered, were simply not relevant for the contemporary NGVLA designers and "digging up old stuff" was really just a waste of time.

However, what this argument overlooks is that, while today's designers and engineers undoubtedly do have access to much more, and better, technology than existed in the 1930s, it is also true that the fundamentals of the physical world have not changed at all since that time. Furthermore, despite Global Warming, there are some things that will never ever be made worse nor improved, nor altered in any way, by human technological "progress." For example, although our knowledge of both hydrogen and helium is now much improved, neither actually provides any more lift today than it did in the 1930s. The passing years have not increased the density of the atmosphere nor weakened the force of gravity, and the power of the wind is similarly undiminished. And the same is true for other meteorological phenomena, such as the build up and discharge of static electricity, the viscosity of the air, and the effect of temperature on the expansion and contraction of gases. All these are still exactly the same as they were - as indeed, are human beings. We have not changed in our basic requirements; or our physical strengths and endurance; or inherent fragility and general vulnerability when working alongside machinery. Thus the environment in which any future NGVLA will have to operate is identical to that of its forebears in the 1930s.

Consequently, the physical problems, and the challenges presented by nature that face today's designers, who have no practical experience of VLAs, are the same as those faced by the PGVLA designers, who had a great deal of practical first-hand experience with VLAs. And thus careful study of their chosen solutions to these same challenges – i.e. the big rigid ships of the 1930s – will allow a deeper understanding of what they, the designers, initially perceived, and later subsequently found by experience, to be the real problems associated with the operation of real very large airships in the real world.

Therefore, the thinking behind the CLOSHRP, and its true purpose, was not as many believed to dig up and catalogue some of the old solutions and offer them to the CL design team as ready made answers, or even as shortcuts, for direct implementation today. Rather, it was to use old ideas, designs and systems to try to understand the questions that the PGVLA designers and operators were trying to answer, and thereby to identify the underlying problems they were trying to solve. The hope was that then it would be possible to examine these problems and see how well each of the 1930s solutions had achieved, or had succeeded in approaching, its aim. Only thereafter would it be decided whether to actually propose the use of any 1930s solution as was, or whether to upgrade and modernise it, or whether perhaps to abandon the old idea altogether and start again with a modern solution for a now more clearly defined and better understood, real, quantifiable problem. The omnipotence of modern technology is thus something of a side issue and the true purpose of the HR project was primarily to acquire knowledge and understanding.

Moreover, the existence of better, or more sophisticated, technology today and tomorrow, is only going to be of significant advantage to future VLA designers if the reason that the PGVLAs failed, and that they are thus not around today, doing the jobs for which they are seemingly so perfectly well suited, was because of a lack, or a failure of the technology available in the 1930s. However, as was shown in **Section 2.7.1.** there is a second and often overlooked aspect to this, namely the part played in operations by "technique," and if the real weakness in the PGVLA systems were due in large part to operational difficulties then no amount of technological improvement, either now or in the future, is going to help.

A further common assumption, which was certainly widespread and deeply rooted in the early days at CL, and which added weight to the apparent inappropriateness of studying the PGVLAs, was that the NGVLAs would not be of a rigid construction. The argument was that the weight penalty is too great and our modern materials are strong enough, and our stress calculations clever enough, to make the single-chamber giant blimp into a viable proposition. However, interestingly, many of those who decried the old "outdated" ideas of the 1930s were quick to suggest the application of the equally old fashioned rigid airship GH methods whenever serious ground handling problems arose. For instance, the use of a mechanical "dolly" or "stern beam" to control the tail, as when seeking to align the airship with its shed, was commonly accepted without question. This conveniently overlooked the fact that the tail structures of the rigid airships were reinforced internally to withstand these ground handling loads, and adoption of this system, for a giant non-rigid blimp, would have necessitated the incorporation into it, of what was effectively a rigid airship tail, thereby adding considerable weight to the finished article and great deal of complexity to its inflation and assembly processes.

This cherry-picking of partially understood concepts from the past, reveals once again the old truth that a little knowledge is a dangerous thing, and thus, the misunderstanding of PGVLA systems and procedures, or the appearance at a critical decision-making moment in an NGVLA project, of an apparently "proven" idea from the past as the "solution" to a serious problem, can lead to the embedding and reinforcement of erroneous beliefs and an entirely false sense of progress. Such historical cherries can also create a biased assessment and a distorted view of a truly new idea and thereby actually lead to the stifling of innovation.

Therefore, to be of value, detailed information resulting from an HR project must be critically assessed, the more so because not all that has been recorded is relevant, nor indeed necessarily factually truthful. And here, regardless of how the PGVLA solutions were described in their time, (or even sometime afterwards,) by those involved in the devising, operating or witnessing of them, it is very important to keep in mind, that some of the claims made for them may not have been genuine. In addition, it is equally necessary to recognise that, regardless of its source, information on its own has no intrinsic value. In order to be of value, information has to be understood and, just as a piece of text, when taken from another language, must be skilfully interpreted after it has been translated, so too, the results of HR on the GH of airships also requires expert analysis to enable its proper comprehension. As history shows:

> "The mere acquisition of German airships and material failed entirely to reveal to their new owners [the British and French military authorities] the secrets of their construction and operation. It would appear that in their almost frenzied efforts to reap airship benefits, they had quite forgotten the extensive German background; they certainly appear to have been unwilling to acquire operating and construction knowledge gradually and by the historical and basic method of the sweat of the brow and the usual pioneering grief." (Rosendahl, 1938 : 361)

Caution is thus required.

> "It is an axiom that the entire forty years history of the giant rigid airship is one whole saga in its own right, and the many attempts made by historians to dissect and dismember its numerous parts have seldom met with satisfaction. Logically it makes sense to open up for detailed examination the specific area or sector of interest for special attention, but only when it is viewed in the perspective of contemporary activity can the discoveries made be properly assessed." (Chamberlain, 1984 : xv)

Such assessment, however, requires a great deal of expert knowledge - which in this case, thanks to the Knowledge Gap, can only come from a study of airship history.

Furthermore, when contemplating the broader picture and the "whole saga" of the PGVLAs, there are self-evidently also some wider issues to consider. Many of these lie beyond the scope of this particular investigation, as for example the popularly held beliefs that the apparent failure, and the subsequent disaster-studded disappearance, of the PGVLAs was largely due to a combination of technical problems, political decisions and plain bad luck.[1] However, there are other theories that do involve GH, not least the growing suspicion, (evinced by the several authors quoted in **Section 2.1**,) that the "GH problems" of the large airships were never actually properly solved at all, and that inadequacies within the 1930s GH systems played a significant, if unrecognised, part in the demise of the PGVLAs.
This theory, however, is of fairly recent origin, and contemporary authors frequently held a very different view of the effectiveness of the GH systems with which they were familiar.[2]

[1] Meyer, 1991 : *Airshipmen, businessmen and politics 1890 – 1940*
[2] There were of course also those who had serious doubts about large airships in general – e.g. most notably, Spanner, 1929

"The dirigible was little thought of, up to recent years, because of its bulk. The very volume that made it safe in the air ... made it liable to destruction by the winds, especially when on the ground. Added to this was the difficulty of landing and mooring the huge airship. These disadvantages have been overcome, if we can judge by the performance of the *Los Angeles* and the *Graf Zeppelin*, both in the air and on the ground." (Hylander, 1931:xiv/xv)

So, it would appear that either the 'old guys' were wrong to claim that GH problems had been solved, or, possibly they did find satisfactory solutions which have subsequently been forgotten If the latter is true then maybe these solutions can be rediscovered by careful and focussed HR? However, if the former is the case, then this is extremely serious for any future NGVLAs because it means that despite statements to the contrary, there has never been a solution to some of these fundamental problems! And if the highly skilled and enormously experienced experts of the past were defeated by them after years of empirical experiment, then wholly inexperienced modern-day novices should be extremely careful, otherwise the NGVLA developers may simply make the same mistakes as their forebears and think that they also have solved these complex problems when they have not. Making such assumptions could be disastrous both physically and financially for the NGVLAs.

Thus, unless the NGVLA developers properly appreciate what were the specific questions that their predecessors were trying to answer, then they cannot truly and objectively judge how well they succeeded, and nor can they understand the reasons behind the choice of the technological solutions. It is thus the author's conviction that the development of the NGVLAs must start from a detailed study of the history of similar aircraft. The nearest thing to them are the extinct Zeppelins of the 1930s, and it is essential that these should be thoroughly investigated, along with their operational GH systems and the incidents that befell them, in order to avoid the risk of repeating past mistakes, reinventing the wheel and of falling into the same trap. A key objective of this thesis is thus to reduce the risk that what is being proposed for the NGVLA GH will not be cost-effective, and on the other side, also to minimise the chances that some valuable GH past-concepts will be overlooked or missed. Finally, extracting as much information as possible, concerning the GH of the PGVLAs, from their surviving written records will allow some suggestions and guidelines to be drawn up for the NGVLA developers that are based on the discoveries of the CargoLifter historical research project.

4.2 Aims

The overall objective of this thesis is to demonstrate that Historical Research (HR) is of vital importance for any future NGVLA development projects, because it offers an effective way of understanding the many obscure and intractable problems that stem from the combined effects of the "Knowledge Gap" and the "Skill Gap" as identified above. Furthermore, the Analysis of Historical Airship Activities, (AHAA) permits identification of those GH problems actually encountered by the PGVLAs that remain as a serious but unrecognised threat to the NGVLAs, and it offers ways of circumventing, or at least minimising the impact of those, which all future NGVLA designers will somehow have to address. In particular, detailed study of written records associated with the GH of the PGVLAs, makes it possible:-

Aim 1 - To isolate, and define, the fundamental GH problems generic to all airships, and to identify some of the unresolved GH issues that remain relevant, or which appear to be major risks to future NGVLA development projects.

Aim 2 - To expose and correct some of the misunderstandings that have arisen since the end of the large rigid airship era, concerning the capabilities of, and the procedures actually used by, the PGVLAs; also to find answers to some of the difficult and/or misleading GH questions encountered during the CargoLifter project, which have the potential to cause NGVLA designers to waste their time and effort, and which will thereby inevitably impede any further NGVLA projects.

Aim 3 - To unearth methods, suggestions, plans, interesting ideas, and/or potentially viable concepts etc., put forward or conceived by experienced engineers and acknowledged PGVLA experts, for GH systems that were untried, unproven, or insufficiently tested, perhaps because they were ahead of their time, but which are now possibly achievable with today's more advanced technology, and which might help to improve or facilitate the development of NGVLAs and their GH.

Aim 4 - To suggest a strategy and establish guidelines for future NGVLA GH development.

The method by which these aims are to be accomplished is as follows:

Aim 1 Method – The method chosen to reveal the generic GH problems fundamental to all types of airship, regardless of their size or intended purpose, and to identify unresolved PGVLA GH issues and risks still relevant to the NGVLAs was to:

a) break down large airship ground handling (LAGH) into a list of specific tasks
b) use the task list as a basis for collection of unresolved issues from the PGVLA GH systems
c) trace the evolution of airship GH systems throughout history
d) extract data on ground-based accidents and ground related incidents such as unassisted and/or forced landings
e) analyse the findings to identify the fundamental generic GH problems

Aim 2 Method - The method chosen to reduce the damaging effects of the "Knowledge Gap" by correcting misunderstandings concerning the PGVLAs and finding answers to some of the difficult CargoLifter GH questions was to:

a) collect apparently contradictory or incompatible statements from the history of airships
b) investigate some of the apparent contradictions and establish which facts are false
c) confirm the correct version from within the written records
d) select some of the difficult GH questions that bedevilled the CargoLifter project
e) find pertinent references in the evolution of PGVLA GH systems

Aim 3 Method - The method chosen to find potentially viable untried GH concepts was to:

a) compile a list of experienced, knowledgeable PGVLA designers and engineers
b) collect LAGH ideas from sources such as excerpts from books, historical references, patents, papers from conferences, articles from journals, periodicals, magazines & etc.,
c) select some of the most potentially useful untried ideas put forward by PGVLA experienced personnel

Aim 4 Method - The method chosen to suggest a strategy for future NGVLA GH development was to;

a) summarise the findings of the HR project with conclusions and recommendations
b) lay down suggested guidelines for NGVLA projects to help minimise GH risks, costs and development time, while they also maximise safety, reliability and the chances of success.

4.3 Requirements

In order to achieve the stated aims it was first necessary to collect relevant historical material and to use it to compile lists, databases and tables of information on which to base the study. These compilations, some of which were begun as part of the CLOSHRP, included:

- list of large and very large airships
- list of PGVLA airship bases and GH facilities
- list of GH accidents and incidents
- list of unassisted or forced landings
- list of GH related patents

From these "first order" lists,[1] and other historical sources, it was then possible, by fairly simple analysis, to work out, and then to assemble, further "second order" lists. These were a vital part of the study. Interestingly, (and perhaps revealingly in view of the general lack of interest in GH identified among the problems in **Section 2.1**), although the work involved in making these compilations was more time-consuming than difficult, and their potential value to the NGVLA designers is self-evident, the author could find no evidence that such compilations and listings had ever previously been attempted. These novel, "second-order" lists, which are specific to Large Airship Ground Handling (LAGH), included:

- list of generic GH tasks
- list of unresolved LAGH issues
- list of myths or erroneous beliefs
- list of difficult or unanswerable questions
- list of untested but potentially viable LAGH ideas and useful future concepts

Some of the above mentioned first and second order lists can be seen to be common requirements for the realisation of more than one of the stated aims of this thesis. However, there are also one or two points that require initial clarification because they are fundamental prerequisites to the whole research project.

[1] The first order lists are included as Appendices to this work. Many are extensive, and where they proved to be excessively long, then only sample pages of them are given as examples. The second order lists are less clearly defined and are either referred to or have been included in the text as appropriate.

5 THE PREREQUISITES

In order, both to collect information of potential relevance to the GH of the NGVLAs from the PGVLA archives, as mentioned above, (**Section 3**), and also to extract meaningful conclusions from such collected material in the preparation of this analytical investigation, it was necessary firstly to establish a novel and purely ground-based perspective of airship operations. The author could find no evidence that any such revealing and different, change of viewpoint had previously been devised or drawn-up.

Secondly, when attempting to assemble and analyse the collected archival material, it was soon apparent, that there was also a need for a clear definition of some common but carelessly used phrases which were intrinsic to the investigation. These terms were "Large Airship" and "Ground Handling."

Thirdly, when studying documents from the PGVLA era, there was also an obvious need to understand precisely what was being written about, from which arose the requirement for a "Glossary of Terms" in order to define the meaning of many arcane, out-dated and/or foreign words.

Fourthly, there was need to review the previous work on the GH of large airships.

Finally, there was need for an overview of the history of airships, in which to set the context of their development, and from which could be derived by investigation, an outline of the way in which GH systems had co-evolved to support them. In view of the volume of material, this overview/investigation of airship and GH history will be dealt with in its own section.

5.1 The need to establish a GH perspective

The fact that there are no large airships in existence today means that there is a natural tendency for everything to do with the development of the NGVLAs to be seen from the point of view of those who are trying to create them – namely the designers.

From a designers' creative perspective, it seems perfectly logical, when contemplating the development of any brand new machine, (including a gigantic airship) to start with it operating under some theoretically benign set of "normal" conditions. It is then a simple matter to make things progressively more difficult for it by changing its circumstances, and developing the operating procedures to bring it ever closer to the conditions it will encounter in reality. Thus the author found that it was common practice among the designers and would-be developers at CargoLifter to start all discussions on the *CL160* GH procedures from the assumption that the airship was already in flight.

From here, the debate then centred on how the *CL160* was going to first, pick up, and then subsequently to put down again, its payload. This was not unreasonable, considering that these two unprecedented procedures were fundamental to the success of the company, and that financial backing had been raised on the assurance that viable systems for conducting these complex manoeuvres could be found.

However, leaving aside, these hugely important, but (still to this day) entirely theoretical ideas, then the next operational question that appears is, how will the airship make a landing? Thus, from the "designers' view" the perceived sequence of required GH Procedures looks rather like this:

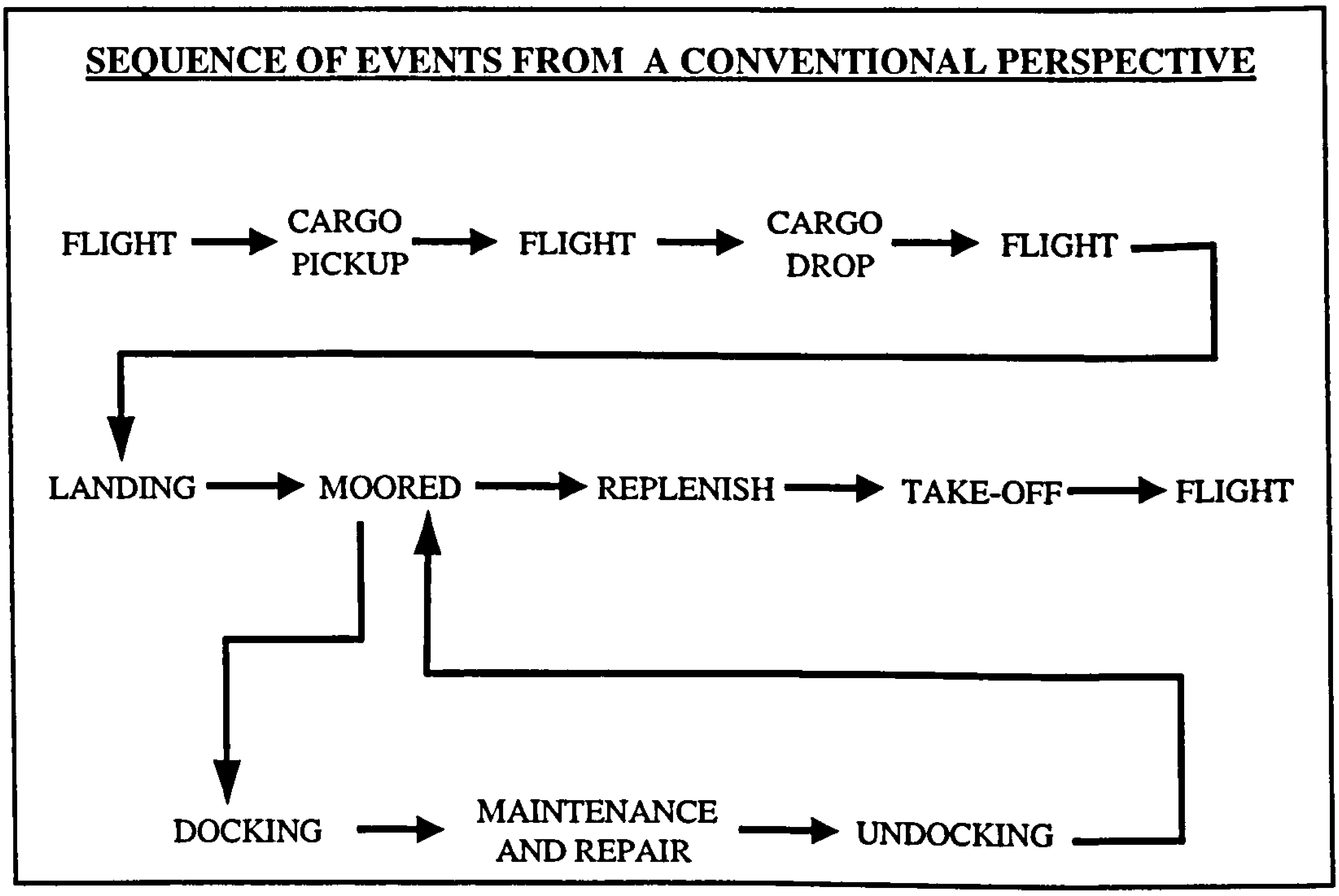

Figure 5.1 -The Conventional Sequence Of Procedures

The disadvantage of using this sequence, from an operational point of view, is that it makes the enormous presumption that the airship has been successfully launched to start with - i.e. any problems associated with taking-off have already been solved. The historical records show that this is a very dangerous assumption to make; and even moving out of the hangar carries large risks - as Eckener proved in 1911.[1]

But there are further difficulties with seeing things from this conventional viewpoint. For instance it means that anyone attempting to design or develop GH systems for a large airship, who adheres to this sequence of events, is constantly presented with situations that require equipment that appears out of nowhere. For instance, going from "Flight" to "Mooring" brings a mooring mast suddenly into the picture, (with all its connections and support systems fully-functional), while moving from "Mooring" to "Docking" presupposes that there is a complete hangar for the airship to "Enter" into. Furthermore, when using such a sequence in order to design these enormous, and complex structures, it seems perfectly obvious, and sensible, for the mast and hangar, to be reverse engineered from the airship's dimensions. So from the designers perspective the GH equipment and ground-based infrastructure can simply be built to fit onto, or around, the machine they will be required to service.

The problem is that, once again, this process makes sweeping assumptions, and, for example, it skips over the need to have initially inflated the airship inside the hangar in the first place. Thus vitally important, and necessary, equipment (such as cranes in the hangar roof, and anchor points in the floor, for example)

[1] See Chapter 1, Section 1.2

tend to be overlooked and having been initially left out of the calculations they are then inserted into the plans as an afterthought. Inevitably this means they are designed as add-on attachments to a building that is probably already drawn and dimensioned, and for which the stresses and strains have been already calculated, and which may even be partially built.[1] This then leads to GH systems that are far from optimal, and, in the case of roof-cranes, in all probability their lifting capacity will be severely restricted by the loads that the already-designed hangar roof can additionally bear. In addition, the add-on crane structure itself is more than likely to intrude into the already-calculated hangar free space, where at best it will be a hindrance to the airship's movements, and at worst it may even reduce the available working space sufficiently to restrict, or even diminish, the size of the airship that can actually be built inside the hangar. This is neither helpful nor cost-effective, and consequently, some other view point is required.

In the conventional, design-led view, the GH procedures start in mid air and end up with a moored airship that needs to be moved inside a hangar. In reality, this cannot happen: the airship must first come out of its hangar before it can get airborne. But, it cannot come out of its hangar until it has been inflated, and it cannot be inflated until it has been assembled. Therefore, it is the author's conclusion, based on his previous hands-on experience in pioneering the development of prototype LTA systems – albeit for very small airships,[2] and the mooring systems for a range of even smaller tethered (kite) balloons,[3] - that, when considering the GH for the NGVLAs, and particularly when attempting to design their GHE and devise its operating procedures, a far better way to approach things is to view events chronologically from start to finish.

Such a GH based viewpoint, would then take any new airship from its design on the drawing board, through its construction phase, via its inflation, and hangar exit, and on to its first flight. Only then would such an operationally biased sequence fall into line with the conventional or designers view, and follow the airship back from flight operations, via the landing to the safety of a secure mooring system and ultimately back into the hangar again.

The first GH task in this chronological sequence therefore becomes to fill the airship with gas and, only once this is done, to think about trying to move it outside. Thus, starting with a newly-built, but as yet un-inflated, blimp airship – for example, a US Navy K-ship - and referring to the procedures [4] approved for it, (See **Appendix D**) the requirement is almost immediately revealed for some sort of crane to help inflate it. This leads naturally to such ideas as retractable cranes that are integrated into the hangar roof structure, which can then be purpose built to take the extra internally suspended loads, while maximising the enclosed available working space. Thus, rather than a building for housing the airship (as it is most commonly perceived) the hangar can now been seen to be in truth a huge specialised jig for assembling the airship; one that is clad simply to keep out the weather. In all cases this change of viewpoint starts everyone thinking along rather different, far more realistic lines than is the case when either a "load-pick-up" or a "landing" is seen as the first manoeuvre to be accomplished.

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[1] This is what happened at CargoLifter with their hangar at Brand.

[2] G-ATDK "WASP" (1966); G-AVSL "Chitty Chitty Bang Bang" (1967) and G-BAWL "Santos Dumont" (1973/5)

[3] Flying Pictures "Topshot" camera-blimp series (1987/90), NOFO "Oil on Water" (1993) and MRU Cardington (1995)

[4] "Sequence of events for Inflation and Assembly of U.S. Navy K-Type Airships" extracted by the author from GAC, (1944)

Thus, in the author's opinion, to avoid repetition of effort and constantly back-tracking, it would be far more logical for the whole NGVLA design process to follow a sequence more like this:

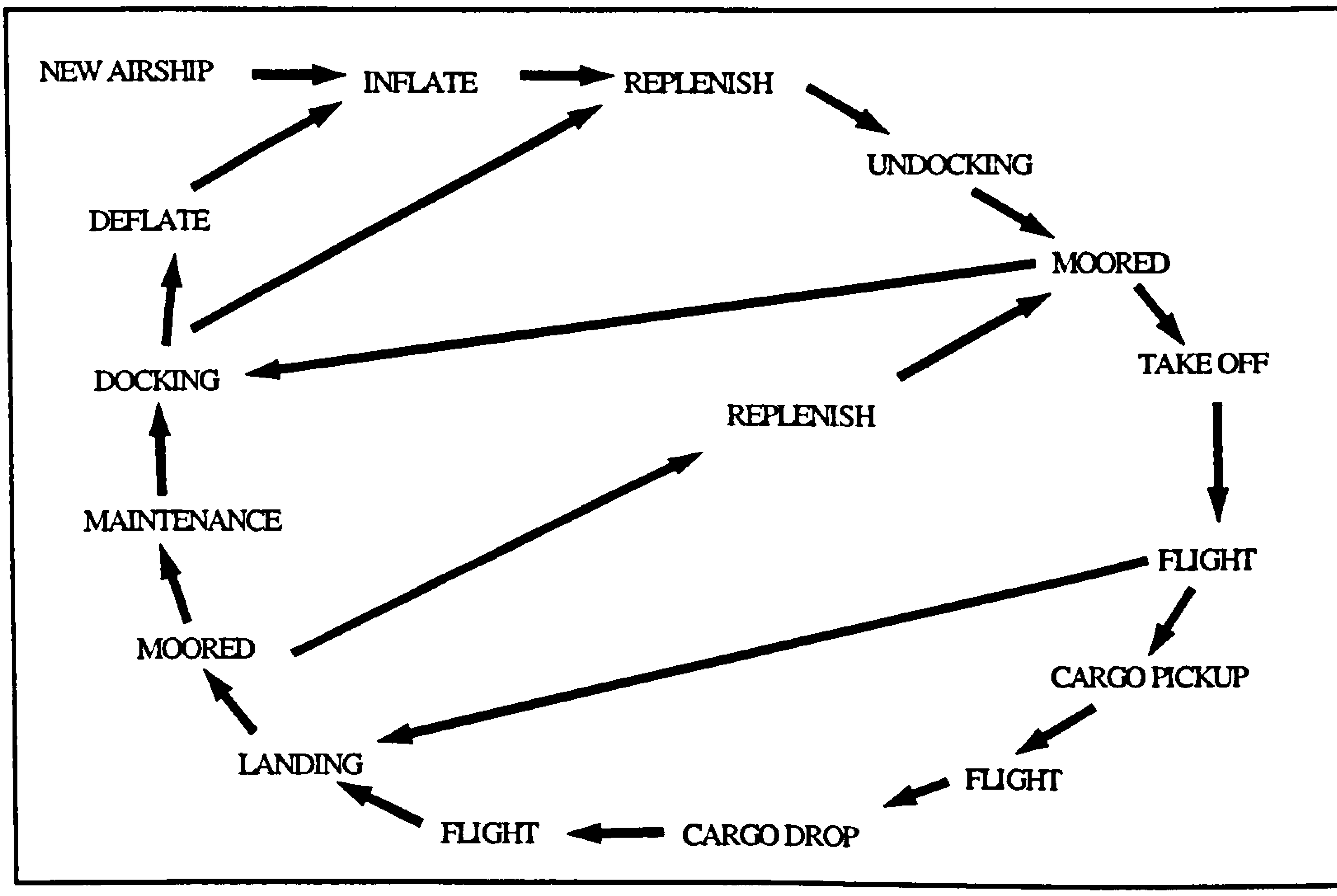

Figure 5.2 - The CargoLifter Procedural Sequence from a GH Perspective

The big advantage of this approach is that it focuses on the need for each step to be successfully completed before a further one commences and it allows a sequential "storyboard" of events, and associated procedures, to be drawn up. This in turn, reveals the need for any and all GHE *in the order in which it will be required* and thus automatically ensures that nothing gets missed out.

However, in setting out to draw such a story board, another subtle but important difference between the designers and operators immediately rears its head. When drawing an airship (or any other aircraft, or vessel for that matter,) it is accepted practice, in the process of design, to have it "flying" from right to left on the page – i.e. with its nose to the left and its port-side facing the onlooker. Thus the orientation of the object and of its x, y, and z axes are once again taken as set in stone, at the start of any discussion, without any thought really being given to it. Yet, neither of these conventions are particularly useful when planning procedures from the GH perspective, and in fact, when planning a "comic strip" of sequential events, viewing things in this way is confusing for the eye. Thus:

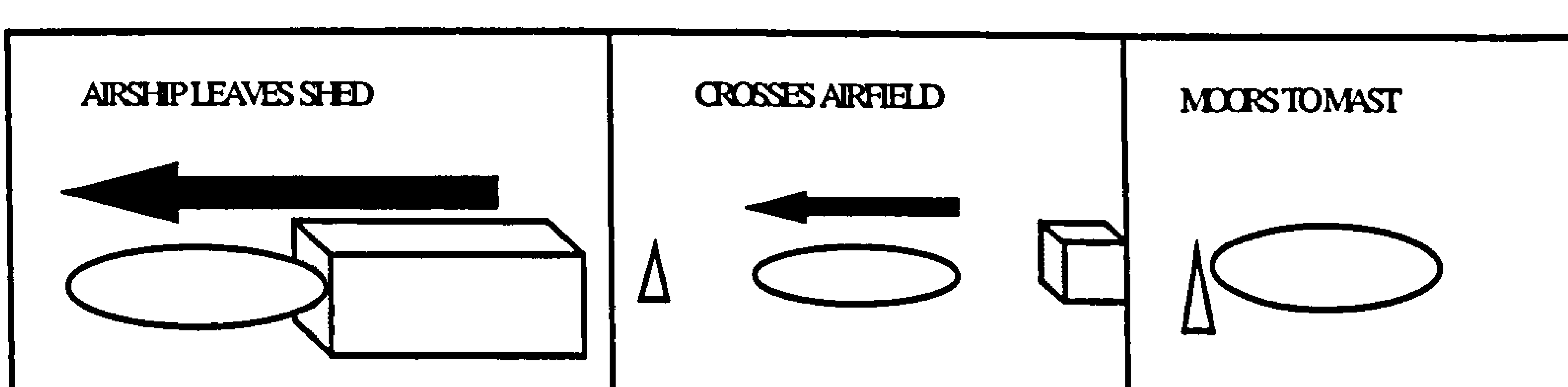

Figure 5.3 - Conventional story board of undocking

Consequently, when considering the planning of a GH sequence it is far more logical to turn the airship around so that it faces the other, unconventional way, and to draw it from its starboard, or right-hand side, if for no other reason than that English is read from left to right, so captions and directions flow with the movement and it is easier to envisage the airship moving through time in the same direction. Thus:

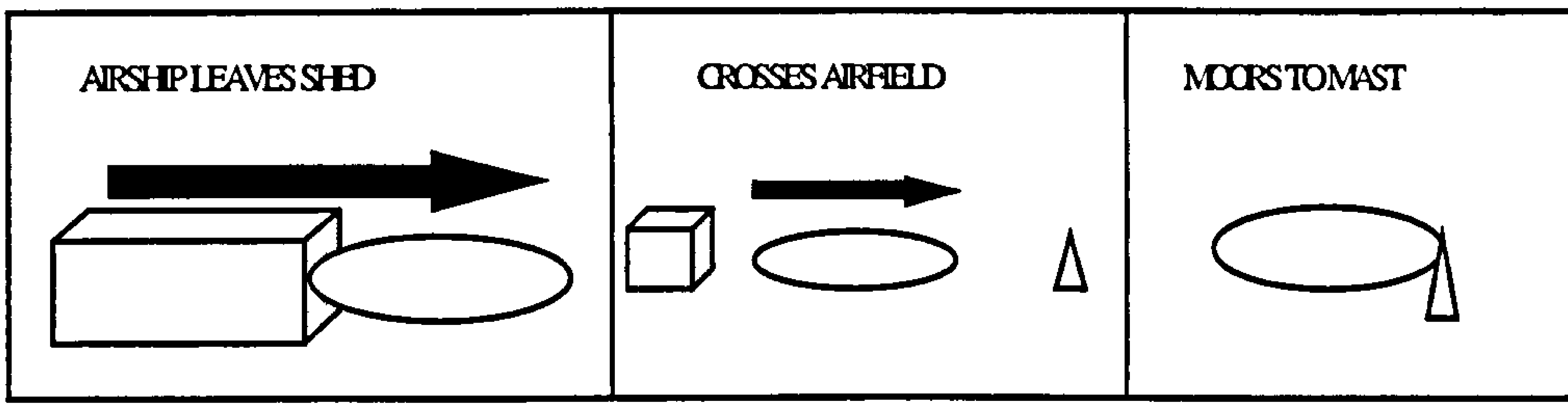

Figure 5.4 – More logical story board of undocking

It is the author's opinion that anything which increases the clarity and understanding of the GH topic and of its complex and multifarious component parts is to be encouraged. This is especially so for the words that are used to describe it.

5.2 Understanding the terminology

The much heralded arrival, and the subsequent disappearance, of a succession of airship development programmes, conducted separately, by both civilian and military organisations, in several different countries, each with its own languages and oral traditions, over a period of roughly one hundred years, has left behind a legacy of half-understood, misused, abused and transmogrified words, that can, and do, lead to a great deal of confusion and wasted time. This is a fact that has frequently been commented on in the past by many authors, historians and airship engineers:

> "The science of aeronautics being a very recent development, its terminology is not yet exactly defined so that confusion is likely to arise from the various interpretations of every term." (Bleistein, 1925)
>
> "Though our English language can be rich and beautiful, it is notorious for its lack of consistency. Some terms used in the airship field are affected by this, which makes for confusion and inconvenience." (Cochran, 1980:2.9)
>
> "AEROSTATICS FOR AIRSHIPS ... Much confusion has arisen by there being no standard definitions of weight terms." (Lewitt, 1925:41)
>
> "There has been some confusion over the definitions of the various weight configurations of an airship. These should be related to the terms used for heavier-than-air aircraft, wherever possible, despite some inconsistency." (Craig, 1999b:235)
>
> "...in its heyday, the rigid dirigible airship was often called a "zeppelin," or "zepp" for short. ... However, using that term to denote rigid airships in general is confusing when it is also necessary to refer to vessels produced by the Zeppelin works, to those produced by other makers, to the revered Count [Ferdinand von Zeppelin] himself, and to the [two] airship[s] "Graf Zeppelin" named after him." (Cochran, 1980:2.11)

The potential for this "Terminology Problem" to generate time consuming confusion and misunderstandings for the NGVLA developers of the future, (and therefore also to waste their money,) is evidenced by this example from an internal CL memo:-

"... in a meeting last week it was found that the expression "trim" was used in different manners. That is a reason to put it into the glossary. Before doing this, I would like to have a basic agreement about the definition. My proposal is the following:

- Trim - activity taken to move either the centre of gravity or the centre of aerodynamic forces (or both) in any direction.
- Pitch Trim - activity where the c.g. or centre of aerodynamic forces is moved in longitudinal direction resulting in a changed attitude of the ship.
- Roll Trim - activity where the c.g. or centre of aerodynamic forces is moved in lateral direction resulting in a changed bank angle of the ship.
- Ballast (verb) - activity where the total mass of the ship is changed. This could also cause c.g. shift, but that is then trim.

Notes: This definition means that trim is restricted to attitude/ roll influence but does not include weight changes, which is covered by the verb "ballast." Trim in general does include also movement in vertical direction. This makes sense to me as it will result in a different state of equilibrium, too ..."

However, the problem of "trim" is not restricted to airships. Their close cousins the submarines have also had similar difficulties with this same small word:

> "We should point out that this special usage of the word 'trim' <u>is</u> confusing ... The only advice we can give is: judge from the context which meaning applies." (Burcher & Rydill 1994:43)

Such advice may be helpful in the specific case of reading a book, but it does not solve the problem in general. For historians, and for other researchers in the field, when attempting to collect material concerning the PGVLAs from archives and libraries, confusing words remain a serious problem that can easily lead to the waste of much research effort. And it isn't only single words that are a problem:

> "An accurate comparison of the airships built in different countries can be a challenge. Different countries use different units of measure, different lifting gases, different standards for the lift imparted by the same gas, different definitions and categories of elements of their airship structures. The published figures never seem to be gathered with direct comparison in mind." (Hall, 2000:8)

So a researcher into airship history, endeavouring to make comparisons, really needs to know all of these "different" words, and their multifarious usages - and even then can still be left wondering.

> "...many of the records (particularly of the World War II airships) include such words as "wrecked", "destroyed" and "lost" when what was actually meant was "deflated"... These mishaps [i.e. deflations] were readily corrected with new envelopes ..." (Shock, 1994:xi)

Thus the unwary newcomer can easily be perplexed to find a US Navy blimp apparently rising from the dead and taking part in an operation, perhaps only days after it had been reported as being subject to an event, which elsewhere in the aviation world would have terminated its career and probably killed all its occupants.

Then there is jargon:

> "Where the mooring operation demands this speed [dead-slow], it is obtained by attaching a four-fold manila purchase to the main wire where it leaves the base of the mast and leading the purchase to the niggerhead of the winch." (USN A.F. Notes, (undated) : Method IV. Part D. 46.)

Or this from the memoir of a US Navy blimp pilot:

> "Normally, in moderate to light winds, the lugs holding the nose cone are pulled and the pelican hook is backed off a tad for the trim check. The pilot then almost backs the ship off the mast as it's [*sic*] tripped loose and the mast pulled away." (Moore, 2004:144)

It should be remembered here that there is a considerable difference between the meanings of the words "pilot" and "captain" when used in context at sea, or in the air, and that most of the large airships of the past were developed by navy personnel whose traditions and usages are very different from those now prevalent in modern aviation. Moreover, jargon can also cause confusion simply because procedures have fallen from use and appreciation of their meaning has thus been lost:

> "A good normal landing is a smooth trail-rope landing rather than a handling-line landing as the latter is really too much of a stunt with the present and future immense airships." (US Navy, 1927:IX-45)

However, confusion and a diversity of terms are not only limited to the aircraft. Significantly for this investigation they also affect the GH and the ground support infrastructure:

> "On the matter of terminology, a mention should be made of the origin of the word "hangar." This is from the French, *hangar*, which in its initial usage means a shed or shippon. It is of course, in common usage in international aviation circles. However, the word for an airship building in English terminology is traditionally "shed"... The German word *Halle* would perhaps be more appropriate for general usage as it gives a much stronger impression of the vastness of such structures." (Dean, 1989:6)

Here a mixture of foreign and unfamiliar words are shown to be part of the problem, but familiar words may also be so over-used that they too can become equally bewildering. Take "**docking**" for example:

> "The fixed **docking** systems also demand precise control of the airship. ... The craft is lined up by the engagement of a **docking** probe and secured by a mooring latch. The **docking** assembly is free to rotate to follow wind conditions." (Howe, 1999:316)

> "The development of mooring circles and railroad masts [at Lakehurst] reduced the need for very large ground crews and made **docking** operations possible in relatively strong crosswinds." (Althoff, 1990:68/9)

> "...the '*Macon*,' used a large and substantial mast. The mooring line was attached prior to **docking** to enable it to be winched onto the mast." (Howe, 1999:307)

> "The virtue of a mast was the operational flexibility it afforded in terms of independence from a hangar. A returning airship could postpone **docking**, for example, if conditions on the field were unfavorable for this delicate maneuver." (Althoff, 1990:32)

> "... the ship [*Graf Zeppelin*], moored to the travelling stub mast, was walked out of the hangar, made fast to trolleys fore and aft which ran on the **docking rails**. When clear of the hangar and mast, the ship was released from the trolleys and held on the ground by the ground crew." (Dick & Robinson, 1985:48)

> "The restraining sandbags are being removed from the [*Graf Zeppelin*] gondola's **docking rails**. ... Another shrill blast on the whistle. "*Schiff hoch*!" comes the command. "Up ship!" The group of handlers holding the control car by its **docking rails** literally throw the giant ship into the air." (Botting, 2001:9)

> "Mechanical assistance [at the Lakehurst hangar] was augmented further by three **docking rails** or trolley slots; bow and stern handling lines would be made fast by tackles to mobile trolleys during the **docking** evolution." (Althoff, 1990:12)

Thus, "docking rails" are either part of a railway track that is fixed to the ground, or they are strong-points fitted to an airship gondola for the ground crew to hold onto. Whereas "docking" on its own, may mean, in the nautical sense, either the whole process, or the specific act, of taking the Air-"ship" into its Air-"dock" (or "hangar", or "shed", or "Halle") or, alternatively, it may be used, as in NASA's "space age" jargon, for the whole process, or for the specific act, of merely attaching an airship's nose cone onto a mooring mast.

Consequently, the corresponding opposite term, "UN-docking" is equally ambiguous and many of the modern small blimp operators now prefer to use "masting" and "un-masting" to cover the latter case. However, in view of the fact that the very large airships of the past often needed a "mast" of such gigantic physical proportions that it was commonly referred to as a "mooring tower" it will be interesting to see whether the NGVLA operators of the future will choose to follow this pattern of usage, and bring "towering" and "untowering" into common parlance.

For the record, the author's suggested solution for this particular term would be to adopt the common working practice of today, *and* hold to the old navy ways at the same time, by the universal acceptance of the appropriate prefixes. Thus the whole process of connecting/disconnecting, to and from the mast, i.e. the "Masting" process, would consist of "RE-masting" and "UN-masting" while the process of entering/exiting the dock, i.e. "Docking" (or "Shedding"?) would encompass the "RE-docking" and the "UN-docking" procedures respectively.

Unsurprisingly, there have previously been some serious attempts to sort some of these linguistic problems out. In Britain they range from publicly available articles for enquiring young minds - e.g. "The language of the air"[1] - to official government documents such as "Standardisation of data for airship calculations,"[2] which, latter was only intended for use by experienced airship engineers and designers.

> "Standard definitions have recently been drawn up by the Air Ministry, but up to the present they are only used in official circles." (Lewitt, 1925:41)

In the USA the National Advisory Committee for Aeronautics (NACA) produced in 1926 - TR 474 "Nomenclature for Aeronautics" which runs to 35 pages. Furthermore, many books on the history of LTA aviation in general and many published works on the history of airships, do also contain their own "Glossary of Terms."

Unfortunately, many of these attempts to clarify and explain some of the terminologies have, with time, served only to add further layers to the confusion, and this in turn confirms, that the whole subject of determining the meaning of words is, in reality a vast area of specialist study. Indeed, in attempting to understand the nuances of historical material concerning the GH of the PGVLAs, the author found that here again, he had unwittingly swum into some very deep waters. For example, an entire book has been written solely on the origins of the three words "Airship, Aeroplane, and Aircraft." [3]

Nevertheless, shortly after the initiation of the CargoLifter Operational Support Historical Research Project, (CLOSHRP), it was found necessary to commence the compilation of a Glossary in order to define the more unfamiliar, and old-fashioned words, for no other reason than that the company was German based, and that many of the young designers, who were joining the CL Development team, and starting to request information from the PGVLA era, did not have English as their first language.

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[1] Middleton, c.1920 : 258

[2] Wyn-Evans, 1921

[3] Stubelius, 1958

In addition, it was hoped that the existence of an historically based Glossary would also help to highlight some other areas of confusion and thereby to:

a) Show where different words are used to describe the same thing
b) Show where the same word is used for different things, or has different meanings
c) Show how the meaning of words has mutated with time
d) Show how misunderstandings of terminology can become the source of myths
e) Show how many useful LTA words have been stolen by other industries and disciplines
f) And finally, to perhaps discover terms that might help NGVLA development in the future.

An example of this latter idea was recognition that the old orders as used by the PGVLA officers, may well become of use again. The reason being that instructions must be clearly understood in order to avoid confusion. Any misunderstandings between officers, and the crew-members on a watch, can have disastrous consequences, and the NGVLAs are intending to develop unprecedented manoeuvres for which orders and instructions will have to be evolved from scratch. But, there is already a large working lexicon of words and phrases that would go a long way to solving part of this problem, and which has already been tried and tested both onboard, and on the ground around, very large airships during their normal flying and ground handling operations. This previously proven lexicon has now fallen into disuse and been overlaid by HTA usage and practices. However, it seems foolish to start with a completely blank sheet of paper, and to relearn all the PGVLA lessons the hard way, when it is possible to take a shortcut and to use the old terminologies - at least as a basis for these new procedures. After all, as has been noted with some irony: "Two months in the laboratory can easily save two hours in the library." (Dick, 2002)

In practice, the scale of this undertaking, in compiling and defining such a universal Glossary, due to the large number of terms involved, and the complexities caused by the way in which many words have either changed their meaning, or been adopted and adapted to cover different circumstances, meant that the volume of work involved soon proved to be beyond the means of the author working on his own. It was therefore decided that a quicker way to arrive at a workable lexicon for the CLOSHRP would be to simply collect and collate the most comprehensive Glossaries from previously published works on airship history, and to use this "Glossary of Other People's Terms" as a basis for the investigation. Unfortunately, even the fusion and integration of this previously published material into a single document proved to be a formidable task in itself; one that was far from complete at the time of CargoLifter's collapse in 2002.

In the end, even a greatly reduced, and incomplete version of this compilation of other people's glossaries proved to be too large in its entirety (more than 50 pages), to sensibly include as an Appendix to this thesis. Thus, only a sample of alphabetical sections are appended for readers' interest as **Appendix E.**

Prior to the closure of the CLOSHRP, the further possibility of expanding and updating the HR LTA terminology collection, was also considered. This "Complete VLA GH Glossary" would have incorporated words from other areas of activity, which while not normally associated with airships, nor even with any form of aviation, were considered likely to involve processes similar to those procedures envisaged for NGVLA GH in the future. The intention was thus to search for potentially relevant words and phrases in such diverse sources as these:

- Glossaries from literature for leisure pursuits, (e.g. Sailing, Climbing, Mountaineering etc.,);

- Rule Books governing modern-day industries, (e.g. Freight Transportation, Cargo-Handling, Oil and Gas Exploration, Submarine Survey, Mining, Construction, Maritime, etc.,); and
- Health and Safety Regulations concerning employees in other disciplines, (such as Ropes & Rigging; Cranes & Hoists; Man-riding equipment, and the Mooring of VLCCs and other ships).

It is to be hoped that such a Complete VLA GH Glossary may one day be compiled.[1]

5.3 Definitions

It is normal for the definitions section of a thesis to contain some fairly straightforward explanations of the various terms that are to be found in the text. However, in the case of this investigation, two of the commonly used word combinations referred to in the title, are ill-defined, and both have been somewhat carelessly used in all previous works on the subject. These terms are "Large Airships" and "Ground Handling." Because these terms are fundamental to the whole HR project, it was necessary before digging into the archives to attempt a clearer definition of them.

5.3.1 What is a "Large Airship"?

In view of the fact that, as shown in previous sections above, approximately 1,000 airships have been built and flown in the past, and that a great proportion of them used GH procedures that are clearly going to be either inappropriate or rather difficult to adapt for use with any future very large airships, it was apparent that some way of focussing the research, and of limiting the numbers of airships adjudged worthy of detailed study by the CLOSHRP, needed to be devised before the investigation could proceed. Such a filtering system is similarly a basic requirement for this thesis.

The most obvious way to reduce the numbers involved would be to extract only "large" airships from the records; but the author could find no agreed definition of what a "large airship" actually was. Conventionally, airships are categorised by the type of structure within which their lifting gas is contained. Thus, in most, if not all, published histories of LTA flight,[2] the PGVLAs are categorised as being either "rigid," "semi-rigid" or "non-rigid." While this classification method does seem to offer an immediate and straightforward way of sorting large from small, owing to the fact that all the rigid airships were effectively 'large' and all the non-rigid ships have been considerably 'smaller,' (with the "semi-rigids" lying somewhere in the middle), it was recognised that adoption of this simple definition would close-off certain areas of investigation, and this could potentially exclude much that was of great value to future NGVLA projects. Furthermore, virtually from the company's beginnings in 1996, and prior to the author's enlistment, CL had determined that a rigid construction method was uneconomic for their purposes. They had therefore declared their intention of building a gigantic non-rigid airship. Consequently, focussing the CLOSHRP research solely on "rigid airships" would threaten to reinforce the misunderstandings of those within the company who were unable to see the relevance of an HR project to their 21st century problems.

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[1] Subsequent to the closure of the CargoLifter project, the author was made aware that there is also a British Standards Institute publication entitled "BS 185-7:1969 Glossary of aeronautical and astronautical terms. Lighter-than-air aircraft (aerostats)"

[2] e.g. Rolt, 1966; Robinson, 1973; Cochran, 1980; Dick & Robinson, 1985; Althoff, 1990; Mowforth, 1991;

Moreover, for this thesis, rather than assisting future NGVLA projects with their decision of which type of airship to build, it would introduce a similar bias and invite dismissal of the GH topic, or at least perpetuate the denial of its importance at an early stage. It was also recognised that whereas, the "heavy operations," as used by the US Navy blimps through to the 1960's, were not in themselves appropriate for the NGVLAs, there was, nevertheless, every reason to suppose that much of the work that had been carried out at the time, in establishing these modern blimp GH procedures, might well be of some worth. Certainly, it would be unwise to completely ignore this work, or to exclude the records of the Goodyear and US Navy experiments, if for no other reason than that they were part of the world's most recent large-scale airship development programme, and thus are the most technologically similar to the present day.

Therefore, it was evident that what was required was a more subtle and inclusive definition of the term "large airship" - one which would limit the area of interest to be researched while also yielding the maximum in terms of GH system diversity and of lessons learnt. Thus further ways of categorising the PGVLAs were investigated and a refinement of the conventional classification system was sought.
A first step was to view the conventional classifications from the Ground Handling Perspective outlined in **Section 5.1**. This revealed, perhaps unsurprisingly, that when it comes to GH, all three airship types have little to choose between them - although, plainly there are some significant differences. Most notably, the non-rigid airship's absolute reliance upon its internal pressure for the maintenance of structural integrity, means, that the blimps, in general, require much closer, and therefore more costly, monitoring, than do their rigid counterparts. In addition the blimps also afford fewer, and less accessible, strong points, for the attachment of restraining ropes &c., and generally lack integral structure to facilitate ease of access for inspection and maintenance. From the point of view of handling, or keeping control of any particular airship when it is on the ground, however, it's structural composition, and the associated problems caused by it, are actually of far less significance than its sheer size.

> "One of the greatest dangers an airship faces, is its vulnerability when being handled on the ground in strong winds. This is a particularly hazardous procedure when entering a shed. Wind eddies over the building can make an airship, which is lighter-than-air, leap around alarmingly. The larger the airship, the greater the problem." (Mowthorpe, 1999:64)

> "Their smaller size [the *L-10* and *L-20* class Zeppelins], compared with the larger ships which came later, was always remembered as a good point, easing the handling on the ground that was always the biggest problem with any airship." (Brooks, 1992:93)

Thus, the "largeness" of airships is acknowledged to be of fundamental importance when it comes to the ground handling of them, although the term itself remains ill-defined.

Initially, the idea of relating largeness directly to airship length was discounted on the grounds that, as previously stated (in **Section 2.3**,) "the length of an airship gives no real idea of the inertial forces that its pilot has to deal with." And moreover, because the same holds true for the GH team, as also stated, "A far better guide to this can be gained from a comparison of the internal volumes ..." For example:

> "The *R-101* [as first flown] was seen to be a short, plump craft, with the length-to-breadth ratio of 5.5 to 1. Thus, though it was 43 feet shorter than the famous *Graf Zeppelin*, its greater diameter (by 30 feet) gave it actually twice the volume of hydrogen ... approximately 5,000,000 cubic feet." (Hylander, 1931:203)

It was therefore suggested that another obvious way to categorise the PGVLAs according to their size would be to ignore their length and simply to use the "volume" of gas each contained. However, when reviewing the historical records, this term proved to be equally problematical simply because in many instances it is not at all clear what exactly is meant by an airship's "volume." There is certainly no universally agreed definition of it. On the contrary:

> "Most published data on airships are unreliable and often contradictory.... [and] there are usually wide discrepancies in recorded figures for gas capacities. This is because of confusion with 'nominal capacity' (usually 95 per cent of full) and with the air volume of the hull. There are also frequent errors of conversion to and from metric units." (Brooks & Griffin 1973:55)

Furthermore, with non-rigid, pressurised airships, calculating the volume of lifting gas within them is complicated by the fact that, even when moored in a hangar, the contents of a blimp airship's multiple inner chambers can, and do, vary constantly in accordance with fluctuations in the ambient meteorological conditions. Specifically this means that although the 'gross' volume of the entire envelope stays constant, the percentage taken up within it, by the 'net' volume(s) of the air-filled ballonet(s), is forever changing as the interactions of temperature and barometric pressure result in compensatory pumping and venting of the chambers in order to maintain the correct hull pressure. Therefore, to simplify things, the maximum total 'gross' theoretical volume of all the gases enclosed within the entire fabric envelope, (i.e. as it would be at "pressure-height," full of gas, with empty ballonets), is frequently given in preference to the actual or normal volume of the lifting gas. However, even here there is a problem because non-rigid envelopes are also susceptible to volumetric change for another reason – they stretch:

> "The best known of these [earlier types] was the World War II Navy K Ship or ZPK, of which 133 had been built. It was a medium sized machine, 251 feet long with a volume of 425,000 cubic feet (435,000 with stretch, or dimensional relaxation, as the contractor liked to call it)." (Mills, 2004:127)
>
> "Envelope design volume for the cotton [*ZPG-3W*] envelope was 1,465,000 cubic feet and was expected to increase to 1,516,000 [1] cubic feet due to stretch of 3½ %." (Shock, 1994:III-26)

This dimensional slippage is less of a problem for rigid airships, where the gas cell membranes are usually restrained within a system of nets and/or cables. Nevertheless, obtaining any universal agreement as to an accurate method of recording the lifting gas capacity within rigid airships is still all but impossible, and the calculation of it is similarly beset with many of the same problems. For example, the combined total of the volumes of lifting gas contained within the multiple gas cells (or bags) of any particular airship, when it is ready for operation, or in flying trim, is different from the volume that could be theoretically contained within those same gas cells, when they are filled to their absolute capacity (i.e. at that airship's "pressure height"). Moreover, this number (be it in cubic metres or cubic feet) is different again from the total combined volumes of all the gas cells, plus all the air enclosed in the spaces between them, and that within the enveloping outer skin of the hull surface cover. But, there are further complications, derived as always, from one or two exceptional cases:

> "The length of this air cruiser is 770 feet, with a diameter of 100 feet. The seventeen lifting-gas cells can use 2,295,000 cubic feet of hydrogen; they occupy only three-fifths of the volume of the hull. The lower two-fifths contains twelve fuel gas cells with a capacity of 1,482,000 cubic feet; so that the total volume of the *Graf Zeppelin* is about 3,700,000 cubic feet." (Hylander, 1931:260)

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[1] "The demonstrated volumes (based on actual weigh-offs) of the four [*ZPG-3W*] airships were 1,545,000, 1,542,000 and 1,544,000 cubic feet for the cotton envelopes. The demonstrated Dacron envelope volume was 1,509,000." (Shock, 1994 : III-27)

Another possibility suggested for the CLOSHRP was to devise a classification formula based on the length to diameter (L to D) ratios of the PGVLAs. The thinking behind this was that it is commonly accepted as a fact that the rigid structure has generally led to craft of this type being longer and thinner than the non-rigid varieties. However, the idea was abandoned as being too complicated and because it produced no clear division between large and small in the spectrum of classes it generated. A further system based on sub-dividing the PGVLAs according to their behavioural characteristics, and on their ability, for instance, to swivel their engines, (and thus to hover or non-hover) was similarly dismissed as it resulted in a grossly unequal division and some strange bedfellows.

Finally, it was determined that, while it was not ideal, and there were anomalies, the overall length was actually the simplest way to categorise the PGVLAs and that careful positioning of the dividing line not only allowed inclusion of the GH systems devised for the largest and latest of the US Navy's blimps, but also results in a clear division between "large" and "small" airships with an easily memorable "rule."

To achieve the desired reduction in the number of airships of interest, while maximising the diversity of GH systems available within the "large" category, it was first necessary to compile a table of all the major types, or different classes,[1] of airship that have existed in the past, and to put them in order of their increasing length (See **Figure 5.5**). If, a line is then drawn at the exact half-length point (246 m being the defining maximum) then, some 77 classes of airship are reduced at a stroke to 44. Conveniently, also the last and largest of the US Navy blimps, the *ZPG-3W*, is actually on the dividing line,[2] and there are few exceptions stranded on the wrong side of the line. Only Nobile's semi-rigid "*Roma*" (128 m / 420 ft) and the final extended version of the German Army's blimp "*Gross Bassenach M-IV*(c)" (127 m / 416 ft) - were longer than 123 metres, whereas only one airship with a conventional [3] rigid structure of less than 123 metres in length appears ever to have been built. This was Eckener's "*Bodensee*" (*LZ120*), which was under 400 ft long when first built but which was subsequently stretched to 426 ft (129.8 m) in its final incarnation.

Thus, if "Large" is defined as - greater than 123 metres (403 feet) in length, and "Small" as - less than 123 metres in length, then this conveniently also divides the PGVLAs quite cleanly into their conventional "rigid" and "non-rigid" categories and also results in the easily memorable "123 metre length rule" to use as a filter for the historical material. Interestingly, although the division between large rigids and small non-rigids has previously been commented upon, it does not seem to have been precisely delineated nor seriously employed for the categorisation of airships prior to this study.

Therefore for the purposes of this investigation, a "Large Airship" is an airship that is more than 123 meters (or 403 feet) in length.

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[1] **See Appendix F - Comparison of airship classes by length**

[2] *ZPG-3W* overall length = 403.4 feet (Shock, 1994 : III-26)

[3] Assuming one discounts the three small and unconventional "Metalclads" ('*Schwarz*,' '*City of Glendale*' and '*ZMC-2*')

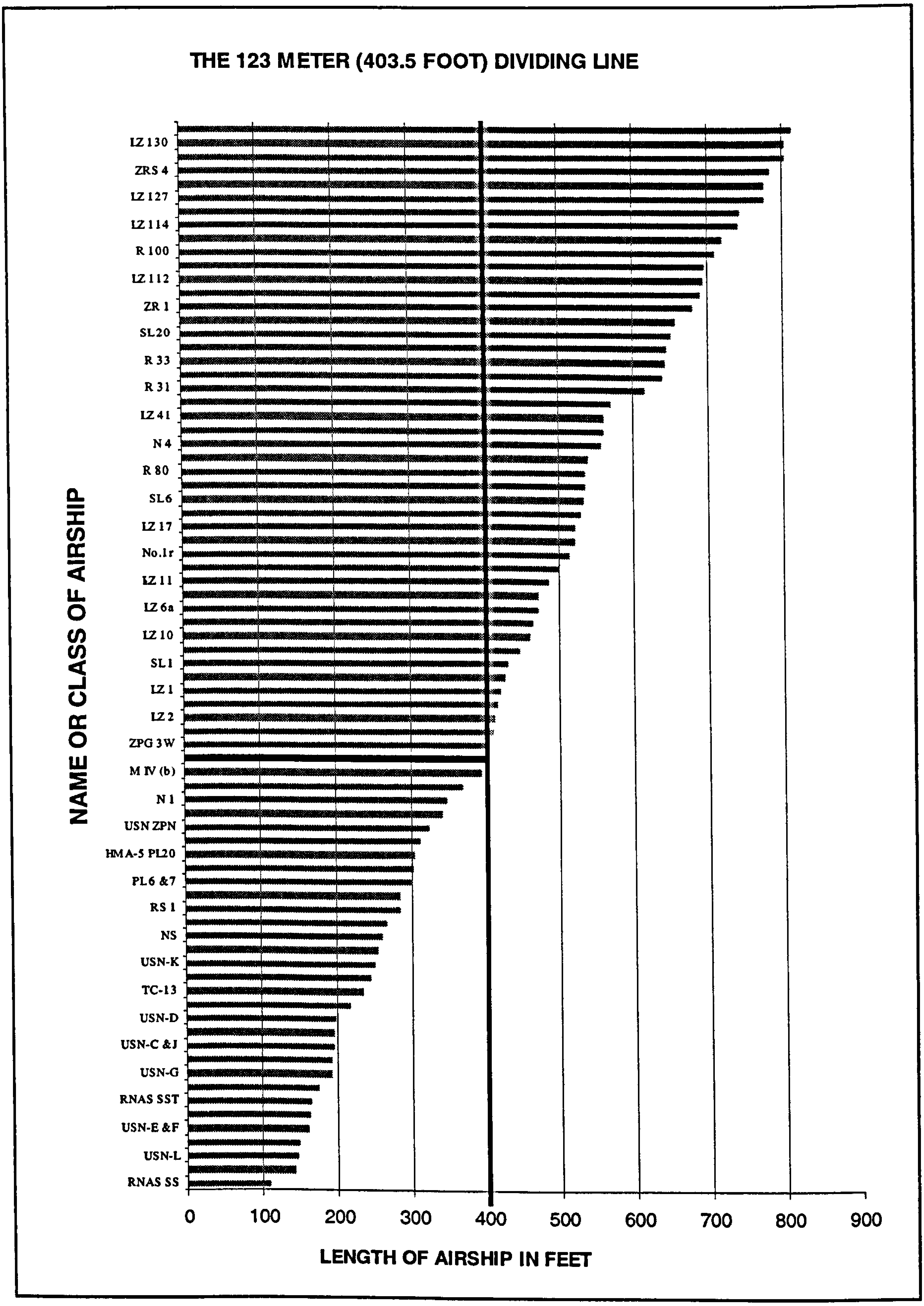

Figure 5.5 – Airship types in order of length to show 123 metre (403.5 feet) divide
NB – For clarity only alternate airship name/classes are shown here.
The full list of classes is given as **Appendix F**

5.3.2 What is "Ground Handling"?

When attempting to define the term "Ground Handling," for the purposes of this investigation, it quickly became clear that conventional definitions were somewhat lacking. For example, here is a seemingly straight-forward and simple description of the ground crews' tasks, which can be found in the Ground Handling manual of a small modern blimp: [1]

> "The ground crew have two main roles: the launch and recovery of the *GA-42*, (and) to ensure the airship remains secure when moored." (Flying Pictures (Airships) Ltd., c.1988:3)

However this definition excludes some vitally important and problematical processes in which both GH personnel and the GHE would appear inevitably destined to play a major role for the NGVLAs. These additional tasks are revealed, and listed here, as "problems" under item (b).

> "The ground problems of airships, outside of mooring, involve in general terms:
> (a) the landing of ships from flight and
> (b) the moving or handling of the ships over the ground and in and out of hangars."
> (Rosendahl, 1927)

Thus, the problems the ground crew of an airship have to solve, according to Rosendahl's description, (and despite his listing them as being only two in number), are really four-fold.

1. The landing;
2. Movement over the ground;
3. Movement in and out of buildings, and
4. Mooring.

Quite why Rosendahl should have pushed "mooring" to the "outside" of his list can only be conjectured at but perhaps he felt it to be of a lesser magnitude than the other problems? Or maybe he perceived that in his day it was a problem that had been more nearly solved? Whatever the reason it serves to illustrate the fact that different operators at different times have each viewed the subject of GH rather differently and consequently have expected rather different things from their "ground crews" (see next **Section - 5.4 Previous Work on Topic**). This makes defining the term somewhat problematical and it maybe the reason that there seem to have been so few previous attempts to do so (See **Section 2.1 The Problem of the Cinderella Profession**). Indeed, among all the books referenced at the end of this thesis the author could find only one definition of the actual term "Ground Handling." It is this:

> "GROUND HANDLING - The processes involved in the loading, unloading, servicing and movement of an aircraft on the ground or at a mooring facility." (Mowforth, 1991:102)

This seems on the face of it to be a perfectly good and workable definition and, indeed, it was used as the basis of a paper on this topic,[2] given by the author, at the time of the closure of the CargoLifter Project, to the Airship Association Conference in Cambridge in 2002 ("The Cambridge Paper").

However, this definition introduces a further dimension to the debate by adding "loading, unloading and servicing" (presumably replenishment and supply of vital substances and consumables?) to the 'moving' and 'mooring' tasks already identified. It is also in close accordance with GH as it is understood and accepted within modern HTA practice.

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[1] "The *GA-42* Airship Ground Handling and Mooring Manual"

[2] Camplin & Schaefer, 2002 - see **Section 4.1 – Origins of the Thesis**

This might be seen to be a good thing - except that it omits entirely two procedures, previously mentioned above as being of primary importance, by both of those with extensive hands-on GH experience of small (Flying Pictures) and large (Rosendahl) airships - namely the launch and the recovery (or landing). Here is further confirmation of the point previously made that there is a very great, but largely unrecognised, difference between what is accepted as the norm in modern HTA practice and the opinions expressed by those whose experience and expertise lies exclusively within the arcane world of LTA flight.

In order to obtain a more detailed and all-inclusive definition of the term "Ground Handling" it would perhaps be rewarding to delve further back into the airship's LTA roots and see if the world of ballooning can offer a clearer understanding of what are the irrefutably necessary "processes" that lie behind the term. However, here again, as far as the basic modern hot air balloons are concerned, there is not a lot on offer. This is one of the only definitions related to the GH topic that the author could find:

> "Ground Crew - Persons who assist in the assembly, inflation, chase, and recovery of a balloon." (FAA, 2001:G-4)

The important distinction here, in comparison with the foregoing, is that the balloon crew's job is seen as being to assist with every process involved in the operation of the aircraft, all the way from its initial assembly right through to the final recovery of it after it has landed and been deflated. In airship terms this would equate to a ground crew that would help to:

a) transport and collect its constituent parts;
b) construct the airship;
c) fill it with gas;
d) load it;
e) launch it;
f) provide logistical support during flight operations;
g) capture it;
h) unload it;
i) deflate it, and
j) pack the components for transportation by road.

In short, the ground crew would do everything that the pilot doesn't, and it is apparent, from study of the history books, that in the long slow evolution of the airship from its origins as a 'motorised-balloon,' the ground-based personnel have at times been asked, and indeed expected, to do all of these tasks. What all this reveals is that there is today no universally agreed point at which the GH for an airship – particularly a very large airship - really begins, nor what it consists of, and nor where it should end. This needs to be addressed.

5.3.2.1 Defining the GH tasks

By means of reference to the previously mentioned "ground based perspective" (see **Section 5.1 The Need to Establish a GH Perspective**) it is possible to identify a list of ground based actions or tasks, every one of which, in the course of building and operating any new airship, (and regardless of its size or function,) will have to be addressed by someone, and which the "ground crew personnel" are almost certain at least to be involved with, if not entirely responsible for.

In The Cambridge Paper the authors identified 21 such tasks:

Fig. 2 The Generic Ground Handling Tasks

1. **Inflation** - fill the airship with its lifting medium
2. **Weigh-off** - measure and adjust the static buoyancy
3. **Undocking** - move airship out of a hangar
4. **Mooring** - keep control of airship when not in flight and protect it from damage
5. **Replenishment** - re-supply consumables necessary for normal operation
6. **Systems testing** - prove fit for purpose and/or of certifiable standard
7. **Flight preparation** - make ready for specific mission in foreseeable weather
8. **Launch (take-off)** – initiate controlled transition from mooring to flight
9. **In-flight monitoring** - track mission progress, stand-by to give assistance
10. **Load exchange** - load and unload payloads
11. **Capture (landing)** - control transition from flight to mooring
12. **Maintenance** - routine inspections, cleaning, etc. of airship and GH equipment
13. **Repair** - mend or replace damaged or time expired parts
14. **Expeditionary site set-up** - establish and service temporary operational bases
15. **Gas management** - maintain lifting medium within designated parameters
16. **Storm mooring** - keep control of the airship in normal windy weather
17. **Enduring extreme weather** - protect the airship against abnormal weather
18. **Breakaway and emergency touchdown** - logistical support for unplanned "abnormal" flight to an unknown destination
19. **Retrieval from remote landing site** - logistical support for planned "abnormal" return flight OR wreckage retrieval
20. **Docking** - move the airship into a hangar
21. **Deflation** - remove lifting agent without damaging airship structure

However, subsequent research and analysis by this author has led to the conclusion that these 21 tasks are something of an underestimate. To some extent this number is merely a matter of classification and doubtless it can be argued that many of these divisions are arbitrary, nevertheless, a start has to be made somewhere and if the tasks are defined, or sub-divided by the range of skills, or areas of specialist knowledge that whomsoever carries out the task will have to be proficient in, then it becomes apparent that there are at least 40 actions which can be, and have been in the past, lumped together and/or loosely described as "Ground Handling."

Continuing with the practice established in The Cambridge Paper, these actions can be termed "The Generic Ground Handling Tasks" and taking them roughly in the order in which any, and every, newly-built airship might expect to encounter them in its lifetime, they can be listed and defined thus:

001 **Preparation of the Ground Handling Infrastructure** - design, build and test GHE (shed, mast, rails, &c.)
002 **Preparation of the Ground Support Infrastructure** - design, build and test GSE (tanks, pumps, pipes &c.)
003 **Protect infrastructure** (Groundside Security) - protect the infrastructure from unauthorised interference
004 **Protect airship** (Airside Security) - protect the airship from unauthorised interference
005 **Assemble airship structure** – connect, lay-out, erect or suspend component parts
006 **Inflation** - fill the airship with its lifting medium
007 **Buoyancy management** – keep the airship close to neutral buoyancy by on and off loading ballast weight
008 **Gas management** - keep the lifting medium within designated parameters of pressure and purity
009 **Systems testing** (for certification?) - prove airship is fit for purpose (includes initial lift and trim test)

010 **Preparation of Airship** – obtain permissions from airfield authorities etc., and connect airship to GHE
011 **Undocking** - move airship out of shed with the GHE
012 **Taxiing** or transit - move the airship on the ground with the GHE
013 **Mooring** - keep control of the airship when it is not in flight
014 **Endure extreme weather** - protect the airship from hail, ice, snow, dust and other weather conditions
015 **Storm mooring** – protect the airship from strong wind
016 **Replenishment** - re-supply consumable items necessary for normal operation
017 **Load payloads** (LEP) and/or people
018 **Preparation for flight** - weigh-off etc., for specific mission in foreseeable weather conditions
019 **Launch** (take-off, lift-off or release) - controlled transition from mooring to flight
020 **In-flight monitoring** - keep track of mission progress, stand-by to give assistance
021 **Capture** (landing or touchdown) - controlled transition from flight to mooring
022 **Unload payloads** and/or people
023 **Maintenance (airship)** - routine inspection, cleaning and checking of airship systems
024 **Maintenance (GHE and GSE)** - routine inspection, cleaning and checking of GH systems
025 **Repair (airship)** - mending or replacing damaged or time expired airship parts
026 **Repair (GHE and GSE)** - mending or replacing damaged or time expired GH parts
027 **Emergency break-away pursuit** - logistical support for unplanned abnormal flight to an unknown destination
028 **Emergency situation** – crash (includes forced landing at both home base or a remote location)
029 **Emergency situation** – fire on board airship or associated with GHE
030 **Emergency situation** – structural failure or damage
031 **Emergency situation** – loss of lift (e.g. resulting from stuck valve)
032 **Emergency situation** – injured/sick personnel on board airship or associated with GHE
033 **Set-up temporary ops base** – move GHE from home base and establish a temporary or "expeditionary" base for mooring airship at remote site
034 **Service airship at remote mooring site** – capture and moor airship at remote site and supply consumables and precisely measured quantities of fuel, ballast and lifting gas
035 **Retrieval from a remote landing site** – launch airship at remote site and monitor planned abnormal return flight (i.e. may be with damaged airship)
036 **Retrieval of wreckage** – supervise uncontrolled removal of lift and salvage components
037 **Remove or "strike" temporary ops base** – dismantle and transport GHE and GSE from remote site
038 **Re-docking** - move airship into shed
039 **Deflation** (includes dismantling) - controlled removal of the lifting agent without damaging airship components and disassemble structure
040 **Weather monitoring**

Clearly, this is an even more "formidable" list than the 21 identified in the Cambridge Paper. However, it seems inevitable that all these tasks will at least have to be considered by the developers of any future NGVLAs, even if they are not precisely defined, allocated or assigned to any particular group of people at the start of any project. Equally clearly, for the purposes of this investigation, 40 complex, interwoven and imprecisely defined procedures are far too many to be properly investigated. Some way will have to be found – as with the numbers of the airships themselves - to reduce the number to more manageable, and ideally more memorable, proportions.

One obvious way, commonly believed to be the most convenient way, to reduce the number of tasks at a stroke, is to take the task list and simply "fold it in half" by combining as a single topic all those events that appear to be most closely allied. There are, for example, some tasks which might logically be expected to involve the use of the same equipment, and thus, on the face of it, these could quite legitimately be paired up and treated as one. For example:

Inflation (assembly) and Deflation (dismantling)
Undocking (move out of shed) and Re-docking (move into shed),
Launch (release from moorings and take-off) and Capture (land and re-connect to moorings),
Loading and unloading,
Set up (establish) and take-down (remove and clear up) remote operational bases

However, the problem with doing this is that it presupposes that these pairings are a mirror-image of their opposite number, and it engenders the belief that they are composed of procedures which can be run in reverse order. In many instances this is not the case. Take for example the procedure for connecting a large airship to its mooring mast, as it was commonly done in the 1930's.

> "To make the usual "flying moor" ... the airship would fly slowly towards the mast and drop three wires – a mooring wire and two yaw guys – from the nose. All three would be connected [by ground crew members standing on the ground] to lines leading to winches at the mast ... The airship would now drop ballast and rise vertically under the control of the winches, lateral drift being prevented by the yaw guys ... the main winch would now draw the nose down until this [mooring] cone [suspended on a vertical axis from the extreme nose] engaged the corresponding cup on top of the mast and was locked into it by spring latches. Flying off from the mast **used essentially the same procedure in reverse.**" (Mowforth, 1991:35) **[GC emphasis]**

This would seem to suggest that, when leaving the mast, the airship would reverse away dragging the three wires – a mooring wire and two yaw guys – with it. It would then move forward, to slacken and lower the wires to the ground so that the ground crew could "disconnect" them, finally allowing the airship to climb away, reeling in its halves of the three wires as it did so. But this is not what was actually done.

> "Even when the [newly moored] ship's bow cone was secured in the mast cup, much work remained to be done, for "*the ship is never safe until in all respects ready to take the air instantly.*[1] " The ship's main mooring wire and the yaw lines had to be hauled back into the ship, and water ballast and fuel loaded, while the cells would be topped up with helium as necessary. At the mast a skeleton crew ... was on board at all times ... to fly the ship if she were forced to slip from the mast in an emergency." (Robinson & Keller, 1982:75)

> "The top portion of the mast to which the vessel is attached is designed to rotate ... It should be noted that mooring and release are entirely mechanical, requiring the services of but a few men; ... and - what is an important point - that the release of a ship is a matter of seconds only ..." (Pratt, 1920)

> "He [the captain of *R100*] gives the order 'Flying stations' and we go to our various allotted posts. The supply services such as gas, water, petrol, electric light and telephone are disconnected and the gangway hauled up. ... On the winch platform [in the airship's nose] we receive the order 'Prepare to slip.' This is passed to ... [the officer in charge of the tower] ... who gives the order 'Take strain on the wire' – a mast hand inside the tower then screws down his wheel and draws the mooring pendant taut. Then, 'Out stops', and the spring stops holding the ship's cone in the mast's cup are withdrawn, and the airship is left riding solely by its mooring-pendant – a short length of wire with an eye at the mast end and a stopper in the ship's cone. A report is made to the control car as to the state of the airship as shown by a device in the bows ... water is dropped ... until the indicator shows a quarter of a ton either side of zero. A message then comes from the control car ... to the Mooring Tower Officer who gives the order 'Ease up on the wire.' The wheel holding the pendant will be slackened off. ... The Captain will order ... 'Stand by to slip,' quickly followed by 'Slip,' all this being repeated to the Tower Officer, who finally orders 'Slip,' and the bar, holding the hinged hook fast in the eye of the pendant, is lifted. The bow lifts slowly, drawing the cone out of the cup, the mooring-pendant with it, and the ship is free. To make sure that she will lift clear the top of the tower, another half ton of water is let go as she lifts clear. As soon as the ship is well clear of the tower the engines are rung up to the required rpm and away we go, gradually gathering speed and height while the tower recedes ... " (Meager, 1970:160/1)

[1] US Navy Rigid Airship Manual, 1927 : IX-97

Thus there is no necessity for the airship to pull the wires with it and then to wait around, dangerously near to the mast, while the ground crew do the disconnecting. Therefore, it is evident that the procedures for an airship leaving its mooring tower are not simply the reverse of the attachment procedures, and nor is the procedure for taking an airship out of its shed the reverse of that for putting it back in again - although, this too is commonly believed to be the case. However, here too it is necessary to go into some little detail to understand the reasons.

Consider an airship inside a shed that is aligned with the prevailing wind. If the nose of the airship is attached to a "mobile mast" which is capable of driving itself forward by means of an in-built "locomotive," or an attached "tractor," and the airship's tail is held by a separate mobile, but unpowered, anchoring device (commonly a "beam" in US Navy parlance,) then it is a simple matter for the mast to tow the airship out of the shed dragging the beam along with it. However, this relies on the pull from the mast being transmitted to the wheels of the beam through the generally fairly fragile airship structure – unless this has been foreseen to be a problem, and:

> "... a system of interconnecting tension and compression members has been designed and built which rigidly holds the [stern handling] beam a fixed distance from the [mobile] mast and is stronger than the full tractive effort of the mast locomotive. On one occasion while the ship [*ZR3 - Los Angeles*] was being walked out of the hangar, the beam fouled on a protruding part of the hangar floor and was definitely stopped against further motion. Using the interconnecting spreader-bar system of towing, this merely resulted in stopping the mast and airship, the locomotive spinning its wheels but doing no damage to any part of the ship or handling apparatus." (Bolster, 1932:119)

So far so good, but now consider what happens when trying to return the airship to the shed. Either the beam must now tow the mast to put the airship back in tail-first as it was, or, the airship must enter the shed mast-first and end up facing in the opposite direction. Of course, neither of these is a serious problem in itself, assuming the engineers have done their work properly and provided, either a "tractor" to pull the beam, or doors at both ends of the shed. However, the latter solution has the big disadvantage that, (assuming the same weather conditions,) in order to align the airship with the shed axis, the tail must initially be turned into the prevailing wind and, subsequently on its second removal from the shed, via the other set of doors, the airship will emerge down wind of the building and have its tail facing into wind.

Whatever the decision, it is plain that the GH procedures for entering the shed are going to differ significantly from those for leaving it, and that, as with the mast connections, lumping these two procedures together in the mistaken belief that they mirror each other, is quite wrong and disguises the true nature and complexities of them. Thus it is deemed wise, certainly at the start of this investigation, to keep all these 40 identified procedures as separate entities unto themselves, and consequently another way is needed of reducing their number and of bringing the field of study into more manageable proportions.

Looking again at the list of tasks it can be seen that some are fairly obviously subsets of others. They consist of selected procedures from within a larger, more thorough, and more complex, sequence. For example, the initial lift and trim tests, including the very first experimental "weigh-off" of a brand new airship, immediately following its construction-assembly-inflation process, will inevitably be much more detailed, and involve far more cross-checking, than a check "weigh-off" after a gas top-up or re-purification when that same airship has been in operation for some time. Moreover, this lesser procedure will in turn almost certainly encompass and exceed all that takes place within the regular (perhaps) daily (or weekly?) pre-flight "weigh-off" that must precede that airship's every mission.

There are also some events that can be classed as exceptional, and some which will involve abnormal procedures. These include both planned events – such as inflations and deflations – and unplanned events - such as extreme weather; serious but not critical in-flight equipment failures; retrieval from forced landing at remote site; fires; floods; and other occasions when the flight crew reach the limits of their own resources and need external assistance or rescue. Furthermore, all the tasks will have a preferred, or a required location, and thus one possible way to sort and shorten the list would be to decide where the tasks are most likely to be, (or will unavoidably have to be,) done, and whether they are likely to be rare or every day occurrences. A simple table will help to sort the tasks by their location and frequency:

\ Location List of Tasks \	Inside shed	Outside at base	Remote Site	Every day	Rare event
001 Preparation of G H Infrastructure	X	X			X
002 Preparation of G Support Infrastructure	X	X	X		X
003 Protect GH & S infrastructure (Security)	X	X	X	X	
004 Protect airship from interference	X	X	X	X	
005 Assemble airship structure	X				X
006 Inflation	X				X
007 Buoyancy management	X	X	X	X	
008 Gas management	X	X	X	X	
009 Systems testing (for certification?)	X	X			X
010 Preparation of Airship (lift test)	X				X
011 Undocking	X	X		X	
012 Taxiing or transit		X		X	
013 Mooring	X	X	X	X	
014 Protect Endure extreme weather		X	X		X
015 Storm mooring		X	X		X
016 Replenishment	X	X	X	X	
017 Load exchange payloads and/or people	X	X	X	X	
018 Preparation Flight & Weigh-off	X	X	X	X	
019 Take-off, lift-off, launch or release		X	X	X	
020 In-flight monitoring		X	X	X	
021 Landing, touchdown or capture		X	X	X	
022 Unload payloads and/or people	X	X	X	X	
023 Maintenance (airship)	X	X	X	X	
024 Maintenance (GHE and GSE)	X	X	X	X	
025 Repair (airship)	X	X	X		X
026 Repair (GHE and GSE)	X	X			X
027 Emergency - break-away pursuit		X	X		X
028 Emergency – crash		X	X		X
029 Emergency – fire on board	X	X	X		X
030 Emergency – structural failure	X	X	X		X
031 Emergency – loss of lift	X	X	X		X
032 Emergency – injured personnel	X	X	X		X
033 Set-up temporary ops base			X	X	
034 Service airship at remote mooring site			X	X	
035 Retrieval from a remote landing site			X		X
036 Retrieval of wreckage		X	X		X
037 Remove or strike temporary ops base			X	X	
038 Re-docking		X		X	
039 Deflation (dismantling)	X	X	X		X
040 Weather monitoring and forecast	X	X	X	X	

Table 3 - The GH Tasks By Location And Frequency

There is however, a danger in making such a table, in that each of the 40 procedures can now be seen to have three different facets, each of which is quite likely to require its own modified set of procedures and thus could claim to become a task in its own right. For instance Gas Management inside the Shed could easily involve different equipment (and thus also crew skills/training) from that used in the same process outside on the Home Base Field, or, indeed from that transported by road to a Remote Location. The result is that the list of 40 Generic GH Procedures has now grown to encompass some 120 potential separate actions, or events, all of which would seem to involve some participation of the "ground crew."

Notwithstanding that not every box in the table has a cross in it, and, for instance it is obvious that the Setting Up of a Remote Base is never going to take place Inside the Shed, just as the Assembly and Inflation of a VLA is unlikely ever to take place in an unprepared open field, it is still clear that the size and complexity of "Ground Handling" is increasing rather than being reduced as was the intention.

Furthermore, if, for example, one were to exclude from the area of study, all those events which are categorised as 'rare' in this table, and which take place exclusively 'inside the shed,' then the list of tasks is only actually reduced by three items - 005 Assemble airship structure; 006 Inflation and 010 Preparation of Airship. Plainly this "inclusive" method of sorting the GH tasks is the wrong way to go.

It should be kept in mind that the impetus behind this definition of the term "Ground Handling," is not only to limit the list of tasks for the purposes of making things more immediately amenable for this thesis. It is also hoped to be of assistance to any future VLA project developers. Thus, given the length of the list, and the diversity of topics it encompasses, along with the range of skills which are going to be required in order to accomplish all these various tasks, it would seem that a better way to provide a useful service to the NGVLAs would be to establish who, within any future project, might be best suited to carry them out. Moreover, it seems virtually certain that the personnel who will be involved in making these decisions and in carrying out the actions, for any NGVLA projects, will have come from a background of HTA operations and, consequently, bringing the ground operations as closely into line with modern aviation practice would perhaps also be advantageous.

It would therefore seem sensible to draw another table, one that is "excluding" in that it seeks to hand-over responsibility for as many of the 40 tasks as possible, from the ground crew, to other departments who are perhaps necessarily already involved in them, or who have in interest in them, and who might reasonably be expected to contain personnel with the requisite skills and qualifications to carry them out. Rather than maximising the complexity of GH and of multiplying the tasks on the list, and thereby empowering the ground crew, this would aim to exclude them or minimise their involvement, and to limit the number of actions that will need their participation. The adoption of this method will allow, it is hoped, a greatly reduced area of study for this thesis to be identified while, at the same time incidentally offering a possible way of making considerable savings of both cost and manpower for the NGVLAs.

However, redefining GH by excluding all those procedures which are, or conceivably could be, shared by another department within the organisation, in order to leave a residue of "pure GH" procedures that the ground crew can claim to be entirely their own, requires the identification of the other departments and/or interested parties. There need not be many of these, and some of them are obvious – as for example, the Flight Crew. Plainly they will be involved in much that the ground crew do, that is related to the airship's flight operations. Equally it seems a natural divide to take all those processes that happen inside the shed and pass responsibility for them over to some sort of assembly/construction or Production Team, while events out on the field at the home base, along with such problems as "security" will almost certainly fall within the jurisdiction of an Airfield Authority. Finally, in accordance with HTA practice, it would seem logical for all those procedures that require the supply of consumable materials (fuel, helium and the like,) along with many of the routine maintenance and repair tasks, to be passed over to a loose network of Specialist Sub-Contractors, and/or agencies of licensed operatives and Ground Support experts.

\ Department responsible List of Tasks \	Product team	Flight crew	Airfield authority	Specialist contractor	Ground support
001 Preparation of G H Infrastructure	X		X	X	
002 Preparation of G Support Infrastructure			X	X	X
003 Protect GH & S infrastructure (Security)			X	X	
004 Protect airship from interference			X	X	X
005 Assemble airship structure	X			X	
006 Inflation	X	X			X
007 Buoyancy management	X	X			X
008 Gas management	X	X		X	X
009 Systems testing (for certification?)	X		X		
010 Preparation of Airship (lift test)	X	X			X
011 Undocking	X	X	X		
012 Taxiing or transit		X	X		
013 Mooring			X		
014 Protect Endure extreme weather		X	X		
015 Storm mooring		X	X		
016 Replenishment		X	X	X	X
017 Load exchange payloads and/or people		X	X		
018 Preparation Flight & Weigh-off		X			
019 Take-off, lift-off, launch or release		X			
020 In-flight monitoring		X	X		X
021 Landing, touchdown or capture		X	X		
022 Unload payloads and/or people		X	X		
023 Maintenance (airship)	X	X		X	X
024 Maintenance (GHE and GSE)	X		X	X	X
025 Repair (airship)	X	X		X	X
026 Repair (GHE and GSE)	X		X	X	X
027 Emergency break-away pursuit			X		X
028 Emergency situation – crash			X		
029 Emergency situation – fire on board		X	X		
030 Emergency situation – structural failure	X			X	
031 Emergency situation – loss of lift		X			X
032 Emergency situation – injured personnel			X		
033 Set-up temporary ops base					X
034 Service airship at remote mooring site				X	X
035 Retrieval from a remote landing site		X			X
036 Retrieval of wreckage	X				
037 Remove or strike temporary ops base					X
038 Re-docking		X	X		
039 Deflation (dismantling)	X		X	X	
040 Weather monitoring and forecast			X	X	X

Table 4 - The GH Tasks Distributed to Other Departments

The interesting thing about compiling this second table is that it now becomes apparent that GH *per se* has disappeared completely. All the other departments seem quite able to take over the various tasks and incorporate them into their own spheres of expertise without much difficulty. There are no gaps in the list, indeed there are plenty of places where there are several possible candidates who appear qualified and able to take on the GH tasks – albeit that some of these will be dependent upon the specific type of airship that is being used or the role that it is intended to undertake. Thus, rather than reducing the GH to a more manageable number of categories, and helping to define the term, this analysis seemingly fulfils the commonly expressed wish of getting rid of the (expensive and problematical) ground handlers altogether.

That is the problem with GH - it is either all or it is nothing. As soon as there is admission of the need for it, it takes over everything and becomes hugely complicated, riddled with intractable questions and impossible to pin down, but as soon as there is an attempt to minimise it, or to question the justification for it, then it promptly reveals a slippery tendency to disappear entirely. There seems to be nowhere to draw a sensible line, and this begs some questions that lead right back to the roots of this investigation. Why do the modern blimps, like the *Skyships* (of the 1980s) and the *Lightships* (of the 1990s) have dedicated ground handlers, if other departments within their organisations can apparently do the job just as cost effectively? Moreover, why did the equally cost-conscious US Navy not do away with them in the 1940s? And more to the point why does the most recently produced *Zeppelin NT* which famously claims to operate with a minimal groundcrew bother to have any at all?

The answer is simply because they cannot do without them. The why of this is perhaps easier to envisage if the life of the airship is seen in terms of the sequence of the events it will encounter in chronological order, along the lines of those given above in **Figure 5.2 - The CargoLifter Procedural Sequence from a GH Perspective.** Some of the labels in this diagram should be recognised as "states" in which there is continuity and stability, whereas some of the others are actually transitional "phases" that involve sudden or vigorous activity and where events are much more unpredictable. The airship is at its most vulnerable when it is passing through a transition phase, as for example when it moves from a "docked" state to a "moored" state via the transitional "undocking" phase. Or, when depletion of its consumables dictates a need for it to depart from the relatively stable and predictable state of "flying" and return to the greater safety of a "moored" state but can only get there by taking its chances through a transitional "capture" phase. It is the job of the ground crew to handle the airship during these brief periods of uncertainty and to make these transitions as quick and safe as possible. Thus the ground crew fill in the gaps between the other departments and provide back-up where it is needed. Therefore "Ground Handling" is essentially the glue that binds the enterprise together, and if there are any tasks which might be claimed as belonging wholly to the ground handlers then they are those where the other teams have the least overlap – as for example when the airship is operating at a temporary location or from a remote "expeditionary" site.

Nevertheless, a manageable and memorable list of specific GH categories is still required for this investigation, and armed with the foregoing understanding, it is now possible to return to the list of potentially responsible departments and, (without specifying all that each might reasonably, or in extremis, be asked to undertake,) to leave with each, those tasks that clearly fall generically within their sphere of expertise, and to reclaim those where they are weakest and regroup these under the heading of "Ground Handling."

Consequently, all events that happen within the shed will be largely left to the Production Team; all provision of the services and infrastructure connected with the operations that take place out on the field will generally be considered to be under the aegis of the Airport Authority; all supply and replenishment of consumables, along with maintenance and repair will be carried out by Ground Support in conjunction with Specialist Contractors, Consultants and Suppliers; and the Pilots and Flight Crew will retain control of all events leading up to flight and those that occur during it, while the airship has no physical connection to the ground. This leaves the Ground Crew as intermediaries between these other groups, backing them up where necessary and taking responsibility for the transitional phases that the airship will pass through during operations - especially where this concerns operations away from the home base at an Expeditionary Site or any Remote and Temporary Location.

Thus, for the purposes of this investigation:

- Production is defined as consisting of all procedures that are necessary in order:

  to assemble and/or construct the airship
  to inflate the airship
  to monitor and maintain the airship's structure while it is inside the shed
  to monitor and maintain the airship's buoyancy while it is inside the shed
  to repair or replace any damaged parts of the airship while it is inside the shed

- Airfield Authority is defined as ownership of all procedures that are necessary in order:

  to provide security for the airship, the infrastructure and equipment inside and outside the shed
  to inspect and maintain all GHE and GSE infrastructure and equipment outside the shed
  to obtain all necessary permissions for ground and flight operations at the home base
  to enforce and comply with environmental rules and health and safety regulations
  to provide emergency services to deal with fire, deflation, and injury to personnel
  to inspect and maintain all storage facilities for consumables on the airfield
  to provide a weather monitoring and forecasting service for airship and ground crews

- Ground Support is defined as all procedures that are necessary in order:

  to provide and maintain facilities for communication between all parties
  to ensure quality and replenish the consumables (fuel, gas, ballast, lubricants, food, drink &c)
  to inspect and maintain the airship's structure, systems and equipment in working order
  to repair or replace any damaged parts of the airship while it is outside the shed

- And thus, in conclusion, the term "Ground Handling" is defined as all those remaining procedures that are necessary in order:

  to prepare the airship and the GHE for operation outside the shed
  to monitor and control airship buoyancy while it is outside the shed
  to move the airship out of and back into the shed
  to move the airship over the operational area
  to keep the airship safe and secure when it is moored (at home base and elsewhere)
  to assist the airship in withstanding changes and effects of the weather
  to load and unload the airship payload (ballast, cargo, sensors or passengers)
  to assist the airship flight crew with preparation for flight (weigh-off and trim)
  to launch the airship
  to capture the airship
  to establish and remove temporary operational bases at remote locations, and
  to carry out all of the above tasks at any temporary, remotely based sites.

Furthermore, this somewhat unwieldy list of tasks can be rendered more easily memorable if the job of the ground crew (i.e. the "ground handling") is simply summarised as this: Use of the GHE in order to :

1. Protect;
2. Prepare;
3. Move;
4. Moor;
5. Load;
6. Launch;
7. Capture, and
8. Camp-out with airship.

Perhaps therefore, in conclusion, the "ground crew" (if defined as comprised of both "ground handlers" and "ground supporters") could best be summarised as: "those who carry out all necessary duties in order to preserve and maintain an airship while it is in the "moored" state and who facilitate all the transitional phases that allow the airship to safely arrive at and depart from this state."

5.4 Previous work on topic

In the course of the CLOSHRP a certain amount of literature and documentation that either was, or at least purported to be, concerned exclusively with the detail of the PGVLA GH systems, and of the procedures that were evolved for use with them, was brought to light. The author unearthed some of this material himself, on his visits to the London archives (Patent Office, British Library, etc.,) on behalf of CL, but he was unaware of the origin of many of the other documents and photocopies, which appeared in the company library, especially those from America. However, in the preparation of this thesis, which was initially financed by the company in accordance with their policy of promoting the academic improvement of their employees, the author was given unlimited licence and access to study relevant sections from all the collected materials.

The abrupt termination of the CL project in 2002 brought an end to the collection process and thus, the body of work relating to GH within the CL Library cannot by any means be said to be exhaustive. Nevertheless, in view of the fact that no such investigation, or assemblage of documentation, seems to have been previously attempted, and given that there was sufficient material for the author to form an opinion as to the potential value of the different types of material collected, a summary of the GH literature which was unearthed is deemed appropriate here. In the interests of maximising the usefulness of this study for those conducting any similar future investigation, the following compilation includes material from the author's own personal collection, which was amassed prior to his involvement with CL and, also subsequent to the closure of the company, on privately arranged return visits to some archives.

5.4.1 Published and unpublished sources

There are a few commercially available books that deal exclusively with the GH facilities devised for the PGVLAs.[1] Among the most notable of them are these:

[1] Many of these titles are now out of print but most are available via specialist dealers

- *Airships - Cardington: A history of Cardington airship station* by Chamberlain, G. (1984) – gives details of GH systems developed at one British base.
- *Pulham pigs: the history of an airship station* by Kinsey, G. (1988) – gives details of GH systems developed at one British base.
- *Housing the airship* by Dean, C. (1989) - is the definitive work on almost all the airship sheds ever built but makes no mention of the mooring systems, or the mooring masts, and scant reference of the methods used to move the airships in and out of the buildings.
- *American airship bases and facilities* by Shock, J.R. (1996) – gives an overview of airship GH infrastructure in America, from the American perspective.
- *Airship sheds in Friedrichshafen* by Bauer, M. (2001) – gives details of GH systems developed at one German base.

Although these publications are exceedingly valuable sources, and much useful information can be gleaned from them, from the point of view of developing GH systems for the NGVLAs, they do have some shortcomings. Primarily, all these works have a tendency to deal with the evolution of the PGVLA GH infrastructure (i.e. the hardware) rather than the specifics of the systems that were used, and the way in which the actual GH procedures (i.e. the software) developed. This is perhaps excusable considering the fact that all of this material was written by historians, with hindsight, long after the equipment was actually constructed and used.

> "... hindsight is the bane of history. It is corrupting and distorting and pays no respect to the way life is really lived - forwards, generally blindly, full of accidents, fortunes and misfortunes, patternless and often adrift. ... Hindsight is the easy way to mop up the mess which we call history; it is too often the refuge of the tidy-minded, making neat patterns when the dust has settled. As often as not, when the dust was flying, no one at the time knew what the outcome might be." (Bragg, 2003:39/40)

The fact that all the PGVLA development programmes ended abruptly, either due to financial curtailment, (as at the end of a war,) or following one of their infamous disasters, which thereby removed many, if not all knowledgeable personnel, [1] and left a climate of opinion where no one was interested to know the minutiae of GH, meant that there was no incentive to write anything on the topic for posterity. Moreover, when each airship programme was actually in process, it was anticipated to be the start of an industry, or a system, which was going to solve the world's transport problems and it was hoped, would lead on to the imminent construction of dozens, if not hundreds, of similar airships. Consequently, there was no reason to write down the early experiments, particularly when ground handling the prototypes, and certainly there was no thought to pass this mass of detailed information on to future generations. Thus, it appears that there is, today, no publicly available material on the evolution of the GH techniques, simply because little or nothing was published by practitioners at the time for public consumption, and there were no contemporary books written on the subject of GH per se.

However, some of those who were of an age to have had experience with the PGVLAs did subsequently write their memoirs, and there is quite a lot of very detailed description of the GH systems, and of the problems encountered, and of the empirical trials which were conducted, hidden in such books as these:

- *My airship flights 1915-1930* by Meager, G. (1970); and
- *Airship pilot no. 28* by Williams, T.B. (1974); both of which deal with the British programmes, and
- *Graf Zeppelin & Hindenburg : the golden age of the great passenger airships* by Dick, H.G. & Robinson, D.H. (1985) – which deals with both the German and American systems.

[1] See below under 5.4.2. – List of key personal and experts killed in crashes and disasters

This latter source is quoted extensively later in this study as an example of the quality of information that is available by means of historical research.

There is also one thoroughly excellent, privately printed, recent study, mostly of the American systems, which gives insight into some further possible reasons for a general lack of similar material:

- *A research of rigid airship ground handling* by Shock, J.R. (1998)

  "There are several excellent sources that thoroughly cover the airships, however, the support equipment and process assumed a secondary role, since it was complicated, not as interesting and required lengthy explanation." (Shock, 1998:3)

There are, however, many unpublished written records, which have survived and, with regard to the British airship development programmes, these chiefly consist of government and other official files; notes, memos & etc., from such places as the Royal Airship Works at Cardington, as well as personal letters and memoirs that are to be found in such collections and repositories as the Imperial War Museum; the RAF Museum; the Royal Aeronautical Society Library and the Public Record Office. There are also large collections of similar material in both Germany and America. Unfortunately this material is, for the most part,[1] uncatalogued and unsorted, and thus, although the author and others on behalf of CL, had begun to mine this resource, the true quantity and quality of the GH information that still lies waiting to be discovered, within these repositories, is impossible to estimate.

5.4.2 Airship GH manuals

Because most of the large airships of the past generation were, almost without exception, prototypes, it seems that in many cases no one was tasked to write the GH manuals for them. Everything was changing so fast that nothing became well enough established to be written down, and more often than not, the project then ended abruptly following one of the infamous disasters - many of which also resulted in the deaths of those who were, or who would have been, writing the manuals in due course. The list of those key people caught up in disastrous crashes who took invaluable and irreplaceable knowledge to their graves at critical moments in the history of airship development is surprisingly long, and if the loss of their lives was a personal tragedy, then the loss of their knowledge and expertise was a devastating blow to everyone who will ever share enthusiasm for their treasured cause of LTA flight.

<u>List of some key personnel and experts killed in crashes and disasters</u>[2]

- *L1* and *L2* (1913) – "experienced German naval personnel"
- *AP-1 blimp/airplane hybrid* (1916) - Usborne
- *R38* (1924) – Maitland, Campbell, Maxfield
- *Shenandoah* (1925) – Lansdowne
- *Akron* (1933) – Moffett
- *R101* (1930) – Richmond, Scott, Irwin, Johnston, Rope, Hunt, Atherstone, Colmore, Giblett
- *LZ129* (1937) - Lehmann

  "Practically all the experienced [German] naval airship personnel were lost in the L1 and L2 disasters." (Robinson, 1994:46)

[1] Although some progress is being made, most notably at such collections as the Rosendahl papers at the University of Texas, which has got as far as an index of the file boxes that can be viewed via the internet.

[2] See also Appendix G Who was who

> "... unfortunately, the wreck of the *R-101* wiped out almost everybody in England who knew anything about airships, leaving only two or three, and it was almost impossible for them to start again because of lack of trained personnel, either in engineering, design, or operation ..." (US Congress, 1933 - Harpham :445/6)

Nevertheless, during the course of the CL research project, a number of Flight and Operations Manuals,[1] for various airships from previous generations, were discovered and placed in the CargoLifter company library. It should be kept in mind that these listed documents are only those which were brought to the author's attention, and there is every likelihood that there are many other manuals in existence, lurking in forgotten corners of archives. Although some of the manuals which turned up at CL do have sections dealing with GH, there are few that are specifically GH Manuals, and because the focus of this investigation is exclusively on material that is likely to assist with the GH of 'large' (or super-large) airships, the search results can legitimately be divided into two groups:

- Those concerning small blimp airships, and
- Those written for large rigid airships

Of the first group, the overwhelming majority concern the "heavy" operational systems (already shown to be inappropriate or too problematical for the NGVLAs) and are thus of lesser interest for this study - with perhaps the exception of the US Navy Blimp manuals, for the largest of the post Second World War types, from which were derived the GH procedures used by the 'large' *ZPG-3Ws*.

There is also a second group of 'small' blimp manuals which, although not strictly 'Historical,' are nevertheless of some interest. These are the manuals for modern blimps that are currently certified and flying, and which have thus been successfully integrated into the modern world of HTA regulations. As this integration process is a further barrier that the NGVLAs will have to cross if they are to succeed, a list of some modern blimp manuals are included for reference.

However, it is the third group containing those manuals for the PGVLAs with details of the vertical mooring methods, and information on other GH systems and procedures used by the rigid airships between the two world wars, which appear to be most suitable as a starting point for the NGVLAs, and consequently that are the most potentially interesting for this study.

Taking these three groups in the order of their increasing interest, the most notable manuals which came to the author's attention were:

5.4.2.1 Manuals for Modern Small Blimp Airships

- **Skyship 600 series** - AIRSHIP OPERATIONS INC. (1998) Operations Manual Part 4 - Ground Handling Manual (USA : Airship Operations Inc.)
- **GA-42** – FLYING PICTURES (Airships) Ltd., (c.1988) The GA-42 airship : Ground handling and mooring manual. (Unpublished draft)
- **Aeros 40B Skydragon** - WORLDWIDE AEROS CORP. (2001) Ground Handling Manual – FAA approved for Aeros 40B "Sky Dragon" (California, USA : Worldwide Aeros Corp)

[1] Or in most cases photocopies of them

5.4.2.2 Manuals for US Navy blimps

- US NAVY, (1920) Notes on the operation of non-rigid airships (Washington D.C. USA: Government Printing Office)
- US NAVY, (1957) Ground handling of airships, evaluation of equipments and development of techniques (Final report). NAS Lakehurst Report serial No. 3-57, Project TED LAK AC 7038 (Lakehurst NJ, USA : Airship Test and Development Department, US NAS Lakehurst)
- US NAVY, (1958) Handbook - airship ground handling instructions (rough draft). NAS Lakehurst Report serial No. 1-58, NAVAER 01-1F-501, Project TED LAK AC 7063.1 (Washington D.C. USA : US Bureau of Aeronautics)
- GAC/NASA (1981) Study of ground handling characteristics of a maritime patrol airship. Final Report. Prepared by Goodyear under contract No. NAS2-10448 (Akron, OH, USA : Goodyear Aerospace Corporation)

5.4.2.3 Manuals for Large Rigid Airships

- **British Rigid 23 Class** - ADMIRALTY, (1918) Handbook on Rigid 23 Class Airships.[1]

This Handbook, which was published by The Admiralty in 1918, seems to have been as close as the British ever got to writing an operations manual for their large rigid airships. Only four airships of this class were ever built; *R-23*, *R-24*, and *R-25*, (all of which made their first flights in autumn 1917) and *R-26*, (which first flew in spring 1918); and because these were effectively a series of prototypes, with very short operational lives, it is apparent that the GH procedures for them were similarly in a process of rapid evolution. Consequently, this manual makes only one passing reference to the duties to be performed specifically by ground based personnel. It is to be found under "Stations and Duties of Crew - General Orders" and it reads in full:

> "Duty Crew - To consist of a crew made of No. 9 crew and crews under training. They will sleep in the shed, and will gas ship, when this is to be done, before 8 a.m. This crew is to remain on board after working hours and is to be in the shed by 10 p.m. and relieve at 8 a.m. daily." (Admiralty, 1918: 71)

Apart from underlining the importance of round-the clock vigilance, this is of little value in the search to an understanding of the techniques that were practised and the knowledge which was accumulated by the ground crews of the time. This handbook, however, does contain much detailed information on the testing and flying of the British 23-class rigid airships but "The contents of chapters" makes no actual mention of either "ground crew" nor of "handling." There are some references in the text to what is clearly GHE (e.g. "hauling down ropes") but instruction is limited to the flight crews' perspective with regard to on-board stowage etc. There is no mention of any procedures for "Undocking," nor for "Mooring," nor "Take-off," nor "Landing." In short, this volume seems to have been a work in progress which was never completed.

- ***LZ 120 "Bodensee"*** - Eckener, (1919) Introduction to "Bodensee" flight manual: Brief instructions and practical hints for piloting Zeppelin airships for the flight personnel of the "DELAG" ("Revised extract from the "Practical Instructions" written by order of the former leader of Naval airships") (published as an Annex in Robinson, 1964)

This is an extremely valuable document which, as the introduction states:

> "... reveals the secrets of Dr Eckener's consistent success where many others have failed – careful, conservative and prudent airship handling, together with a profound knowledge of the

[1] Reprinted and published in 2005, jointly by The Naval and Military Press in association with Imperial War Museum.

> physical laws and weather conditions governing the operations of the monster gas bags filled with hydrogen. His homely aphorisms and sage advice ... appear on every page of the this 45-year-old manual."

The problem, from the GH perspective is that this is a "Flight Manual" and as such is clearly written from a pilots perspective for pilots to learn from. This is shown by the fact that of the 17 pages of small font text, only 5 are concerned with topics involving ground based personnel. Nevertheless the sections on 'Take-off against the wind,' 'Landing in various conditions' and 'Lying out in a storm and at anchor' represent a wealth of detailed information that is of unparalleled importance - coming as it does, from the authoritative voice of prolonged personal empirical experience. This text should be made compulsory reading for all would be NGVLA developers, and also the regulators, although whether the latter, schooled under the modern HTA regime, will be open minded enough to allow gigantic airships in the future to perform the previously common place procedure of a down-wind take-off, ('The take-off before the wind') whereby "... the ship, on the command "Up Ship!" is thrown up aft ..." by several hundred personnel, is somewhat doubtful.

- *ZRS-1 "Shenandoah"* **and** *LZ-126 / ZRS-3 USS "Los Angeles"* **-** US NAVY, (1927) Rigid airship manual (Washington D.C. USA : US Bureau of Aeronautics – Navy Department)

This extremely detailed volume is essentially an expanded and updated version of the previous one. Its origins in Dr Eckener's work are unmistakable:

> "It is hardly possible to lay down hard and fast rules for making landings under various conditions, for the number of factors to consider is great and the possible combinations are almost unforeseeable. Every landing turns out differently ..." (Eckener, 1919:VI)
>
> "It is hardly possible to lay down definite rules for landing an airship under all the various situations as the variety of possible combinations and complications is practically endless. Each landing is different in some respect from all others ..." (US Navy, 1927:IX-45)

Indeed, there is no pretence that this is anything other than an American rendering of the German state of the art:

> "The following notes represent the best German practice as well as our own." (US Navy, 1927:IX-8)

However, there are some major and significant differences, chief of which is the superimposition of the problems that occur when the rare and expensive, non-flammable helium is substituted for the cheap and plentiful, but all too combustible hydrogen. Secondly, there are now several sections which do deal, quite comprehensively, with GH and plainly these are based on the American experiences with their own home-built "*Shenandoah*" and their German imported "*Los Angeles*." The extent to which Eckener himself was involved in writing this document is not clear, but his influence is overwhelming, and it is more than likely that the purchase of the German airship did involve also supply of an operations manual to accompany it. Either way, this is a good example of the knowledge transfer process in action, which will be dealt with in **Section 6.1.1.** below.

The big problem with this manual, from the point of view of those who wish to provide safe and reliable GH facilities, and procedures, for the NGVLAs, is that it was written at a time when labour was cheap, and before the necessity of mechanisation had been fully realised. Thus nearly all of the procedures described are either too dangerous or too expensive to even contemplate for current or future use. However, where this 'Airshippers' Bible' does have great value, is that careful reading of the processes involved, allows the underlying problems to be revealed. As stated previously in this work, conducting a study of the GH procedures used by the PGVLAs does not imply that there is necessarily any intention of actually using them – but a clear understanding of the problems that the hugely experienced designers and engineers of the 1920s and 1930s thought they were trying to solve, does allow for the selection and application of the most appropriate and most cost effective modern solutions to those fundamental, intrinsic difficulties which the NGVLAs will unavoidably have to face.

- *ZRS-5 USS "Macon"* - US NAVY, (1934) Operation manual – ZRS-5 USS Macon. Serial No. 13 (photocopy of typewritten extract received by Inspector of Naval Aircraft, Akron, Ohio on Feb 1 - 1934) (Akron, Ohio USA : Goodyear-Zeppelin Corp.)

While this is the most recently produced 'large' airship manual that has come to light, and thus potentially should be the most useful, in reality it contains little of value simply because it is written from the airship manufacturer's point of view. Presumably, the authors of it – Goodyear – as manufacturers of the airship, had no reason, nor remit, to write down details of the US Navy's own GH procedures. There is thus hardly any information concerning the GHE itself. For example:

> "BOW CABLE ARRANGEMENT – It is understood that on each side of the ship a trolley is used, standing on docking rails 80 to 100 feet distant from the axis of the ship. It is further understood that the cable from station 213 is loaded twice as much as that to main frame 170." (US Navy, 1934)

There is no information on what this 'trolley' is, or how it is 'used', or how the cables are fixed to it, or how many men are needed to operate it. Even the distance from the 'docking rails' is an approximate value. Furthermore:

> "The lower vertical fin structure is designed for a permissible vertical reaction to the ground (ground reaction) by a cradle **or other means**, of 4000 pounds. ... The control car structure and main frame 170 are designed for a permissible ground reaction by a cradle car **or other means** of 1100 pounds. Both ground supports, at the lower fin and at the control car, **are assumed** to be of such construction that they will permit the ship to roll freely ..." (US Navy, 1934) **[GC emphasis]**

Plainly this is written from the point of view of the airship and the intention was to supply general information which would allow the *Macon* to be used with a variety of different GH systems. Thus the specifics of how to use, or in what manner any of this equipment was fashioned, are omitted, and are perhaps recorded elsewhere – hopefully in the US Navy archives? However, here is confirmation of the point raised at the end of **Section 2.2** that many so-called 'GH manuals' were actually written as an adjunct to the airship's certification process and as such, merely help to obscure the fact that there is, in reality, a distinct lack of information concerning the GHE and the procedures used by the PGVLAs.

- **Commentary on US GH systems** - ROLAND, (1978) Handling Rigid Airships on the Ground (photocopy of typewritten "... short essay on the subject ... prepared largely from memory by the author who, at this late date in life, recalls and records events of the past which might otherwise be lost to posterity." Registration No. TXU 13-060 (Library of Congress – Oct 25 1979)

This unofficial memoir contains much useful information, and on occasion even some illustrations, of the techniques and procedures mentioned in the foregoing "*Macon*" Manual. When read in conjunction with it, these 40 pages give some valuable insight into the reasons for, and reasoning behind, the evolution of the US GH systems, and, in the introduction, it also emphasises the scarcity of similar information. Thus,

> "To the best of my knowledge and belief, these papers constitute the only record of its kind ever compiled to cover exclusively a phase of rigid airship operation extending over a period of five years." (Roland, 1978)

- **The external forces on an airship structure with special reference to the requirements of rigid airship design** : R.38 prize paper 1928. In Journal of Royal Aeronautical Society XXXIII (225) : 726-811 (Roxbee Cox, 1929)

This prize-winning paper was the only serious scientific study discovered, in the course of this investigation, that dealt specifically with a large airship when it was in a "Moored" state. Although the Ground Handling section forms a relatively minor part of this work, it nevertheless represents the pinnacle of achievement in terms of quantifiable data and scientific method from the PGVLA era. This work is thus highly recommended as a starting point for anyone intent on furthering the science that will be necessary to underpin any NGVLA development projects in the future.

5.4.3 Summary of previous work on topic

There is really only one manual for large airships that is of any real value when it comes to the GH for the NGVLAs, and it is that which was written by the US Navy for their rigid airship programme in 1927. This work is based largely upon Hugo Eckener's experiences with the *LZ126 Los Angeles* and the earlier and smaller *LZ120 Bodensee.*

> "Our manual handling and landing methods are to a large extent based on those passed down to us from German practice where abundance of manpower was always available." (Rosendahl, 1927)

However the original text was written for rigid airships that were filled with hydrogen gas and operated by ground crews that consisted of hundreds of subservient and disciplined military personnel. Considering that neither hydrogen nor large numbers of people look likely to be available for the first NGVLAs, and bearing in mind Netherclift's assertion (as quoted above in **Section 2.8**) that: "*... in the 1990s wages are no longer reckoned in shillings per week and – certainly for a large airship – such labour intensive methods are no longer economic. Mechanised handling will be essential.*" (Netherclift, 1993:13) ... it is evident that what is required is an updated version of this "Airshippers' Bible," a version which incorporates the lessons learned by all three of the major large-airship-building nations, in their attempts to mechanise the GH processes for the helium-filled giants that were built and flown after 1927, and one which properly looks at the processes and problems from a ground based perspective.

5.4.4 Patents

A separate area of interest is GH related Patents, and the original intention, at the start of the CLOSHRP was to use the abstracts from the British Patent archive as a source of potentially useful GH ideas that had perhaps been forgotten or overlooked. However, as the study progressed it was recognised that the full text of the patent applications themselves generally contain a great deal of extremely detailed information on how equipment was intended to be used, and from this, the actual problem as foreseen or understood by the inventor, could sometimes be deduced, and furthermore, other closely related problems were often mentioned in passing. Thus some patents proved to be, not only a source of potentially useful ideas, but also on occasion to reveal what did, and, equally importantly, what did not work.

The only problem was that there is no discrimination within the patent process itself, and the existence of an application, or indeed the grant of a full patent, is no guide as to whether the idea was, or was not, a realistic or practical proposition. Moreover, it must be borne in mind that even if an idea were to be a practical proposition there is no guarantee, if and when it was ever realised, or taken into the field, that any particular patented device was actually used in the way its inventor intended. Also, some ideas just did not work. This drawback with Patents had also been previously noted in the USA:

> "Patent Office files contain many patents on airship handling equipment. A perusal of these and other literature leads to the conviction that there is very little new in regard to airships. However, most of the devices that have been proposed are either conceived without regard to the practical side of airship handling or are themselves so complicated as to be impractical. ... There is no substitute for actual experience in designing and actually trying out various equipment." (Fulton, 1929:55)

Nevertheless, here, side by side in the British collection there are some extremely good ideas from PGVLA experts that are juxtaposed with what amounts to rubbish. Thus the ideas of experts that were felt to be so good, or so commercially valuable that they needed protection from competitors, are filed alongside, and mixed up with completely unrealistic and unworkable dreams, that have come from crackpot inventors, who in many instances seem to have little, if any, idea of how any sort of airship works, or who determinedly solve non-existent problems and try on occasion to defy the Laws of Physics.

Therefore the researcher really needs to know who was who in the world of airship development, and it is only when armed with the names of those who really knew the problems of the PGVLAs, that it is possible to see whether a patent is likely to hold information of real value. Moreover, much also depends on when, in a particular career, the patent was taken out, and those recorded early in a career, before the serious lessons had been learned, will probably be of less value than those that were applied for later on.

One example of how the detailed information from Patents, when combined with knowing who was who, and how the PGVLA development projects were inter-related, can be used to reveal the growth of successful ideas, and the eclipse of others, was quoted by the author in the Cambridge Paper in 2002.[1] In this it was shown that George Herbert Scott, having flown as Captain of the *R34* and witnessed at firsthand the problems of the, then state-of-the-art, "three-wire mooring system" went on to invent and patent a vertical mooring system for large airships using a retractable mast-head (British Patent No. 178,568). This worked so well, that he was approached by the Americans, who licensed the idea from Scott, and installed it on several of their own mooring masts.

Meanwhile, the eminent Dr Barnes Wallis of Vickers, (later to become designer of the *R100* for Commander Denistoun Burney's Airship Guarantee Company) who had far less operational experience than Scott, had previously patented a horizontal method of mooring large ships onto masts (British Patent No. 131,072). This idea, not only seems to have disappeared shortly after it was patented, but its failure

[1] Camplin & Schaefer, 2002

was later mentioned in an official memo – albeit probably one written by one of Wallis's competitors on the opposing *R101* development team:

> "It will be noted that except for one or two very early patents relating to the original **unsuccessful** Vickers' mooring mast, the dates of Commander Burney's patents are all later than those given in the above list." (Air Ministry (undated) : Appendix E) **[GC emphasis]**

This illustrates that it is necessary to know not only the names and the career progression dates of the individual patent applicants and/or holders, but also something of their employers, and of the political situation at the time a patent was claimed, as well as the idea's place in the sequence of events during the evolution of the PGVLAs. In this we are fortunate that the number of people who had actual knowledge of large airships and who really understood the problems associated with the GH of them is not very great.

> "There is but a comparative handful of people in the world today who have first-hand knowledge of them [airships]." (Rosendahl, 1938:361)

This means that the task of collecting and compiling a list of knowledgeable persons in whose names potentially serious, and thus useful, ideas were Patented is not too demanding. A project to collect all the GH Patents held at the British Library for the period from 1900 until 1940 was thus started, by the author, as a forerunner of the CLOSHRP. And shortly thereafter, a collection of names was also started, as they came to light, with the intention of compiling brief biographies of the 'major players' within the PGVLA development projects of Britain, Germany and America. Sadly, both of these projects were left unfinished when CL closed in 2002. However, the incomplete lists, such as they are, are included as Appendices to this work. (See **Appendix G - List of GH Patents** and **Appendix H - Who was Who**) The collection of further Patents from other countries where large airship development was known to have taken place, such as, Italy, France, Japan and Russia, was also envisaged but never started.

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6 AN OVERVIEW OF AIRSHIP HISTORY AND THE EVOLUTION OF GH

6.1 The airships and the transfer of technology

There are many books which deal with the history of airships. A number of them are listed among the References and in the Bibliography at the end of this study. They include:

- General LTA histories : Delacombe, 1910; Hylander, 1931; Rolt, 1966; Hood, 1968; Jackson, R. 1971; Oppel, 1987; Brooks, 1992; Owen, 1999;
- General airship histories : Sprigg, 1932; Robinson, 1973; Meyer, 1980; Botting, 1981; Ventry & Kolesnik, 1982; Gütschow, 1985; Griehl & Dressel, 1990; Meyer, 1991; Mowforth, 1991; Mowthorpe, 1999; Topping & Brothers, 2001;
- Histories of specific airship programmes : Santos-Dumont, 1904; Higham, 1961; Masefield, 1982; Robinson & Keller, 1982; Chamberlain, 1984; Morrow, 1987; Abbott, 1989; Althoff, 1990; Shock, 1994; Robinson, 1994; Mowthorpe, 1995; Treadwell & Wood, 1999;
- Histories of individual airship achievements and disasters : Toland 1957b; Vaeth, 1959; Nobile, 1961; McKinty 1972; Abbott 1973; Deighton & Schwartzman 1978; Countryman, 1982; Jamison, 1994; Duggan, 1998; Botting, 2001;
- Memoirs and Biographies of those with first hand experience of large airships : Pratt, 1920; Lehmann & Mingos, 1927; von Buttlar Brandenfels, 1931; Shute, 1954; Eckener, 1958; Meager, 1970; Morpurgo, 1972: Williams, 1974; Dick & Robinson, 1985; Bentele, 1992; Johnston, 1994; Tittel & Schmidt, 1995; Meyer, 1998;

From these, and other published sources, the author was able to compile a comprehensive (but not exhaustive) list of the dates on which most of the world's airships made their first and last flights. (See **Appendix I**)

This work enabled a picture of world-wide airship development to be built up, and charts were then produced to show the countries, and the time frames within which, the main development of the previous generations of both small and large airships had occurred. For brevity, semi-rigids are classed as blimps.

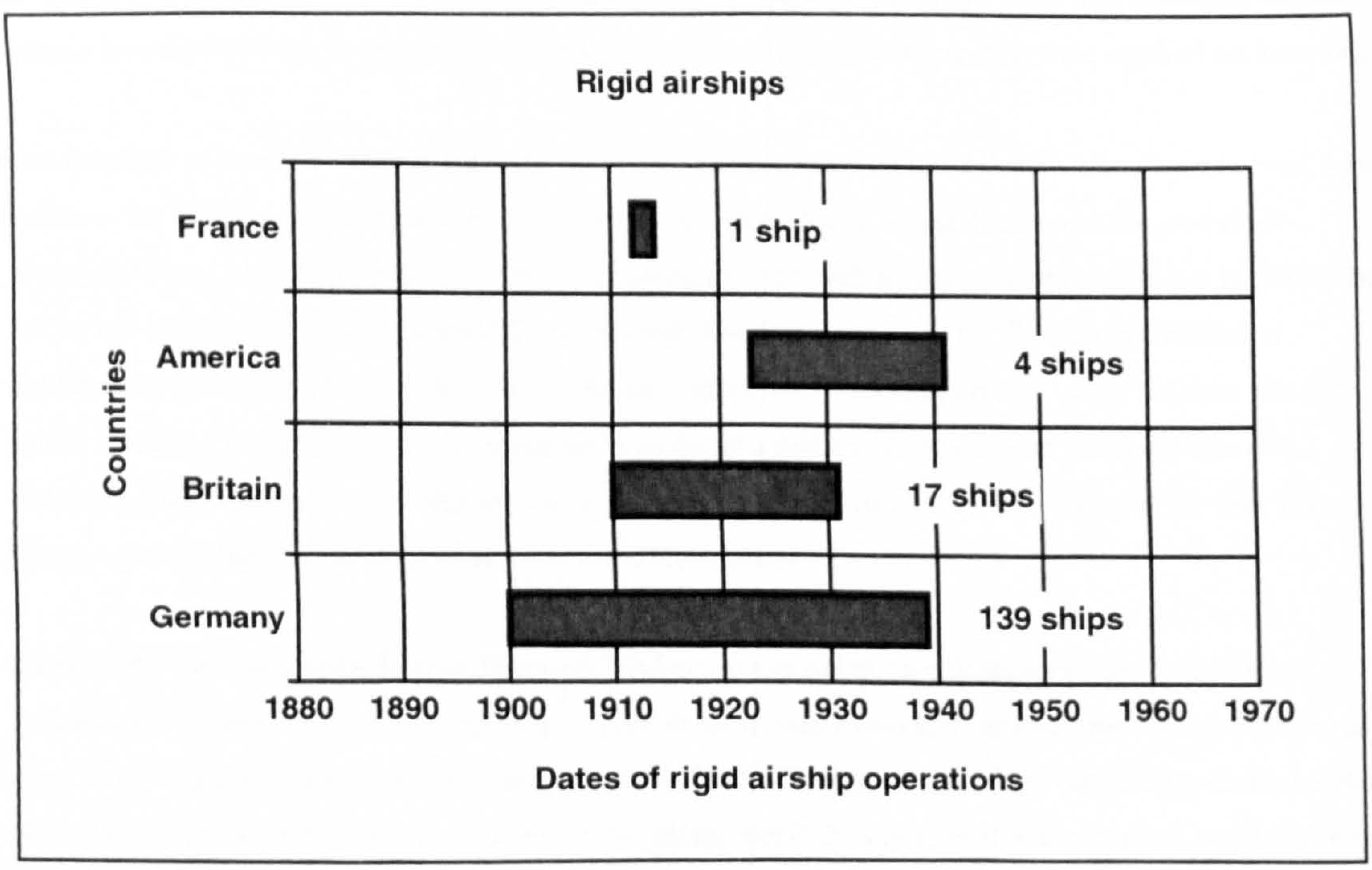

Figure 6.1 – The development of rigid airships

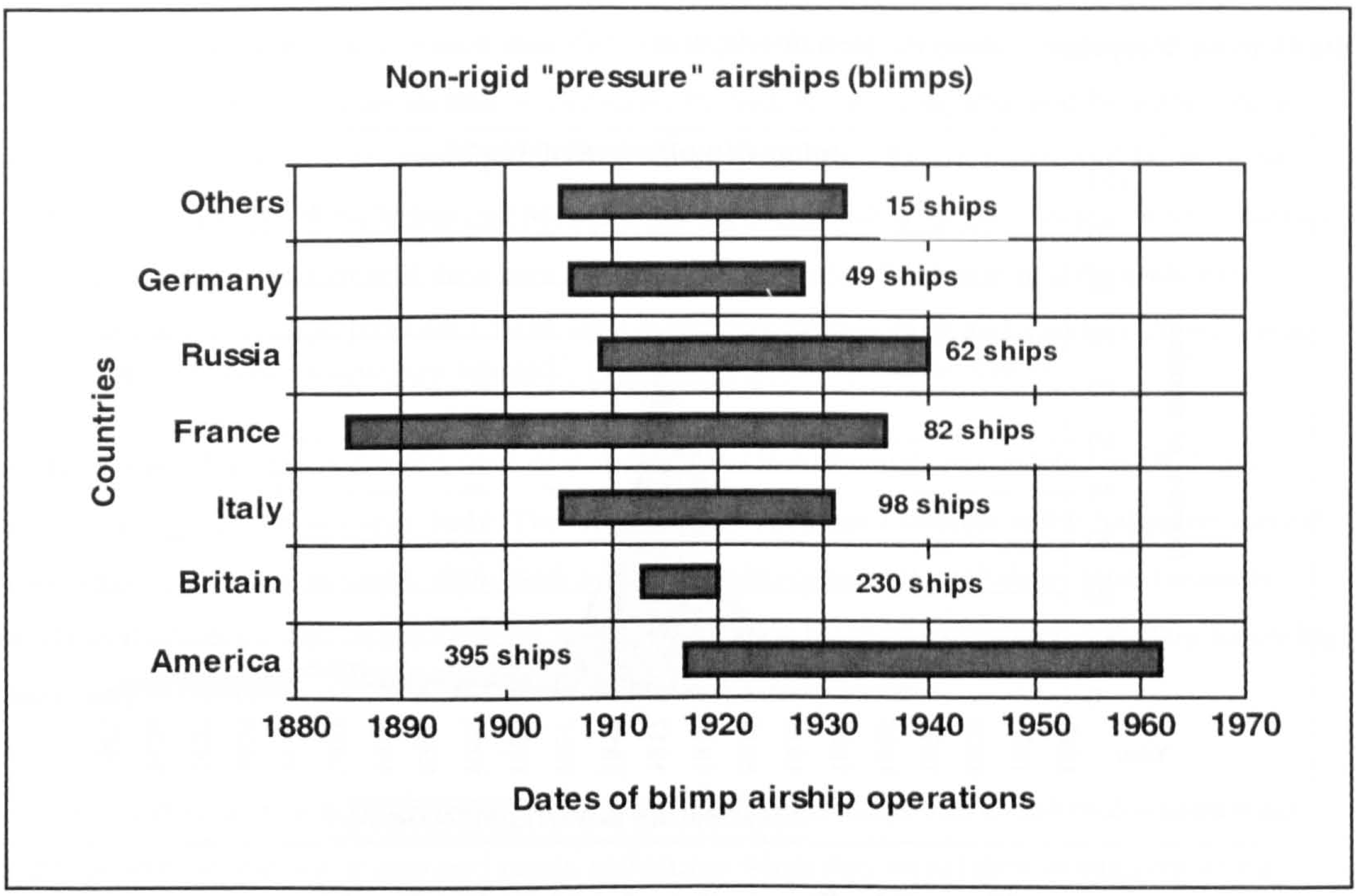

Figure 6.2 – The development of blimp airships

These charts revealed that in general terms the blimps and the rigid airships had evolved intermittently, in most instances separately, and that they were built and operated largely in response to military demands in time of war – note the British First War Blimp programme. The episodic nature of the development programmes, the proliferation of airships in times of war and the attempts at their subsequent utilisation can be seen from the following two charts. These were produced by simply counting up the number of airships reported as being extant at any time within any given year, regardless of their true operational status. The first chart shows how the US Navy blimps blossomed during the Second World War:

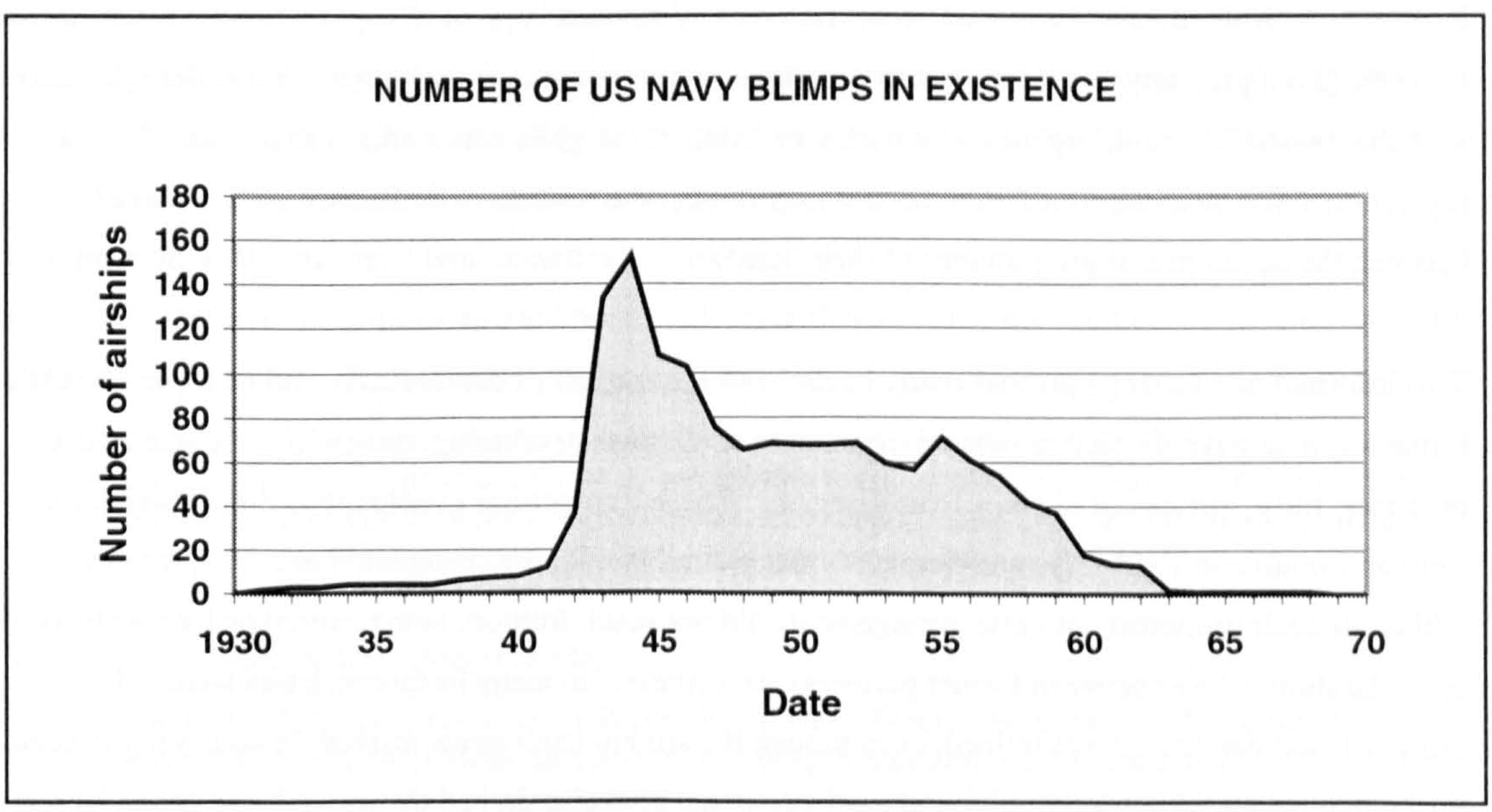

Figure 6.3 – The number of US Navy blimps in existence

While the second chart shows the equally dramatic numerical increase and the overarching dominance of the German 'Zeppelins' during the First World War:

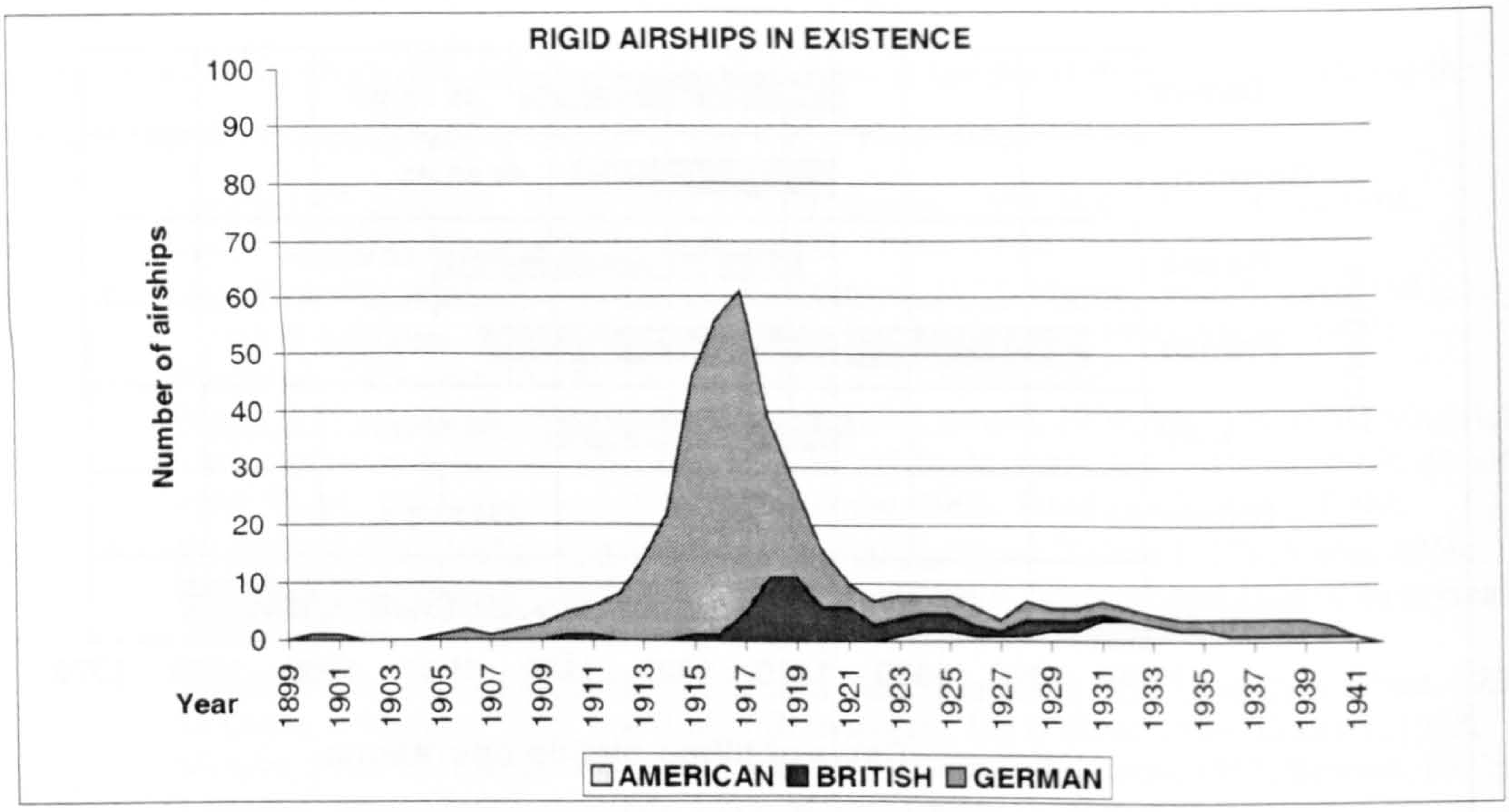

Figure 6.4 – The number of rigid airships in existence

However, it is important to keep in mind that this simplistic analytical method does give an artificially high impression of the numbers of airships which were actually operational at any one time, and that, for example, although the German Navy did indeed operate 72 airships throughout the course of the hostilities in the First World War, the truth is that:

> "The navy had never possessed more than nineteen airships in commission at any one time – and that number only for brief periods in 1916 and 1917. The year that America entered the war saw a total of 39 airships commissioned, but losses and the constant development which rendered many ships obsolete, thereby forcing their retirement from service, kept the naval airship strength reduced numerically." (Lehmann & Mingos, 1927:300)

Furthermore, it should also be noted that the numbers of airships "operated" by the various countries can never be given precisely due to the fact that airships were on occasion exchanged, or transferred, either with the owners' consent, (by means of trade), or without, (as when captured,) or in payment for war reparations. This resulted from, and was also inspired by, the sporadic transference back and forth between the development programmes of their 'hardware,' 'software' and 'wetware.' (See **Section 3.2**)

This information exchange process really began with the success of the Germans and their pre-First War blimps, which inevitably led to other governments of the time purchasing, or making arrangements to purchase, fully operational airships from Germany. These transactions eventually included both large rigid and small non-rigid ships and frequently the ground handling was exported as part of the deal. Although a fair proportion of these arrangements did not reach fruition, being overtaken by events, (such as declarations of war between former partners), nevertheless in many instances, bases were still prepared, and personnel were trained, even though the airship itself never arrived. In addition, the need for large numbers of low-skilled ground crew personnel also encouraged the use of local, cheap labour for 'menial' tasks, which often left behind a reservoir of exploitable knowledge when circumstances changed.

Thus there is a list of countries that either imported the technology voluntarily, or where the conquering German military set up bases and imposed their GH techniques, and then retreated leaving the know-how behind. These third-party countries include – Denmark, Poland, Russia, Bulgaria, and Belgium, and a few later ones from the passenger carrying era of the DELAG such as - Brazil, Spain, and Japan. Also, the Americans had bases in the West Indies and Morocco, as did the British in Greece. A few other countries also made their own way and created their own independent networks of contacts and dependencies:

> "In the years between 1905 until 1931 were in Italy 98 airships built and a further 20 were either sold or with Italian know-how erected." (Translated from Gütschow, 1985)

The Japanese Navy, for example, had a total of 9 airships, the last of which was deleted in 1932, and several of these were purchased from Italy. The Russians also took great interest in the Italian semi-rigid design and imported several airships, along with knowledgeable personnel, including, most famously, General Umberto Nobile, who retreated to the Soviet Union after his public humiliation in Italy following the "*Italia*" tragedy of 1928.

However, it was in time of war that most of the technological information was transferred – sometimes when airships were shot down or captured intact, sometimes when they were taken in payment of war reparations, and occasionally by straightforward theft:

> "It was during this same month [April 1913] that a German Army airship *ZIV (LZ16)* ... on a factory test flight was forced down on a French Army drillfield [at Lunéville]. The German aviators were most hospitably entertained by the gallant soldiers ... But, of course, Gallic sympathy was not without reason. Whilst the Krauts were being entertained, French experts rapidly photographed and made drawings of as much of the equipment, etc., aboard the ship as they could ... how much of the material gathered was passed into English hands is uncertain, though British officers were invited to inspect her." (Higham, 1961:69/70)

The French, not only generously shared their ill-gotten information with the British but also passed it on to the Americans, thereby doing much to excite the US military's interest in acquiring their own airships. This led eventually to probably the most famous of all technology transfers when the formation of a joint-venture between the American Goodyear and the German Zeppelin companies resulted in the wholesale haemorrhage of knowledge to the USA in the form of Dr Arnstein and "the twelve apostles" who, in 1925, were persuaded to transfer their allegiances from Germany and move with their families from the shores of Lake Konstanz near Friedrichshafen, to the shores of Lake Wingfoot near Akron, Ohio.

Thus, as was stated in the aforementioned report to CargoLifter - *Preliminary outline for ground handling CL-160* [1] (hereinafter the CL Preliminary Report):

> "Although the evolution of airships, and the advances made, can be viewed more or less as a linear, chronological progression, with one leading onto the next, it is more accurate to say that the different types co-evolved - with virtually every conceivable hybridisation between them under-going trial in the various countries concerned, at one time or another."

And there was considerable exchange of ideas :

> "One particular aspect stands out with clarity and significance; so intense and so constant was the cross-fertilisation of ideas, in some cases by legitimate and legal exchange and in others by espionage, that no part of airship history can be studied in isolation with an adequate comprehension." (Chamberlain, 1984:xv)

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[1] Camplin, Bischet & Watson, 1998.

The complexity, and the import, of this web of knowledge and intrigue, and the way in which such events as war, and the mergers of companies, has affected the evolution of the world's airships, can be better understood if the era of their major development is viewed in diagrammatic form. Thus:

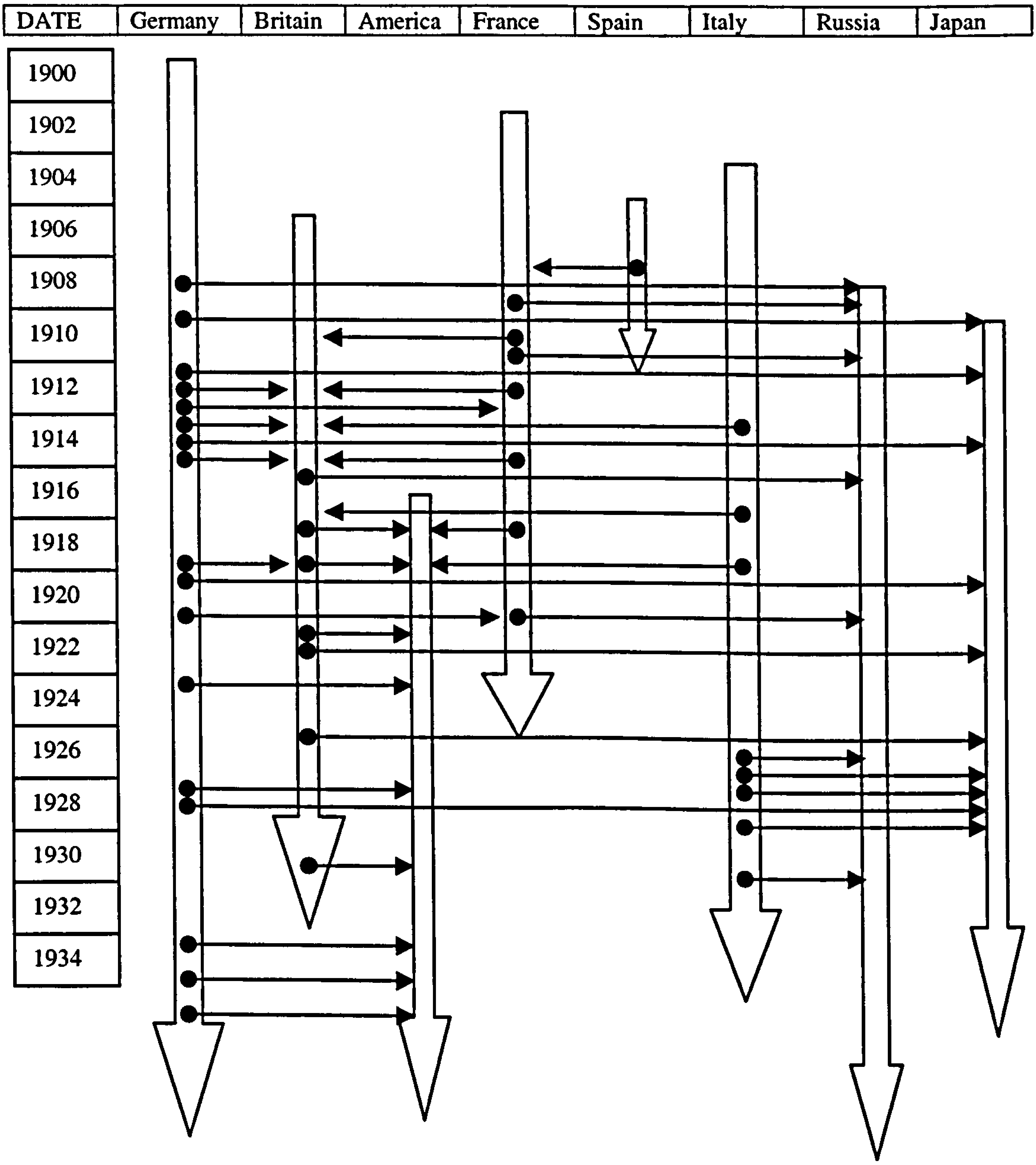

Figure 6.5 – The Transfer of Airship Technology

These transactions (black arrows), involved exchange of information and personnel as well as the airships themselves, and, in the process some of these latter came to be owned and operated by more than one country in their lifetimes. Whereas a few of the transferred ships had long and eventful careers, flying under the flags of their new owners, others were never flown at all. Some were used instead for ground crew training, others were dismantled so that details of their construction could be studied and copied, while some were just left to decay or broken for scrap. Deciding which country to allocate some of these airships to, and their exact dates of operation, is consequently something of a problem.

Nevertheless, the diagram clearly shows: a) the way that early French enthusiasm later evaporated; b) the overarching dominance of Germany as a net exporter of knowledge; c) the late awakening, but seemingly insatiable acquisitiveness of America, and d) the pivotal part played by Britain in acting as a go-between.

However, the focus of this investigation is not with the airships themselves but rather with their GH infrastructure and the systems that were used to handle them when they were on the ground. Therefore it is necessary to examine briefly the way in which these GH facilities, and the procedures used along with them, were first established, and also to understand how they evolved over time.

6.2 The evolution of GH systems

As has been shown, GH is an extremely complex subject, and tracing its multifarious facets back to their origins is further complicated, not only by the above mentioned interchange and interplay occasioned by the transfer of technology between the various countries, but also by the timing of world events. Some development programmes arose in time of war and were cloaked in an atmosphere of military secrecy, while others flourished openly under civilian regulations in times of peace. Some were run, quite literally, in deadly serious competition, whereas others enjoyed a free flow of information, and benefited from a spirit of friendly co-operation. Many, were run concurrently, whereas others evolved consecutively with one following on from the ruins of another, and while some were founded on purloined reparations granted by protocols and treaties, a further few were kick-started by corporate deals, trade agreements and goodwill gestures. Consequently, establishing who knew what, and when, and which events triggered which innovations in each country, is far from simple, and the drawing of a similar GH version of the diagram for the Transfer of Airship Technology - shown above as **Figure 6.5** - is all but impossible.

Moreover, there is a further problem here, in simply presenting the GH information in a readily understandable manner. It is caused to some extent by the quantity of material available, but in large part by the three-dimensional nature of the subject. There are, or were, (as shown above in **Section 5.3.1,**) some 70+ types of airship, 46 of which may be classed as "large airships" and they evolved in several different countries over a period of more than 40 years. It is thus relatively straightforward to trace the history of these through time. However, for each and every individual airship there are arguably, (as shown in **Section 5.3.2,**) some 40 or so, different procedures that may be classed as GH, and even if these are reduced to eight categories, as is suggested, there is still (as explained in **Section 3.4.3.4.**) an information matrix that contains several thousand fields. Conducting a linear narrative to follow each procedure as it evolved through time, revealing how it was modified and improved by experience, (or adapted to suit each class or airship type,) and how it was then changed by the events that occurred to every individual airship to which it was applied, is clearly impossible within the confines of this study.

Nevertheless, in a work of this nature, where previous studies of the subject are by implication charged with neglect of detail, a thorough and detailed explanation is plainly necessary. Thus, as with the definitions given above in **Section 5**, some way of focussing the investigation has to be found, that will reduce the quantity of data to be processed without reducing the quality of the end product. This will be examined in a discussion in **Section 7.**

The problem of how to present the GH information (hereinafter "The Matrix Problem") was first encountered by the author, and his colleagues at CargoLifter, in the autumn of 1998, when, during the writing of the CL Preliminary Report, the full scale of the complexity and interwoven nature of the subject became apparent. The solution adopted then, was to separate, (in so far as it is possible to disentangle them,) the systems developed by the three major countries involved in the PGVLA development – Germany, Britain and America – and to deal with these in sequence. In view of the success of this method, and for want of any alternative, a similar division and structure will thus also be adopted generally throughout this investigation.

The reasoning behind this decision is that from the collected First and Last Flights (**Appendix I**,) it can be seen that the history of the world's airship development programmes, may fairly conveniently be divided into three distinct chronological eras according to the predominance of different types of airship. Thus:

a) the pre-rigid or "proto-airship" era: - wherein un-powered free-flying balloons, and a succession of small, poorly-propelled, blimp-type craft (closely related to balloons, and most of which were civilian-built "one-offs") made what were generally single down-wind flights, between 1783 and about 1900;

b) the rigid airship era (or "golden age" of the airship): – wherein the large rigid airships co-existed, and evolved alongside, a "first wave" of military blimps, (dominated in numerical terms, by the intense British First World War programme) and culminated in the impressive achievements of the Italian semi-rigids, from 1900 through to 1939; and

c) the post rigid (or "modern") era – wherein a "second wave" of military blimps (dominated in numbers by the US Navy blimps of the Second World War,) developed techniques such as the "heavy operations" which were taken up by the modern, and largely civilian owned, airships that continue in operation up to the present day, and thus spans from 1940 to 2000+.

However, from a GH perspective, the golden age really needs to be further divided into two parts, in accordance with the predominance of the GH systems that the different types of airship would have used, and thus, for the purposes of this investigation these four eras can be identified as :

1. - the proto-airships – small blimps operating as balloons (1783-1899)

2. - the first wave blimps and semi-rigids – pioneering horizontal GH methods (1899-1939)

3. - the rigid airships – developing the vertical GH methods (1899-1939), and

4. - the second wave blimps – perfecting horizontal "heavy operations" (1940-2000+)

Furthermore, in view of the fact that this study is concerned with the re-discovery of GH systems for "large" or "very large airships," and that the methods that were devised for small airships are extremely unlikely to be of use to the NGVLA developers, as has been previously shown,[1] it is possible to reduce the area of interest still further and to concentrate only on those sections within the eras where "large" airships were predominant. Thus, application of the "123 metre rule" – as defined in **Section 5.3.1** – reveals that there are really only two areas of serious interest to this study:

3. - the rigid airships – developing the vertical GH methods (1899-1939), and

4. - the second wave blimps – perfecting horizontal "heavy operations" (1940-2000+)

[1] **see Section 2.3 – Scaling up existing procedures**

Moreover, the era of the "large" rigid airships (era 3) can itself be fairly easily further broken down into three quite clearly defined separate subdivisions according to the development programmes that took place in each of the three major countries concerned:

3a. - The German rigid airships (1899-1939)

3b. - The British rigid airships (1910-1930)

3c. - The American rigid airships (1920-1935)

In addition to which, it is really only the latter part of the 4th era - the second wave American Blimp programme - that contains airships large enough to qualify for inclusion in this study; namely that part specifically dealing with the non-rigid *ZPG-3W* programme. Although this can be said to run roughly from 1955 through to 1965, it should be recognised that many of the GH procedures used by the biggest blimps were actually established earlier on, in the 1940s, and honed to reliability by small blimp wartime operations. This 4th era was omitted from the original CL Preliminary Report, nevertheless there is much of relevance in this work and text from it, with some additions, forms the basis of the next section.

6.2.1 Analysis of the three major rigid airship GH systems

In the CL Preliminary Report it was stated that –

> "Although our historical research project is not yet complete it has already revealed that the inherent complexity of the subject can be reduced in essence to three key mooring methods and for simplicity we have chosen to refer to them by their country of origin. They are thus:-
>
> - The German System - whereby the airship descends into the hands of several hundred men who simply hold on it for the duration of the landing, or manhandle it onto a low mooring mast, or if weather conditions allow, walk it directly into its hangar.
> - The British System – whereby the airship is attached by its nose to the top of a tower or high mast and is serviced via its nose attachment point while it is allowed to weathervane with the wind, and is only taken into its hangar for major overhaul or in extremis.
> - The American System – whereby the airship is captured by motorised "mules" and hauled down close to the ground to rest upon a wheeled "dolly" which allows it either to weathervane around a fixed "stub" mast, or with tail fin clamped to a "stern handling beam" to be pulled by winches, or driven directly into its hangar, by a self-propelled "Iron Horse" running on rails or caterpillar tracks."

Having concluded that "the three systems are by no means mutually exclusive," the report then embarked upon a brief tabulated analysis of the major advantages and disadvantages of the three systems. Although this analysis does not cover all the aspects of GH subsequently identified by the author, it does help to encapsulate many of them and to reveal the difficulty of comparing the numerous ways in which the GH tasks have been organised and tackled in the past. Therefore, an amended, updated and expanded version of the preliminary analysis is given here.

6.2.1.1 The German System [1] –

- whereby the airship descends into the hands of several hundred men who simply hold on to it by means of ropes, cables, lines, handles and/or purpose-built hand-rails, for the duration of the landing. Or, who, if weather conditions allow, manhandle it with assistance of rudimentary GHE (i.e. "lauf-katzen" or "running-cats") and walk it directly into its "Halle." Take-off is, in this case, literally the reverse of this procedure. The airship is walked out of the shed and thrown into the air. As here:

[1] Also virtually indistinguishable from the early British and American systems

"Thursday, 15 August 1929 ... The ship [*Graf Zeppelin*] is ready ... The *Himmelstreppe* is taken away and the passenger door shut ... The restraining sandbags are being removed from the gondola's docking rails. The great ship ... hovers just above the hangar floor, weighed off fore and aft with meticulous exactness ... A little water ballast is spouted out ... to correct the trim one last time, and then the order is given: "*Remove supports*!" The Ground Officer blows a sharp blast on his whistle. Another order is barked through a megaphone: "*Zeppelin, marsch*!" It is 4.25 a.m. The army of ground handlers, two hundred strong, begins to haul the leviathan out of its hangar, walking the ship forward with quick, rhythmic steps and a steady, highly co-ordinated pull on the handling lines ... Soon the *Graf* is gliding smoothly out into the open, onto the take-off field ... and then another order is given "*Taue los*!" - "Let go lines!" The handling lines are let go; the ship hangs in the air at the height of a man's shoulders, only restrained by the men clinging onto the gondola's rails. ... Another shrill blast on the whistle. "*Schiff hoch*!" comes the command. "Up ship!" The group of handlers holding the control car by its docking rails literally throw the giant ship into the air." (Botting, 2001 : 9)

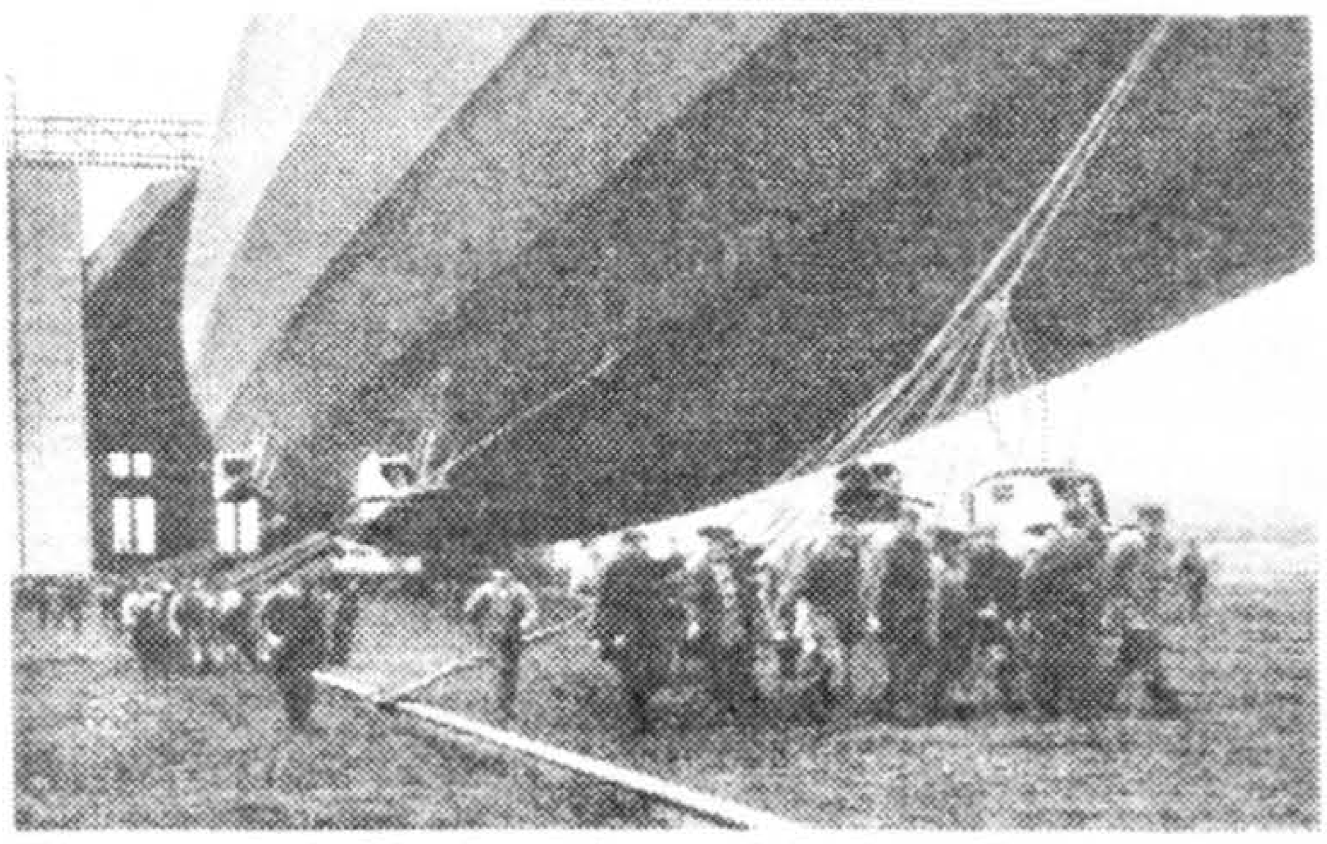

Figure 6.6 :Undocking with Laufkatzen

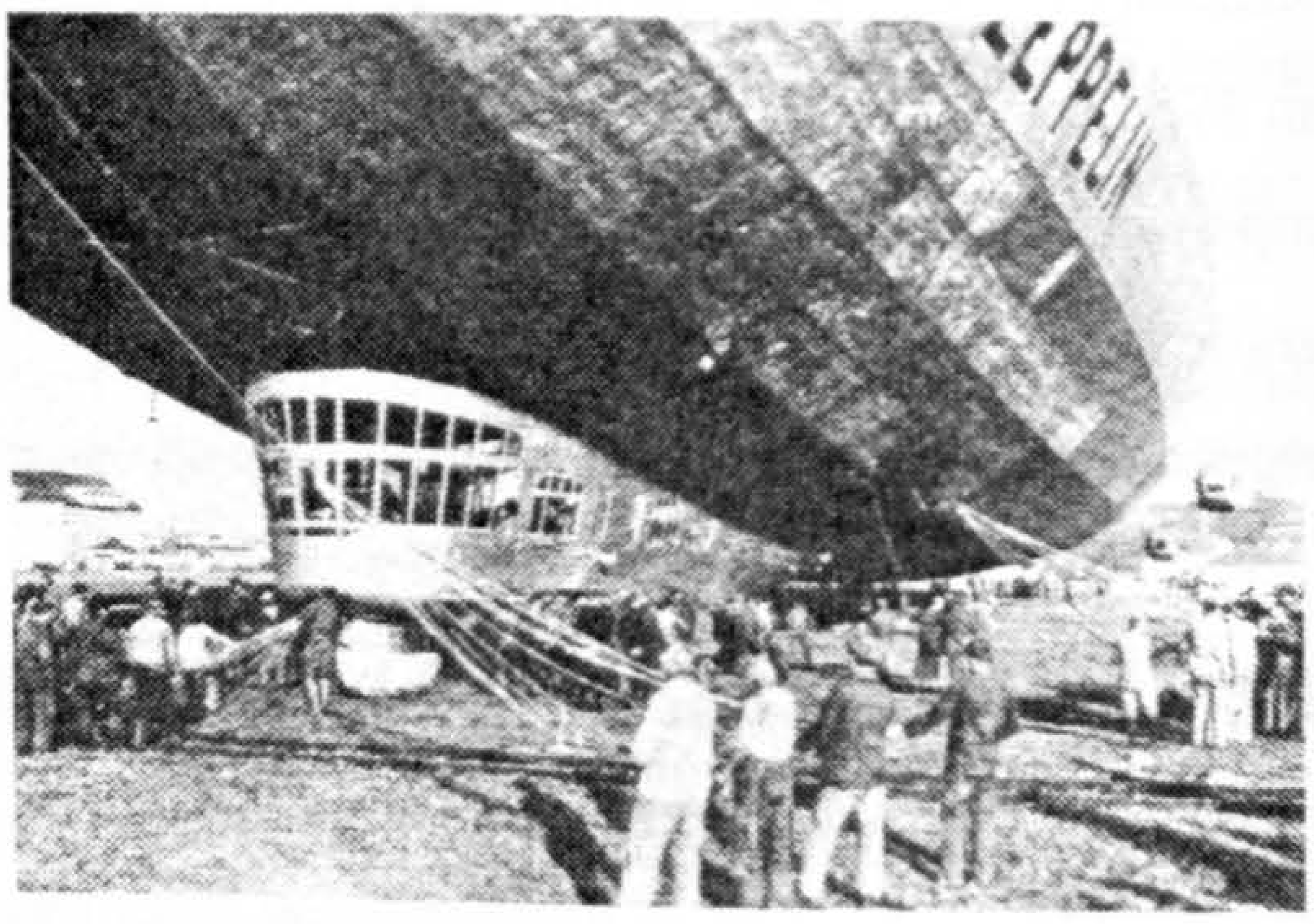

Figure 6.7 : LZ127 prepares for launch

ADVANTAGES OF GERMAN SYSTEM

Minimal infrastructure required on field
No mast to impact with airship or obstruct other aircraft
Airfield surface has low maintenance cost (grass mowing)
Flexible and adaptable to weather conditions including low level wind shift
Fewer crew in calm weather cuts costs but requires accurate forecast of winds
Airship can be walked over low obstacles and wet ground
Quick turnaround possible in calm weather
Minimum strong points required on hull – saves weight and affects design
Heavy take-off assisted by crew pushing
Compatible with all types of visiting airships that carry suitable handling ropes
Easy access from ground

DISADVANTAGES OF GERMAN SYSTEM

Need trained crew pre-assembled on site, ready and able to work throughout both landing and launch
Dangerous - men can and do frequently get injured
High cost of wages and injury insurance
Airship does not weathervane of its own accord
Cannot land in rough weather
Cannot enter or leave shed in cross wind
Ground crew can become exhausted if prolonged bad weather prevents shed entry
Cannot use with mast system because hull structure not strong enough in the nose
Difficult to weather a storm
Ground contact can damage structure during rough weather
Communication between crew is difficult in bad weather or at night
Low level Temp inversion can cause problems during landing
Airship subject to ground turbulence
Gas and water ballast top-up difficult
Landing requires valving off gas
Cargo has to be hand loaded (maybe not today?)
Major engine maintenance or structural repair difficult
Snatch loads on handling line connections (due to gusts) are very difficult to predetermine

+++++++++++

6.2.1.2 The British System

- whereby the airship is winched by its nose to the top of a tower or high mast and serviced from the mast head while it is allowed to weathervane with the wind. It is only taken into a shed for major overhaul or repair. Take-off from the mast is a backward down wind climb. The system was initially developed for small blimps in 1917 and later adapted for the larger rigid ships that followed.
  Viz.:

  > "...Extended trials under service conditions with S.S. Airships moored to one of these masts were made at Pulham Airship Station. The system proved to be an unqualified success. Airships have since been moored out in all kinds of summer and winter weather, including winds up to 55 miles per hour and heavy snow and thunderstorms. ... Following on the successful results [with blimps] ... the Vickers patent landing and mooring gear ... [was designed to enable] a rigid airship to land and remain moored in the open air for extended periods in any state of the weather without the use of sheds and large handling parties ... mooring and release are entirely mechanical, requiring the services of but a few men ... movements to and from the moored ship are made entirely under cover [via tower elevator and covered walk-way] and ... release of a ship is a matter of seconds only, as compared with the much longer process of bringing a ship out of a shed." (Pratt, 1920)

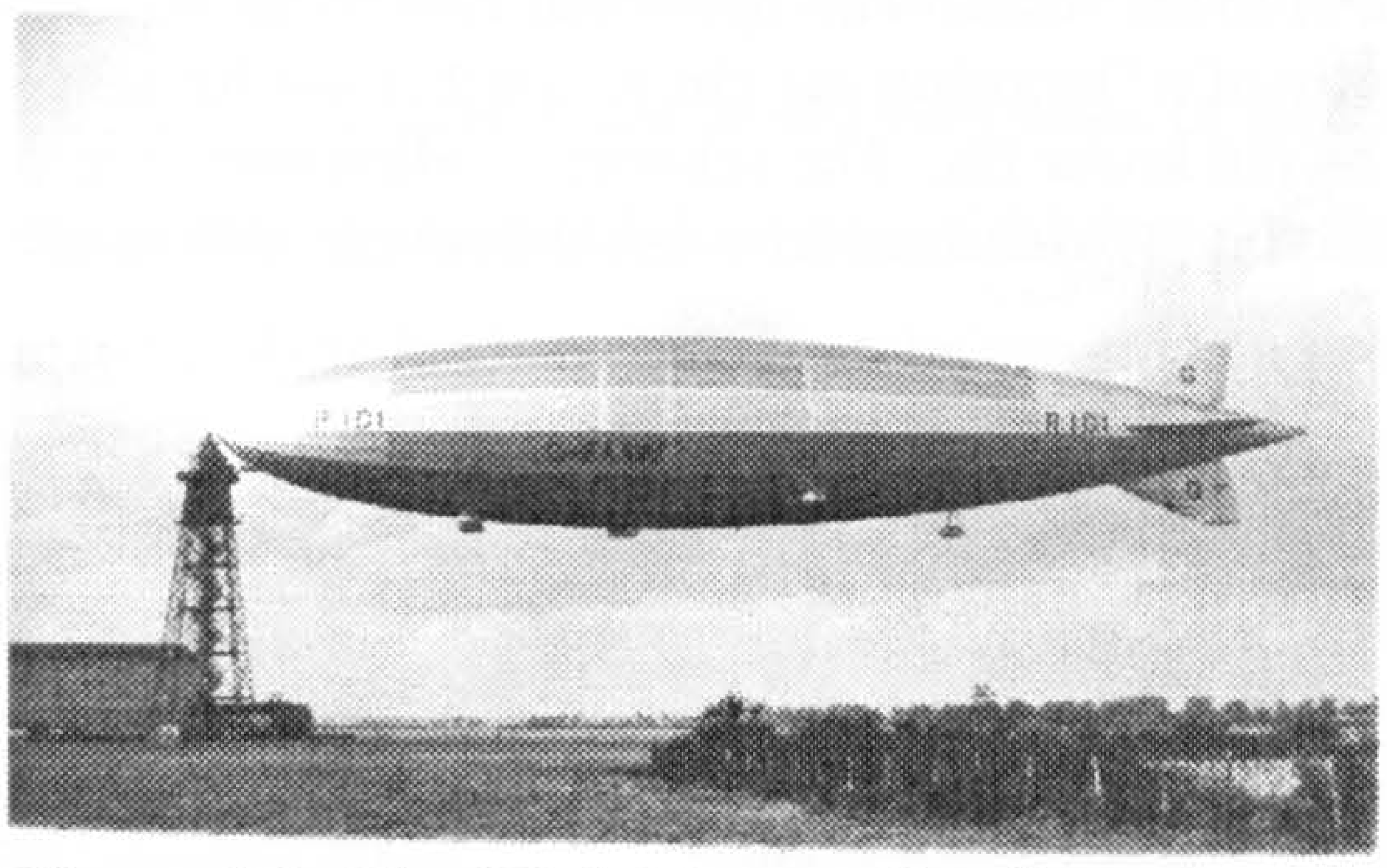

Figure 6.8 :The High Mast at Cardington

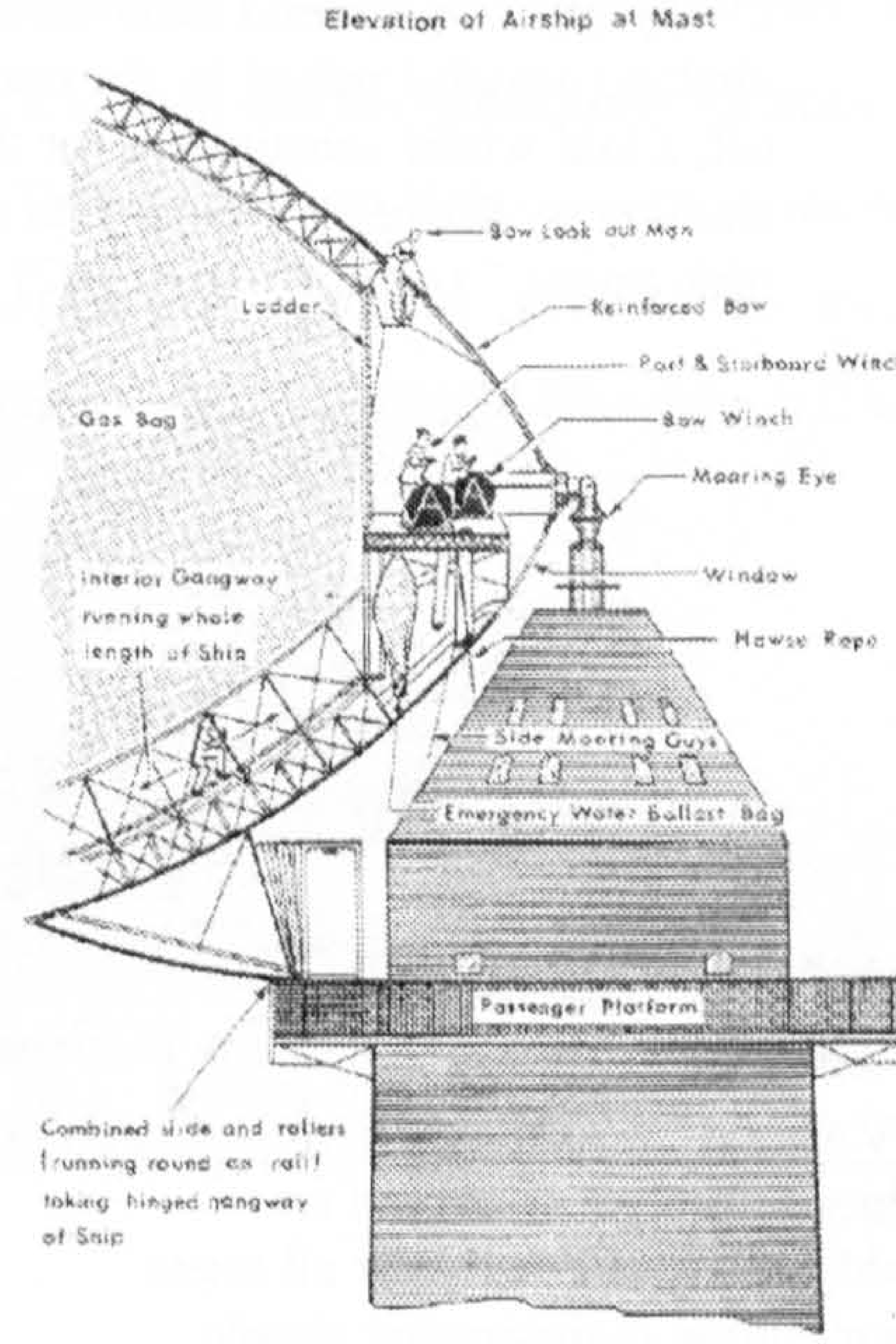

Figure 6.9 :Mechanics of Mast Head
(Masefield, 1982:344)

<u>ADVANTAGES OF BRITISH SYSTEM</u>
No ground contact
Minimal number of groundcrew needed (e.g. 12)
Airship accessible from mast even in worst weather
Fewer ropes and handling lines
Airship can be captured in strong wind
Airship can fly away in strong wind
Airship maybe above level of lowest temperature inversions
Airship free to slew sideways or rotate fast
Minimal airfield maintenance (grass mowing)
Minimal stress on airship hull (loads are primarily longitudinal tension)
Re-fuelling and ballasting can be quick via masthead pumps
Easy to monitor weight of people and equipment on board
Security assisted by restricted access
Moored airship can withstand gale force winds (e.g. *R101* survived 83 mph gust)

<u>DISADVANTAGES OF BRITISH SYSTEM</u>
Restricted access via nose cone walkway[1] limits quick turn around
Major engine maintenance difficult from outside
Airship must be flown at all times (i.e. qualified aircrew on board 24 hrs a day)
Airship needs constant adjustment of ballast to counter ever-changing ambient weather conditions
Drag weights endanger groundcrew
Mooring difficult in unstable air and airship may "kite" (i.e. *Los Angeles* headstand manoeuvre)
Tower infrastructure and construction expensive
Tower cannot readily be moved from site to site (unless mounted on a ship at sea)
Snow or hail or heavy rain can ground the tail
Tower is an obstacle to other aircraft even when not in use
Shed entry/exit still depends on manpower
Mast connection requires compatibility with visiting airships

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[1] Restricted access may now have become a positive advantage in a world threatened by terrorists intent on planting bombs

6.2.1.3 The American System

- whereby the airship is captured and held close to the ground by mechanised means, such as motorised "mules," then coupled to a "stub" mast and a wheeled "dolly" or "stern-beam." These then allow the "low-moored" airship to either weathervane around the mast with its tail held by the rail-mounted beam or, to be moved directly into its shed, by a self-propelled "Iron Horse" (mobile mast) running on rails, or caterpillar tracks. Take-off is vertical and requires either positive buoyancy, or vectored thrust. Note that mechanisation creates a lexicon of new terms, and the use of machinery increases complexity of procedures:

> "The problem of holding and moving the huge but relatively fragile ship [*Akron*] in strong crosswinds, dictated a system which travelled on rails. Consequently the old docking rails and trolley slots were replaced by tracks for a … mobile mast with a rectangular base riding on four railroad trucks. … In the new system, *Akron*'s lower fin rested on an eighty-five-ton stern beam or "Bolster beam," … Attached by a bridle arrangement to reinforced points on the *Akron*, the beam resembled a very long flatcar which travelled broadside with the ship … The rail mast and beam undocked *Akron* to a "hauling up circle" … [and] when the mast reached its center the beam was transferred from the hangar's tracks to those of the circle. A small locomotive then towed the beam around until *Akron* was parallel to the wind. The beam was removed and the airship (usually) pulled by the mast to the centre of a "mooring out circle" farther out for take-off, a taxi wheel substituting for the bumper on the lower fin. The scheme … eliminated the small army formerly required on the ground, and it provided security against severe side loads in high winds." (Althoff, 1990 : 92)

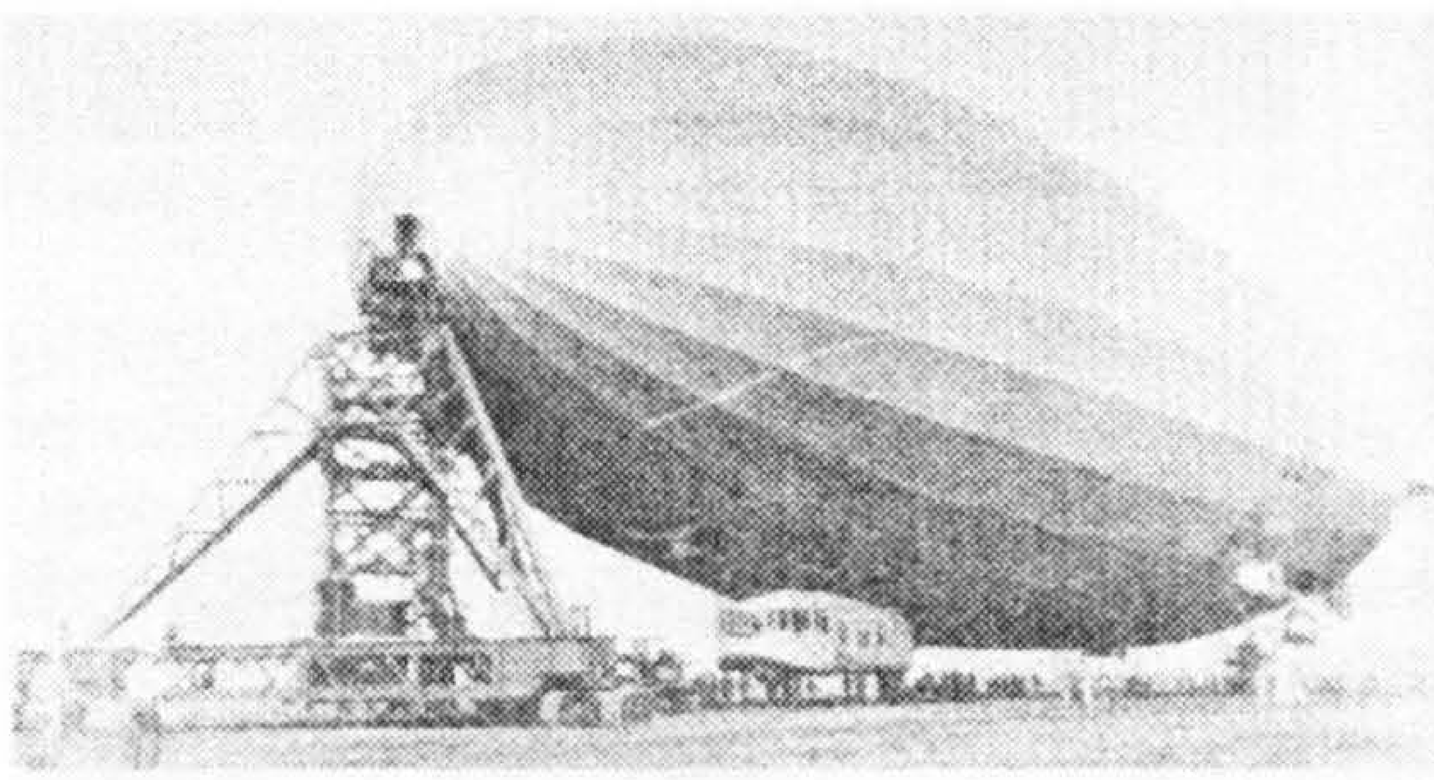

Figure 6.10 :Macon on mobile mooring mast

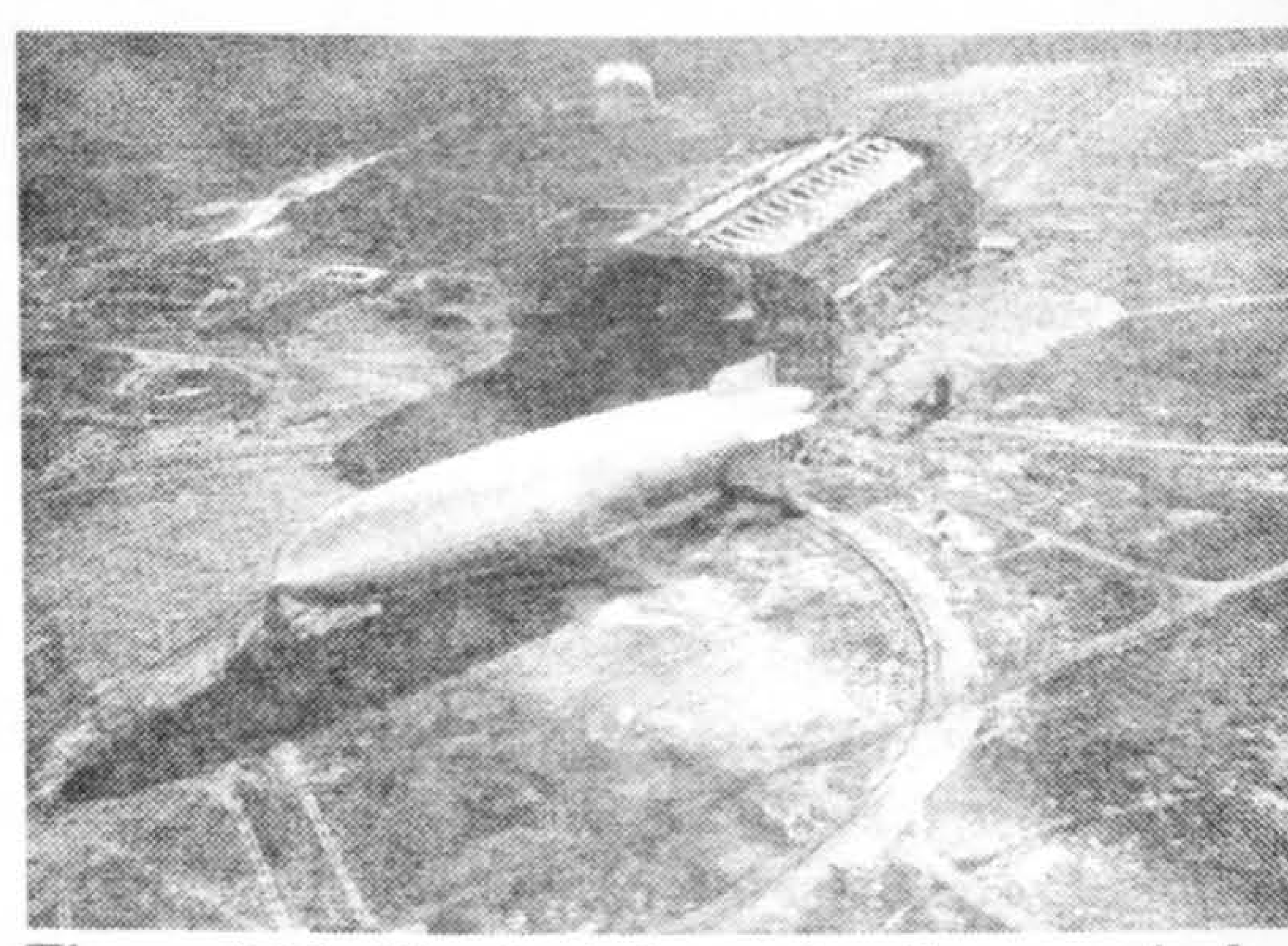

Figure 6.11 :The Lakehurst hauling-up circle

<u>ADVANTAGES OF AMERICAN SYSTEM</u>

Reduced number of ground crew
Airship easily accessible at all times
Major engine maintenance simple
Can enter and exit hangar in strong wind and cross-winds
Quick turnaround easy in good weather
Re-fuelling via pumps
Gas and water top-up easy
No need for drag weights
Mobile GHE means no obstruction to other aircraft when not in use

<u>DISADVANTAGES OF AMERICAN SYSTEM</u>

Puts a lot of stress into airship hull and fins (i.e. adds weight to basic structure)
When landing airship is vulnerable to ground impact until stern beam is attached
Communication with vehicle drivers difficult (not so true today)
High initial cost of rail and track laying, also specialised vehicles - Iron Horse, mules, winches, etc
High cost of maintenance (GHE and airfield/trackway)
Noise from GHE engines makes verbal communication no longer possible
Capture and take-off difficult in strong wind
Temperature inversions and low level wind-shifts can cause serious problems
Dependent on closely co-ordinated or synchronised movements of large and heavy vehicles
Light take-off requirement diminishes operational capability by reducing initial payload
Multiple access complicates monitoring of people and equipment weight on board
Increased risk of stowaways and sabotage
Mechanical breakdown of small components can have catastrophic effects
Subject to all railway type failures such as de-railed wheels, icing, loss of traction and frozen points
Large vehicles and machinery can cause injuries to crew

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6.2.1.4 Summary of the Three GH Systems

In their summing up of the original version of this somewhat simplistic analysis of large rigid airship GH and mooring systems, in the CL Preliminary Report, the author and his colleagues concluded that:

> "As can be seen the result is not at all clear cut. There is no universally accepted way of mooring very large airships that can be guaranteed to work in all weathers. Furthermore our research has shown that the systems in all three countries were undergoing a process of almost frantically rapid evolution when they were somewhat abruptly terminated by the tragic and much publicised crashes of their respective prototypes. (British "*R101*" in 1930; American "*Macon*" in 1933; German "*Hindenburg*" in 1937.) There are therefore many tantalising questions remaining, which have been left hanging unanswered in the air since the demise of the rigid airships." (Camplin, Bischet & Watson, 1998)

Moreover, the problem facing the NGVLAs, especially for those whose declared purpose is to offer the facility of carrying cargo, or heavyweight freight commercially, and of competing cost-effectively in the highly competitive, financially constrained and environmentally sensitive world of modern transport, is that they will require to use as the very basis of their operations, a system that is significantly different from, and more advanced than, any of the three outlined above. This can be seen if the three systems are reduced to their fundamentals and the component procedures are placed in sequence, and these are then compared with the sort of system foreseen as necessary for an inter-continental CargoLifter-type VLA.

Comparison of the four GH Systems

The "old" German *Halle* based sequence

> Load - replenish –undock – launch – capture – redock – unload – replenish – reload - &c.

The newer British high mast sequence

> Undock – walk across airfield - capture/transfer to mast - moor
> Load – replenish – launch – capture - moor – unload – load - replenish – launch – &c.
> Moor – launch to groundcrew for walking across airfield – Redock

The final American low-mast system

> Moor in shed – undock – moor on field
> Load – replenish – launch – capture – moor on field – unload – load - replenish - launch - &c.
> Moor on field – redock – moor in shed

Future theoretical system predicated by CargoLifter

> Moor in shed – undock – moor on field
> Load – replenish – launch
> Mid-air replenish – mid-air unload – mid-air reload – mid-air replenish – mid-air unload – &c.
> Capture - moor on field – redock – moor in shed

The differences are perhaps clearer and more easily understood when viewed in diagrammatic form (overleaf). However, while this division of the subject into the three identifiably different systems as tried and tested by the PGVLAs does much to help encapsulate the extent of the GH problem, and to force some order onto its complexity, it must be emphasised that the foregoing represents only a snap-shot of these systems, moreover, it is one that is taken at the end of their respective sub-divided era, as identified at the start of this section. Consequently it does nothing to reveal the beginnings of these systems, nor the subsequent evolution of their respective infrastructures and the actual GH procedures that were developed for the PGVLAs, and indeed for all the other types and sizes of airships in the other eras.

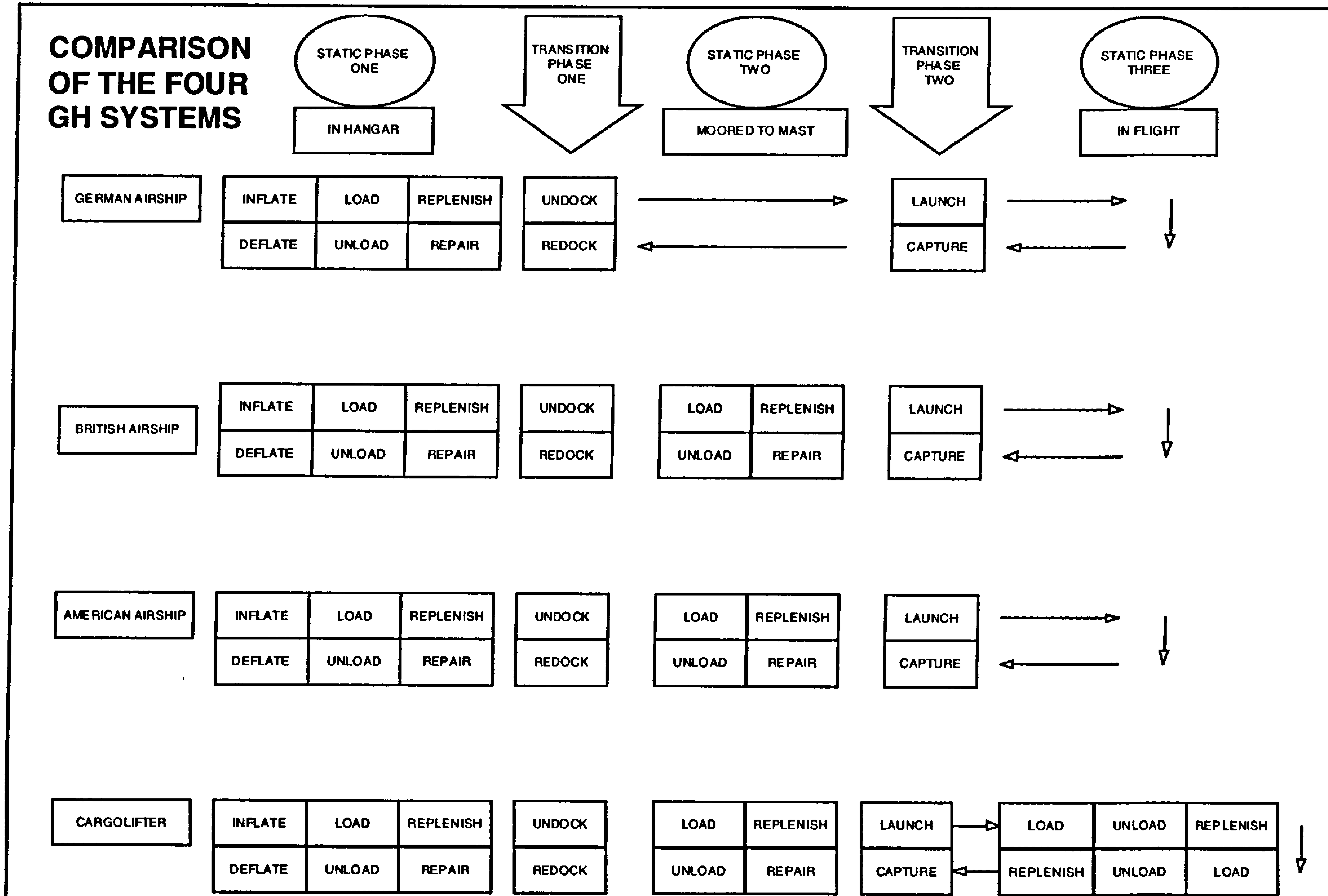

Figure 6.12 - Comparison of the four GH Systems

6.3 The origins of airship GH procedures

In general, the earliest balloons, both gas and hot air, were inflated, flown and cleared away after they had landed, all within a 24 hour period. The same was true for the earliest airships and things stayed pretty much like this for the next hundred years, with only the preparation and assembly of the various devices taking ever longer, as the complexity of their structures increased. In general terms too, the ground crews of these early flying machines, both balloons and airships, were really comprised of two differently skilled groups - specialists in inflation and a chase crew. Although there was little to distinguish either of them from those who handled any of the free flying LTA craft throughout this period, in an unexpected branch of the science, there was official recognition of the "profession" surprisingly early on.

From the very beginning there had been a tendency with many gas balloons, due to the unreliability of the gas production methods, towards inflation on one day and flight on the next. Also, on occasion, when the weather was fine, and the landing was gentle, the flights of these early balloons might be continued into a second or even a third day, (and this was particularly so after more than a century of development and experience,)[1] but generally balloons in the first era of LTA flight were not kept inflated for protracted periods.

There was however, one exception - a group of people who had the incentive, and thus the desire, to increase the longevity of their balloons and, as was pre-requisite for all airships, to keep them inflated for several days or preferably weeks. These were the military, who pioneered the use of observation balloons in time of war. The first of these on record was built by Jean Marie-Joseph Coutelle for the French Armed Forces of the Revolution, barely ten years after the very first Montgolfiere ascent:

> "... the balloon ... was called the "Entreprenant"... The bag was made of silk ... impregnated with varnish said to be so impermeable that after two month's inflation the balloon would retain most of its lifting power ..." (Stehling & Beller, 1962:36)

It was handled by the world's first "professional" ground crew. Their composition already showing early signs of the breadth of talents and skills that would be required by those who, in later years, would choose to follow in their footsteps and devote themselves to the care and preparation of buoyant aircraft.

> "On April 2, 1794, the first air corps in the history of the world was formed. It was known as the *Première Compagnie d'Aérostiers* ... There were twenty-five men in the corps, each being selected because he was experienced in some form of artisanry useful to the aerial mission. There were masons for laying furnace brick, carpenters for making and keeping the basket in repair, and chemists to regulate the gas-generating system and to test the varnishes used on the bag. To help with the riggings, two fishermen were recruited ..." (Stehling & Beller, 1962:37)

Although many of these particular and peculiar talents have now fallen into disuse among modern ground crews, they serve to demonstrate the point made previously that a large part of ground crew training is specific to the actual aircraft the crew will handle. (As in all things associated with airship GH – the devil is in the detail.) However, other of these very early methods were, and still are, universally applicable and some have scarcely changed at all in the intervening centuries. For example the rope-grabbing ground crews of today's modern blimps will have much affinity with this description:

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[1] An excellent first-hand account of such an overnight stop with a free-flying gas balloon appears in Hardy, 1986:62-66.

> "Sixteen ropes hung from the "Entreprenant," the ends in the hands of the *Aérostiers*. The men leaned ladders against the stone wall, climbed them, and jumped down and waded through the ditch onto the outer bank. Wet from the high humidity of the summer night, slimy from their dip in the water, plagued by the mosquitoes spawned in the stagnant liquid, they towed their machine across the field." (Stehling & Beller, 1962:46)

And not a lot had changed 67 years later, in the American Civil War, when John Wise undertook to provide a similar observation balloon to assist the Union Army with its advance into Virginia in 1861:

> "A detail of twenty men and their officer emerged at two o'clock Sunday morning from the Columbian Armoury, where the balloon had been inflated. Overhead, the aerostat danced in the light breeze. The men jockeyed the mooring ropes to coax the huge machine past telegraph poles and wires lining Pennsylvania Avenue. A bright moon outlined the detail's way through Georgetown and across the Aqueduct Bridge, which spanned the Potomac River. When they reached the Virginia Shore, the men began following the Chesapeake and Ohio Canal. Their path was narrow, heavily arched by overgrown shrubs and tree branches. Soldiers hacked the way clear so that the balloon could move on. Occasionally, the growth became too thick ...Then the men took to the water, sometimes wading, sometimes swimming, with the ends of the mooring ropes tied to their waists." (Stehling & Beller, 1962:71/2)

Furthermore, some 55 years later again, in the middle of the First War, almost identical procedures were still acceptable, in extremis, for a large German rigid airship - even with an entirely *ad hoc* ground crew:

> "So our forced landing [of the *L6* in a wood at night] had turned out fairly successfully after all ... I tried to find out what would be our best way on foot back to the landing ground [at Nordholz]. ... I wanted ... some opening between the village and the wood through which I could pass with my ship in tow. ... all the crowd that had gathered together – men, women and above all the schoolchildren ... were distributed over the various handling lines, and each group was taken charge of by one of my crew. And thus we set off in the direction of the airship base, which was about a mile and a half away. When we had gone half-way we saw innumerable little lights approaching us through the wood. They were the ground staff from the landing ground ... coming to meet us ... They took over the transport of the airship ...[and when] we came across the first obstacles to our progress along the road ... a coil of handling guys was drawn up into the ship, dropped down from the bows on the farther side of the telegraph wires, and seized by the men, whereupon the same process was repeated at the stern. ... As soon as we were out of the wood the wind began to blow very much harder ... So we decided to send a party on ahead, who ... sawed down the telegraph posts and laid the wires on the ground ... Our main concern was to get the ship back into the shed. By 1.30 a.m. this had been accomplished ... " (Von Buttlar Brandenfels, 1931:83/5)

From this it can be seen that, in LTA GH, if a simple procedure works adequately then there is really nothing to force a change to it, or in other words, as the saying goes "if it ain't broke don't fix it." Consequently, and interestingly, the corollary to this, is that GH procedures, which supersede those that are intuitive, or plain common sense, (such as pulling LTA craft around with ropes,) are only going to be devised in direct response to occasions when things have gone seriously wrong - i.e. after there has been an accident.

So, in contrast to the largely performance-driven development, and incremental improvements of the airships themselves, the evolution of their GH, has in the past been driven, almost exclusively, by accidents and disasters. This is of profound importance to this investigation because it provides an opportunity for some of the PGVLA GH procedures to be studied in detail.

6.3.1 Accidents and incidents

In the normal course of events, it is true to say that nothing gets written down if it is considered "normal" or simply common knowledge. Thus, a mediaeval scholar, plucked from his time and placed in a modern dwelling, would be hard put to find any literature within it explaining in simple terms, how he could activate any means of illuminating the room. Everyone today knows what a light-switch looks like and where one is likely to be found. Who needs written instructions?

Similarly with the historical records concerning the PGVLAs, and particularly with their GH procedures. Nobody wrote down what was known to everyone around them as common knowledge, because there was simply no point. However, there were two exceptions – handbooks (i.e. instruction manuals specifically intended to pass on knowledge to future generations of students) and, records of exceptional events wherein the norm was departed from, and where there were perhaps lessons to be learned that could save either time, or money, or peoples lives and limbs (i.e. accidents). Thus, both of these would seem to be vitally useful for this investigation, and would indeed be so, apart from the fact, (as explained above in **Section 5.4.2 –Airship GH manuals,**) that there is not a great deal of GH information available in the surviving manuals simply because so many of the experts who should have written them were killed before they could complete the task. As a consequence, reports of extreme and unusual events (i.e. accidents and incidents) wherein the common GH knowledge was invariably written down, assume a great significance as a potential resource for this study.

Indeed, careful reading of the records stemming from the subsequent accident investigations, official inquiries, and the like, that were produced in response to the many unplanned events that befell previous generations of airships, makes it possible to glean much of the day to day procedures that were in use, as they were applied or employed at the time to deal with these events. They also detail something of the manner by which these methods were confronted, and perhaps confounded by the incidents that arose, and therefore reveal the driving force or reasoning behind any GH "improvements" that resulted from them. However, before searching out specific reports for the CLOSHRP, the author found that it was necessary to know where, and more importantly when, the major accidents with which such writings were likely to be associated, had actually occurred. By reference to the same history books listed above as sources for **Appendix I**, it was possible to compile a further comprehensive list of the major accidents and minor incidents that befell the airships of the past. (See **Appendix J – Accidents and incidents**)

This list was by no means exhaustive, but as can be seen, it is extensive because there were a great many accidents. However, classification of these is again something of a problem largely because perception of what constitutes an 'accident' has changed considerably over the years. Events which would undoubtedly cause chaos today were taken as commonplace and quite acceptable in the past. For example, if Von Buttlar were to start chopping down telegraph poles today, in order to get his ship back to it's shed, it is extremely improbable that he could do so without attracting the attention of the local 'accident and emergency services.'

Just how such an event would be recorded today, and passed on to future researchers by the media and statisticians alike, is debatable. Suffice it to say that this incident, recorded as an anecdote in Von

Buttlar's memoir, was not classed as an 'accident' in his time. Nevertheless, he did write it down in some detail, and without this record future generations could easily believe, wrongly, that despite its obvious simplicity, such an inherently dangerous procedure could not succeed and was thus never done. Therefore there was a requirement for unusual GH events and relatively minor incidents of a similar nature that were recorded to be collected, and an example of these is given in **Appendix K - Unassisted landings.**

Furthermore, information concerning the bases themselves was also collected and this is given in **Appendix L - The airship bases.** From this, and the compilations in **Appendices I & J**, a list of events can be extracted that with hindsight, seem to have been influential in the evolution of GH, and from this an overview of the way in which the GH infrastructure developed by the PGVLAs can be derived.

6.4 The evolution of GH infrastructure

[NB – The amount of computer memory required by the large number of illustrations in **Section 6.4**, has necessitated their removal to - **Appendix M : GH infrastructure illustrations]**

In the conventional view of airship history, it is usual to dismiss as largely irrelevant, all the early pioneering attempts at dirigible flight – i.e. "Era 1" prior to the appearance of Santos Dumont in the late 1890s - on the grounds that there was insufficient propulsive thrust available to make the concept viable. However, from a ground based perspective things are rather different, and there are a number of important events which occurred within this "proto-airship" era that are deserving of note and inspection.

It is true, that virtually all of the very early small blimps that took to the air between 1783 and 1899 were little more than one-day wonders, and in GH terms they were handled much as the free-flying balloons of their day – i.e. they were inflated in the open air, and dismantled when, and wherever, they landed. It is also true that a majority of these contraptions, never flew a second time, and in this they followed a tradition begun by the Montgolfier Brothers, whose fragile "smoke" balloons were usually damaged beyond repair by the impact of their first landing.

> "Heretofore [1899] I had emptied the balloon of all its gas at the end of each trip, as one is bound to do with spherical balloons. Now I saw very different possibilities for dirigibles. ... my 'No. 3' had lost so little gas (or, perhaps none at all) at the end of its first long trip that I could well have housed it overnight and gone out again in it the next day." (Santos-Dumont, 1904 :126)

However, closer examination of the method devised in 1783 for inflating the world's very first man-carrying balloon, reveals that it bears a remarkable degree of similarity to that used for the last and largest of the big rigid airships in 1938;[1] and even to that used by today's modern blimps.[2] Therefore, although 'inflation' was adjudged, in **Section 5.3.2**, to be one of the tasks that might safely be excluded from those allotted to the overburdened ground crew, in this instance, in order to find the origins of airship GH, and to understand how the infrastructure for it developed, it is necessary to take a brief excursion into the early history of ballooning and to look at how the very first of their kind were inflated.

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[1] *LZ130 Graf Zeppelin II*

[2] For detailed breakdown of these procedures see **Appendix D - US Navy K type blimps - inflation sequence**

6.4.1 Evolution of the airship shed

The first balloons, built by Joseph Montgolfier at Annonay, in France, in the summer of 1782, were simply paper bags. These were held upside down over a fire, until they filled with smoke, whereupon they were released. However, the succession of the ever larger "Montgolfieres" that Joseph and his brother Etienne went on to build throughout the following year, (culminating in the first, manned, free-flight from Paris by de Rozier & d'Arlandes, on 21st November 1783,) were much more complicated devices. They were still constructed of paper, but now in sheets stuck onto canvas, and these strengthened panels were then buttoned onto a gigantic framework of bamboo poles. Thus, the first problem that the brothers faced was how to keep the highly combustible balloon away from the heat of the fire while persuading the inherently unrestrainable and freely ascending lift agent – heat, or as they believed at the time, smoke – to enter into the chamber prepared for it.

Their solution, to what was essentially the world's first GH problem, was to hold the balloon above, and away from, the fire by building it (the balloon) on top of a raised dais. This solution, of raising the body of the balloon higher than the supply point of its lifting agent, was universally adopted by the succeeding generations of would-be LTA flyers, and it appeared to be the only viable solution at least until the advent of pressurised gas in portable cylinders a hundred years later on.

However, while the Montgolfier Brothers' raised platform did protect the balloon from the fire - safely down on the ground below - and conveniently acted as a wind shield that helped to stop the smoke from blowing sideways, unfortunately, thus elevating the balloon also created and exacerbated a second GH problem. This was how to stop the enormous, fragile and progressively more buoyant structure from itself being blown sideways by the wind before the inflation was complete.

The Montgolfier Brothers' solution to this second problem was to anchor the top (or "crown") of their balloon by means of a rope strung like a washing line between two upright poles. These can be seen on either side of the raised dais, beneath the ascending balloon in **Figure 6.13** (See **Appendix M**). This system too became an accepted norm for the inflation of balloons in general and was soon to be seen in use by other pioneer aeronauts at subsequent smoke balloon ascents elsewhere - see **Figure 6.14**.

So, from the very dawn of LTA flight, there were found to be three fundamental GH requirements.

- Firstly, a means to counteract or negate the effects of the wind.
- Secondly, a suspension system to support, or even take the entire weight of, the "empty" structure, prior to and during its assembly/inflation.
- And, thirdly, some means of gaining access to the underside of the structure to enable control of the incoming lift agent and attachment of the payload impedimenta - gondola &c.

Of even greater import for the history of GH, within days of the first manned free-flight, by a smoke-filled Montgolfiere, the generic nature of these three fundamental requirements was reinforced by the first free flight of a gas-filled balloon. Although this device was of an entirely different construction, and operated on a completely different lift principle, its GH requirements soon proved to be identical to those of its predecessor.

On the 1st of December 1783 Professor Jacques Charles took off from the Tuileries in the world's first hydrogen-filled gas balloon. In contrast to the paper Montgolfiere, the "Charliere" gasbag was made of silk panels that were sewn together and made gas-tight with a coat of lacquer. This "envelope" was encased in a net of knotted cord and from this was suspended a wickerwork "gondola" that carried the pilots and their ballast bags full of sand. These latter, used in conjunction with a simple cord-pull valve at the top of the balloon, were the means by which the device was operated, and allowed the pilots, by venting gas (lift) or ejecting sand (weight), to establish, and then to precisely balance a state of "equilibrium" between the *quantity* of lift agent and the payload weight suspended from it. This was in contrast to the Montgolfieres, wherein, the pilot, by increase or decrease of heat, could directly, albeit crudely, adjust the *density* of the lift agent itself, leaving the payload weight unchanged - save for the coincidentally beneficial diminution-by-consumption of the onboard fuel.

The superior nature of the gas balloon, both in flight and in its GH, was apparent almost from the start and sandbags with a net, were soon to take over the role of anchoring and controlling the inflation of gas balloons the world over. Indeed they remained as a vital part of all gas balloon ascents for the next 200 years and are still used in modern blimp inflations. However, initially the washing line method as described here was preferred (see **Figure 6.15**).

> "In order to facilitate the entrance of the gas into the balloon two long poles are erected. These are furnished with pulleys, through which a rope, attached also to a ring at the top of the balloon, passes. By means of this contrivance the balloon can be at once lightly raised from the ground, and the gas tubes easily joined to it. When it is half full it is no longer necessary to suspend the balloon; on the contrary, it has to be secured, lest it should fly off." (Marion, 1870:26)

On the 3rd of December 1783, just two days after Professor Charles' very first gas balloon ascent, a distinguished French engineer (Lieutenant Jean Baptiste Marie Meusnier) presented a paper to the Académie des Sciences in Paris. His *Memorie sur l'equilibre des Machines Aerostatiques* suggested the idea of using an air-filled 'ballonet' to control the pressure of the gas within the balloon envelope, and six months later, the world's very first airship was fitted with one and made its debut.

> "At his [Meusnier's] suggestion a ballonet was used in the first elongated balloon ever to take the air. This venture was promoted by the Duc de Chartres in 1784 and the balloon, 52 ft long, 32 ft deep and 30,000 cubic ft capacity was built by [Prof. Jacques] Charles and the brothers Robert. It was intended to be dirigible (i.e. steerable), ... but the method of propulsion was so completely ineffective that it scarcely merits the term. ... This machine took off from St Cloud on the 15th July ... [and landed]... near the Chalais Meudon." (Rolt, 1966)

The method by which this first airship was inflated is not known but it seems likely to have been similar to that used for the spherical balloons of its day, especially as the upright poles are still clearly in evidence later on, at gas balloon ascents that were made elsewhere as the novelty of aerial-ascending devices spread to other countries (see **Figure 6.16**). Indeed, as time passed, so it appears that the system was refined and that at least in England in 1785, the number of poles was actually increased for a short while, as evidenced by **Figure 6.17 - Mr Arnold's ascent.**

While little is known of the GH procedures involved in the inflation of Mr Arnold's gas balloon, much can be gleaned from an exceedingly detailed sketch that was made of the arrangements for the ascent of his immediate predecessor, Vincent Lunardi, whose second balloon had been inflated and prepared at the exact same site in London, a few months previously. Close study of this drawing [1] (**Figure 6.18**) reveals evidence of equipment that was designed to deal with all three of the basic GH requirements. Taking them in order, firstly, it can be seen that there are three vertical poles or "masts" on either side and behind the balloon, and that these have fabric "sails" strung between them. These sails are billowing in the wind and this reveals that, whatever their true function, they must have acted to some extent as a wind screen for the envelope during inflation, and thereby fulfilled the first of the three fundamental GH requirements.

With regard to the second requirement, the balloon appears to be full, and the top of the picture is cropped. This unfortunately makes it impossible to see if the empty envelope had been initially suspended in some way. But, at the top of the picture, there is the suggestion of angled beams that are pointing upwards, and not only could these easily meet in the middle to form some sort "sheerlegs" or elevated anchor point, but there seems little reason for their existence otherwise. Moreover, it is undoubtedly clear that during the gassing-up process, the balloon, in switching from needing support to needing restraint, has been inflated within a large mesh net, and that this is now anchored down with the numerous weights that are to be seen standing atop the raised platform.

Thirdly, the fact that Lunardi's balloon has been inflated on a raised platform reinforces the point that he had foreseen a requirement for space beneath the gasbag to allow access for its connection to the gas production equipment (the large wooden casks). In addition to which it is evident that a second reason for raising the gas balloon has now also been found. The platform is set at such a height that when the balloon is fully inflated, the ornate passenger-carrying gondola, seen situated off to the left-hand side, can be easily carried in underneath and attached to the net in preparation for the ascent.

But, there is evidence that a fourth fundamental requirement has also been identified. There appears to be a high fence surrounding the whole site. The function of this, presumably, is to protect both the balloon, and those "ground crew" conducting the inflation of it, from the crowds of excited spectators whom, it can be safely assumed were massing outside. Hoards of people are a feature at nearly all early balloon ascents, and they dominate many depictions of them, as in **Figure 6.17**, when Mr Arnold flew from the same site in the same year. Indeed, it should be noted that many of the very early attempted balloon inflations became the scenes of some very serious riots when large crowds of onlookers, many of whom had paid to witness the spectacle, were frustrated by the failure of the balloon to ascend as promised.[2] Crowd control was thus established as an essential part of GH from the outset and Lunardi's fence reveals that by mid-1785, the need for protection from curious onlookers had been identified as such a serious GH problem that was worthy of a considerable financial investment in infrastructure.

Furthermore, there is also to be seen, in the right-hand foreground of the Lunardi picture, the base of a fourth upright pole that appears to have been tipped backwards away from the balloon and out of the picture - perhaps to make way for the gondola connection? Whatever the reason, it is apparent that what had actually been erected, prior to the balloon inflation, was a four-sided, combination-wind-and-people-screen, that both protected the gasbag from the weather and prevented the *hoi polloi* from seeing

[1] Rolt, 1966: 97 "Inflation of Lunardi' second balloon in St George's Fields, 1785"

[2] Prior to Lunardi's ascent both Tytler in Edinburgh, and Chevalier de Moret in London, had caused riots and others had come close.

prematurely what others perhaps had paid to see. Taken in conjunction with the fence, this screen structure can be seen as a rudimentary, and temporary hangar, and as shown in **Figure 6.12**, this was indeed the next step in the evolution of LTA GH infrastructure. However, with equipment designed to address all four elements of the fundamental GH requirements, Lunardi's system may lay claim to be the progenitor of all subsequent airship inflation systems - up to and including the largest of the PGVLAs. The truth of this can be traced pictorially (**Appendix M**), and the same four fundamental systems:

a) a roof and screens (or hangar walls) to provide protection from the weather,
b) secure perimeter walls and doors for protection from people,
c) suspension systems (or roof cranes) to assist with assembly/preparation by support of the empty or partially buoyant gas chamber, and
d) a raised platform to allow access to the underside of the vessel and facilitate attachment and control of gas and ballast,

can all be seen in use, unchanged in their essentials, in photographs of airships that were taken more than one hundred years after the preparations for Lunardi's balloon flight were sketched, (**Figures 6.28; 6.31; 6.34**). Indeed, these same solutions to the fundamental requirements can be seen throughout the PGVLA era and derivatives of them are still in use by modern balloons and blimps (**Figures 6.21; 6.30; 6.36**).

Part of the reason for the seminal nature of Lunardi's system, as it was sketched, lies with the fact that this, his third gas balloon inflation, was early enough in the infancy of LTA flight for the major problems to have been identified, but too soon for divergent solutions, or separate mitigation strategies to have taken effect. He is thus effectively using a smoke-balloon inflation technique to inflate a gas balloon, and here it should be recognised, that in terms of their GH, the rigid airships - have much more in common with the Montgolfiere smoke-balloons than they do with either blimps or gas balloons. This stems from the previously unremarked fact that while "airships" are conventionally categorised by their structural type - i.e. "rigid," "semi-rigid" or "non-rigid" - "balloons" are defined, either according to their lifting-medium - i.e. "hot air," "gas" or "Roziere"[1] - or by their purpose - i.e. "free-flying," "tethered," and "passenger-carrying," &c. Interestingly, the application of the airship categories onto balloons reveals a very simple reason for this; all the balloons built since the demise of the Montgolfieres have been of only one structural type - i.e. "non-rigid." The concept of a *rigid* free-flying balloon died with the Montgolfieres and the overarching supremacy of their *non-rigid* gas-filled rivals thereafter, not only eclipsed their achievements but also removed any need for differentiation by structural description.

The significance of this one-sided dominance is that the complete absence from history of any rigid aerial vehicles, for a period roughly from 1789 to 1899, meant that while techniques for inflating, moving and mooring the non-rigid gas balloons were tried, tested and honed to perfection, (most frequently in time of war,) (see **Figures 6.13; 6.15; 6.16; 6.18; 6.20**), the parallel procedures for the rigid craft were in large part abandoned and ignored. They remained so until the arrival of the airship as a viable proposition.

Notwithstanding, the advances made in "mooring-out" and "bedding-down," (**Figure 6.19**) - helped in no small part by the British military's invention of portable pressurised cylinders for the transportation of

[1] Named after Pilatre de Rozier who was first to fly in a "combination balloon" with compartments containing both hot air and gas

compressed hydrogen, which allowed for quick deployment of observation balloons in remote places, (and which idea was quickly taken up by armies elsewhere, **Figure 6.17**) - there was one piece of infrastructure from the early days that never went away entirely. Although the gas balloons evolved techniques for operating out in the open they did retain the occasional use of "Balloon sheds." These, however, were expensive to build and maintain and were thus reserved almost exclusively for construction purposes. They were places where gas cells could be made, mended and given test inflations without having to depend on good weather. (**Figures 6.22: 6.25**) The facilities for fulfilling the basic gas cell needs were consequently developed in association with these various military Balloon establishments.

Thus, when, at the end of the 19th century, the airship re-emerged from theory into practicality, the shed with its accoutrements was already developed as a concept. All it needed was modification to suit specific needs and both Santos Dumont with his French blimps, and Count Zeppelin with his German rigids, were able to pick up where the early pioneers had left off, and to take what they needed from the gas balloon systems. The British military also turned their gas balloon lessons toward the development of airships.

> "By the year 1903 it had become imperative that Britain should build an airship for her Army. An airship, however, could not be built until there was an airship shed in which to erect and house it. There was no room for such a shed in the existing Balloon Factory [at Aldershot] ... Therefore it was proposed to erect an airship shed locally ..." (Walker, 1971:54) (**Figure 6.24**)

> "I needed a building for the housing of my air-ship between trips. ... I should need my own workshop, my own balloon house, hydrogen plant, and connection with the illuminating gas mains. The Aero Club had just acquired some land ... and I concluded to build on it a great shed, long and high enough to house my air-ship with its balloon fully inflated, and furnished with all the facilities mentioned." (Santos-Dumont, 1904 :126/9) (**Figure 6.26**)

This was not, as Dumont claimed in the picture caption on page 271 of his book "the first of the world's airship stations" - Renard and Krebs at Chalais Meudon (**Figure 6.23**) beat him by many years, although the idea can be traced right back to the genius of Meusnier in 1784 (**Figure 6.14**). Neither did Santos Dumont significantly add to the science of LTA GH infrastructure. Count Zeppelin, on the other hand, at virtually the same time, was making a quantum leap with his famous floating shed at Manzell on Lake Konstanz. (**Figure 6.27**) The reason being his perhaps unconscious advance in what is now known as functional integration.

Here it should be remembered that, as stated in **Section 5.1**, the rigid airship shed was really an assembly jig that was clad to keep out the weather. So while its first function is "protection," for the airship and shelter for the people who are building or servicing it, the shed also serves to assist with "preparation" - by provision of such ancillary equipment as suspension and anchoring systems, along with access for connection of gas supply and the attachment of fins, gondola, &c.

> "For docking the airship in a shed there is a choice of supporting her from above by slings; from below by shores; by a combination of slings and shores; or by keeping the airship "light" and holding her down by lines forward and aft." (Fulton, 1929:61) (**Figures 6.33; 6.34; 6.35**)

However, with his floating shed, which weathervaned passively according to the wind, Count Zeppelin actually integrated a third function; going one step further along the chain of the necessarily sequential GH events, identified in **Section 5.1**, as being those that every airship must inevitably pass through.

By automatically aligning itself with the wind, the Zeppelin floating shed(s)[1] went beyond "preparation" and also assisted with the next phase - that of "moving" the airship out and in again. It was thus the first major component of GH infrastructure specifically designed to facilitate airship *flight* operations. Sadly, it proved to be a little too far ahead of its time.

> "Apart from the floating sheds at Lake Constance, which were abandoned after one of them sank in a storm, the German solution was the revolving shed. Otto Krell, who designed the 1911 Siemens-Schuckert ship, had built her in a single revolving shed at Biesdorf. This was later copied in enlarged form at Nordholz, the more famous of these expensive solutions to the ground-handling problem." (Higham, 1961 : 41/42) **(Figures 6.45; 6.46)**

However, such buildings were really early attempts to solve a different set of problems; those that lie beyond Protection and Preparation of the airship, and for them a different GH infrastructure comprised of further specialised equipment was found to be necessary.

6.4.2 Evolution of mooring masts and loading systems

It is important at this point to emphasise something about "airship bases" that is yet again commonly overlooked - there are several different sorts of them. Moreover, the airship's needs, and consequently the GH infrastructure required, at each of these different sorts of base, are themselves very different. This is an important distinction to make, and it also applies to HTA craft. For example, Boeing build at Everett, but there is no commercial air traffic, and the same can be said for Long Beach, Filton and Warton, and even Toulouse has limited commercial flying. The obvious conclusion is that test flying and commercial operations don't mix well.

The same was true for the PGVLAs and, although many bases were not specifically labelled as such, it is possible to identify in the historical records, at least six different sorts of base that were found to be of use and upon which very different GH facilities and infrastructures for the moving, mooring, loading and launching of large airships were established. These different categories of airship base include:

- Construction and assembly
- Operational or terminal/hub
- Training and experimental
- Planned temporary operations or "expeditionary" base (full facilities at remote location)
- Unplanned temporary or "emergency" base resulting from forced landing
- Anchorage or resting place (only for refuelling and/or crew/load exchange)

It is also important to note that whereas a shed has a universality of purpose, in that it can provide protection for any airship that will fit inside - and, in most cases also contains equipment that can then accommodate a degree of preparation, or repair, (i.e. ladders, hoists and tie down points) - the same cannot be said for the mooring equipment out on the field. This, by its very nature, is far more airship specific, and indeed, many of the competing PGVLA mooring systems were incompatible with the airships from other nations, or even with succeeding generations of their own. Most frequently, latterly, this was because the mast height did not fit with the airship's diameter, as shown for example with the American "Wellman" telescoping mast, **(Figure 6.10)** which was made extendible in height in order to accommodate a range of differently sized airships that were planned for the future but were never built.

[1] There were in fact two built on the same site, one after the other.

However, there were other reasons for incompatibility, such as a lack of suitably reinforced strong-points at the correct location on the hull, or, as with rail-mounted, tail-holding devices, simply because the new airship was longer than its predecessor and the radius of the rail-track circle was too small.

All this is indicative of the fact that so many of the PGVLAs were actually still in the prototype stage. There were one or two exceptions - most notably the German Navy Zeppelins of the First World War - but in general most projects never really got far enough along the development line to establish any national, let alone international, standard. The author and his colleagues at CargoLifter commented on a further aspect of this in their preliminary report:

> "Comparison between the methods is also compounded by the comparatively small number of cycles of use that some of these systems were subjected to. And it is difficult today to put a value on a mooring system that had barely been tested before it was demolished. For example the high mast at Cardington successfully held the *R101* safely moored through a week of 60-mph gales that culminated in a peak gust of 83 mph. ... This feat is impressive and such a performance should obviously not be dismissed lightly. Yet the *R101* only made 12 flights in its lifetime, while its sister ship the *R100*, popularly believed to be the more successful of the two, only made 10 flights, of which 3 were the voyage to Canada. This begs the question of how many times the Cardington high mast was actually used?
> Compare this with the lifetime total of:
> - 590 recorded flights for *LZ127 Graf Zeppelin*;
> - 338 for *LZ126 Los Angeles*;
> - 73 for *ZR4 Akron*;
> - 58 for *ZR1 Shenandoah*; and
> - 54 for *ZR5 Macon*."
>
> (Camplin, Bischet & Watson, 1998)

Of these, the cream of the PGVLAs, only the twins *R100* and *R101* in Britain, and *ZR4* and *ZR5* in the USA, were truly compatible with their siblings - although not with the other pair - and whereas *LZ126* did share its mooring facilities with some of the others, and *LZ127* was on occasion wrestled into the Lakehurst Shed for repair, (and further damaged in the process,) in truth, all these airships were differently equipped for their own unique blend of mooring systems. Some of these are shown above in **Section 6.2** on pages 143/5 as **Figures 6.6** to **6.11.** Consequently, there are a very great number of more-or-less, one-off, GH and mooring devices, comprising a wide array of subtly different masts, towers, trucks, dollies, trolleys, mules, cars, cradles, beams, tugs, towing-vehicles, railway-tracks and purpose built locomotives, most of which have been described in detail by historians in the past. For this reason, it is not deemed necessary to investigate the vagaries of their various careers, nor their disparate contributions to the science of GH, and nor to provide illustrations to more than a few of those felt by this author to be the most interesting or significant. See **Appendix M - Figures 6.38 to 6.50.**

Suffice it to say that the situation for the VLAs was very different than it was for the blimps, which were produced in large numbers, in both World Wars, and which could all use the same, or at least very similar mooring systems. In large part this commonality stemmed from the process of hardening in the field that the gas balloon had undergone in the hands of the military. It began originally with the need to move, moor and preserve the gas of, the *Entreprenant* (**Figure 6.13**) and it continued seriously with tethered observation balloons during both the American Civil War (wherein Count Zeppelin first encountered LTA flight) and the Boer War. Specifically the real advances came from the aforementioned "bedding-down" and "mooring-out" techniques that were devised. These consisted of simply removing the suspended impedimenta from beneath the gas bag and then pulling it down until it was squeezed between it's retaining net and the ground. **(Figure 6.19)** This was done either manually by hooking sandbags onto the net or by mechanical means with ropes and winches attached to ground anchors or "screw-pickets."

It was found that these simple means were perfectly workable in all sorts of terrain and weather conditions, and that this was a quick, cheap and flexible method of creating sufficient pressure in a non-rigid gas bag for it to withstand the force of the wind - even up to gale force. More importantly, there was no need for any form of external pressurisation to be supplied, and this technique, combined with the invention by Col. Capper and the Royal Engineer's, of portable gas-cylinders, **(Figure 6.17)** freed the gas balloon from its reliance on, and need for a protective shed. This allowed Boer War observation balloons to be inflated, and kept for days on end out in the open air, and even inflated on river-boats, **(Figure 6.40)** thus making them of some practical military use and bequeathing to future generations of airship-makers a reliable and cost-effective method of inflating virtually all and any type of gas cell, regardless of shape or size. Gas bags restrained by nets can be seen inside the large rigid First War Zeppelins **(Figure 6.32)** and in use with the RNAS blimps of the same date **(Figure 6.29)**. Furthermore, these methods of inflation with sandbags and of mooring under tensioned nets still remain in use today. **(Figures 6.21 and 6.30)**

However, whereas spherical balloons are equally affected by the wind from whichever direction it blows, the same is not true of an elongated airship gas bag. Thus, a balloon can be put back into service as soon as the wind's strength decreases, but a blimp must wait until the wind also blows towards it's nose. Realigning the squeezed-down envelope to meet a changed wind-direction is impossible as even a slight cross-wind will make re-fitting of control-car and fins exceedingly difficult - not to say dangerous - for the groundcrew doing the work. Moreover, the bigger the airship the worse the problem becomes, and this was a serious limitation with regard to their usefulness in general prior to the First World War.

The French in particular, had some initial success when they attached a large downward-pointing spike to the bottom of their control cars, thereby allowing some of their early non-rigids, to pivot into wind as gusts came and went, but the idea was abandoned after *Le Patrie* was literally torn from the hands of her numerous ground crew and blown out to sea. Thereafter the problem was tackled by the British military who solved it for their First War blimp's in two ways. Firstly by seeking shelter:

> "Mooring of the small non-rigids was carried out on the ground in quarries or bays cut into woods away from their bases which greatly assisted the value of their operations." (Williams, 1974:151) **(Figure 6.37)**

Secondly, by the development of the nose mooring mast. Initially, work on this was done by Vickers at Barrow with small blimps, (using the double-headed Masterman Mast,) and latterly it was taken up and perfected at the dedicated experimental base near Pulham, where large rigid ships, such as *R28* and *R33*, tested the famous high mooring mast. The culmination of this work, some ten years after the Armistice, was the erection of a Mooring Tower at Cardington **(Figure 6.8)** and of others in Canada, Egypt and India. However, the success of these early trials led the Americans in 1922 to build their own high mast at their new Naval Air Station at Lakehurst, and, then to licence Major Scott's patented, tower-top connection system for use with their own home built *ZRS-1 Shenandoah*. The subsequent break-up of this airship in mid-air; the Americans prolonged experimentation thereafter with their German-built

LZ126/ZRS-3 Los Angeles, along with their eventual disenchantment with the high mast and development of the low- or stub-mast, are all well-known and well documented elsewhere. (These latter, and the associated GH procedures, are also examined in detail in **Section 9.3.1**).

Less well-known, but far more potentially interesting from the GH perspective, are the American trials of the Ford mast at Dearborn, (**Figure 6.38**) with its "vertical railway" for lowering an airship to the ground - two airships did use the mast but the railway was never tested - and the fitting of a mooring mast onto a sea-going ship, (**Figure 6.42**) which was a proven success.

> "Through the night, and during the following day, the *Shenandoah* was on the mast with no trouble, experiencing fresh breezes to calm, and swung in a complete circle around the *Patoka*'s masthead, safely clearing all top hamper. The duty watch found that even with daytime superheating, it was much easier to keep the airship trimmed and ballasted than when on the mast at Lakehurst, with convection currents rising from the hot sand." (Robinson & Keller, 1982:88)

In later years, both *ZRS-3* (**Figure 6.41**) and *ZRS-4* had a similar experiences on this same system. Moreover, the method of capturing the airship's mooring lines at sea, forced a reduction of ground crew numbers, to more or less those who could fit into a small boat - and it also explored the potential for yaw-guy booms - an idea that was proposed in a British patent (GB 252,517) by Barnes Wallis in 1926.

In terms of simply mooring out with very large airships, these various systems really represent the state of the art, and it is important to keep in mind that the large rigid airship has yet to pass through a similar hardening process to that experienced by both the gas balloons and the blimps. Indeed, in reality, there have really been very few attempts at operational hardening of VLAs to allow prolonged survival outside of a their sheds. Chief among them are *Graf Zeppelin's* regular visits to Brazil and Spain, (**Figure 6.39**) *Shenandoah's* 19 day circuit of the USA, and a handful of brief exercises wherein *ZRS-3 Los Angeles* and *ZRS-4 Akron* used expeditionary masts at Camp Kearney and on board *Patoka* in the West Indies.

As to which is the best, or most cost-effective, mooring system for VLAs, there is unanimity that for plain and simple mooring, holding them by the nose is the winner, but opinion is sharply divided on all else - particularly with regard to mobility and handling on the ground.

> "The high mast cannot be used for docking and handling purposes and requires an added "transporter" mast, if a mobile mast is to be used as the nucleus of a mechanical docking system. The stub mast can easily be made a mobile unit at a reasonable cost, thereby performing an additional very important function. Transition of an airship from a high mast to a "transporter" mast for docking is an added operation and may be a hazardous one. No such added features are involved in the use of the mobile stub mast." (Rosendahl, 1931a)

6.4.3 Evolution of mobile and mechanical mooring

As with mooring, the moving, loading, unloading, launch and capture procedures that were devised for, and practised by, the PGVLAs involved the tests and trials of a great many diverse, one-off, highly specialised and often purpose-built machines. Here again, all of them have previously been depicted and described elsewhere and thus tracing the adventures, fortunes and misfortunes of these innumerable, and in many cases complicated, devices, lies beyond the scope of this present investigation. Consequently in this section, too, the illustrations are limited to those where it is apparent to the author that significant progress in the science of GH was made. (**Figures 6.45** to **6.52**)

In terms of infrastructure evolution, there was very little progress made, with regard to the loading and moving of airships on the ground, until Dr Eckener had his accident coming out of the shed at Düsseldorf in 1911 with *LZ8* (see **Figure 1.1**). His immediate installation thereafter, of rail-mounted trolleys ("laufkatzen") to hold the airship's mooring lines, and to keep it central during its passage through the shed doors, (see **Figures 6.6** and **6.7**) marked a turning point and was the forerunner of a succession of rail-mounted and other mechanical devices that were used to move airships on the ground. Curiously, having initiated the process, the Germans then lost interest in pursuing the idea and all further development was left to the other countries - although the British also made little serious effort at the mechanisation of moving their ships on the ground despite some early success: "*Towing trials of rigid R-26 by a tank at Pulham showed some promise.*" (Williams, 1974:151) **(Figure 6.47)**

However, thereafter they too seemed happy to revert to the old proven method of men pulling on ropes. Meanwhile, in America, the famous "Iron Horse" **(Figure 6.48)** was succeeded by many subtle variations on the same theme - some were self propelled and others were tractor-towed; some were telescopic, others were of a fixed height; and while some incorporated devices for holding the airship tail, **(Figure 6.50)** others let it float free and weathervane. The final significant breakthrough came with the invention of the "hauling-up" circle, and the much vaunted "Bolster Beam," which allowed for the automated alignment of the VLAs with either the axis of their shed or with the wind. This system was installed on both East and West coasts of America, **(Figures 6. 11** and **6.49)** at the home bases of both the US Navy's last and largest rigids *ZRS-4* and *ZRS-5*.

In terms of loading, little was ever done to improve the original German steps (*Himmelstreppe*) into the crew/passenger accommodation and passing items in through the doorway. **(Figure 6.43)** Or of simply hoisting objects up into the ship's belly while it was safely secured inside its shed. This was partly because no PGVLAs were ever purpose-built to be solely freight-carriers. Nevertheless, everything from bombs to passenger's baggage - including on one occasion an automobile **(Figure 6.44)** - was loaded and carried by these means. "*A conspicuous feature of the freight-carrying space [on LZ129] is the huge hammock and sling for cumbrous articles such as motor cars.*" (Coke, c1937:91/2). The only significant variant was that used by the British, who loaded all passengers into their Imperial Airship Scheme prototypes - *R100* and *R101* - via a lift (elevator) in the high mast, with a "gang-way" then leading from the mast head to the airship's interior. **(Figure 6.9)**

The American contribution to this was to perfect the system, tried and then neglected by the others, of loading and unloading aircraft onto their flying aircraft carriers - *ZRS-4* and *ZRS-5* - while they were in mid-flight. This allowed a significant extra quantity of fuel to be lifted at launch and greatly improved the "mother" ship's operational endurance. The reliability of the system, and it's potential for crew-exchange, were demonstrated by *ZRS-4* in the course of one single flight during which 300 "hook-ons" and "drop-offs" were made. Some years later, after the Second World War, another in-flight crew-exchange method was also demonstrated by a US Navy blimp using a winch-suspended "basket." **(Figure 6.52)**

And finally, and perhaps most surprisingly, it seems that the most neglected of all the GH procedures that were devised and used by the PGVLAs, in terms of their refinement and improvement, were those dealing with the launch to, and capture from, flight. Where one might have expected there to have been trials of some sort of "Launch-catapult" or a "Landing-arrester-hook-and-wire" there appears to have been none. Even through the last season's flying of the last passenger-carrying PGVLA - *LZ129* - which was unquestionably the most sophisticated of them, and which by 1936, stood to benefit from all the lessons and preceding experience amassed in both Germany and America, the ground handlers are seen in photographs to be using the most primitive manual GH equipment for launch and capture (**Figure 6.51**).

6.4.4 Summary of GH evolution

To sum up, broadly speaking, the history of airship development, which began in France, moved, over a period of some 200 hundred years, via Germany to Britain, and then finally on to America. The common thread in all four countries is that the driving factor behind the airship's evolution was war and that the GH was modified largely as a result of, and in response to, serious or damaging accidents. Moreover, in all three of the major countries, Germany, Britain and America, there seems to have been a pattern in their parallel processes whereby, speaking in very general terms, the Army initially perceived the potential usefulness of airships and commenced trials. After a short, and usually expensive, test period they discovered that there were limitations for their purposes and transferred their working ships and crews to the Navy, who then took on the project, and by application of maritime practices made it work; but at a huge physical and financial cost. This was borne in time of war, but could not be supported when peace ensued and civilian safety regulations were enforced. Thereafter, the amount of financial investment necessary for continuation, involved both the government (civil service) and the private sector, who alternated, erratically, between over-enthusiastic investment and panic-stricken withdrawal of funds until the projects finally collapsed. The exception was in Italy where, curiously, the Army managed to develop their own brand of semi-rigid airship and to develop it with considerable success until the project was eventually brought down by political intrigue and a media-led witch-hunt against General Nobile.

In terms of the actual GH infrastructure and equipment, this inconsistency of financial support, and lack of experienced or informed management at the highest level, resulted in a bewildering array of incomplete systems, partially tested hardware and deeply-ingrained, false assumptions. While the largest of the airships were generally the losers in all this, the blimps benefited hugely, not least in the freely-gifted inheritance of rigid airship sheds. These were gigantically proportioned for the smaller ships' needs but allowed them a freedom in experimentation with construction and operational techniques that would otherwise have been impossible. The result was that whereas rigid airships were fitted tightly into the sheds they bought and paid for, the blimps got space enough to turn around in and could run from bad weather into man-made harbours that in other circumstances would have been far beyond their means.

In evaluating the overall successes and failures, the strengths and weaknesses, of the various projects of the previous generation, it cannot be ignored that the largest of these "ships of the air" began their development on water; (in Count Zeppelin's floating sheds,) were operated most reliably in three separate countries by Navy personnel; achieved many of their most famously successful flights over water (*R34, R100, LZ127*); and that among the most efficient GH systems ever tested, in terms of small ground crew numbers, was a mooring mast mounted onboard a sea-going ship (*Patoka*).

7 DISCUSSION

7.1 Defining the area of investigation

As stated at the outset of this investigation, and confirmed in the preceding historical overview, ground handling is a very large and complex topic. Although poorly defined, it can be said at least to extend over a period of 200 years and to encompass a huge number of events in three or more separate countries. Even when such events are listed as single line entries and reduced to a small font, (as has been shown at the end of this investigation, with the sample pages from **Appendix I - Chronological list of events** and **Appendix J - Accidents and incidents**) there is still an enormous amount of data to manage.[1] Furthermore, as explained in **Sections 3.4.3.4.** and **6.2**, the topic is also three-dimensional in nature and can be perhaps best presented in the form of a three-axis graph or Matrix, which will contain many thousands of fields. Consequently some way of reducing the amount of data has to be established.

In **Section 6.2** it was shown that some reduction was possible by:

a) Elimination of the small blimp GH methods that are extremely unlikely to be of use to the NGVLA developers, and

b) focussing on GH systems for "large" or "very large airships" as defined by application of the "123 metre rule" that was explained in **Section 5.3.1**

By these means it was shown that although the history of airships may be conveniently divided into four "Eras" of development, that there were really only two of serious interest to this study, with the result that approximately 1000 airships are summarily reduced to some 300. The two eras of interest are:

3. - the rigid era – developing the vertical GH methods (1899-1939), and

4. - the second wave blimps – perfecting horizontal "heavy operations" (1940-2000+)

Moreover, it was also shown that Era 3, the era of the "large" rigid airships, can itself be fairly easily further broken down into the three quite clearly defined subdivisions, according to the development programmes that took place in each of the three major countries concerned:

3a. - The German rigid airships (1899-1939)

3b. - The British rigid airships (1910-1930)

3c. - The American rigid airships (1920-1935)

In addition to which, the latter part of the 4th era - the American Blimp programme - was also identified as being of some interest. This is that section which contains the last and largest of the US Navy's non-rigid blimps, some of which (specifically the *ZPG-3Ws*) were as large dimensionally as the smallest rigid airships, and all of which used the most advanced US Navy GH techniques.

However, having taken an overview of the GH systems evolution and it's infrastructure development, it is now possible to see that a further reduction in the area of interest can be made by applying this same principle to all three of the sub-eras and concentrating only upon the latter part of each. Obviously, for the

[1] **Appendix I in full, runs to 14 pages, and Appendix J to 9**

NGVLA developers, knowing what did *not* work, in the past, can be of great value, however, as a starting point for their new airships, those GH systems and PGVLA machinery that were of proven worth would seem to offer the most likely short-cut to success and to minimise their risk of "re-inventing the wheel."

Furthermore, by declaring this intent, it is possible to identify a precise number of individual airships that were firstly, "very large" and secondly, that were operational at the end of their respective development programmes, and thus, for which the GH was either of proven reliability, or was in the process of testing perhaps the most advanced ideas that were promoted and endorsed by the most experienced personnel. Therefore, this investigation is primarily interested in the GH of those airships that are included in the following "classes" of airships - as they were developed in each of the three major countries.

7.1.1 The selected large airships

GERMAN OPERATED AIRSHIPS - 4 classes containing <u>8 individual aircraft</u>

- Zeppelin 'x' class - 3 airships
  - *LZ112 (German Navy L70);* First flew 7/1918 ; shot down 8/1918
  - *LZ113 (German Navy L71);* F/f 7/18 ; dismantled 1923
  - *LZ114 (German Navy L72)* (later French *Dixmude*); F/f 7/20 ; exploded mid air 12/23
- Zeppelin 'y' class - 2 airships
  - *LZ 120 (Bodensee)* (later Italian *Esperia*); F/f 8/19 ; dismantled 7/28
  - *LZ 121 (Nordstern)* (later French *Mèditerranèe*); F/f 6/21 ; dismantled 9/26
- Zeppelin *Graf Zeppelin* class - 1 airship
  - *LZ 127 (Graf Zeppelin);* F/f 9/28 ; dismantled 1940
- Zeppelin *Hindenburg* class - 2 airships
  - *LZ 129 (Hindenburg);* F/f 3/36 ; burned 5/37
  - *LZ 130 (Graf Zeppelin II);* F/f 9/38 ; dismantled 1940

BRITISH OPERATED AIRSHIPS - 5 classes containing <u>7 individual aircraft</u>

- The 33 class - 2 airships
  - *R33 (G-FAAG);* First flew 3/1919 ; dismantled 1928
  - *R34;* F/f 3/19 ; wrecked 1/21
- *R36 (G-FAAF);* F/f 4/21 ; dismantled 1926
- *R38 (ZR-2);* F/f 6/21 ; broke in mid air 8/21
- *R80;* F/f 7/20 ; dismantled 1925
- The Imperial Airship Programme class - 2 airships
  - *R100 (G-FAAV);* F/f 12/29 ; dismantled 1931
  - *R101 (G-FAAW);* F/f 10/29 ; crashed 10/30

AMERICAN OPERATED AIRSHIPS - 4 classes containing <u>8 individual aircraft</u>

- US Navy *ZR-1 (USS Shenandoah);* First flew 9/1923 ; broke in mid air 9/1925
- US Navy *ZR-3 (USS Los Angeles)* (formerly *LZ126*); F/f 8/24 ; dismantled 12/39
- US Navy *Akron* class - 2 airships
  - US Navy *ZR-4 (USS Akron);* F/f 9/31 ; crashed 4/33
  - US Navy *ZR-5 (USS Macon);* F/f 4/33 ; broke in mid air 2/35
- US Navy *ZPG-3W* class - 4 non-rigid blimp airships
  - *ZPG-3W (1) serial number 144242;* F/f 7/58 ; crashed in sea 7/60
  - *ZPG-3W (2) serial number 144243;* F/f 9/58 ; deflated 1962
  - *ZPG-3W (3) serial number 146296;* F/f 10/59 ; deflated 1962
  - *ZPG-3W (4) serial number 146297;* F/f 3/60 ; deflated 1962

There are thus 23 individual airships which can be defined as "large" enough, and for which the GH procedures can be expected to be sufficiently well developed to be of potential use to the NGVLAs.

However, this is only half the story because the GH of these selected airships was entirely dependent upon the facilities, the infrastructure and the ground-based hardware that was available to them at their various bases. As noted in **Section 6.4.2** there were several different types of PGVLA base and the story of their development, although less well documented than the airships themselves, is just as long and complicated. Therefore, it is equally necessary to reduce the number of bases and to eliminate from the study all those, for instance, that were devoted solely to small blimps, or at which, little or no contribution was made to advancing the science of GH. By reference to the information collected in **Appendix L** it is possible to identify, and to select a manageable number of bases, upon which the above listed large airships spent most of their time, or where there is either evidence, or good reason to presume, that potentially interesting GH infrastructure was developed and/or used.

7.1.2 The selected large airship bases

Unfortunately, unlike the airships, there is no obvious way to categorise and sort the bases other than by the aforementioned description of their main activity (i.e. Operations, Construction, etc. see **Section 6.4.2.**) however, this is complicated by the fact that many bases served several purposes in their lifetimes. Some were the scene of intense activity during one particular programme and were then abandoned, while others were constantly updated and re-used, or re-equipped for another purpose after a period of inactivity. Therefore, for convenience, six bases have been selected from each of the three countries, that were owned or operated by them and which seem to have been either the most active in each country or sites where the most innovative large airship GH was carried out.

GERMAN AIRSHIP BASES

- Friedrichshafen, (Construction, Experimental development) - longest manufacture
- Berlin, Biesdorf - (Operations) - rotatable shed
- Frankfurt (Operations) – most recent passenger hub
- Nordholz – (Operations) - most airships
- Ahlhorn - (Operations) - most Halle
- Recife, Brazil – (Expeditionary) - remote regular destination

BRITISH AIRSHIP BASES

- Barrow-in-Furness (Construction) – manufacture and experiment - water mooring
- Howden (Construction) – big sheds and accidents
- Cardington (Construction, Operations) - biggest airships, mooring to tower
- Pulham (Experimental development) - high mast invented
- Croydon - (Expeditionary) - wooden mast
- St Hubert, Canada - (Expeditionary) – remote destination

AMERICAN AIRSHIP BASES

- Lakehurst (Experimental development, Operations) – largest and longest in service, Iron Horse
- Akron – (Construction) - the Airdock
- Sunnyvale (Operations) - latest GH, Bolster Beam
- Camp Kearney (Expeditionary) – reinvigorated and enlarged
- Dearborn (Expeditionary) – railway mast
- The "Patoka" – (Expeditionary) - floating mooring mast

7.2 The risk from GH accidents

This investigation has uncovered several areas of concern, commonly grouped under the heading of GH, that clearly have great potential to impact on the NGVLA projects. Not least is the risk posed by GH accidents, which, as shown in the charts that compare those of LTA and HTA (**Section 2.2**) are not only a considerably greater threat for airships but also somewhat anomalous. For instance, the US Navy blimps, which were smaller in size, and later in time than the rigid airships, can be seen to have suffered a significantly higher proportion of ground-based accidents. It is therefore evident that the dangers from GH apparently got worse as time passed and experience was gained. Considering that many individuals within the ground crews who handled the blimps were able to build on their personal experiences with the rigids, that weather forecast accuracy was greatly improved between 1925 and 1945, and that the blimps were filled with supposedly "safer" helium, this finding is strange to say the least. Perhaps all the more so in view of the tremendous amount of ingenious problem-solving contributed during the Second World War - plus the almost frenzied technological advances made in the subsequent "Cold War" that were assisted by the enormous military budgets of the 1950s "Arms Race."

Bearing in mind also, the point previously made, that the blimps were in many cases using sheds inherited from their much larger forebears, and that consequently, for a lot of their operational time they had enormous sheltered spaces to manoeuvre in, with disproportionately large doors - which luxuries were denied the rigids - it is also strange that the blimps then suffered so many accidents coming *out* of these shelters. It would be logical to expect the opposite, when the crews were more likely to be tired and struggling to get back inside the shed in deteriorating weather with failing light. Why they performed so badly when, in theory the men were physically fresher, and within limits, they could choose their moment of exit with ships that were in "mission-ready" condition, is something of a mystery.

What this means for the NGVLAs, which will obviously have access to even more accurate weather forecasts, and are certain to use helium, and as this study has revealed, will *force majeure* have inexperienced ground crews, is unclear. However, it is possible that the fault lies with the statistics and the paucity of data available for large airship accidents. This, in turn, is founded on the rarity of the aircraft themselves, and compounded by the fact that direct comparisons of historical data for the different types of airship are hard to make. The various airship operators not only defined their accidents and incidents differently, thus leading them to record different events, but they also tended to change their definitions as time passed. The picture is also distorted by losses due to enemy action.

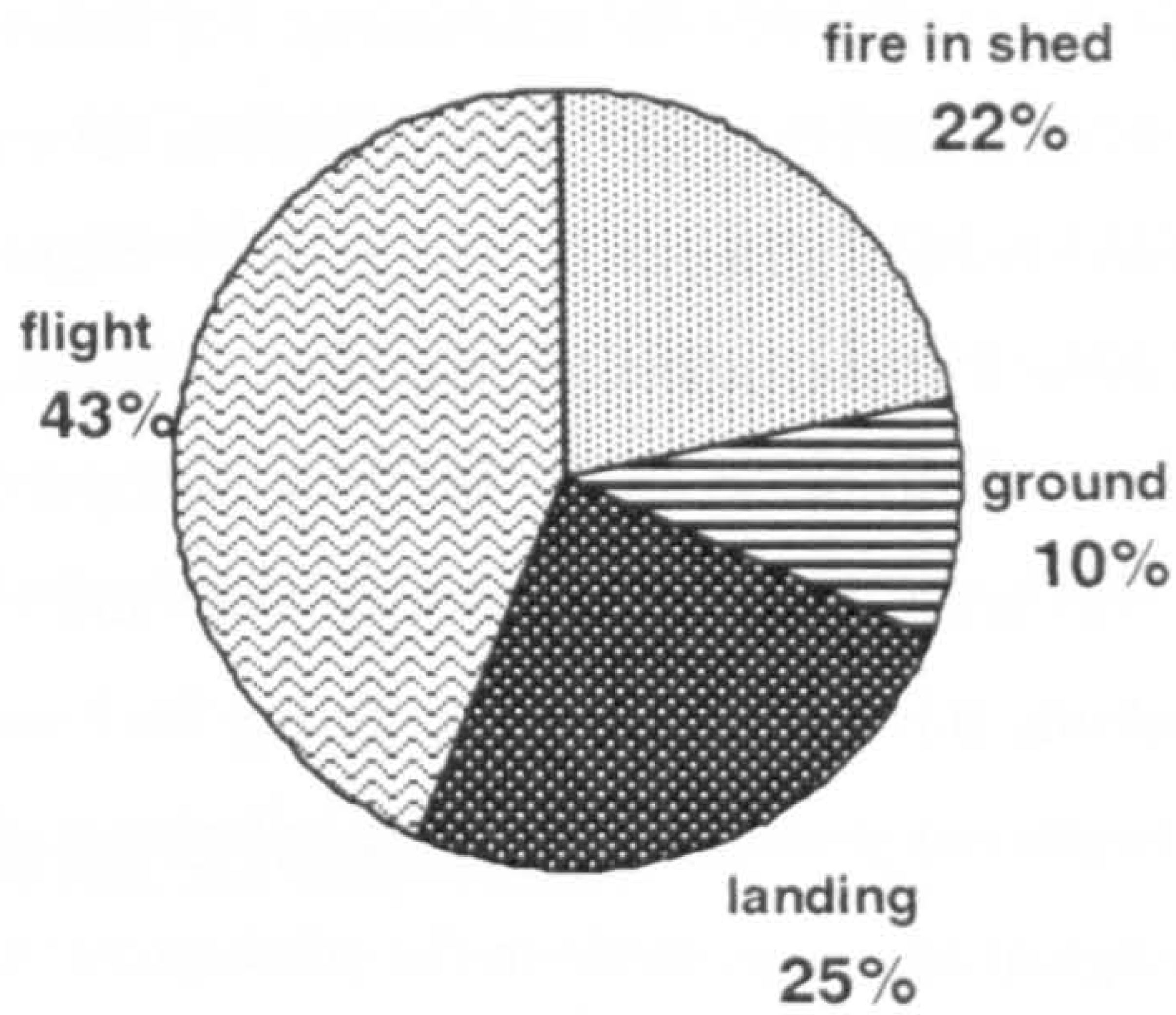
It is thus instructive to compare the chart for PGVL rigid airship accidents (previously given as **Figure 2.3**) with both the records of US Navy post war losses that include their largest blimps (**Figure 2.4**) and with data not previously given, from reports of US Navy blimp accidents during the Second World War (US Navy, 1946).[1] This latter report covers the period of their most intensive operations:

> "...with 119 non-rigids operational in March 1944, gradually reducing to 10 in 1961 ... This huge fleet ... was only able to operate so efficiently because of the handling experience which stemmed from the early rigid programme." (Mowthorpe, 1999:138)

[1] NOTE: The nine US Navy K-type blimps lost in the one fire at the NAS - Richmond hangars have been included in this chart.

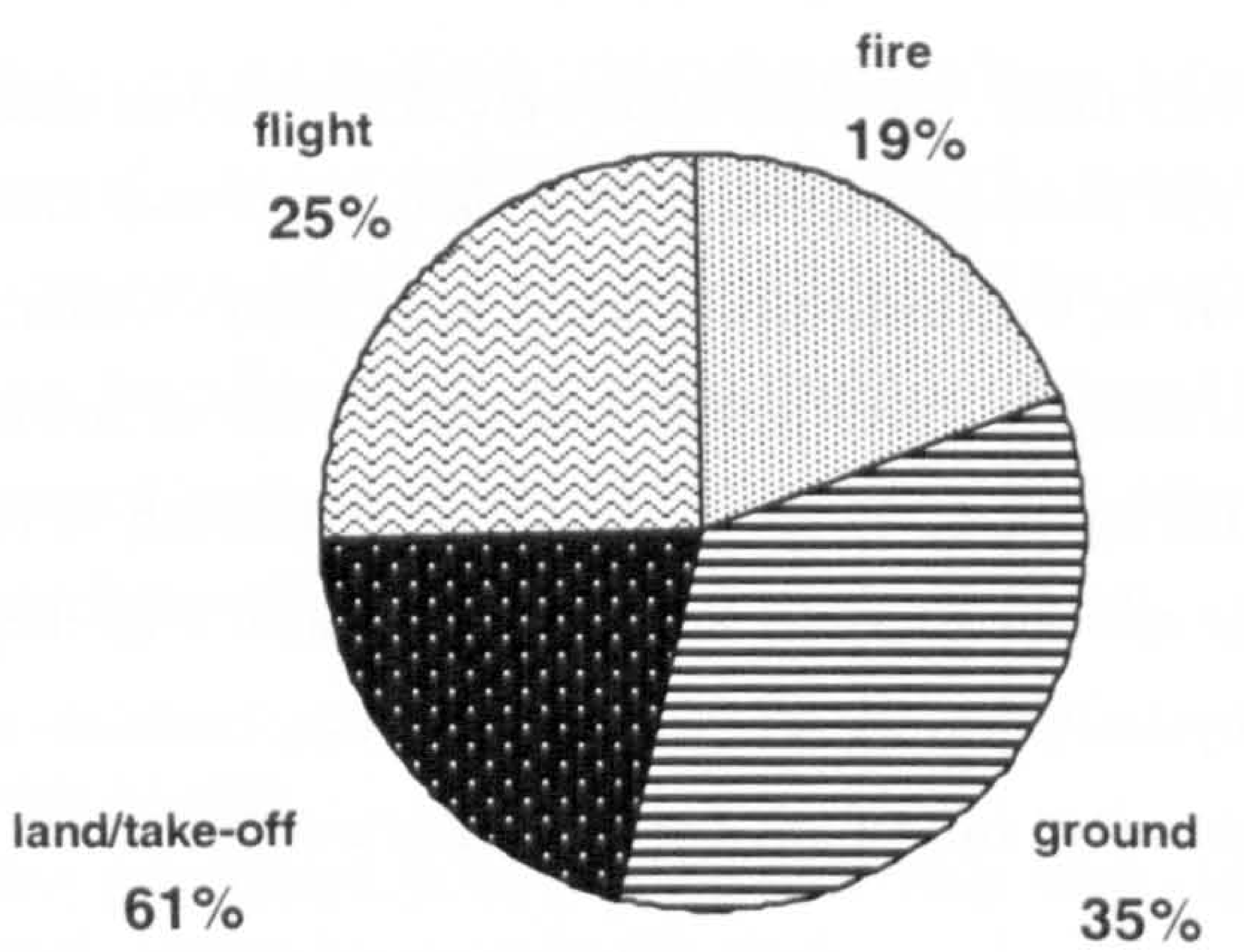
Comparison of accidents in different programmes

Rigid Airship losses 1900 - 1940 (Brookes & Griffin, 1973)



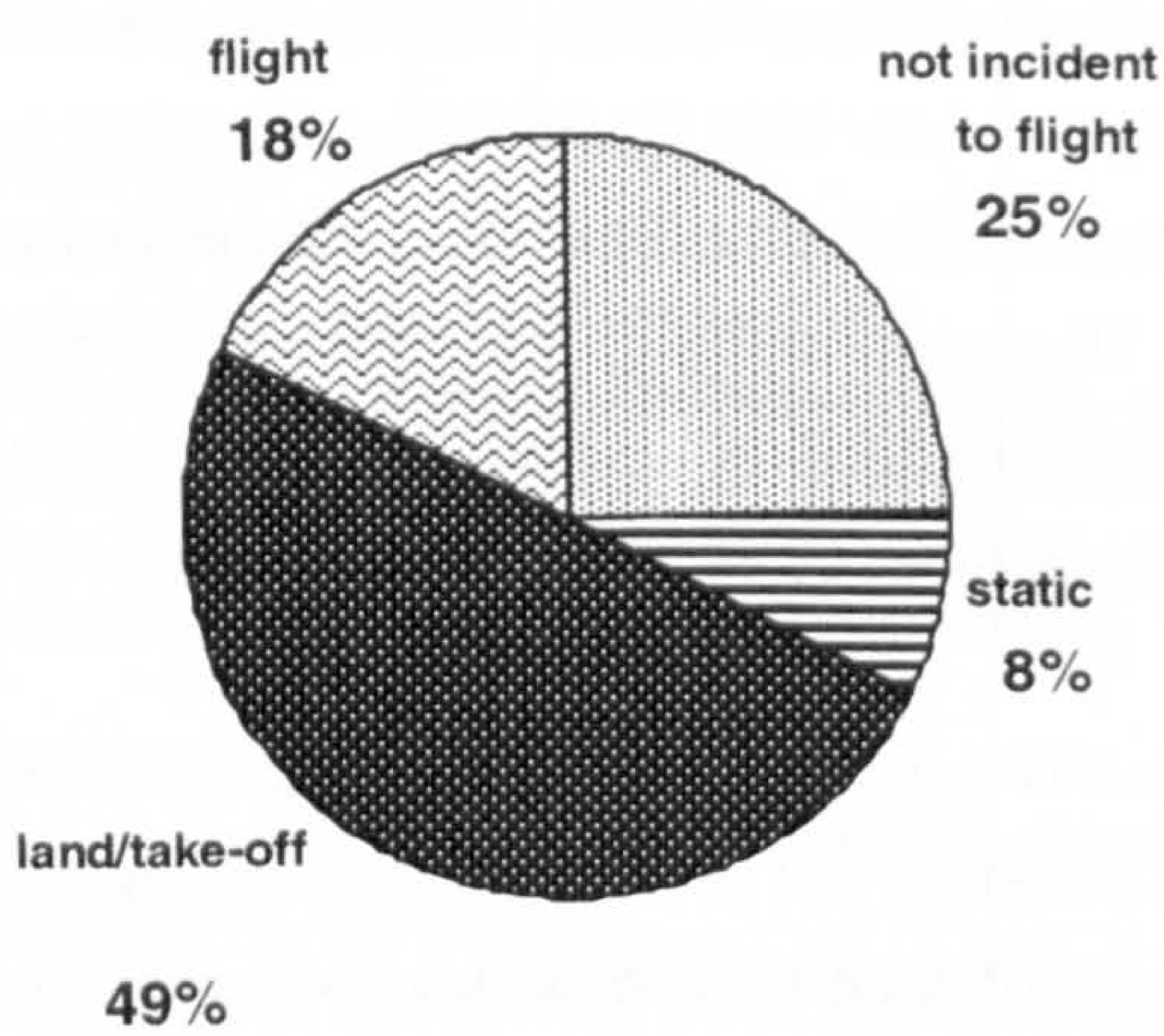
- Circa 120 rigid airships
- More than 120 metres long
- From 3 different countries
- Over a 40 year period
- Military and civilian rules
- Skilled and unskilled crews
- Hydrogen and helium filled
- Vertical landings
- High and low mooring masts

US Navy WW II Blimp accidents (US Navy, 1946)



- Circa 150 non-rigid blimps
- Less than 100 metres long
- From 1 country
- Over a 4 year period
- Military only
- Professional groundcrews
- Helium filled
- Horizontal landings
- Low mooring masts

US Navy blimps - 1946 / 1961 (Tripp, c.1961)



- Circa 60 non-rigid blimps
- Less than 120 metres long
- From 1 country
- Over a 16 year period
- Military only
- Professional groundcrews
- Helium filled
- Horizontal landings
- Low mooring masts

Figure 7.1 - Comparison of rigid and blimp accident statistics

On the face of it these charts, with their ill-matched categories, are not a very close fit - apart from the obvious fact that ground based accidents are predominant in all. However, in the last case, and in the same source document complied on behalf of the US Coastguard, there is further analysis of the same US

Navy post-war blimp accident reports. In addition to the "phase of flight" in which these incidents occurred, there is also a re-classification of them according to the actual "cause of the accident." If the last pie chart in the foregoing Figure is thus redrawn using the alternative breakdown of numbers then the match is somewhat closer - in particular with regard to the "flight" percentage of rigid airship accidents.

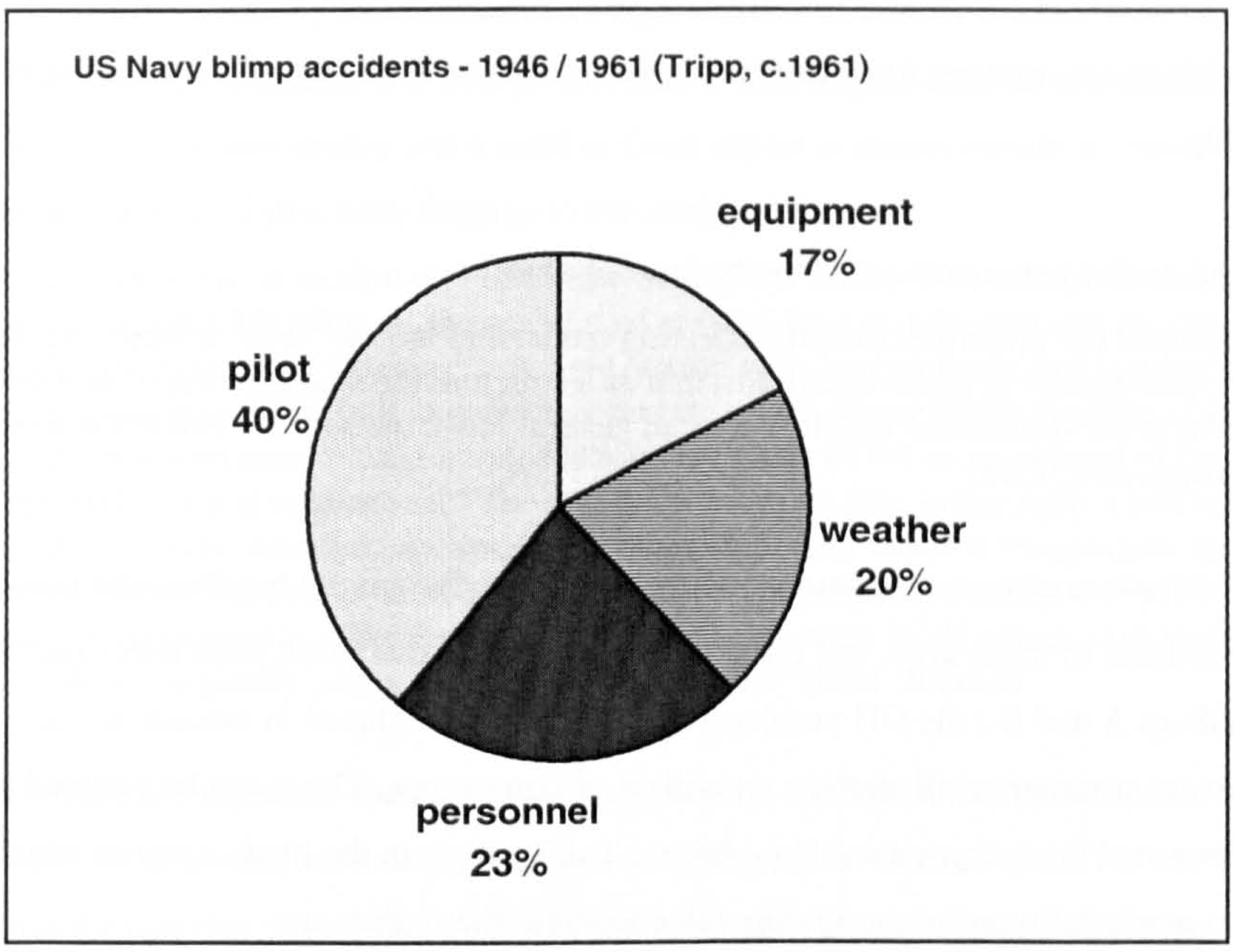


Figure 7.2 - Causes of US Navy post-war blimp accidents

The difficulty of making accurate data comparisons from past airship programmes that are necessarily based on relatively small numerical samples (where a single event can have great effect on the statistical results), means that it would be unwise to conclude with absolute certainty that all future airship programmes will always, and inevitably, be similarly prone to accidents on the ground. It must be remembered that a very large proportion of all the airships in the past projects were actually prototypes and that their ground crews were thus learning as they went. This alone would be expected to have markedly increased the frequency of all types of accidents. However the fact that the rigid airship programmes, (which were developed over a forty year period, by three separate countries, for both commercial and military purposes, through times of both financial feast and famine and many of which used large and unskilled ground-crews,) produced a pattern of accidents that is very similar to that of the largest and most sophisticated pressure airships that have ever been built, i.e. the US Navy post-war blimps, (which were developed some thirty years later, were generally less than half the size of the rigids, were used exclusively for military purposes, suffered no real shortages of funding or unexpected U-turns of policy, and were operated by America's most experienced and professional crews - who worked in small, highly-trained and disciplined teams, and who also had the benefit of previous experience with the rigid ships,) does tend to point to such a conclusion.

If nothing else confirms the importance of GH, these similarities between the accident patterns of diverse and differently targeted past projects does suggest that the developers of any future super-large airships should be exceedingly cautious in their plans for manoeuvring their creations on or near the ground.

7.3 The generic physical GH problems

By reference to the foregoing compilations of airship information - as given in **Appendices I, J, K and L** - and by study of the historical material collected from archives and libraries, it is possible to establish where the biggest and most common problems were encountered by the PGVLAs. Moreover, by comparing the evolutionary process of VLA GH, as it occurred in the three major countries, it is possible to distil these problems into generic fundamental problems that are applicable to all sorts, types, classes and sizes of airship.

As a start point, all airships are constrained by the laws of physics:

> "As an aircraft the principles directly affecting the airship are the 'laws' concerning the pressure, velocity, and density of gases and fluids, and as a structure the stability, stress, and strength of solids. These are limitations which decree, in general form, the sort of vehicle the airship must be." (Sprigg, c.1932:13)

These laws and limitations also create some significant problems for ground handlers and notwithstanding the complex interactions of these laws, and the properties of matter that result from them, (as outlined briefly in **Appendices A** and **B**,) the GH problems that arise can be reduced in essence to six fundamentals that are common to all airships regardless of size or type. These can be grouped as three "physical" problems and three "operational" problems. Taking them in the likely order in which the ground crew for a newly built prototype airship will encounter them, they are:

The Generic Physical GH Problems :

1. The Fragile Shell
2. The Variable Buoyancy
3. The Wind and Weather

The Generic Operational GH Problems :

4. Access
5. Launch
6. Capture

7.3.1 The fragile shell

If it is assumed that a generic airship (of any size imaginable) has been designed and assembled and is ready for use, waiting in its shed, then irrespective of whether it is a rigid structure, or a blimp that requires constant pressure for its structural integrity, the first task for the ground crew is to move it outside. It should be borne in mind that such a move may be done without anyone actually being on board the airship, and that the airship structure does not even have to be complete. For instance, it is conceivable that the certification process might call for a newly built airship to be attached to its newly built mooring mast for a period of mooring-out trials, but for this there is no absolute necessity for its propulsive engines to have been installed. In which case, reducing the manoeuvring of an airship to it's simplest form, it is simply a bubble of gas that needs to be held and moved. Furthermore, it does not matter what moves the airship, whether it is teams of people pulling on ropes or mechanical devices, provided they keep control of it - and it at this point that the fragile shell becomes a problem.

In order to move the airship it must first be released from its anchor points and then manoeuvred by attachments of some sort. The number and positioning of these, necessarily strong and thus heavy, points is critical because Lighter-than-air flight dictates use of the lightest possible construction materials and the displacement of a large volume of air.

> "The importance of good weight estimation and control during all phases of the design of an airship, especially in the early stages, cannot be over-emphasised." (Craig, 1999b:235)

Consequently all airships are by definition exceedingly delicate structures that have an enormous inertial mass. This inescapable combination of a large momentum and fragile, ethereal architecture means that the slightest impact between any airship and a solid or fixed object is almost certain to result in a disproportionate amount of structural damage to the airship. Moreover,

> "Symmetry of cross-section represents the triumph of theory over reality. A theory of stress calculation simplification vs. the realities of gravity, load distribution and the resultant built–in tendency to structural "hogging." A rigid airship with longitudinals and bracing divided about the cross-section of the hull in perfect symmetry seems theoretically capable of equal resistance to a given aerodynamic stress applied across any plane of the cross-section of the hull: horizontal, vertical or diagonal. The reality seems to be that, either such a hull is adequate to deal with a given aerodynamic stress in the vertical plane where it compounds the "hogging" stress and thus the ship is overbuilt to deal with anticipated aerodynamic stress in every other plane, or the design is adequately strong to deal with stress in all planes save vertical, and no more than marginally adequate in the vertical plane." (Hall, 2000:5)

What is true for the aerodynamic loads is equally true for the GH loads, and some idea of the magnitude of the problem for the ground crew, and of the extraordinary achievements of the PGVLA designers, can be drawn from the fact that were a hull of one of the latest and largest of their ships to be cut in half vertically, (as was actually done to lengthen the R101) then the cross section of bare metal exposed would amount to not much more than an eight inch square - for an unsupported girder that is 700+ feet in length.

Thus, the fragile shell, which it should not be forgotten in the case of the non-rigid "pressure" blimps is merely a multi-layered fabric bag, inevitably has to have a limited number of attachment points and/or handles, and these can only take so much load and may be very restricted in their permissible pull angles.

> "For the *Los Angeles* the mechanical-handling gear at the stern of the ship is towed by cables to the ship itself, ... Differences in airship construction make themselves felt in this handling problem at this point. In a ship not designed for mechanical handling, it was necessary to apply the loads at carefully selected points and always in proper directions relative to the structure. Although satisfactory means were found, nevertheless this feature complicated the design of the mechanical handling equipment for the *Los Angeles.*" (Rosendahl, 1931a)

Moreover, tension and compression must be kept within strict limits and in contrast to the maritime world where super-tankers and VLCCs can be pushed sideways by a couple of tug boats pressing on strategically placed bulkheads, no such luxury is possible for the ground handlers of VLAs. In general terms, airships do not bounce; they crumple, and any contact of an airship hull with a fixed, or heavy solid object, risks a potential disaster. Consequently point loads such as those unavoidably generated by a ground impact protection device (or an under-carriage) are a real problem and they will be all the more so for designers and ground handlers of the NGVLAs, because the larger an airship gets, the more inertia it has and the worse the problem becomes.

So the first generic GH problem is how to hold onto the hull and manoeuvre the airship without damage to its fragile shell.

7.3.2 Variable buoyancy

The second problem is that the buoyancy of an airship is constantly changing. As shown in **Appendix A** this stems from the interacting laws of physics and is very much affected by changes of temperature. However, even inside a shed, with climate control and air-conditioning, the lift of any gas-filled aerostat [1] will fluctuate, day by day and even minute by minute as ambient external barometric pressure changes.

This is nothing to do with whether the craft itself is pressurised or not. Buoyancy will constantly vary for all gas-filled airships, regardless of type or structure, and the risk of damage to the fragile shell means that the finely balanced equilibrium between lift and weight must always be kept within strict limits. Of course these limits may be very different for different types of aerostat, and for example a rigid framework with half empty gas cells may still be able to be moved, provided the GH equipment supports it in the right places, whereas this would be impossible with a pressurised airship. Nevertheless, loss of buoyancy is a problem for all airships and if left unchecked it can easily cause structural damage. Conversely, an unchecked increase in buoyancy may overstrain the hold-down points or make moving the airship dangerous for the ground crew. So, buoyancy control is essential from the moment an airship is first inflated, and it must be maintained without interruption until the ship is finally deflated - and the method by which it is done must be guaranteed and reliable.

This brings to light the absolute need for the buoyancy to be constantly monitored, something that in itself is not as simple as it at first appears - particularly where the airship is large, with perhaps multiple gas cells or compartments that may heat and cool independently, and where there are several access points via which weight may be added and removed. Here, yet again, the devil is in the detail, for regardless of how the buoyancy is actually monitored, (i.e. what the sensors are, and where they are located,) and by what means the accuracy of the measurement is guaranteed, the information generated has ultimately to be displayed at some specific location where action can be taken to maintain the correct "EQ." The control car/gondola is naturally a first choice, but monitoring of the buoyancy must begin as soon as the gas is put into the gas cell(s), and with a large and complex prototype it may be many days into the assembly process before the two components - gas bags and gondola - are united. A second, back-up monitoring station, perhaps incorporated into the mooring machinery, is thus an attractive option - to all except those who have to pay for it. Whatever the method, the fact remains that the ground crew must have a reliable way of knowing the airship's state of buoyancy both before, and throughout the duration of, any attempt to move the airship out of its shed. Moreover, this information is vital for the operation of large airships:

> "During the night, in a closed hangar, the temperature drop lags behind that of the outside air; by rushing the ship out and taking the air at once before temperature equalization takes place, it is practicable to get off with fair superheat. By taking off with superheat and landing after the sun's heat begins to wane, the ship can land without having any excess buoyancy to overcome by releasing helium." (Rosendahl, 1927)

So the second problem fundamental to all airship GH is provision of some reliable and accurate means for the constant monitoring, control and physical adjustment of an airship's ever-changing buoyancy.

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[1] NB - Naturally fluctuations of buoyancy are not a problem for devices that derive their lift from hot air, but due to the present rarity of such craft, and the fact that to date, no one is proposing to apply this principle to the NGVLAs, the GH of them is excluded.

7.3.3 Wind and weather

The third problem is the weather. As soon as any airship leaves it's shed it will feel the influence of the weather and particularly of the wind. The fragile shell means that the airship must be allowed to weathervane and to turn it's nose into wind in order to present the least resistance to it. Any attempts to hold the airship across the wind risk damage to the hull structure. So the transit out of the shed and across the airfield to the mooring place, must either be quick, or allow the airship, while it is being moved to its new location, to swing into alignment with whatever wind is blowing.

> "While the principles of handling airships are much the same as those for handling surface vessels, in airships we have a third dimension. We also have to deal with wind, gusts, eddies which may have an almost instantaneous effect on an airship and which make it necessary to keep the airship constantly under control and to anticipate if possible the changes that are likely to occur. The analogy of bringing a sailing vessel to her dock with canvas spread is a crude one but conveys some idea of the what airship handling may involve." (Fulton, 1929:55)

Indeed, the strength of the airship hull may be the defining factor for some manoeuvres:

> "It may be interesting to know that it was the vertical strength of the Los Angeles' structure aft that determined the maximum wind velocity in which that ship could be handled in and out of the shed." (Rosendahl, 1931a)

Furthermore, rain and sun may also alter the buoyancy while the airship is in transit. Thus an accurately forecast weather-window, that is foreseen sufficiently far in advance and is of sufficient duration for whatever translocation or manoeuvre of the airship is intended, is vital, and as with the buoyancy, there must also be constant monitoring and awareness of the weather throughout the procedure.

At the end of an initial transit manoeuvre from its assembly shed, when an airship arrives at its launch or mooring site, there are three options. These are:

1. Turn around/reverse and go back inside, or
2. Let go so the airship flies (preferably under control,) or
3. Hold on – i.e. moor the airship securely.

Assuming for the sake of argument that the airship is launched to flight then the next problem for the ground crew will be to catch it again. And here the wind and weather create even more difficult problems. The reason being that all aircraft are affected by the wind to some extent, but airships are peculiarly disadvantaged. Their gigantic proportions make them slow to respond to the helm and their tiny tail fins deny them the ability to weathervane automatically like other aircraft. When hit by side gusts, airships in flight naturally turn away from them thereby exaggerating the diverting effect until a counteracting force is applied to push them back on course. Because of this, airship pilots must constantly steer to correct their craft's unpredictable movements in three dimensions and ground handlers must be prepared for an airship that can be moved suddenly by the wind, either forwards or backwards, up or down, or to either side. It may also yaw freely and even rotate completely about its vertical axis. It may pitch more than 45 degrees above or below the horizontal axis and also roll a little. Furthermore, in very gusty or turbulent conditions, an airship may combine several of these movements simultaneously so that a gentle, controlled touchdown at a prearranged spot is virtually impossible.

Assuming further that the airship is recaptured satisfactorily without damage, then it will have to be moored and here again, quite apart from the wind, there are also several other formidable meteorological phenomena that the ground crew of any moored airship will, on occasion, have to contend with.

These include - Solar radiation and ultra-violet light : Snow and ice : Dust and fog : Heavy rain and hail : Lightening and the build up of static electrical charge : and Storms.

So the third inescapable generic GH problem is the wind and weather.

7.3.4 Mooring and access

The fourth fundamental problem is of a different order to that of the preceding three - but it is no less important nor easy to solve. In many ways it can be seen as a resultant of the immutable physical constraints outlined thus far. It stems from the inescapable requirement that, when an airship is on the ground, and out in the open air, it must somehow be held securely so that the combined effects of its positive buoyancy and the wind cannot carry it away. As an airship is moved from it's shed, across an airfield and on to a mooring site, changes to its buoyancy may be caused by fluctuations in sunshine, or ambient barometric pressure, or air temperature variations, or leakage of gas, or accumulations of rainwater, or wind-chill, or combinations thereof. All of these must be constantly monitored and compensated for as failure to do so can result in loss of the airship. And yet, even while the airship is in transit, there must be guaranteed access for personnel to the airship's life-support systems at all times.

The wind and weather may change. The forecast may be entirely wrong, but whatever happens, the airship must be held secure and regardless of the time of day (or night,) the season of the year, or the state of the airship's buoyancy, people and things have to be constantly got on and off it. Needless to say this addition or removal of weight will itself also affect the buoyancy. Nevertheless, provision must be made for passengers to embark and disembark, for luggage and cargo to be on- and off-loaded, for engineers to carry out routine inspections and maintenance, and for crew members to generally service, clean, refuel and replenish consumables, in preparation for the first, or the next flight.

Thus whatever the airship is moored to, must both allow access to its interior and enable it to ride out whatever extremes of weather may eventuate - including perpetual changes of wind direction and even storm force winds that may last for several days - without the airship sustaining any structural damage. The scarcity of anchor points on an airship's surface adds to the difficulty, however, the fragile shell does also mean that there are likely to be only a limited number of possible access points, which makes the balancing act that is buoyancy control a little easier to monitor and adjust.

One of the major lessons learned during the prolonged period of GH experimentation conducted by the PGVLAs is that by far the best way that has been discovered to date, of achieving a secure mooring that will also allow guaranteed all-weather access, is by means of a mooring mast:

> "The report by Captain Thomas on the conclusion of the trials of R-33 at Pulham up to 21st July 1921 read: It was definitely proved by the foregoing experiments that the system of mooring to a mast, and leaving and landing thereto, is entirely sound ; that a ship would successfully ride out all types of weather ; that she could leave the mast in any weather she could fly in ; and (notably the hauling-in and yaw-guy winches) she would be able to land in winds of over 30 mph. The ship did not show excessive deterioration excepting the gas bags which is probably caused by the adhesive used between the skins and the fabric. Ordinary routine work can be carried out on the ship at the mast and work such as changing an engine or a gas bag performed. " (Williams, 1974:151)

Thus the fourth generic problem is mooring and access.

7.3.5 The launch / release (or take-off)

The fifth problem is how to let go of the airship controllably. The launch must be carried out without damage to the airship or injury to crew members. Weather monitoring and forecasting is obviously vital. Changes of wind speed or direction and temperature inversions may cause the launch to be aborted. Systems failure may also cause launch abort and the ground crew must be ready to react or the ship will be lost. However, the fragile shell means that the ground crew can only offer limited hands-on assistance.

Prior to launch the buoyancy has to be adjusted to suit the pilot's requirements for the intended mission. The major problems for launch are thus: How to establish precisely, before the airship is released, how buoyant it is. Then, how to weigh it off, by adjustment of ballast in an unpredictable wind, and lastly how to avoid it hitting the mooring mast when it is let go? The winds that blow very close to the ground are locally extremely sensitive and forecasts of them are not very accurate. Temperature (and humidity) prediction is worse and the measurement and accurate prediction of air density (which is really what an airship needs) is non-existent because no other human activity needs it or is perturbed by changes to it.

Although some minor structural damage on take-off might not be as catastrophic for an LTA craft as it would be for its HTA counterpart it is nevertheless true to say that:

> "Unless the airship leaves the hangar and the ground safely, it cannot be considered airworthy for the accomplishment of its mission." (Rosendahl, 1938)

7.3.6 The capture / touch-down (or landing)

The sixth fundamental GH problem is how to capture an airship at the completion of its flight. The difficulty stems from the craft's ability to fly in two completely different ways at the same time. Although classed as aerostats and capable of being flown like balloons, modern small blimps are nearly always operated like aerodynes, and the PGVLAs also flew a lot of the time in similar fashion. However, unlike all other aerodynes, which use aerodynamic lift to keep themselves up, airships sometimes do the reverse and adopt a nose down attitude to counteract excessive buoyancy. This usually occurs at the end of a long flight when they have used up most of their fuel and may be short of ballast weight. If they slow down or stop in this positively buoyant state, they will float upwards and like any other gas balloon, will continue to ascend until they reach their "pressure height" - possibly several thousand feet above the ground.

This capacity to change from aerodyne to aerostat makes landing an airship far from simple and gives the pilot five possible ways of changing and controlling altitude. These are:

- To vector the thrust from propellers and push directly up or down.
- To use engines to increase or decrease airspeed.
- To alter the angle of attack:
  - aerodynamically with elevators, or
  - statically, by movement of ballonet air, or redistribution of ballast weight.
- To alter buoyancy by
  - ejecting ballast to make the craft lighter, or
  - releasing gas to make it heavier.
- Lastly, to and change the airship's density by use of meteorological conditions to "superheat" or "super cool" the lifting gas.

All this results in a bewildering variety of possible trim states in which an airship may make its approach to a landing. So, as stated above, an airship arriving for capture can be light or heavy, nose-down or nose up, and be in the process of translating quickly or slowly from one to another. Depending on the weather conditions, specifically on the speed and direction of the wind, an airship can also be travelling at a wide range of ground speeds, with consequent different inertias, and it can approach from any direction.

It is thus important to realise that all airships are free-floating in three dimensional space and thus have 6 degrees of freedom. These are: roll, pitch, yaw, surge (or thrust,) heave and sway (or side slip). An airship pilot's top priority when landing is therefore to bring the craft down very gently and to aim for as little vertical speed as possible at the moment of touchdown. This is no easy task:

> "The use of the ship's rudders and elevators to counteract the effect of lateral and vertical gusts while mooring is generally of little value. The use of these moveable surfaces during the mooring operation in gusty conditions is generally sluggish and tardy, and on the whole unprofitable. Human instinct is not able to detect or interpret gusts sufficiently in advance to prevent their effects; it is difficult also to know when to shift the controls to counteract for the opposite gusts." (Rosendahl, 1931a)

On their part, ground handlers must ensure that an incoming airship always decelerates slowly and never encounters anything solid before it comes to rest, for a glancing blow from a relatively small but firmly fixed object can cause catastrophic hull damage. The task is complicated by the fact that airships have no brakes, and mechanisation of the capture process is hampered by the fact that there are a strictly limited number of precisely positioned attachment points available on the fragile hull, as stated in the first fundamental GH problem.

> "Deflations were the most common accident [for the US Navy blimps], but they were often due to events not directly related to flight problems, i.e. striking hangars, masts, or other ground handling problems." (Shock, 1994:xi)

7.3.7 The generic requirements for an effective GH system

So, to sum up, a universally effective GH system for all airships must:

- protect an airship's fragile shell from damage yet hold it securely for prolonged periods in all weather conditions,
- be able to accept and counteract the effects of both negative and positive buoyancy,
- provide easy and safe access for personnel in all weathers,
- provide full facilities for service and repair in normal operating conditions and for emergency systems support in all weathers,
- facilitate a quick, safe, reliable and cost-effective turnaround.
- allow an airship to be correctly weighed-off and trimmed for its anticipated mission,
- ensure an unobstructed take-off, in all weathers,
- allow an airship to land and/or take-off both aerodynamically and aerostatically,
- cater for an airship approaching to land from any direction, over a wide range of ground speeds with a touchdown at any angle of attack,
- be able to deal with an airship landing forwards, backwards, sideways or vertically, and
- in all cases result in a soft, slow impact,
- cope with unpredictable gusts of wind during a landing and while an airship is moored.

8 UNRESOLVED GH ISSUES

The foremost aim of this investigation has two parts and whereas the preceding section has established that there are essentially six generic GH problems for airships of all sizes and types, the purpose of this section is now to fulfil the second part, and identify some of the GH issues from the PGVLA era that remain as a potential threat to the NGVLAs. In so doing, it is first necessary to re-emphasise that GH is an enormously complex topic, that it covers a whole range of loosely interconnected and often poorly defined disciplines and that, in all matters concerning GH, the devil is in the detail. Many of the procedures involved require extremely specialised skills that are specific to a particular type, or class, of airship, and consequently there are an enormous number of wide-ranging subjects and of individual actions, that are commonly classed as GH. The potential for unresolved issues to be found amongst all this is thus very great indeed.

Moreover, the seriousness of some of these unresolved GH issues for the NGVLAs should not be underestimated, for, as has been shown, while the size of an airship makes little, or no, difference to its vulnerability, the larger an airship is, the greater will be the media attention focussed upon it and the higher the financial penalty becomes for what may be, initially, a minor error of judgement. Furthermore, the historical records reveal that, when handling airships on the ground, even the simplest of actions, or even a non-action by a single individual, can create chains of interacting events that may lead on to an exponential number of possibly damaging consequences, some of which may even be catastrophic. Thus, failure to recognise and resolve some of the problems encountered by the PGVLAs does offer a really serious risk to the future success of the NGVLAs.

The aim of this section is therefore to illustrate, by means of quotes from the historical records, some of the most important of those unresolved, or only partially solved issues from the past, and to identify, with occasional reference to quotes from recent, aviation related, and other relevant material, some of those which in the author's opinion remain a genuinely serious threat to the VLAs of the future. These are the issues that will be dealt with in this section:

INDEX OF UNRESOLVED ISSUES

8.1 General GH issues - including some old ones perceived to be new!

There are a number of important general issues related to the GH of VLAs where HR might be expected to reveal useful information. These include several old chestnuts that are popularly perceived to be "new" issues. Some of these topics are simply too large or ill-defined to be dealt with adequately in this small study. For example:

> "The main problems involved in providing adequate airship terminals (exclusive of repair facilities) may be classed under three headings:
> (1) Landing the airship from flight by mechanical means
> (2) Servicing the ship and mooring it out in the open
> (3) Housing and unhousing the ship when necessary, by mechanical means that will reduce the danger and increase the utility of operation; this includes moving the ship between the mooring location and the dock." (Rosendahl, 1931a)

Nevertheless, there are some specific subjects that do need to be drawn to NGVLA developers' attention:

8.1.1.1 Ropes and rigging

Ropes and cordage no longer play a significant part in modern HTA aviation and there is little use for them today either in aircraft construction or in operational practices. The days of the old "string-bags" are long gone and the regulatory authorities have little need for expertise on the subject. However, the same is not true for LTA, and, this lack of knowledge will cause some problems for the NGVLAs, as was pointed out in a communication by the author to the LBA/TAR study group in 2003.

"... It should be remembered that there are a whole range of very different uses for ropes that can be foreseen on large airships and that the safety requirements for each will consequently also be very different. Consider for example the properties required by the following:

***Control cables** – to constantly move the rudders and elevators in flight*
***Valve lines** – to occasionally control gas valves and ballast water tank valves*
***Catenery curtain** – permanently loaded cables that attach the gondola to the envelope*
***Fin rigging** – to hold the tail fins steady and transmit side loads to the envelope*
***Handling lines** – to hold the airship during construction and when in transit*
***Mooring lines** – that are used briefly to steady the airship during capture/landing*
***Tag lines** - to draw the airship's lines through the mast head and onto anchor winches*

Nose connection line – to pull the airship onto the mast during capture/landing
Yaw guys - to prevent the airship hitting the mast during capture/landing
Handrails and crew safety lines – to allow access to all parts of the ship for inspection
Lifting/lowering lines - for inboard winches or cranes to move such items as engines

In addition we should not forget that the large rigid airships of the past also carried two long and heavy "trail" ropes. Their use may not be required in the future but we would be unwise to dismiss them as totally unnecessary until after the first of the next generation of very large airships has made test flights.

The decisions on the type of rope to be used in each situation – whether man-made fibre, or wire, or a combination of both (e.g. for electrical conductivity!) - are far from simple, and the care and maintenance of the various rope types - multiple twisted strands, plaited, woven, encased or single strand - also needs to be addressed. Add to this the potential for the different types of terminations and connections – knots, splices, whipped eyes, thimbles, swaged sleeves, bonded 'pultrusions' etc., - coupled with the wide range of different possible materials from which each of these might also be made, (to say nothing of the interaction between them e.g. electrolytic action of dissimilar metals!) and the uses and abuses to be expected during year-round, all-weather, operation (e.g. loss of strength due to abrasion, or fatigue from constant knotting/unknotting) and the complexity of the topic becomes clear.

There is also the point that it was found in the past that the airships could be lightened considerably if much of the GH equipment stayed on the ground. Thus the winches that pull the ropes, which are vital for the safe connection of the airship to its mooring mast, or for aligning the airship with the shed, are most likely to be classed as ground equipment. However as Martin Penn has pointed out in his comment on a previous paragraph, if a mooring line breaks at a critical moment then the "whiplash" or "snapback" effect as the tension is suddenly released can be very dangerous to people and structures. Thus it seems inevitable that the TAR should be very clear about winches and who is responsible for their design, operation and maintenance.

... it is apparent that there are a wide variety of problems that are unfamiliar and somewhat alien to the modern world of aviation. It is however a well researched and well regulated topic in other industries where peoples lives are similarly at risk, e.g. Ships, Cranes, Elevators and lifts, and Rock climbing.

With Martin's point about ropes breaking in mind, I recently found this [following quote] *I therefore suggest that the TAR study group initiate some research into the whole topic of ropes and their uses, and especially into other codes of practice that have evolved in industries other than aviation, before making any decisions on this topic that may later be regretted.*" (Camplin, 2003)

The following is the excerpt referred to. It comes from a mooring manual written for the maritime oil tanker industry by The Oil Companies International Marine Forum in 1989.

> "SNAPBACK – The most serious danger from synthetic ropes is "snapback" which is the sudden release of the energy stored in the stretched synthetic line when it breaks. ... Synthetic lines normally break suddenly and without warning. Unlike wires, they do not give audible signs of pending failure and they may not exhibit any broken elements before completely parting. When a line is loaded it stretches. Energy is stored in the line in proportion to the load and the stretch. When the line breaks, this energy is suddenly released. The ends of the line snap back striking anything in their path with tremendous force. ... A broken line will snap back beyond the point at which it is secured, possibly to a distance almost as far as its own length. If the line passes around a fair-lead, then its snap back path may not follow the original path of the line. ... It is not possible to predict all the potential danger zones from snapback..." (OCIMF, 1989:34)

The current HTA practice is far less aware of, or concerned to regulate, such things:

> "We shackled the cables to the tow points on the main gear [of the bogged-down Lockheed Electra] and stretched out a lot of very cranky steel cable. Only those who have worked with heavy steel cable know what I mean. Loose strands cut through gloves like hypodermic needles. It kinks and twists given the slightest chance. You do not want to stand near it when it is under strain." (Vasko, 2001: 19)

However, the very real danger to a large airship from a single broken rope is shown here:

> "The landing in Rio, [*LZ129 Hindenburg* first S. Atlantic crossing; March/April, 1936] was not so uneventful. ... A ground crew of two hundred and forty men was on hand but ... The entire field was under about six inches of water from heavy rains. Because of the difficulty in handling the ship in these conditions, it was decided to keep the stern in the air until the ship could be put on the mast. This resulted in getting the nose cone below the cup on the mast and **shearing off the mooring cable, making it impossible to use the mast. The ship was then walked ... into the hangar.** ..." (Dick & Robinson, 1985:114/117) **[GC emphasis]**

In other words, the airship only survived because it was in the hands of 240 experienced men, and the weather was such that the airship could be walked into a shed. Moreover, this shed was not only conveniently situated nearby, but was both large enough to hold the airship in question and not occupied by another airship at the time. Had any one of these factors been absent or different, then the happy ending to the story would have been so too.

Other airships came close to disaster for similar reasons, as these three accounts of the same event attend:

> "In addition, when landing [*R100* first time in Montreal] they did in the ship's main rope as on the second flight, but they have a spare out here." (Shute, 1954:122)
>
> "Also replaced [prior to the *R100* return flight to England] was the ship's main [mooring] wire which had been pulled in two after coupling to the mooring arm. Lieutenant Commander Pressey, in charge of the mast, concluded that the wire must have been kinked because there could not have been more than a 15-ton pull on it." (Countryman, 1982:97)
>
> "After [*R100*] landing it was found that the main wire had been damaged badly due to disconnecting it while under tension. During, or rather just after, the landing the main mooring-wire had become so badly kinked that it had to be scrapped. The cause of the kinking was that during the hauling down of the airship the wire is put under great strain which tends to stretch it and unlay the strands. This can be seen on any crane for lifting heavy loads ... The reason our wire kinked itself was that as soon as the strain was taken off the stretched or unlayed strands suddenly tried to lay themselves up again so fast that some of them ballooned and twisted themselves into a kink. This is a serious difficulty, as the cost of a new wire is no bagatelle ... We tried various remedies, but I am not sure to this day if we did finally overcome it definitely." (Meager, 1970:163)

In the author's experience at CargoLifter, the full danger to the NGVLAs from rope failure was not appreciated. For example, it was on occasion suggested, most frequently by experienced HTA pilots, that if the partly moored airship "got into difficulties" then the *CL160* pilot should have the capability to cut his mooring ropes and initiate a go-around. However, anyone who thinks this is going to be a useful option simply has not thought of the consequences, and here again, the devil is in the detail.

If for example an NGVLA were to follow the tried and tested mooring method used by the large rigids - as was indeed proposed for the CargoLifter prototype - and to be halfway into the process, connected to the mooring mast by one or more mooring lines, and the pilot, or a ground crew member were then to cut these connections for whatever reason. It is necessary to consider these points. Firstly, does the snap-back of the cut ends cause a) damage to airship; or b) damage to the GH equipment; or c) injury to personnel? Any of these may render a second attempted landing impossible.

Secondly, what happens to the cut ends? Where do they end up? Do they fray into a "horses-tail"? This then begs the crunch questions : How long does it take for both air and ground crews to restore the severed ropes to their correct lengths again, or more specifically, how will each cut end be turned back into something that is compatible with its counterpart and allows them to be re-connected? Do the crew simply tie a knot or do they replace the broken cable with a new one? If the latter, then the airship will have to carry a permanent weight-penalty of "x" number of spare cables, plus the means of exchanging them, and allow access to both the new, stored cables and to the connection points whereon the old cables are still in situ. Even if these connection points are undamaged by the snap-back they may still be out of commission. For instance, there maybe cable that has jumped out of fair-leads or pulleys and piled up loose on the floor, or on winch-drums, and this will need to be rewound before it can be used again. Also, if the cable ends unlay then they may jam in their fair-leads and the actual cut part may therefore be physically out of reach. Both ground and air crews will have their own separate problems here.

Bearing in mind also that if a rope can simply have a new end/connector refashioned onto it's now shortened length, then the question arises as to why this rope was so long to begin with? All the airship systems are required to be the lightest possible configuration that can carry out their designated task – i.e. to contain the least superfluous material. If the airship can now be landed, in the emergency conditions, with a much shorter rope than that which was being used for the first attempt, then it must by definition be normally carrying "excess" weight. There is nothing wrong with an airship carrying spares, it just means that the design philosophy and the allocated weight budget will have to be amended. Furthermore, if the airship can be landed without using the cut ropes at all, then why have them in the first place?

Consequently, if ropes are present, they must be necessary, and if they are necessary, they must work, and thus, because their failure threatens the airship's survival, it follows that if these ropes are cut, then they do not work and the airship is in a critical condition. So, a safe landing cannot be made until full functionality is restored and the idea that a pilot, or his ground crew, would willingly cut the mooring ropes is thus nonsensical.

And then there are knots. These require great precision – one wrong crossover creates a completely different knot with different properties. If the NGVLAs are to use mooring ropes then such detail matters.

> "...some knots are more prone to jamming than others, that is ... they become particularly difficult to untie. This tendency to jam is important in selecting knots that are expected to endure heavy loads yet require frequent tying and untying. It seems that no one has solved the problem of how to test that property reproducibly and objectively ..." (Warner, 1996:201)

And knots have caused serious problems for large airships in the past:

> "... there was a stiff land breeze that made it difficult to manage the long hull of the dirigible [Count Zeppelin's *LZ-2*]. The wind drove the airship ahead of the tug, making it necessary to drop the tow-line. But even so small an accident as a knot in this rope spelled disaster; the airship could not be freed from the tug until its bow with its steering apparatus had been pulled into the water. This broke the steering gear." (Hylander, 1931:150)

It is thus evident that the ground crews for any future VLAs will need to be at least as skilled in the use of ropes, and as knowledgeable of the lore concerning them, as are today's sailors. The NGVLA designers will also have to understand all matters concerning rope, including the reasons behind its various types and usages. This information is freely available in the world of modern sailing:

> "If a constant load is applied to a rope, such as by suspending a fixed weight, the rope continues to stretch slowly and, if the load is a substantial fraction of the breaking strength of the rope ... the rope will eventually break. ... Some extrapolated figures suggest that, even with a load of 20% of the breaking strength (listed as the safe working load for many industrial applications)

the rope would break through creep within a few years ... in practice, of course, weathering would have weakened the rope sufficiently to cause a break before that." (Warner, 1996:194/5)

The regulatory authorities, who in seeking to establish a basis for safe working practices for the NGVLA ground crews, will also need to know the advantages and limitations of different fibres as well as something of the history and evolution of rope, along with the state of rope-making technology today. In so doing they will also need to come to terms with, and perhaps incorporate into modern aeronautical manuals some old nautical knowledge and terminologies. For example:

"... strengths may vary somewhat with the lengths of the fibres from which the ropes are made: the longer the fibre the stronger the rope. The fibres are first twisted into yarns, the yarns are twisted (or laid) into strands, the strands are twisted (or laid) into ropes. Ordinarily, the yarn is twisted in one direction, the lay of the strand is opposite to that of the yarn, and the lay of the rope is opposite to that of the strand. When, however, we want a flexible and unkinkable rope, the strand is laid in the same direction as the yarn, and the rope is then known as a "reverse laid" rope." (Jutsum, 1941:83)

"All ropes are measured by their circumference, and they reeve through a common wood block whose length is three times their size, and through a clump block twice their size. Calling the size of the rope, in inches 'C' we can find its strength as follows:

Breaking strength = C squared over 3 tons.
Proof strength = C squared over 4 tons.
Safe working load for occasional lift = C squared over 7 tons.
Safe working load for continuous working = C squared over 18 tons.

When a purchase is put on to the fall of another purchase, as with a luff upon luff, the resultant purchase obtained is equal to the power of the first purchase multiplied by the power of the second purchase. We have to make an allowance for friction (an addition of 10 per cent of the weight for each moving sheave)." (Jutsum, 1941:84)

"The life of Wire Rope depends principally upon the diameter of drums, sheaves, and pulleys; and too much importance cannot be given to the size of the latter. Wherever possible the size of the pulleys should be not less than 700 times the diameter of the largest wire in the rope, and never less than 300 times. The diameters of drums, sheaves, and pulleys should increase with the working load when the factor of safety is less that 5 to 1. The load should not be lifted with a jerk, as the strain may equal three or four times the proper load, and a sound rope may easily be broken. ... Examine ropes frequently. **A new rope is cheaper than the risk of killing or maiming employees.**" (Jutsum, 1941:72/74) **(GC emphasis)**

8.1.1.2 Crew training and skills

The preceding issue further underlines the absolute need for all those involved with the GH of the NGVLAs to know what they are doing and to be skilled in carrying it out. This comes back to training, and even though the seriousness of this has been recognised in the HTA world, it is difficult to see how such a scheme as that following can be applied to the first prototype NGVLA:

"[Aeropass] adoption on a national basis will raise standards in both the practical and academic fields of all those who operate in an airport's ground environment, an environment that has been described by the UK Health & Safety Executive as one of the most dangerous to work in. Only by operating to the highest levels of competency and safety ... will it start to claw back those huge sums of money lost each year to accidents and damage." (Mason, 2000:47)

However, the risks of using large airships without expert crews are well documented:

"The war would not wait for training. And I am sure it will not be taken as any personal reflection on those brave men when I say that the majority of the accidents which destroyed Zeppelins resulted from sheer inexperience." (Lehmann & Mingos, 1927:110)

It would seem that perhaps the answer lies yet again in a closer alliance with the sea and that future airship crews should initially be sought among the ranks of trained sailors. After all there is a strong bond between airships and their sea-going counterparts.

"Clambering about in and on top of an airship flying at 40-50 mph, 1,500 ft above the waves is very reminiscent of sailors working in the rigging of a tall ship, shortening sail in a squall." (Mowthorpe, 1999:xv)

"As with surface vessels, some officers will develop into better "airship handlers" than others." (Fulton, 1929:58)

"I think that any officer who has handled a surface ship and then qualified for a command of a rigid airship is better able to command that ship. The question of seamanship is closely allied with so-called "airmanship", and in my opinion the handling of a surface ship has many points in common with handling an airship." (US Congress, 1933 : Dresel :135)

And there is a wealth of experience to learn from at all levels:

"...[the practical seaman of short experience when learning to tie knots] must remember that proficiency in what is really skilled workmanship, amounting almost to an art, can only be gained by much practice and perseverance, and should gladly avail himself of any advice or help he may be able to obtain from his more experienced ship-mates." (Jutsum, 1941 : Introduction)

8.1.1.3 Communications – visual or audio?

There are also some problems that are not of a physical nature but which are nonetheless related to GH and which offer a threat to the NGVLA development programmes. One such is the common presumption that communication between ground staff for large airships will be best done by means of "modern" radio links such as those used in the HTA world today. These, however, are not infallible:

"... during the night they towed a B-720 into a hangar door. ... With only a few mechanics on duty they had enlisted a rampie to "watch the left wingtip as we tow the big Boeing in." He did exactly that and watched it run into the door and crumple. He was a very good watcher, but poor at communicating." (Vasko, 2001:19)

"A large tow tractor [at Frankfurt Airport in October 2000] had just had its towbar uncoupled ... The ramp agent ... was hit by the reversing tow tractor. ... The driver was alerted to the collision only through calls from ramp personnel nearby. ... This is a tragic accident and a reminder of how dangerous the ramp is as a workplace when communication and visual contact are lost among ground staff." (Lamprecht, 2000/2001:46)

The important point here is that "visual contact was lost" and it is often overlooked by advocates of modern systems that the "old-fashioned" visual signals, as practised by the PGVLAs are not actually inferior to an audio-based system but are actually an alternative, independent system that in many ways is safer. For example, the sound of a short verbal response may easily be missed in a noisy environment, moreover, it is a transitory event that requires active repetition on the part of the sender, (who is perhaps busy with other things,) whereas a visual signal, continues to work, and may be constantly and repeatedly checked by the receiver, until it is cancelled. With the adoption of mechanical GH systems in the future, and the use of unavoidably large and noisy vehicles, the problem of misheard information is likely to be greatly increased rather than eliminated. Indeed, the advantages of passive, silent visual signals have recently been shown in the responses by the military (who are not short of hi-tech audio-based solutions) to the spate of "blue on blue" or friendly fire accidents that have occurred on the battlefields of the Middle East.

Thus, there would seem to be a considerable potential benefit to the NGVLAs, by the incorporation into their comms system, of something similar, or even based upon, the proven "Flag codes" as used by the PGVLAs. In Britain these evolved from Navy flag signals and started with the First War Coastal blimps who, in failing to reach their home base would fly a triangular 'forced landing' pennant to indicate that their 'emergency landing crews' should start to run cross-country to retrieve them. By the time of the Imperial Airship Scheme this had become a reliable and simple code.

> "As soon as the Captain of the ship [*R100*] is satisfied as to trim [after main wire connection to the ground during landing sequence], he will order a white flag to be shown from the control car as a signal to the officer in charge of the mooring-tower, that he may commence to haul in on the main winch. As soon as he gives the order to haul in, a white flag is also shown from the tower platform. If for any reason either wishes the evolution to stop, a red flag replaces the white." (Meager, 1970:156)

These flags were just as effective when substituted by coloured lights at night (Countryman, 1982:124) and the need for both audio and visual signals was recognised by the US Navy towards the end of their airship operations.

> "1-21 - It is essential that the GHO be easily identified and it is recommended that he have in his possession the following equipment: a) A metal police type whistle for maximum audio capability in attracting attention over the noise of the airship engines. b) Colored vest. c) Standard signal wands for use during night operations, and a Very pistol with red flares for signalling emergency on field." (US Navy, 1958:4)

8.1.1.4 The siting of airship bases

A further general point that has great implications for GH is the actual location of airship bases. As noted in **Section 6.4.2** there were several different types of PGVLA base and the requirements for each are quite different. The historical records reveal that not only did luck apparently play a big part in the earliest PGVLA successes but that the factors governing a good location are extremely complex. Moreover, once a base is established, unless it is an expeditionary base, it is exceedingly difficult to do anything about it.

> "The influence of location and local characteristics on the value of an airship base is now beginning to be appreciated in this country although the Germans long ago sensed this factor keenly. The same general principle applies to harbours for surface ships ... a harbour continuously beset by fog would never become popular or profitable. And so the location of our one present airship base cannot be passed over without comment. When Lakehurst was decided upon as an airship base, our knowledge of rigid airship operation was largely yet to be gained and in the absence of this proper operating knowledge, naturally other factors, strategical and economical, ruled the selection of a site. Lakehurst was intended largely as an airship construction and experimental station, but it happens that as an airship operating base, Lakehurst is rather unsuitable. Bear in mind the distinction between an airship operating base and an airship construction station; for the latter purpose Lakehurst can be said to be fairly satisfactory. But Lakehurst is handicapped by being in the path of practically every Trans-continental and Canadian border atmospheric disturbance and feels some effect from most passing tropical storms as well as from many secondary barometric depressions that form off-shore and move up the Atlantic Coast. The resulting percentages of undesirable and dangerous handling and flying weather, i.e. of unsuitable airship terminal weather, as viewed from our past and present needs, are therefore high." (Rosendahl, 1927:751)

As with any airfield, the local weather conditions obviously play a big part in the success of LTA operations. However, they are not the only consideration.

> "Because of the limitation imposed on airships flying from a base at high elevation, it is remarkable that the most important development of the rigid should have been at Manzell and Friedrichshafen which are at 400m (1300 ft) above sea level. ... Operating from Lake Constance ... the Zeppelins suffered an unavoidable penalty in their payload/range capabilities because their pressure heights had to be that much higher than if they had been taking off at sea level." Brooks, 1992 : Note 13.)

> "For the first time, [May, 1936] the *Hindenburg* landed at the new international airship base at Frankfurt am Main, where one hangar was finally ready. An advantage of operating from Frankfurt am Main was that since it was only 300 feet above sea level, the *Hindenburg* could lift 13,500 pounds more than in a takeoff at Friedrichshafen, which lay 1000 feet higher."(Dick & Robinson, 1985 : 124/5)

But, despite the altitude penalty, there was a widespread belief in Britain and America that Count Zeppelin had actually chanced upon the ideal site for his first base.

> "The speed of development of the early airships was ... largely controlled by the weather conditions prevailing at their operating bases, and without in any way wishing to diminish the credit due to Count Zeppelin ... I cannot help feeling that his success was to a great extent assisted by the exceptional weather conditions that prevail at his base at Friedrichshafen." (Richmond & Scott, 1930)

> "... weather conditions at Friedrichshaven are very ideal." (US Congress, 1933 - Harpham, :448)

> "Weather conditions at German bases generally do not compare with the more severe conditions under which we have to operate airships."(Rosendahl, 1927)

Thus the NGVLAs would do well to pay careful attention to the intended sites for their various differently-purposed bases. Or more specifically to the micro-climate that prevails at them and to the exact orientation of their sheds.

> "Around every shed or building we find peculiar wind conditions. There is a falling down current at the leeward end of a shed, which extends out a distance about equal to the height of the shed, and curling inwards forms a back draught into the shed. The doors, if in the wind path, create eddies on their leeward side. Thus there is a danger zone to leeward of the shed structure. This zone can be minimized through careful shed and door design." (Fulton, 1929:56)

> "The location of an airship base, the orientation of the shed, if there be one, and the type of shed all have important bearing on the problem of handling airships. The base should be chosen where meteorological conditions are favorable. The shed, if of the fixed type, should be oriented so that the cross wind component will be a minimum **under conditions when it is likely the airship will be docked or undocked.**" (Fulton, 1929:55) **(GC emphasis)**

This last, emphasised, point is another that is often overlooked or misunderstood, for the direction indicated is not the same as that commonly termed as being "into the prevailing wind." The prevailing wind is generally taken to mean the direction from which the wind most commonly blows. From the lay perspective it often means the direction of the strongest winds, as these are the most often noticed, and the shed builders are usually happy to align with this as it minimises the stresses on their roofs. However, the airship is unlikely to be undocked or re-docked in the strongest winds. Thus, in order to maximise the amount of time when docking will be possible, as correctly stated by Fulton, the shed should be aligned with the wind direction that is most common on the site when the wind is gentle enough to permit the procedure to be carried out in safety. However:

> "... we have found it will not be necessary to provide ships that will stand handling into hangars under unlimited conditions or gear capable of serving under extreme conditions, for a study of records has shown that even at Lakehurst on ninety-six per cent of the days of the year the wind drops to less than 20 miles per hour velocity for periods of 2 hours of more." (Rosendahl, 1927)

But it is the "prevailing direction" of this perhaps infrequent, low-speed wind that is important in deciding the orientation of any new shed, and quite what the effects of the changing weather-patterns resulting from Global Warming will have in the future, on the validity of past weather records, remains to be seen.

8.2 Issues relating to specific phases of GH

In **Section 5.3.2 - What is Ground Handling?** - it was shown that although there are at least 40 separate "Generic Tasks" which can be identified as being in some way part of GH, the topic can also be broken down fairly conveniently into just 8 sections. Moreover, these subdivisions or groupings can, for ease of memory, be labelled by their initial letters as PP MM LL CC - standing for Protect, Prepare, Move, Moor, Load, Launch, Capture and Camp-out. Study of the historical records reveals that all of these task-groups have one or more issues that were left unresolved at the closure of the previous large airship development programmes in the 1930's - although it should be kept in mind that these categories are far from adequate to cover all aspects of the topic and many others have had to be excluded for reasons of space.

8.2.1 Protect

It should be borne in mind that there are three separate components that need protection. Viz.:

a) The Airship
b) The GH Infrastructure
c) The Personnel

Moreover, as identified in **Section 6.4** above, there are two aspects to protecting the airship. Firstly there is protection from damage, or interference, by unauthorised personnel - which in modern parlance might more properly be encapsulated by the term "security," and secondly there is protection from the vagaries of the "weather." Both of these are absolutely vital to the physical survival of the airship; both are greatly helped by the provision of a physical barrier or screen; both require constant, unceasing vigilance on the part of those made responsible for the task, and both may require prompt intervention and strenuous physical action to be taken at short notice, in order to mitigate or minimise the impact of an "attack."

8.2.1.1 Security - Terrorism

> "As a point of interest, Santos-Dumont's No. 7, a small fast airship built to compete in the St Louis air race of 1904, was destroyed in its shed at Saint-Cloud – by vandals. That indicates that problems with law and order are not a recent phenomena." (Mowthorpe, 1999:3)
>
> "The Zeppelins and another airship, the *Schuette-Lanz-20*, were destroyed in their hangars at Ahlhorn [5th January 1918]. The case has remained a mystery. The cause of their destruction has not been definitely determined. The circumstances indicate, however, that it was due to sabotage – some criminally inclined member of the station crew at Ahlhorn, or possibly a small group bought with enemy money, must have purposely blasted the ships. ... which could hardly have resulted from causes other than a deliberate attempt to cripple the airship service." (Lehmann & Mingos, 1927:277)
>
> "One of his motives [Lehmann's for flying on *LZ129*] although by no means the only one, was that a warning that an attempt might be made to destroy the ship had been passed to his office by the German Ambassador in Washington. Such warnings were not uncommon and were usually regarded as the work of cranks. A time bomb had, however, once been discovered in the *Graf Zeppelin*, and an attempt had been made in 1931 to sabotage the *Akron*." (Collier, 1974:213/4)

Obviously a *cordon sanitare* can be thrown around the airship when it is on the ground, and in these days of terrorist threats, this is certain to be vigorously maintained. Nevertheless, those guarding the NGVLAs need to be aware that for every nutcase who wants to put a bomb on onboard the airship and destroy it, there are probably going to be a thousand who would rather steal a ride on it.

8.2.1.2 Security - Stowaways

Although seemingly a trivial problem, the ease with which stowaways could sneak on board and hide themselves proved to be a constant nuisance for the passenger-carriers of the past, especially for those large rigid ships which were moored inside sheds.

> "The departure from Friedrichshafen, scheduled for 11 October 1924, proved troublesome. When Captain Flemming weighed the ship [*LZ-126*], he found it puzzlingly tail-heavy. A search revealed two stowaways in the stern portion - a reporter from the International News Service and a photographer from International Newsreel who had sneaked on board in work clothes hoping for a scoop." (Botting, 2001:106)

> "Not long after first light [Sunday, 28 October 1928], while making an inspection of the ship [*LZ-127*], Captain Hans von Schiller discovered a stowaway, a blond-haired, eighteen-year-old American from St Louis, Missouri, who had sneaked on board at Lakehurst carrying nothing but a toothbrush, and hidden himself among the mail sacks." (Botting, 2001:145-6)

> "Take-off [from Tokyo] was set for 4 a.m. on 22 August [1929] ... During its time on the ground the airship [*LZ 127*] had been undergoing a thorough overhaul ... The last items to be loaded on board consisted of fresh vegetables ... and a parachute with which to throw any stowaway overboard - one had already been caught in the hangar earlier in the day, a seventeen-year-old boy dressed in a kimono." (Botting, 2001:188)

And joy-riders are going to be just as hard to deter in the future. Furthermore, the enormous size of the NGVLA structures will offer many hiding places - and human beings were not the only stowaways:

> "The *R34* is best remembered for her transatlantic flight ... [she] took off from East Fortune at 1.24 a.m. on 2 July 1919 bound for New York. ... On board were Brigadier-General E. M. Maitland, CMG, DSO, the officer commanding the British Military Airship Service, a crew of thirty, a kitten and a stowaway - an airman named Ballantyne." (Jackson, 1971:132)

> "Though the Graf [*LZ 127*] was carefully searched immediately prior to departure [15 August 1929], a stowaway of sorts successfully eluded discovery until [the 17th]. Hungry, shivering and distressed, a small black kitten was found in the depths of the ship's vast and complex interior by a rigger on a tour of inspection ..." (Botting, 2001:174)

There are also souvenir hunters to consider:

> "When *SL11* was brought down ... at Cuffley and *L32* at Billericay ... not only were items of value to the Government taken, but firemen and special constables looted the bodies of the dead crew, as it has been said that souvenir hunters did when *Shenandoah* crashed in the United States in 1925 ... On September 28th [1916] it was proposed [by British Admiralty Intelligence that in future] ... around the whole of the wreck a barbed wire fence should be erected and manned by soldiers with fixed bayonets ... At the same time special passes were made out for those authorised to visit a wreck ... Official photographers were to be allowed in, but no neutral pressmen for at least two days after a ship was shot down. Any ship which fell within a town was to be treated by the local police and firemen as major fire and suitable precautions taken. Full printed instructions were issued to the Army in October 1916." (Higham, 1961 : 155/6)

8.2.1.3 Security - Crowd control

Crowds will appear for all special occasions and control of them at these times can be planned for:

> "In the late afternoon of 4 September, [1923] with fifteen thousand spectators, dignitaries, reporters, and newsreel people on board the base, ZR-1 [*Shenandoah*] was walked out for the first time." (Althoff, 1990:28)

> "With complete co-operation of the crowds, the Royal Canadian Dragoons troopers cleared a 300-yard circle around the [St Hubert] mast. ... [*R100* preparing for the 24 hour Canadian flight in summer 1930] " (Countryman, 1982:83)

However, in these days of instant communication, and easy personal transport, simply opening the shed door and revealing to the public gaze, the largest prototype aircraft the world has ever seen, is certain to draw a vast crowd. Thus, on the scale of the NGVLAs, everything will effectively have to be done in public, and the repercussions in terms of local traffic, of a week of even ground-based testing, for a gigantic airship that is visible from a nearby motorway, will have to be considered.

> "Soon, seemingly endless lines of automobiles were snaking from the main gate through the town and throughout the general area. The roads to the village were promptly jammed. This crush of Lakehurst-bound visitors was to be repeated for the arrival from Germany of ZR-3 that fall, and later for visits by *Graf Zeppelin* and *Hindenburg*. But this spring day [31st May] in 1924 was the pacemaker. By 0930, perhaps twenty-five thousand spectators were on hand ..." (Althoff, 1990:40)

"The *Graf Zeppelin's* departure was scheduled for 10 October [1928], but the omens were bad. The Atlantic weather map was a nightmare ... In the end he [Dr. Eckener] decided that the only option was to postpone the departure altogether. The crowd of many thousands wandered away, disappointed and disgruntled." (Botting, 2001:116)

"[*Graf Zeppelin's*] take-off was set for 4 a.m. on 22 August [1929] ... As the day progressed the crowd grew, many arriving on special trains from Tokyo, till around half a million people surrounded the airship field ..." (Botting, 2001:188)

8.2.1.4 Security - Ground crew health and safety

Even if the number of ground crew is reduced to a handful for economic reasons, the danger to those who remain will not diminish. Less people means more machinery, and bigger airships will need bigger and more complex machinery. Even with rigidly enforced codes of practice, along with high levels of training, careful planning and vigilance, big machines are still dangerous, but, for the ground crews of the past the biggest killer of all was something else that has not diminished - the force of gravity.

"R34 herself [on reaching America in July 1919] was in good trim. She was moored by the 'three wire' system at night, but during the day she was pulled down and held by the united efforts of the American ground-crew. Even for these hefty sailors it was an arduous task ... The bright sunlight of the next morning again caused gas expansion ... When the ground-crew tried to haul her down ... they found the job almost beyond them. Men were lifted bodily into the air and dropped heavily back again as the ship rocked violently from side to side." (Abbott, 1973:114)

"... she [the crippled *R34*] descended slowly into the hands of the 400-strong ground-crew, who led her, rolling and pitching, towards the safety of the hangar. They managed to haul her almost within reach of the doors, but because of the boisterous and uncertain wind it proved impossible to ... enter. ...vicious squalls repeatedly lifted her up and then dashed her down to earth again. During one of these gusts, the after car was swung 60 ft off the ground, with some of the landing-party still hanging on to it ..." (Abbott, 1973:140)

"It took 500 men to hold a North Sea class airship in turbulent conditions and even then it was a struggle. Torn hands and broken limbs were common. At least five deaths were recorded from ground-crew members who held on too long, falling from a great height while controlling a bucking airship." (Mowthorpe, 1999:41)

The instinctive human reaction to grip harder when lifted suddenly should never be underestimated. The tiny time taken by the mind to intellectually over-ride the body's in-built emotional response has proved fatal more than once - even for those who were 100% aware of the problem - both in the past and today.

"One of Britain's pioneer airship pilots and most experienced airshipmen Wg Cdr Waterlow always persistently drummed it into his men: 'Never hang onto the guy-ropes if lifted off your feet – let go immediately. Once airborne the airship is the responsibility of its pilot.' ... Sad to relate, Waterlow disregarded his own maxim on 12 May 1917 ... SS-39 ... at RNAS Cranwell ... suddenly broke free. All the rest of the party released except Waterlow who was carried up until he fell to his death." (Mowthorpe, 1999:21)

"[On Sunday, February 26, 1995 in Hayward, CA] The [*Thunder and Colt GA42*] blimp hit the grass short of the landing zone and bounced along the ground until it stopped ... The pilot told the passenger to get out and hold the blimp down. The passenger tripped as he got out and ... When he got back on his feet, the blimp was rising with the pilot holding on to a hold down rail. The pilot lost his grip and fell [to his death] from 200 feet." (NTSB Ident. No: LAX95LA121.)

However, even modern methods and safety awareness cannot guard against all unforeseen events.

"... *Mayfly* needed well over 700,000 c.f. [of hydrogen], not counting what was lost when one of the bags ripped in early May [1911], an accident caused by Able-seaman Palmer falling through the ship!" (Higham, 1961 : 48)

"The twin engine [*Aeros-40B*] airship was landing [Wednesday, June 28, 2000 in San Bernardino, CA,] and there were two ground crew assigned to catch the mooring rope ... the ground handlers collided with one another during this process and the second one fell backward and hit his head on the concrete ramp, which resulted in fatal head injuries." (NTSB Ident. No: LAX00LA242.)

"Marina Pasternak, 32, and Levon Samamyam, 35, both Ukranians, tragically lost their lives whilst working to repair leaks in one of the two ballonets in the envelope of a new four-seater *Skydragon* belonging to World Wide Aeros at San Bernardino International Airport on Friday 28 January [2000]. ... First reports suggest that ... the victims ordered other crew members to shut off the air pump to collapse the ballonet so that they could reach the hole ... With dwindling air in the ballonet they would soon have become confused and rendered unconscious." (Airship, 2000:11)

And if the GH procedures are ever successfully mechanised then there will be danger to ground crew from the big vehicles themselves, as demonstrated by this first previously quoted example and the accident statistics:

"A large tow tractor [at Frankfurt Airport in October 2000] had just had its tow-bar uncoupled from the aircraft ... and was moving back ... The ramp agent in charge had just raised her hand for the "all clear" signal to the aircraft, turned and started to walk away, when she was hit by the reversing tow tractor. The force of the impact threw her to the ground and under the moving tractor." (Lamprecht, 2000/2001:46)

"The air transport industry does not compare well with other industries. In the U.S., the lost workday incidents rate per 100 employees showed an industry average of 1.9 for 1998. The corresponding numbers were 3.2 for the construction industry, considered to be a high risk workplace, and a staggering 8.2 for the air transport sector." (Lamprecht, 2000/2001:47)

There is also sod's law where the solution to one problem causes another one elsewhere.

"The good ship [*L6*] responded instantly [to the dropping of ballast water] and glided gracefully ... over the top of the dangerous building. I was extremely sorry that in lightening the ship I inadvertently gave a shower-bath to the dense crowds assembled on the landing stage ... The stains made on clothes by ballast water are ... extremely annoying, for the water placed in the bags and containers has an anti-freezing mixture added to it which causes ugly patches with rings round them." (Von Buttlar Brandenfels, 1931:102/3)

Thus the ground crew, (and the environment,) will also need to be protected from the side effects of whatever it is that they use to protect the NGVLAs from the extremes of the weather.

8.2.1.5 Protection - Forecasting the weather

There are two aspects of protection from meteorological phenomena that need to be considered. Firstly there is defence against what is actually happening at the moment, and secondly, there is the forecasting of what is shortly to come. Both of these are enormous and complex subjects, and numerous books have been devoted to them - particularly in the latter case. A selection of books and papers that deal with the study of the weather, and with related phenomena as they apply to the GH of LTA craft are given in the Bibliography. [1]

In view of the fact that there will unquestionably be infinitely better, more accurate and more readily accessible weather forecasts available to the NGVLA operators than there were for their PGVLA forebears it is not deemed necessary here to go into any great detail of the services that were used in the past. Nevertheless, there is much in the archives that is of interest on the topic, particularly concerning the

[1] E.g. Smith, 2002; Lapworth, 1994; Huijsmans, 1993; Hikami & Shiraishai, 1988; Watts, 1988; Fujita, 1985; Wallington, 1982; Holford, 1979; Welch, 1979; Viemeister, 1972; Harris, c1969; Lane, 1968; Davenport, 1963b; Sutton, 1962; Kimble & Bush, 1943;

lessons that had been learned towards the end of the PGVLA programmes and the way in which the ground handling procedures finally get the blame when all apologies for unreliable performance have run their course. Here are some examples:

> "For years the British have had available four daily weather maps, and there is no doubt that some day we must increase the number of our daily maps. " (Rosendahl, 1927)

> "When a flight of one of the large [US Navy rigid] ships was contemplated, the aerological officer making the flight ... had charge of the preparation of the proposed forecast. He was assisted in this work by the station aerological officer, who had the weekly forecast duty. ... The usual charts were prepared, and ... analyzed by ... the [airship] aerological officer ... assisted by [the officer] who had station duty ... and upon this analysis he made the forecast for the following 36 hours, that is, "today", "tonight" and "tomorrow." This forecast was the usual Navy forecast, somewhat more detailed than the forecast sent out from the central office of the Weather Bureau, particular attention being paid to the detailed requirements of airship operation." (US Congress, 1933 - Maguire :236)

> "The common conception of wind is that of a mere horizontal flow of air and were this idea always true, flying would be comparatively simple." (Rosendahl, 1927)

> "Throughout the war the British had dwelt upon the fact that unfavourable weather, especially during the winter months, prevented the Zeppelins being sent out. Sometimes long periods would elapse before the North Sea patrol was resumed. But it was only on very rare occasions that it was a matter of inability of the airship to leave its hangar or remain aloft. Generally it was due to reduced visibility over the water. The North Sea in a fog or thick haze made reconnaissance impossible ... " (Lehmann & Mingos, 1927:304)

> "The charge that the Zeppelin of 1914-18 was a fair-weather weapon is borne out by the following statistics showing the percentage of days on which reconnaissance flights were made in the North Sea: "

Year	Days flown		Days total	Percentage
1914	35	Out of	148	23.6%
1915	124	Out of	365	34.0%
1916	89	Out of	366	24.3%
1917	96	Out of	365	26.3%
1918	55	Out of	315	17.5%

(Robinson, 1994)

> "They [airships] are all fragile and dependent on the state of the weather and the atmospheric pressure, though not so much as is generally supposed, for it was officially recorded that during 1918 there were only nine days on which no airship flight took place in the British Isles."
> (Vivian, c1920:168)

> "It was not an auspicious departure [t/o from Lakehurst on 28 October 1928]. Crosswinds forced Eckener to put back the take-off hour twice, to the irritation of passengers and press alike. It was not until two the next morning, six hours after the scheduled departure that the *Graf* was heading once again for New York." (Botting, 2001:145)

> "A number of flights have suffered postponement and even abandonment because of our inability to handle ships in and out of hangars under any but comparatively good conditions."
> (Rosendahl, 1927)

> "This opinion [that an airship is a fine weather craft], even with the earlier airships, was not true. An airship is capable of meeting and successfully navigating bad weather, but in the past owing to the handling limitations was seldom permitted to demonstrate this fact." (Richmond & Scott, 1930)

However, regardless of the availability debate, there are also some very sensible ideas that would still seem to be good advice today.

> ">A - ... In the lighter-than-air [pilot] training there is a ground school with a limited amount of flight training ... I believe the course in aerology should be extended, there should be more

> training in forecasting from maps and a more extensive training in forecasting weather from visual observations ...>Q - I think your suggestion very wise, to wit, that the personnel in control of airships at least should have more fundamental and detailed study in aerology so that each commanding officer and those who may supplant him along the line of succession may be competent independent forecasters. >A - I believe that the airship captain should make his own weather forecast, and he should be an expert." (US Congress, 1933 - Weyerbacher :361/367)

There are also pertinent observations that are equally good advice for those who will be in charge of new generation airships when they are moored or when ground-based movements of them are planned.

> "Is it not true that the captain of a ship is always studying the weather, the captain of any ship, every ship I ever saw, the captain was studying the weather all of the time, looking at the barometer and thermometer." (US Congress, 1933 - Kean :369)

And this latter instrument may become of special interest to the GH team, and to the airship flight crew, when a flight is in prospect. For instance:

> "At Pulham, during the airship mooring mast trials in 1921, on several occasions a difference in temperature between the top and bottom of the mast (100 ft) of as much as 10° F was observed. This was at about 9 a.m." (Scott & Richmond, 1923)

Such events, which generally go unnoticed by all other forms of transport can have dramatic effects on an LTA vehicle. And there is much else under the broad umbrella of "the weather" that will need to be addressed by the NGVLA operators. Especially with regard to the measurement of it:

> "No reliable measurement of the weight effect of rain on an airship has been made so far in England. This effect is naturally less in a wind than in stagnant air, but in either case it rapidly reaches an equilibrium value. The maximum heaviness caused in R33 at the mast by rain appears to have been about 1.5 tons." (Scott & Richmond, 1923)

> "Continuous records of humidity are difficult to make ... For obtaining the humidity in the interior of gas-bags, a distant-reading instrument requires to be developed ... The gas, when it is first fed into the airship, is probably highly saturated, but there is a certain amount of evidence that this high degree of saturation does not remain for long. It appears that a transference of moisture takes place from the inside to the outside of the bag or vice-versa at a reasonably rapid rate. Apart from any question of lift, the amount of moisture in the gas-bags has an important effect on their physical condition." (Scott & Richmond, 1923)

> "2 Atmospheric up and down draughts ... 2.1 General - The information provided ... has been derived from the small amount of published data on measured draught velocities in storms and theoretical work undertaken by the meteorological office. Since the data are related mainly to velocity measurements at high altitudes ...and since the CAA has knowledge of only one measured velocity at low (2 km) altitude ..." (CAA : CAP 471, 1979:13)

Then, too there are observations in the records that may be of use to anyone contemplating the construction of a GH and mooring facility, for there is no real point in building facilities that are very much stronger than the airships themselves.

> "...the accumulated experience of four years of war indicated that eighty miles an hour as then attained for the first time with airships was quite sufficient for all normal requirements with some speed to spare. Our studies in meteorology had shown that weather conditions by and large would not require much further increase in speeds. Since the war observations made throughout the world have confirmed that conclusion, so that a normal speed of eighty miles has now been adopted for the most recent designs for commercial and military Zeppelins. It is fast enough." (Lehmann & Mingos, 1927:286)

And finally, it should not be overlooked that the NGVLA ground crew personnel will themselves also be subject to the effects of the weather. They, like modern blimp crews, will have to stand out in the open air and are often expected to work for prolonged periods in the middle of an airfield away from any shelter.

In the summer they will be subject to dehydration and sun burn (see Risch, 2003). In the winter they are liable to suffer from wind chill (see Moyer, 2002a). Whereas little was done to alleviate these in the past, both are today recognised as problems in LTA sports such as hot air ballooning.

8.2.2 Prepare

As shown in the Prerequisites for this study (**Section 5.1**) the need to take a GH perspective of an airship project, and the advantages of doing so, have been neglected in the past. Moreover, the same is true with regard to the preparation of the airship (i.e. construction, assembly and inflation) for which the equally necessary need to have previously prepared the ground handling equipment (GHE) is again widely ignored. However, where the GHE is of itself a prototype, then the requirement for it to be tested and shown to be fit for purpose, prior to the airship's attachment to it, must appear as an issue at some time in any project with potential to involve considerable delay.[1] The historical records of the PGVLAs reveal how they dealt with this same problem and many of their ideas and practices look to be still applicable.

8.2.2.1 Testing and maintenance of GH Equipment

Obviously much GHE will be specific to any new airship that is built, however, the overwhelming evidence that a mooring mast is the only sensible way for an airship to ride out the wind would indicate the likelihood of the need to test one in the future. For this, although the prolonged period of trials at the British experimental base at Pulham would be prohibitively expensive and unnecessarily repetitious, the methods of testing the last and largest of the British masts - the Cardington Tower - may be of use.

> "Extended trials under service conditions with SS Airships moored to one of these masts were made at Pulham Airship Station. The system proved to be an unqualified success. Airships have since been moored out in all kinds of summer and winter weather, including winds up to 55 miles per hour and heavy snow and thunderstorms." (Pratt, 1920)

> "The ship [*R100*] had never landed before on that tower [Cardington] and the crew had been trained using a kite balloon!" (Johnston, 2001:24)

This tethered balloon enabled the nose latches in the masthead to be locked and released several times and permitted the crew to rehearse each step of the airship nose mooring procedure both cheaply and safely, and at their own pace. The tower itself was initially proof-tested for strength with a sideways pull at the top by the running a cable out on to the airfield and attaching the end to a ground-anchored winch.

8.2.2.2 Assembly and rigging

However, it is during the construction of the airship itself that other little lessons from history can be found useful. For example, this short and apparently insignificant entry in the US Navy's Erection Manual for their K-type blimps hides the fact that here is a superficially illogical modification of the installation procedure that could never have been envisaged by those who designed the ship. Neither would it have been adopted if only a handful of these blimps had been built.

> "Rigging the ship. ... 9. Installation of Bombardier's Window. The bombardier's window should be installed if it has not been installed prior to this time. The window opening is often used in gaining access inside the car at the time the ship is being rigged. There is also a possibility of the window being damaged if installed prior to this time." (GAC, 1944)

[1] **See also Figure 2.11 - Generic NGVLA Development Schedules**

However, small savings in time and cost that can only be distilled from numerous empirical cycles are in the end what make the difference between a project's success or failure. It is conceivable that one day a computer simulation will be constructed, by means of which such short-cuts might be identified for the NGVLAs, but it would need to be tremendously detailed and accurate. Meantime, such knowledge nuggets as the Bombardier's Window are the "horse-shoe nails" for the want of which kingdoms are lost.

8.2.2.3 Gas management and buoyancy control

One of the great debates within the airship community that always attracts much public attention is that concerning the advantages of one lifting gas over another. However, from the GH perspective the only really significant difference between hydrogen and helium is that one is flammable and the other is inert. This means that the fire regulations and the exact nature of the procedures applicable during the time the airship is in the ground crew's custody will be different - although not markedly so as there will still be the need to regulate all handling, storage and movement, of the fuel(s) for the airship and the GHE. Thus, apart from the difference in cost, with the more precious helium leading in general to more difficult and more protracted capture/landing procedures, there is little to choose between the two gases as far as the ground crew are concerned. Neither gas is toxic but both can asphyxiate and both need careful handling.

> "The problem of landing on a field is not particularly difficult with an intelligently handled airship, and provided an adequate ground crew is available to grab the handling lines ... However, the maneuver is more difficult with a helium filled airship that is frequently "light" by several tons, than with a hydrogen filled airship where this light condition can be readily neutralized by valving out gas." (Fulton, 1929:58)

> "Helium losses occur in several ways. There is loss in transportation ; there is a loss whenever helium lies in storage in containers ; there is a loss whenever helium is re-purified ; there is a loss by diffusion when helium is in use in airships. There is a loss, or expenditure, whenever in course of operation it is necessary to valve helium. There are occasional accidental losses which it appears impossible to entirely eliminate. Based on past experience, it has been estimated that operating a rigid airship of the *Los Angeles* type will require one to one and one-half ship-volumes per year. ... with good gas cells it will be less." (Fulton, 1929:46)

> "Hydrogen leakage was also bad as the bags [of *H.M.A. No.1*] were by now nearly two years old and leaking at the rate of 474 pounds of lift per day (or 1.67 percent of capacity) ... Footnote - Goldbeater's skin gasbags were reckoned to last about three years. The troubles experienced by a number of British ships were due to the fact that their bags were produced to meet the original constructional schedule with the result that when ships were delayed in construction, the bags were already part way through their lives before the ship ever flew." (Higham, 1961 : 50/51)

Although Goldbeater's skin is unlikely to make much of a comeback in the future, nevertheless, the principle, whereby the design life of component parts can cause problems for projects that find themselves seriously behind schedule for any reason, remains valid. However, it is during the test processes that the ground crew can expect to play their biggest role in the preparation of the airship.

8.2.2.4 Weigh-off, trim and systems testing for certification

Testing has always been a time-consuming part in the preparation of airships.

> "The young inventor [Santos-Dumont in 1897] found a workshop and a suitable mechanic, in Paris, and here he built a two-cylinder motor that produced 3 ½ horsepower ... It was tried out in an auto race and found wholly satisfactory. ... [when] the basket and motor [for the *Santos-Dumont No.1*] were finished; he suspended them from the rafters of the workshop, and tested the strength of the little propeller geared directly to the crankshaft." (Hylander, 1931:125)

However, it is clear that the NGVLAs will have to allow for an enormous test programme, not only of individual components but also of both the complete GHE and the airship - just as was the case for both the British and American PGVLAs.

> "When a [British rigid] ship was completed, a lift and trim test was undertaken in the shed with the ship floating free, but held down by weights and balances. An adjustment in weights could then be made ... to insure either that the ship would leave the ground or to balance her in a fore-and-aft direction. Once this was done, an engine test in which all the engines were run was conducted either inside or outside the shed with the ship secured. Then out on the field, an inclination test was carried out to ensure that in a dive nothing would break loose and that the ship was properly rigged." (Higham, 1961:XXI)

> "In November 1929 the ship (*R100*) was finished ... the day came when we ballasted her up in the shed for her lift and trim trials, determining accurately for the first time the loads that she would carry. It was a simple procedure; we mobilised a hundred men to hold her by the power cars and control car so that she neither floated up to the roof nor sunk on to the floor. After each readjustment of weights the men let go of her together on the blast of a whistle; we watched to see if she would rise or fall. After a few trials she hung motionless for a minute on end, poised in the air above the floor of the shed. Readings of barometric pressure and temperature completed the process ..." (Norway, 1933)

> "There were a great number of tests made. The particular test to which I refer was ... known as the test of the first bay, that is, the first section of the *Akron* which was built, had placed in it a gas cell, inflated with helium ... and ... measurements were made at all parts of the structure; tensions were taken of wires, as check both on the theoretical calculation as to stresses, and also as a proof test of the workmanship and materials used. On completion of the *Akron*, before she went into the air there were additional tests made on the completed airship. Of course, during construction there were hundreds of tests of materials, tests on various component parts, such as girders, that went into the airship." (US Congress, 1933 - Fulton :340-341)

> "There are two ways [determining the weight of the ship] is done in practice: One way is to weigh on the scales everything that goes into the ship; that is done during construction and a record kept of every weight, every rivet that goes into the ship. The other way is with the completed ship, to fill the ship full of gas and actually balance the ship, determine all of your constants, gas, purity and temperatures, and make a weight determination in that way ..." (US Congress, 1933 - Settle :277)

And there is reference to time-consuming tests and trials throughout PGVLA history from first to last:

> "... in July, 1900 the airship [Count Zeppelin's *LZ-1*] was ready for its trial flight. Needless to say, there had been much feverish energy expended and many weary hours of testing and re-testing during these two years. So much had to be done **without precedent** and on absolutely new ground." (Hylander, 1931:143) **[GC emphasis]**

> "Most striking view of all, perhaps, to the casual visitor, is the wonderful vista of light metalwork as one looks down from the nose the length of the central catwalk ... So strong is this apparently light and airy framework, that the ship [*LZ129 Hindenburg*] was actually taken to a secluded valley in the Alps and turned right on her nose, as part of her final trials, without the slightest ill effect anywhere on her truly colossal body." (Coke, c.1937:91/2)

However such advanced tests can only be conducted after an airship has been taken out of it's shed.

8.2.3 Move

There are many issues concerning the movement of airships on the ground for which material from the historical archives can offer guidance and insight. These include:

8.2.3.1 Undocking

> "There are two general situations with reference to wind : one a wind parallel to the shed axis ; the other, a cross-wind. Assuming the shed has two doors, there are two choices, to windward or

to leeward. We have also conditions of "stern out first" or "bow out first." Thus a choice from among several conditions must be made. The most conservative practice has been to use the leeward door on the theory that in case something goes wrong the airship will be carried away from the shed. But on the leeward side of the shed there is always turbulent air which may cause more trouble than a wind of known direction." (Fulton, 1929:56)

8.2.3.2 Rails v tracked vehicles

"While the *Graf* [in June 1930] had then been brought into the [Lakehurst] hangar on a low travelling mooring mast mounted on crawler feet, [by the time of the *Hindenburg*'s first visit in May 1936] the travelling mast concept had been developed further for the giant *Akron* and *Macon* airships into a massive affair rolling on railroad tracks 64 feet apart, while at the other end the ship's stern and lower fin were made fast to a ponderous "stern beam" 186 feet broad, which also rolled on railroad tracks. Out on the field the stern beam was to be transferred from the rails running straight out from the hangar to the "hauling up circle" on the field." (Dick & Robinson, 1985 : 125/6)

"The suggested motorization of the stern handling equipment ... is not considered a safe solution ... It is believed that one of the most important basic principles for safe operations is that while going in and out of the hangar there should be only one source of power. The soundness of this principle has been demonstrated twice at Lakehurst, when use of such a servo-control might have resulted in damage to the ship. ... a system of interconnecting tension and compression members has been designed and built which rigidly holds the beam a fixed distance from the mast and is stronger that the full tractive effort of the mast locomotive." (Bolster, 1932:119)

"The [K-ship mast] tractor drivers were among the most important persons on the field. They had in tow an aircraft with a mass of more than twenty-five thousand pounds. If they stopped abruptly or turned too suddenly or sharply, the blimp's momentum would keep it moving, with results that could include over-riding the mast and puncturing the bag." (Vaeth, 1992 :42)

8.2.3.3 Broken airship

It should not be overlooked that on occasion the ground crew may be called upon to move an airship that is damaged. For example, an airship that has rigid structure may be physically distorted:

"*R80* suffered major structural failure on her first flight – eighty-three girders are said to have broken and the ship was so distorted that she was returned to her shed with only the greatest difficulty." (Brooks, 1992)

Also the actual attachment mechanism between the ship and its GHE may break:

"On February 22, 1932, the stern [of *Akron*] carried away from the stern handling apparatus while the ship was being taken out of the hangar at Lakehurst. The detaching of this apparatus caused certain damage to the fin, and the ship swung around in the air and the stern then hit the ground and caused further damage. The airship was taken back into the hangar ... A somewhat similar accident occurred exactly 6 months later ... the cause of the first [accident] was an unexpected gust of wind of force greatly exceeding that which might be expected ... The cause of the second was the movement of the ship before the stern handling apparatus was out of the way, running the ship into the stern gear." (US Congress, 1933 - Wiley :54)

A modern analogy to this event, and one that proves it's pertinence to the NGVLAs, was the delayed launch of a Space Shuttle in August 2002, which had to return to the construction dock after the giant crawler vehicle that was carrying it to the launch-pad developed cracks in its side panels.

8.2.4 Moor

There are also many lessons to be learned from the PGVLAs experiments and experiences with mooring:

8.2.4.1 High mast v low mast

> "In discussing the problem of mooring to a mast we are at once involved in the advantages and disadvantages of high and low types of masts. ... At a high mast, the airship can take an angle of eight to twelve degrees, depending upon the height of the mast, before any part of the airship touches the ground. This angle can be kept to within two or three degrees as a rule. However, constant and careful attention to the trim of the airship is required while the airship is riding to a high mast. ... However, carrying out the maneuver of mooring to a "stub" mast is more difficult than with the high mast. There is a danger of some part of the airship striking the ground unexpectedly before the maneuver is completed and the airship is secured ... With ample ground crew, the maneuver can be made but the idea in developing handling methods is to get away from using man power." (Fulton, 1929:58/59)

> "Cost and size of stub masts for larger ships do not increase as rapidly as would be the case with high masts for the same ships. High mast is the more easily standardized for various sizes of ships. A set of stern carriage tracks for each length of ship would probably be required at a stub mast. None is required at the high mast. Tail drag paths are required at high masts, but not at the low. More level terrain is required at the low mast. ... *Stresses.* Moored to the low mast, the stresses during riding are probably greater that at the high mast ..." (Rosendahl, 1931a)

> "... wind velocities nearer the ground are frequently much less than those at the level of the so-called "high" masts; the fact that gustiness is greater a few hundred feet off the ground than at the surface; and that while vertical currents often exist at the level of the high mast they cannot blow into or out of the ground. The lower position should therefore be relatively safer." (Rosendahl, 1931a)

8.2.4.2 Lightning strike when moored

Curiously, although there are several instances in the records of airships that were struck by lightning when in flight, the author has thus far found no reports of any moored airship, nor of any large GH infrastructures, such as masts or sheds, ever receiving a strike, let alone being damaged by one.

> "Of the twenty rigids destroyed in fatal flying accidents (other than those lost by enemy action), it appears that well over half were lost from [violent vertical air currents in thunder storms] or from associated phenomena such as lightning strikes or static discharge." (Brooks, 1992)

8.2.4.3 Ground impact protection

> "However carefully the hauling-down be done, the ship is liable to be bumped against the ground by gusts, for though the landing party can prevent the ship getting away, it cannot deprive her of all movement. Small airships are usually not fitted with any more elaborate buffering apparatus than a pair of landing skids. But rigid and large non-rigid ships are in most cases provided with regular shock-absorbers, which usually take the form of buffer bags inflated with air under pressure. These effectively cushion the impact of the ship should she strike the ground, and, **in spite of their essential simplicity, have proved more satisfactory than the landing wheels and spring or hydraulic buffers which have been given a trial.**" (Pratt, 1920) **(GC emphasis)**

8.2.4.4 Icing and snow removal

> "Although the K [-type US Navy blimp] was rugged, and easy to fly, it was difficult to ground handle and dock in strong and gusty winds. When docking in a strong cross-hangar wind, she would heel over on her single landing wheel and tend to dig her prop into the ground. When moored out in heavy wet snow, it quickly became top heavy, requiring Herculean efforts to remove the props before they hit the ground, and even then sometimes laying over so far that the outriggers were damaged." (Mills, 2004:128)

8.2.4.5 Gas valves

Because gas valves for large airships need to be of large diameter to allow for a large volumetric flow but also need to operate at a comparatively slight differential pressure in comparison to the ambient air, it was found quite possible for losses to be caused by two means. Firstly, by inertia, if the airship rolled in a particular manner, and secondly from wind pressure, as gusts and slipstream caused movements of the outer cover surrounding the valve.

> "There was still the question of the [*R101*] gas valves. ... The cover was also flapping ... and it is considered possible that the gas valves may have been affected ...When these tests were run, McWade found that the valves remained closed up to and beyond the angle of roll of three degrees ... [but] did, however, begin to open at five degrees of tilt so that in extreme conditions of turbulence, with the airship rolling heavily, some loss of gas through the valves would be likely." (Masefield, 1982:228)

Over a prolonged period the loss could be substantial, although the quantity of gas lost by this means depended largely on the specifics of any particular gas valve's positioning and design. When starting from scratch, as is likely for the NGVLAs, even eminent airship designers have been known to get things wrong with their gas valve systems:

> "After the first trial flight [in 1920] the ship [*R-80*] was returned for repairs and modifications. The gas exhaust trunks were modified to prevent the build up of valved gas in the keel ..." (Kender, 2001)

8.2.4.6 Storms and headstands

> "On Sunday, 10th November, [1929] with the ship [*R101*] at the mast [Cardington] the wind began to rise rapidly and ... By the following morning ... was gusting at up to 60 miles an hour accompanied by heavy rain and squalls ... The peak of the storm came ... the wind reached 75 mph ... and at 1600 it registered 83 mph. Then it began to swing and in a cold front line squall, with torrential rain and hail, the wind changed direction through 135 degrees in the space of little more than a minute while gusting up to 89 mph accompanied by a drop in temperature of ten degrees [Fahrenheit] ... the airship swung with the wind and ... rode comfortably at the tower without violent movement ..." (Masefield, 1982:137)

> "With an airship at the mast, sharp irregularities in wind velocity (speed and direction) may affect the ship. These are of three general kinds: (1) common gustiness; (2) vortices, such as dust whirls; and (3) large scale wind shifts, meaning wind shift lines and squalls which bring a wind shift of sufficient duration to swing the ship and cause it to watch [*sic*] into the new wind direction." (Reichelderfer, 1935:98)

Which leads naturally to perhaps the most famous of the PGVLA GH events:

> "At about 1330, [on 25 August 1927] with the *Los Angeles* headed north-northwest, the stern started up ... It was evident that a wind shift was taking place ... as the stern ascended into the colder air at higher altitude, she rose even faster ... [and] reached an up angle of 85 degrees and was standing on her nose atop the [Lakehurst] mast. Then, swinging gradually to port, the airship began to settle toward the horizontal ... [she] had rotated through an angle of 150 degrees and was now heading approximately southeast ... she was housed in the hangar for a thorough inspection ... [and] could have flown immediately after her spectacular head stand, and all damage was repaired on the following day." (Robinson & Keller, 1982:152)

> "Even on the mast K-ships could act up and behave horribly. Wind flow over and around a hangar, superheat, or both could cause them to "kite," lifting their sterns high into the air and their cars well off the ground. Airships, when moored outside, had sandbags weighing thirty pounds [13.6 kg] on board for ballast. Even so, they sometimes kited eighty degrees, standing virtually on their noses." (Vaeth, 1992:42)

The fact that modern blimps now conduct this manoeuvre as a matter of course, and that the *Los Angeles* survived it without any ill effect, leads to the question of whether the VLAs of the future might not be designed to do so too, if they were suitably equipped for it - for instance, with gimballed control panels?

8.2.5 Load

The loading of the NGVLAs will inevitably be airship specific, and in view of the lack of previous attempts at building large airships specifically for the transporting of freight, this is probably the area where least can be gained from historical research. However there are lessons to be learnt from the PGVLAs and from other branches of aviation.

8.2.5.1 On the feasibility of in-flight loading

> "To such proposals as to eliminate mooring masts and landing fields entirely and land passengers from an airship hove-to several thousand feet in the air, by means of an elevator or bucket on a cable from the ship, it needs only be said that while they show a great faith in the airship, they also show a woeful lack of operating knowledge." (Rosendahl, 1931:307)

From which it may be assumed that Rosendahl would not have been a great advocate of the CargoLifter.

8.2.5.2 Vectored thrust

> "He [the director of the *Superman* films] wanted much smaller cartoon-style balloons with little metal seats underneath...we built them exactly as required and simply suspended them by wires from a helicopter... When the helicopter was stationary it created a horrendous rush of wind - even where we were, some 300 feet [91.4 m] below it. It made us shake uncontrollably and we felt desperately insecure. But when the aircraft was moving forward at just five knots the rotor wash dissipated behind us and all was well." (Prescot, 2000:126, 133)

8.2.5.3 Suspended loads

> "We ran through the same helicopter tests with some new barrels of water. The structure held fast. But what we had not contemplated was that each of the barrels on the ends of the three 300-foot-long wires would spin anticlockwise as the wires untwisted themselves." (Prescot, 2000:130)

8.2.6 Launch

There is much in the PGVLA records concerning the controlled transition from mooring to flight.

> "Taking off from the field is not difficult but requires man power to hold the airship prior to the take off. Casting off from a high mast is comparatively simple. Casting off from a stub mast is more difficult, on account of the danger of the tail striking the ground before the airship is clear of the mast. However, the maneuver ... is not so difficult as the maneuver of mooring to a stub mast." (Fulton, 1929:58)

> "The passengers paused long enough for photographs and then proceeded to the mast elevator at 6 p.m. ... Water ballast was dropped to trim the ship as two more stern rollers were uncoupled. The crowds ... heard bells in the power cars acknowledging commands as three engines started up. A policeman stood guard on the passenger platform of the mast while above him four men on top of the mast head awaited the release of the mooring eye from the cup. At 6:17 p.m. the gangway was shipped. Booth leaned from the control car window and signalled the release of the fourth stabilizing weight. One minute later cheers rose from the crowd of 200,000 gathered in a horseshoe which stretched two miles from tip to tip. ... The *R100* [preparing for 24 hour flight] ... slowly withdrew from the orange and black mooring masthead and stopped 200 yards from the mast before reversing her Rolls-Royce engines." (Countryman, 1982:84-85)

> "We watched the [*LZ-127* Graf] Zeppelin being slowly towed out of the hangar into the night and had we leaned out ... could have touched the heads of the ground crew as they removed the heavy cement blocks which acted as ballast and which hung by hooks from a rail which circled the gondola. In perfect order, and in sequence, each man removed a block and took its place as equalising ballast on the rail. The exciting moment of "take-off" had arrived and at a signal the men on the rail heaved **downwards** and let go." (Davies, 1998/99) **[GC emphasis]**

"The car party will lift the car clear of the ground while the linemen slack their lines. At the command and signal "Down," the car party will let the airship [*Aeros 40B Sky Dragon*] [1] return to the ground and when the car is at the bottom of its downward travel, the crew chief commands "Up-ship," at which time the car party thrusts the airship up and into the wind." (Worldwide Aeros Corp. 2001:03-19)

"It is early morning – 3 a.m. to be exact – before we [*Hindenburg* at Frankfurt in May 1936] begin to show signs of definitely getting under way. The huge hangar is suddenly brilliantly lit; there are sounds in the distance of marching men and staccato military commands; and the passengers who have retired to rest begin to emerge ... Underneath our windows appear a double row of hefty and khaki-clad youths ; the atmosphere has turned noticeably cooler, and ... we can see that the huge door at the far end of the hangar has been opened ... Subdued whirring noises indicate the starting-up of the engines ... Another half hour goes by ...The ship's nose is firmly grasped in the cup of the moveable mooring mast, which stands on its rails ready to precede us out into the open. Almost another full hour elapses, however, before everything is finally judged to be in order ; Zeppelin captains can afford to take no risks. At last a final whistle blows and, tugged along by the travelling mast and held in line by the rows of khaki-clad men below us on the ground we move slowly and majestically down the shed and out into the open landing ground. Once outside, however, all hesitation vanishes ; everything is now speed and animation. Swift command succeeds swift command ; in a twinkling, as it were, we are free of our mast, free of the two long lines of men beneath us, and soaring quietly into the upper air. Quickly the engines come into play and we climb ..." (Coke, c.1937:86/7)

However, it is all utterly dependent upon the skill of an experienced ground crew:

"... the experimenter with dirigible balloons must be continually on his guard against little errors and neglects of his aids. I have four men who have now been with me four years. They are in their way experts, and I have every confidence in them. Yet this thing happened: the airship was allowed to leave the aerodrome imperfectly inflated. Imagine, then, what might be the danger of an experimenter with a set of inexperienced subordinates." (Santos-Dumont, 1904:258/9)

8.2.7 Capture

So too, with the controlled transition back again from flight to mooring - the archives hold a wealth of thought-provoking material and reveal many issues that are not immediately obvious but which may have some profound effects on any future NGVLA projects.

8.2.7.1 Wind speed and direction

"... if during the mooring operation, the wind changes direction to any considerable extent, there is a danger of having the wires foul the hull of the ship and also of diminishing their usefulness if their anchorages cannot be readily corrected to the new wind direction. Also it has happened on occasion that the wind direction at the level of approach for landing is diametrically or widely divergent from that on the surface, so that the ship approaching into her own wind direction actually spirals down as she approaches nearer to the surface." (Rosendahl, 1931a)

"Even now, however, we [*Hindenburg* at Lakehurst in May 1936] are not completely 'home.' Our old enemy the wind is especially strong on the ground, and great difficulty is experienced by our landing party in mooring the ship's nose to the grip of the landing mast." (Coke, c1937:93)

"It would appear that ... [*Akron's*] vertical thrust might be of considerable value in overcoming vertical gusts; experience may substantiate this. However, from the suddenness with which gusts strike and from the relative sluggishness of human reactions, I believe the use of vertical thrust during the mooring operation in gusty weather will be a ticklish procedure. " (Rosendahl, 1931a)

8.2.7.2 Static electrical charge

"When a ship was coming in to land ... the wire of the airship [*R33* in 1921] would be dropped, and a man standing in attendance would quickly couple the ends of the two wires together. He

[1] The *Aeros 40B Sky Dragon* : length 43.5m (143 ft), volume 2,508 cu m (88,570 cu ft) = 3 tonne mass

had to be careful to be sure that the airship wire touched the ground before he handled it in order to discharge any static electricity picked up by the airship in flight." (Williams, 1974:137)

"The second problem was that as soon as the ground crew grabbed the [water-filled] barrels [suspended on 300-foot long wires beneath the helicopter] to guide them gently to the ground, they received a fairly aggressive electric shock as the static in the dry air built up in the wires and discharged itself into the ground." (Prescot, 2000:130)

"Sadly, *Schwaben* was destroyed by fire on the ground at Düsseldorf after an excursion flight. The cause was discovered to have been static electricity, which had built up while in flight and caused a spark when two of the rubberised gas-cells rubbed together, igniting hydrogen which was escaping through the valves. The conflagration consumed the ship." (Mowthorpe, 1999:74)

8.2.7.3 Vertical deceleration

A proven technique that would be hard to re-introduce in the light of current health and safety regulations.

"The members of the crew were so trained that when approaching the ground [with a "heavy" ship], every dispensable man climbed outside of the car and hung suspended by his arms from the hand rail. At a distance of six or eight feet above the ground, a signal from me would send them jumping, thus relieving the ship of sufficient weight to check its downward speed. ... The trick in making a safe landing had always worked nicely, although to the uninitiated it must have appeared like an "abandon ship" maneuver." (Lehmann & Mingos, 1927:3)

8.2.7.4 International flights

How will large freight-carrying NGVLAs that do not land when they deliver suspended payloads to remote locations at the end of international flights, conform to the rules of customs and excise?

"... at the third attempt [*Hindenburg*'s] nose tip is at last successfully clipped, and a few seconds later the gangway is let down, and the immigration and police officials clamber on board." (Coke, c1937:93)

8.2.7.5 Stand-by and crew boredom

"Simply put the tasks of a ground crew can be stated as three;
to launch and capture the airship
to keep the airship secure when it is moored, and
to stay sober on days off." (Backlin, 2002)

Although this statement was made in jest by an experienced blimp pilot, it does bring to light a serious under-lying problem - one that faces all airships regardless of their size or the size of their ground crew. The life of a ground crew is not an easy one and in particular the long and unsociable hours of either waiting for an airship to return to base, or of simply keeping watch over it while it is moored, can be boring in the extreme. However, these irregular periods of enforced inactivity are interspersed with hyper-active bursts of work that are often very hard physically, (e.g. moving and loading ballast weight or installing ground anchors) and occasionally dangerous (e.g. running after mooring ropes and climbing inside or on top of the airship). Furthermore, periods of relaxation may be interrupted at any time by an emergency call for all hands - as when a storm arrives or a gas cell develops a leak. This unpredictable life-style with the conflicting stresses of boredom and adrenaline attracts fit young people for whom alcohol can become a problem - especially when the whole exciting circus then goes on the road.

8.2.8 Camp out

As explained in **Section 6.4**, airships other than blimps, and particularly the very large airships, have never actually been "battle-hardened" to the extent of being able to survive for any length of time away from their sheds. The consequence is that there are many unanswered questions and unresolved issues for those NGVLAs intent upon such a cost-effective and independent way of life.

8.2.8.1 Setting-up and removing temporary bases

> "*The Preparation of the Bases* - In Oslo, at Vadsö on the northern coast of Norway, and at King's Bay in the Spitsbergen islands, we [the Italians during preparations for the *Norge* North Pole crossing in 1926] had to create outright the whole organisation necessary for receiving the airship, refuelling it with hydrogen and petrol, and carrying out any repairs that might be necessary. The Oslo base, being simply intended to satisfy the desire of the Norwegian people to see the dirigible, was not particularly important in itself. Still, we had to install a mooring-mast, with all the accessory services and requisite materials." (Nobile, 1961 : 19)

> "The most dangerous time for a blimp is while it's mooring mast is travelling down the road." (Backlin, 2002)

Or when it is caught out by the weather:

> "In the 1980's in upstate New York, he [Goodyear blimp pilot Don McDuff] and his co-pilot, trapped in a line of thunderstorms building up to 50 thousand feet, fought against updrafts carrying the airship to dangerous heights ... and miles away from his own ground crew, but coincidentally (and luckily), another airship crew was in the same area, moving in the opposite direction. They provided a respite from the hair-raising adventure by landing Don's airship and refuelling him while the storm passed." (Riley, 2003)

> "There exists also the additional need for having outlying servicing stations which are not so pretentious or expensive as those possessing a hangar and repair facilities, etc. In other words, airships require not only navy yards or docking yards, but harbours as well. The facilities at airship harbours are those comparable to wharves, moorings, and anchorages for surface vessels, including fuelling, watering, and provisioning arrangements. For an airship, these will consist of a mooring mast and certain servicing facilities that can be conveniently grouped around it." (Rosendahl, 1931a)

> "More important was the refuelling base at Vadsö, and still more so that in King's Bay. The preparation of the materials to be sent to these two bases was made in Rome with the greatest care and lavishness; so that when the time came we should have at our disposal everything which at the last moment might appear necessary. The wisdom of these precautions was shown by the fact that at King's Bay we had to change one of the [*Norge*] engines, replace the rudder, and repair the lower part of the keel. The mooring-masts at King's Bay and Vadsö were entirely built in Italy. The Vadsö mast was set up under the supervision of our chief technician Rossi, helped by three of our workmen. To King's Bay, where both mast and hangar, designed by us in Italy, were built by the Aeroclub of Norway, I sent several officers and workmen, and, to make meteorological observations, my brother, Amedeo, a doctor in physics." (Nobile, 1961 : 19)

> " "Semi-portable" and "expeditionary" masts of either the high or stub varieties have been put into use after quick erection at outlying places. The "floating" mast and base, as represented by the installation on the airship tender *Patoka*, have been in use for a number of years." (Rosendahl, 1931a)

However, the record books show that in terms of living the outdoor-life, although they achieved some great feats and made many impressive flights, the PGVLAs were really very dependent on their sheds:

> "Technically, the *Los Angeles*'s performance ... had been impressive ... for she had been away from the Lakehurst hangar for 27 days, based solely on mooring masts, and had travelled 14,500 miles ... This exceeded the time away from Lakehurst, and the distance covered by the *Shenandoah* in the West Coast flight in 1924." (Robinson & Keller, 1982:170)

8.2.8.2 Breakaway and emergency pursuit

Normally the term "breakaway" brings to mind an airship that is torn from its moorings. Thus the image is one of the *R33* or *ZR1* both of which successfully limped home with large holes torn in their noses after breaking away from their mooring masts.

"The break-away of the *Shenandoah* [*ZR1*] from her mooring mast in January 1924, was due primarily to the jamming of the spindle in its bearings so that the ship was deprived of its freedom to roll, and the large twisting force caused in part by the collapse of the top fin resulted in the longitudinals being torn from the bow cap which carried the bearings of the spindle." (Burgess, 1927 : 282)

However, there may be other circumstances that call for logistical ground support in the case of an unplanned or abnormal flight. These two examples from the list of "Unassisted landings" compiled by the author (and shown in sample pages in **Appendix K**) illustrate the point.

SL 1 made her first flight on October 17th 1911. A control cable broke and the ship made a forced landing across the Rhine, lying overnight in an open field while repairs were being made and gas added. Next day the ship took off and after three and a half hours of circling over Mannheim, she returned to the Rheinau shed.

German Naval Airship L.15 (LZ.48) : October 14th 1915 : Forced landing through fog on moorland near Altenwalde after running out of fuel. Gondola struts and some girders broken by impact. Ground crew arrived by lorry within an hour and walked the ship three miles back across country to its base at Nordholz.

Such events were common occurrences for the small blimps of the First World War and they were not uncommon for the large rigids either, although none of the real giants ever made one. The corresponding idea of "Forced flights" as opposed to forced landings was however conceived as a possible good reason for the abandonment of the British Imperial Airship Scheme.[1]

However, the idea of an "intermediate"[2] or a forced landing is an alien concept to modern HTA aviation but the soft-impact, low-speed crash cannot be ignored as a possibility for the NGVLAs. For example, the question has to be considered of what would happen if a non-rigid, single-skin, VLA moored to a mast in a storm, had its nose cone torn off? A lot would plainly depend on whether the gas cell was ruptured or not and whether there were any crew on board at the time, would obviously play a big part in the events that followed. It can however only be conjectured how quickly the airship would deflate (bearing in mind that the wind will initially be trying to push the escaping gas back into any forward facing hole) and so too whether the ARDD (see below) would operate successfully after a major hull rupture? From the GH perspective, such questions are to a large extent irrelevant, because either the airship survives and then needs to make a landing somewhere, (and somehow) or it is crippled so badly that it crashes downwind of the mooring site. In either case the ground crew will have plenty of work to do.

Moreover, from the GH perspective the difference between a rigid and non-rigid in such an event is again minimal as both will leave a trail of wreckage, of unknown length, that may or may not include crew members who are a) over-excited; b) traumatised; c) injured or d) dead. How far the damaged hull would actually drag, or roll, or fly again, across country is again unknowable but the time/cost/effort involved in clearing up will obviously be affected by this and by other factors such as:

- the weather (visibility, precipitation, temperature, wind-chill);
- the terrain over which the damaged airship has passed (or is strewn,)
- vehicular access to the crash path, and
- the time of day (dark or light?).

---

[1] See (Neon, 1927 : 20)

[2] Regarded as a commonplace and perfectly normal procedure for sport balloons of all types and sizes

In all such events the ground crew are most likely to be not only the first to know what is happening, but also to understand all likely repercussions and possible mitigation strategies. They will thus be best placed to alert emergency services, if needed, or just to stand-by themselves with the right spare parts.

8.2.8.3 Deflation

A final issue that is not currently known or understood within the confines of the HTA world today concerns the controlled removal of the lifting agent without damage to the airship. This can take place in a planned manner - inside a shed [1] - or as a result of an unplanned event - breakaway or forced flight. In both cases, with small blimps, and hot air balloons, it has been found vital to fit them with a rapid deflation device (RDD) or "rip" system that is sometimes automated (ARDD). Whether such a device will be effective for the large gas volumes of the NGVLAs is debatable, and whether the risk of an essentially untestable rip-activating system not working when it is needed to outweighs its potential to go off accidentally when not activated, along with the costs of both in human and financial terms, is again something that will need to be decided. Here are some examples from past experience:

> With Second War Blimps : "... with practically a zero ground speed we decided that it would be impossible to get to the mainland. ... it was decided the only thing to do would be to land the ship [US Navy blimp *J-3*] at Beach Haven. A crowd of from 50 to 100 people had gathered directly below us, and we dropped our trail rope to the ground and shouted to them to hold on and act as an anchor, the intention being to hold the ship in the air high enough from the ground so that we could continue to run our motor without danger to the personnel and keep her directly over the ground crew and to let the gas out of the envelope by pulling the rip cord. ..." (US Congress, 1933 : Thornton, 429)
>
> With First War Blimps : "The captain of a non-rigid always had another choice. In extreme cases he could 'rip' the envelope, causing instant deflation. A seam sewn along the top of the envelope led to a 'ripping-cord' adjacent to the coxswain. A stout pull – about 30 lb. – broke this seam which then released the hydrogen into the air. Although the sudden loss of lift dropped the car(s), engine and crew violently onto mother earth, it seldom caused irreparable damage to the structure or serious wounds. However, this last-ditch operation was seldom used." (Mowthorpe, 1999:20/1)
>
> With a modern Roziere long-endurance balloon : "However, Fossett [on one of his round-the-world balloon attempts] reported that the landing took place in 20 knot winds and that for a time he feared being "dragged forever" as an explosive squib designed to separate the envelope from the capsule failed to fire." (Moyer, 2002)
>
> And with another equally problematical emergency system fitted to a similar Roziere balloon : "... the two men [Lindstrand and Branson] took particular care as they prepared to jettison their first empty fuel tank. As soon as the switch was thrown, and the explosive detonator had severed the tank from its housing, the balloon [*Pacific Flyer*] wrenched upwards ... Branson and Lindstrand knew that something had once again gone wrong with the system of holding the fuel supplies to the capsule. As well as dropping a single empty fuel tank, they had jettisoned two further full tanks ..." (Jackson, 1994 : 199)

[1] Althoff, 1990:261/2

9 A BRIDGE ACROSS THE KNOWLEDGE GAP

The second aim of this thesis is to show that by studying the historical records it is possible to expose and correct some of the misunderstandings that have arisen over the years concerning the capabilities of the PGVLAs, the operational procedures that they actually used, and their the GH systems. Furthermore, extracting knowledge from such first-hand material as survives in the archives, also makes it possible to answer some of the difficult questions uncovered by the author during his participation in the CargoLifter project. These questions were seen to cause confusion and doubt in the minds of designers, regulators, financiers and expert engineers alike, and which thus appear inevitably set to aggravate the formidable task of tackling the NGVLA GH problems. It is the author's opinion that, these misunderstandings are among the generally unrecognised, but more serious, obstacles standing in the way of the development of future NGVLA GH systems. The aim of this section is thus to demonstrate that some of these difficult GH questions can be answered by HR, or at least, that sufficient information can be found concerning them, to enable decisions to be taken, which will greatly diminish the risks and improve the costs, the timings and the safety of any future VLA GH systems.

9.1 Common airship fallacies

The existence of myths, misapprehensions and plain wrong ideas concerning nearly all aspects of airships and their operations, is a well-known problem that has long been the subject of comment and lament by the cognoscenti:

> "There is much misunderstanding and confusion regarding the loss of performance of airships resulting from decrease in the lift of gas, especially from the use of helium instead of hydrogen." (Burgess, 1927:37)

> "Unfortunately too, incorrect information occasionally gets adrift and remains uncorrected, retraction as we know, being the height of uselessness." (Rosendahl, 1931:viii)

> "So far as the layman was concerned the airship world at large might just as well have been a secret society, for all that filtered down to the level of Fleet Street in an age of wartime secrecy and an impoverished media, impoverished, that is in intellect. The result has been a legacy of legends and myths which have prospered and survived. The popular idea of life in the world of airships was, at best, sketchy – while at the opposite end of the spectrum it has become universally ludicrous." (Chamberlain, 1984:xiv/xv)

> "The biggest stumbling-block in the path of airships today is misunderstanding. There is but a comparative handful of people in the world today who have first-hand knowledge of them." (Rosendahl, 1938:361)

Nevertheless, there have been some previous attempts to rectify matters:

> "COMMON AIRSHIP FALLACIES – The following six inventions constantly recur, and have been submitted to the [US] Navy Department many times by aspiring inventors. It is hoped that the explanations of the fallacies of these inventions may save some future inventors much wasted efforts and subsequent heart-burnings. The six inventions are:
>
> 1. The vacuum airship
> 2. Compressing gas or air for ballast
> 3. Artificial control of superheat
> 4. Combined heavier and lighter-than-air craft
> 5. Channel through the hull to reduce resistance
> 6. Wind screen at mooring mast"
>
> (Burgess, 1927:285)

While the first five of these inventions would plainly have varying degrees of impact upon GH, they are more properly to be classed as problems that affect the design and flight operations of an airship. Thus, only Burgess's answer to item six on his list is considered to be within the scope of this present work:

> "By far the most important stresses in an airship lying to a mast result from the transverse wind forces upon the ship, and in fact longitudinal tensions are usually desirable because they reduce the compressive forces resulting from the lateral bending due to the transverse air forces. A wind screen around the bow of the ship would undoubtedly reduce the longitudinal tension, but owing to increased turbulence which it would cause in the air flow it would probably increase, rather than decrease, the transverse forces along the greater part of the ship." (Burgess, 1927:290/291)

Moreover, it should be noted that the truth of this assertion had been confirmed in practice some 15 years previously, when, in May 1911, the very first British-built rigid airship, *No.1r "Mayfly"* was moored, in the Cavendish Dock at Barrow-in-Furness to a floating mast that was fitted with just such a wind screen:

> "This latter contraption [*Mayfly's* mooring] consisted of a pontoon secured by a pivot at its windward end to a concrete bollard sunk in the dock floor ... On the pontoon was a 38-foot mast inclined 23 degrees to windward and attached to it was a cross yard with canvas strips designed to act as a baffle. It was calculated that in a steady 80-mph wind the strain on the nose of *No.1* [*Mayfly*] would amount to only 4 tons. However, as the screen showed a tendency to be steered by the ship, rafts and 5-foot sideboards in the manner of a Thames sailing barge were added to the pontoon. As this also proved inadequate, the baffle was removed and the ship then ceased to yaw so badly ..." (Higham, 1961:48)"

However, despite their constant and frequent refutation, these, and similar misunderstandings persist. Worse still, they can be seen to be actually increasing in number as each new generation is further removed in time from the actual events, and unwittingly builds on previous distortions to add another layer of erroneous "Chinese whispers" to the mixture.

9.2 Myths and misunderstandings

One recent example of this phenomenon, as already shown (in **Section 2.2**), is that there is today some misunderstanding as to the meaning of the term "flying moor" and what was actually involved when an airship carried out this procedure. As always with GH the devil is in the detail. Here again is the erroneous statement:

> "The airship [*R101*] was **flown onto the mast** which often proved to be a long and tedious process. Masts were also developed in the United States. For example, the last United States rigid airship, the '*Macon,*' used a large and substantial mast. The mooring line was attached prior to docking to enable it to be winched onto the mast. **Such a technique is much less fraught with danger than that used by R101.**" (Howe, 1999:307) **[GC emphasis]**

To investigate the misunderstanding it is first necessary to put the airships mentioned into context. The British *R101* (along with it's sister ship *R100*) was operational from 1929 to 1930. The American *Macon* (*ZRS-5*) was operational from 1933 to 1935. Thus, as is correctly implied, the British system was the forerunner, however, the idea that the mooring methods used by these airships were very different, or that the technique used by the British was markedly inferior, is simply wrong.

Furthermore, from this author's experience at CargoLifter, the worst part of this error is the implication, given in the first line, that the British were actually using a technique which permitted a large airship to fly directly onto a mast without the use of mooring ropes or lines. But, no such technique was ever used, and thus the assumption that one does exist, perhaps in a flawed state, and consequently that when found, it may be amenable to modification by application of modern analytical methods, or be brought to cost-effective perfection by means of some new computerised, GPS-guided, thrust-control, is in itself flawed.

What is true is that the *R101* (and *R100*) were moored to a high mast, whereas the *Macon* (and *Akron ZRS-4* before it) habitually moored to a low or stub mast, however, as shown by the following selection of quotes, the method by which they did so is not very different. Here is the real story:

> "In 1919, Pulham finally erected a 'high mast', especially for mooring rigid airships, together with a practical mooring method. This basically meant that the airship flew to the vicinity of the mast dropping a line. This line was connected to [a] line from the mast, laid out across the airfield, then the airship was winched in until a special fitting in the nose connected and locked with a mating piece at the mast-top. There the ship rotated with wind, secure. ... It was a highly refined version of this Pulham mast which was erected at Cardington, Montreal and Ismailia for the proposed Empire routes which the ill-fated R.101 and her sister-ship R.100 were to have used." (Mowthorpe, 1999:64)

In fact, the *R100* did use the high masts at both Cardington and at Montreal and here, in some detail is the procedure that was used on the latter occasion, at the end of that airship's 8th flight.

> "With streaks of dawn showing in the eastern sky the *R100* [on her first landing in Canada] swung in narrowing circles about the St Hubert field. A few minutes before 5 o'clock she turned toward the mooring mast. On the passenger platform stood Lieutenant Commander Pressey, the landing officer, and his assistant at the cabinet controlling all the mooring machinery ... The *R100* had to valve little hydrogen, having collected almost 5 tons of rain water in her ballast bags. As she slowly approached the mast head from the east at a height of about 500 feet, her 900 foot long mooring cable snaked down in swinging loops to the ground. Her aft engines were put in reverse. Pressey's 14 men, 3 of whom watched the winch drums, allowed the wire to discharge any static electricity in order to avoid a severe shock. ... With not a breath of wind the main wire was secured by three of the ground crew and spliced to the ¾ inch cable which had been led from the top of the tower through the mooring arm to a spot determined by the direction of the wind – airships approached a mast head to wind. The ground crew signalled to the ship and the tower. As the engines eased off a little more the cable became taut. ...At 5:13 am, as the variable speed, electro-hydraulic winch was slowly reeling in the wire the airship dropped her first water ballast from frame 3 in the bow to keep an even keel. ... The 750 foot starboard yaw guy was paid out 4 minutes later, coupled with a yaw winch cable from the base of the tower and carried to a snatch block on one of the 24 concrete blocks spaced at 15° intervals on the circumference of a circle of 750 foot radius. ... The port yaw guy dropped and was seized by the waiting ground crew and coupled to the mast's second yaw cable. The last engine stopped at 5:25 am, but the ship continued to release ballast, some of the water drenching the ground crew and those on the passenger and searchlight platforms. ... Dungareed mechanics climbed out of the silent engine cars as the ship's dew drop neared the mooring cup. ... Pressey called "Ship secure" at 5:37 am Friday, August 1 as the ram contracted and locked, allowing the airship to swing freely. ... The mooring in a record 27 minutes versus 35 minutes at Cardington was a signal for rolling cheers from early risers and those who had remained all night." (Countryman, 1982:58-62)

This procedure is identical with that used, in the same year, by *R101* at Cardington, and as can be seen it was neither particularly "long" nor "tedious" - even when the Americans had first tried it out for themselves, six years previously and suffered an equipment failure in the process.

> "On the evening of 14 July [1924] Lansdowne made his first flying moor to the mast, using the English method. The wind was steady at 15 mph, and the ship was at all times under perfect control. The time from the dropping of the main mooring wire until the *Shenandoah* was secured to the mast was 46 minutes, a delay being caused by the failure of the port yaw guy winch to function." (Robinson & Keller, 1982:86)

Thus, in summary:

"To make the usual "flying moor" – as opposed to the more cautious approach in which a large ground crew would first take control of the ship and then walk it up to the mast – the airship would fly slowly towards the mast and drop three wires – a mooring wire and two yaw guys – from the nose. All three would be connected to lines leading to winches at the mast, the mooring wire to one through the top of the mast and the yaw guy lines through the most suitably placed pair in a ring of "snatch blocks" set into the ground in a circle around the mast." (Mowforth, 1991:35)

And here is American confirmation, written by one of those who, as a US Navy ground crewman, had real personal hands-on experience of large airship GH - up to and including *LZ-129 Hindenburg*.

"The procedure for a high mast flying moor follows. The airship approaches the mast slowly headed into the wind at an altitude of about 200'. The mooring wire from the mast has previously been laid out on the ground some 500' to leeward from the mast. As the nose of the airship reaches a point above this mast wire she lowers her main wire to the ground where it is connected with a special coupling to the mast wire. The airship is allowed to rise statically taking the slack out of the mooring wire. The two yaw guy wires are then sent down to the mast head on messenger blocks and connected by couplings to the two yaw winch wires which have already been led from the winches at the base of the mast to fairlead snatch blocks located about 60 degrees to each side of the mast on a 500' radius circle. One of these fairlead block anchorages is located every 7 ½ degrees around this 500' circle so that the ship can moor headed into a wind coming from any direction. The slack is taken out of the yaw lines and all three winches controlled remotely from the mast head pull the airship slowly into the mast until the airship cone is locked in the mast cup. **This procedure is an easy one and can be accomplished with a ground and mast crew of less than a dozen men.** The ship can remain moored to the high mast for any desired length of time." (Walker, 1975:301/2) **(GC emphasis)**

Thus the term "flying moor" in it's true meaning, indicates that the airship remains in flight while its mooring lines are connected to the GH equipment. This is to distinguish it from the method that preceded the use of a mooring mast but which remained that preferred by the German airship experts. Namely:

"The original procedure with *R-24* at Pulham was first to walk the ship to the vicinity of the mast from the hangar, or after landing to a ground crew, connect the mooring wire from the ship to a wire from the mast head, allow the ship to rise statically, and then have the mast winch pull the ship into the mast connection. Later in 1919 the ship was able to make flying moors to the high mast using a ground crew of only half dozen men to connect the wires and operate the winch. Static takeoffs from the mast could be made with even fewer men. Riding out to the mast only one man was needed to operate the ballast pump, and two men aboard to attend the elevator and ballast the ship." (Walker, 1975:301)

"The *Hindenburg* [in 1936] was equipped for either mechanical or manual ground handling: Luftschiffbau Zeppelin personnel, in contrast to the U.S. Navy's, preferred to fly the ship to the ground and walk it to the mast, rather than to make a "flying moor" with the ship approaching the mast in the air and then being hauled down by the main mooring line." (Dick & Robinson, 1985:95)

However, the equipment used in both Britain and America was the same.

"While different in appearance from the Pulham mast, the Lakehurst mast [completed in May 1922] was designed on British principles, and the mooring equipment at the masthead was a copy of that designed by Major Scott for the mast at Pulham. The Lakehurst mast was a stout three-legged steel tower measuring 148 feet to a large lower operating platform, and 160 feet high overall to the gimbals supporting the female cup into which the male cone on the bow of the airship fitted, to be held by heavy clamps." (Robinson & Keller, 1982:74/75)

"The [US Navy] bureau certainly intended that mast mooring [for the *Shenandoah ZR-1*] should take place according to British methods, as set forth at length in reports by Land, Maxfield, and Hoyt on operations with *R33* at Pulham in the spring of 1921. This involved laying the main mooring wire from the mast head out along the ground for about 600 feet in the direction from which the ship was approaching at an altitude of 500 feet. The ship dropped the end of her own 450-foot mooring wire, which was coupled to the mast wire on the ground, and she then released

500 lb of water from an emergency bag forward and rose to about 1,200 feet, approximately two tons light and trimmed down by the tail. She was then hauled down by the winch at the base of the mast reeling in the main mooring wire. At an altitude of 500 feet or so, the ship released two 450-foot yaw lines made fast to the nose. These were coupled to the mast yaw wires and led to snatch blocks bearing approximately 60 degrees from the wind direction, and through the snatch blocks to the yaw winches at the base of the mast. All three lines were reeled taut; then, while the main mooring wire gradually hauled down the ship's nose toward the masthead, the taut yaw lines ensured that she would not swing from side to side, or worse yet, move forward to impale herself on the masthead." (Robinson & Keller, 1982:75)

But, the Americans suffered some unpleasant experiences with their high masts and this led to their devising the low or stub mast. Doubtless it is this that has fuelled some of the misunderstanding as to the meaning of the term "flying moor" even though in truth the attachment procedure remained unchanged.

"But before going into the low mast development, let us put the high mast to bed. In 1925 and 1926 the *R-33* was put back in commission for mooring experiments to the old mast at Pulham and the new permanent 200' mast completed in 1926 at Cardington for *R-100* and *R-101*. The *R-100* used the Cardington mast and the one at Montreal for flying moors on all her flights, and *R-101* made all her flights from and to the very expensive Cardington high mast. It does not appear that the high mast has any real future for a rigid airship program based primarily on the excessive cost of permanent type high masts." (Walker, 1975:302)

"As any future rigid airship program will almost certainly involve some type of low mast mooring, a detailed description of the procedure seems appropriate. The mooring mast is located in the exact center of the riding out circle. At Lakehurst two tracks were provided at circle #1, one on a 438' radius for the *Los Angeles* and her rideout car and yaw guy cars, and a second track on a 643' radius for the *Akron* and *Macon*. Making a flying moor to a low mast is a relatively easy maneuver. The main wire is laid out on the ground 500' to leeward from the mast cup with the coupling eye located at the landing flag. The two yaw guy anchor cars are spotted forty degrees to right and left of the landing flag, or about sixty degrees right and left from the mast cup on the railroad track." (Walker, 1975:303/4) [1]

Thus there are still three wires (1 main line, 1 port yaw guy and 1 starboard yaw guy) and these are dropped from the airship and connected by the ground crew to the ground-based winches. The only significant difference is that in the American system the yaw lines are attached to mobile, rail mounted vehicles ("anchor cars") whereas in the original British system these are fixed "anchor points" that cannot be quickly or easily repositioned if the wind shifts. The importance of the yaw lines and the expensive consequences of not having something to prevent the airship over-riding the mast were demonstrated by an incident that may well have influenced Major Scott in the design of his patented mast head equipment:

"On 21st June [1921] after a thirteen hour trip ... she [*R36*] came in [to Pulham] for what at first appeared to be a normal mast landing in almost flat calm conditions. Having too much way on, the ship overrode the mast and her mooring wire fouled the winch, bringing her up with a jerk that was strong enough to cause the inadvertent release of two forward emergency ballast bags. The bows pitched up sharply, and the lightened ship rose to be brought up standing a second time at the full length of her cable. The severe jerk caused the bows to collapse aft of frame 1. Later, Scottie [the captain] observed that he had experienced jerks just as severe in *R33* without damage. *R36* was brought gently to the ground by valving gas, and while a small handling party manned the guys Scottie examined the damage and ... decided that it would not be safe to fly to the only vacant shed, which was at Howden. ... work was immediately put in hand ... to make room for *R36* [in the Pulham shed]. Unfortunately when *R36* was halfway into *L64*'s berth at 4.30 in the morning the wind rose sufficiently to blow her sideways onto the shed door and damage her port amidships. She never flew again ... [and] was dismantled in 1926." (Johnston, 1994:47)

[1] NB: The Cardington high mast was 61.5 m (202 ft) high. The nose of *CargoLifter CL-160* was estimated at 45 m (147 ft) agl.

Moreover, the vital importance to the NGVLA projects of having experienced and well-trained crews, both on board the airships and on the ground, is also borne out by the American's experiences in learning how to use the tried and tested mast mooring system that they had acquired from the British:

> "Yet when McCrary [Captain of *ZR-1 Shenandoah*] finally attempted a mast mooring, [the first ever in the USA and his first to the new Lakehurst mast] he rejected the well-tried British method and instead followed a procedure dreamed up by his German advisor, Anton Heinen, who had absolutely no experience with mast mooring and had never seen it done! ... He proposed [in his paper "The Operation of Securing an Airship to the Mooring Mast"] that the ship approach the mast "not more than 50 feet above the mast cone" and then check her way by running two engines in reverse. The *yaw* lines (not the main mooring cable) were then to be dropped and rove through the snatch blocks, after which the main mooring cable was to be dropped. During the process the ship, already dangerously close to the masthead, was free to move forward into the mast unless restrained by the engines running in reverse. ... The moment of truth came on 5 November, [1923] when McCrary made his first attempt to moor to the mast using the Heinen method, and experienced total frustration. Late in the afternoon, at 1645, the ship took off after being carefully weighed off on the field. McCrary anticipated she would become heavy with the approach of sunset, but in two attempts to moor to the mast, the *Shenandoah* proved to be light and rose as the engines were set on "idle." The only way to land her would have been to valve helium, which McCrary was not willing to do, and he finally abandoned the attempt owing to the onset of darkness. "The failure to accomplish the mooring on these attempts was not due to any material failure or design," wrote McCrary. "No, it was the method!" wrote Truscott [chief designer of *ZR-1*] on the cover sheet." (Robinson & Keller, 1982:75)

As to the origin of the "flying moor" myth there is a clue in the use of the words "long and tedious" which might indicate that the author has been influenced by the "axe to grind" problem, as explained in **Section 3.4.2.6**, wherein Neville Shute Norway in his memoir "Slide Rule"[1] makes sneering reference to the mooring system devised by his competitors. If true, this is evidence of a far older myth that is still spreading its malicious influence after 45 years, notwithstanding the many less famous, although in some cases far more authoritative, writings to the contrary, that have been produced since. For example, these references by the officer on-board the airship who was actually in charge of conducting the procedure, in contrast to Neville Shute who was only an occasional non-participating observer:

> "For an hour or so we [*R100* on 1st flight]" cruised in the neighbourhood of Bedford and Cardington, and eventually dropped our mooring-wire at a few minutes before 13.00 hours. Our cone was secure in the cup on the tower at 13.30." (Meager, 1970:155)
>
> "We dropped our wire at 15.45 hours and were secure at 16.15 hours ... [*R100* 2nd flight]" (Meager, 1970:163)
>
> " ... we came up into the wind to make a mooring [*R100* 3rd flight and 1st night landing]. As a mistaken aid, the searchlight was shone at the control car and so blinded the Cox'n that we had to request that it be shone [on the ground crew] ... This they did at 22.05 and at 22.40 we received the 'Secure' from the Tower Officer ..." (Meager, 1970:169)

This is not to say that the system was perfect. There were of course many times when there were problems that delayed matters, such as a broken winch or wire, however, in general the time taken seems to have been around half an hour, and contrary to Shute's myth-creating false witness, this is also borne out by independent unbiased testimony from the USA :

> "A "flying moor" can be made to a high mast in a few minutes time and with the assistance of only a handful of men. ... the time for mooring to the *Patoka* mast has run from seventeen minutes to an hour with an average time of around thirty minutes." (Fulton, 1929:58)

[1] Shute, 1954

And finally, while considering myths associated with mooring masts, it was thought by some at CargoLifter that mooring masts were actually totally unnecessary for the NGVLAs. However, HR would indicate that the builders of the first prototype would be wise to consider carefully such statements as these before setting off to design any brand new, unproven, untested mooring systems for their creations.

> "Several fundamental principles have been learned through experience. One is that the extreme bow or nose of an airship is the proper place for mooring attachment and is likewise the best point from which to tow the airship around the field." (Fulton, 1929:57)

> "During the [Pulham mast] tests the [R24] lay out continuously for four weeks, during which the worst weather conditions of the British Isles prevailed. The ship was subjected to gusts of wind blowing with a velocity of up to 50 miles an hour from all directions, and to phenomenally heavy rainfall, three thunderstorms and snowstorms, interspersed with periods of sunshine. The behaviour of the airship was, however, all that could be desired, and demonstrated conclusively the practicability of this system of mooring. ... The ship was steadier in a strong wind than in a light breeze, but perfectly stable under all conditions." (Pratt, 1920:82)

> "Riding to a mast is a comparatively old operation for airships. British airships in the early 1920's rode for long periods to the high mast, remaining there through strong winds, wind shifts, heavy rain, and other stormy conditions. Our *Shenandoah* and *Los Angeles* used the high mast frequently from 1923 to 1927, and the experience gained there led to the development of the stub mast and the improved mobile low mast, one of Lakehurst's outstanding contributions to airship ground handling. The *Los Angeles* and the *Graf Zeppelin* have made hundreds of moorings to the low type of mast and have ridden to the mast between trips as a steamship lies at its anchorage or pier, with no more than the infrequent minor mishaps to be expected in handling any large mechanical apparatus. The low mooring mast, mobile or fixed, is therefore a proven part of airship ground equipment." (Reichelderfer, 1935:97)

> "As to handling, the high mooring masts at Cardington, Montreal and Lakehurst, and the experimental mast at Pulham, of which I was in charge up to the cessation of activities ... proved the soundness of the system. On these masts airships have ridden out gales of 83 miles per hour." (Williams, 1974:194)

Thus it can be seen that by means of Historical Research it is possible to debunk some of the GH myths that have arisen since the demise of the PGVLAs and in so doing to provide considerable insight into detailed procedures which have been tried and tested in the field. There are, in addition, many other misconceptions and false assumptions which will have to be investigated and which the NGVLA developers will need to recognise and to have a clear understanding of. However, it is the difficult questions that are founded on such misunderstandings that are the more serious problem for them.

9.3 Difficult questions

To some extent the myths and the difficult questions can be seen simply as two faces of the same coin. For example, the *R101*'s stated ability to be "flown onto the mast" obviously lies behind the question: "Why can't *CL-160* pilots just "fly" the airship directly onto the mast without groundcrew assistance?"

However, as soon as it is known, that no airship in history has ever done such a thing, then the magnitude and the pioneering nature of the undertaking can be recognised, and the full scale of the tests, time-consuming trials and the expensive prototyping that will be necessary become evident. But each myth also does further damage because each one spawns a plethora of further questions that head off in all directions, affecting all sorts of decisions at all levels of development, and frequently linking up with other myths. Indeed many of the numerous "Unanswerable Questions" that plagued the CargoLifter project, as given in Section 2, although they may appear at first glance to be quite separate and unrelated, are often founded on one and the same absence of knowledge or lack of reliable experience concerning a specific topic. Moreover, some of these questions have huge cost implications for the NGVLAs. For example:

- Is a mooring mast really necessary?
- If it is, then should the mooring mast be a mobile or fixed structure?
- If the mast is mobile, then should it move on railway-lines or crawler-tracks?
- What other ground-based infrastructure will be required in addition to a mast?
- What ground *support* equipment (GSE) will need to be integrated into the GHE?

Furthermore, as shown in Section 3.2 above, these "hardware" questions immediately bring in their train the even more intangible "wetware" questions that are just as critical and potentially equally expensive:

- How many ground crew personnel will be needed to operate the GHE?
- What is the minimum number of groundcrew that will be required for each procedure?
- Why do we need any ground crew at all?

However, from the necessarily naïve view-point of the would be NGVLA GHE developer, where it is impossible to know even the extent of the "unknown unknowns" let alone to evaluate all the financial and technical implications of jumping to a false conclusion, the task of even prioritising the search for solutions and of deciding where the biggest risks lie is something of a challenge. Nevertheless, in order to demonstrate the value of HR, and prove that AHAA can help to fill the Knowledge Gap, or at least give a deeper understanding of the GH problems, it is necessary to select one or two specific questions and to examine them in some detail.

Obviously there are some questions on the list that cannot be answered by these means. For instance, some questions are too vague, some are full of imponderables and some involve precise numbers that can only be guessed at. Others would require immensely detailed research or large resources which are beyond the scope of this work, and while some are simply open questions, others are too CargoLifter specific to be of general interest. In determining which questions to attempt to provide answers to, plainly such unsuitable questions can be excluded at this point. Examples of these include:

- If large airships are so perfectly suited for weight-lifting then why are they not already doing it?
- What skills will GH personnel require?
- How long will it take for the *CL-160* payload to be loaded, and unloaded, or exchanged for ballast weight?
- How long will it take to physically move the *CL-160* into or out-of its hangar?
- How many times each year will the *CL-160* need to go into its hangar?
- What are the wheel loads on a rail-mounted mobile mast large enough to hold the *CL-160*?
- What will be the operational limits imposed by the weather?

There are, however, some questions which would appear to be answerable, even from the limited amount of information that had been collected by the author up to the end of the CLOSHRP. Indeed, one such concerns the number of personnel who will really be needed on the ground for the first NGVLA. This question was actually addressed, albeit hastily, by the author in the aforementioned "Cambridge Paper" of 2002, which contained the following chart (see below) showing the numbers of groundcrew personnel that were actually used by the PGVLAs. In view of the fact that a proper understanding of what the PGVLAs really achieved, in terms of reducing their ground-crew numbers, will be a potentially useful jumping-off point for any planners of future NGVLA GHE, it is deemed appropriate to investigate it further in this study. Thus the first question to be addressed will be:

1. How big were the PGVLA ground crews?

In choosing a second question, a slightly broader topic that was important to GH but, which also had wider implications for the NGVLAs in general, was sought. It was recalled that at the end of the Airship Association's 1st International Airship Conference at Bedford, England, in 1996, the author had been among those enlisted onto a panel of experts which "*... was convened in an open forum, at the request of UK MOD (PE), to answer questions on airship ground handling and command and control.*" (see **Section 2.7**) In view of the fact that, in later years, there was much debate at CargoLifter on this topic, and that there was no consensus as to who was responsible for what, and that, as quoted in the same Section above, the problems of "*Ground crew co-ordination: ground crew chief and responsibility sharing/hand-over between ground crew chief and pilot ... and ... on-mast/off-mast responsibility ...*" [1] had been flagged as a serious issue by the German regulatory authorities, it was decided that the second question to be addressed should look to the PGVLA records and ask:

2. Who was in command?

9.3.1 How big were the PGVLA ground crews?

For the co-authored Cambridge Paper, this author prepared the following chart to show how many men had been used by some of the largest of the PGVLAs. (Some groups have been amalgamated for clarity.)

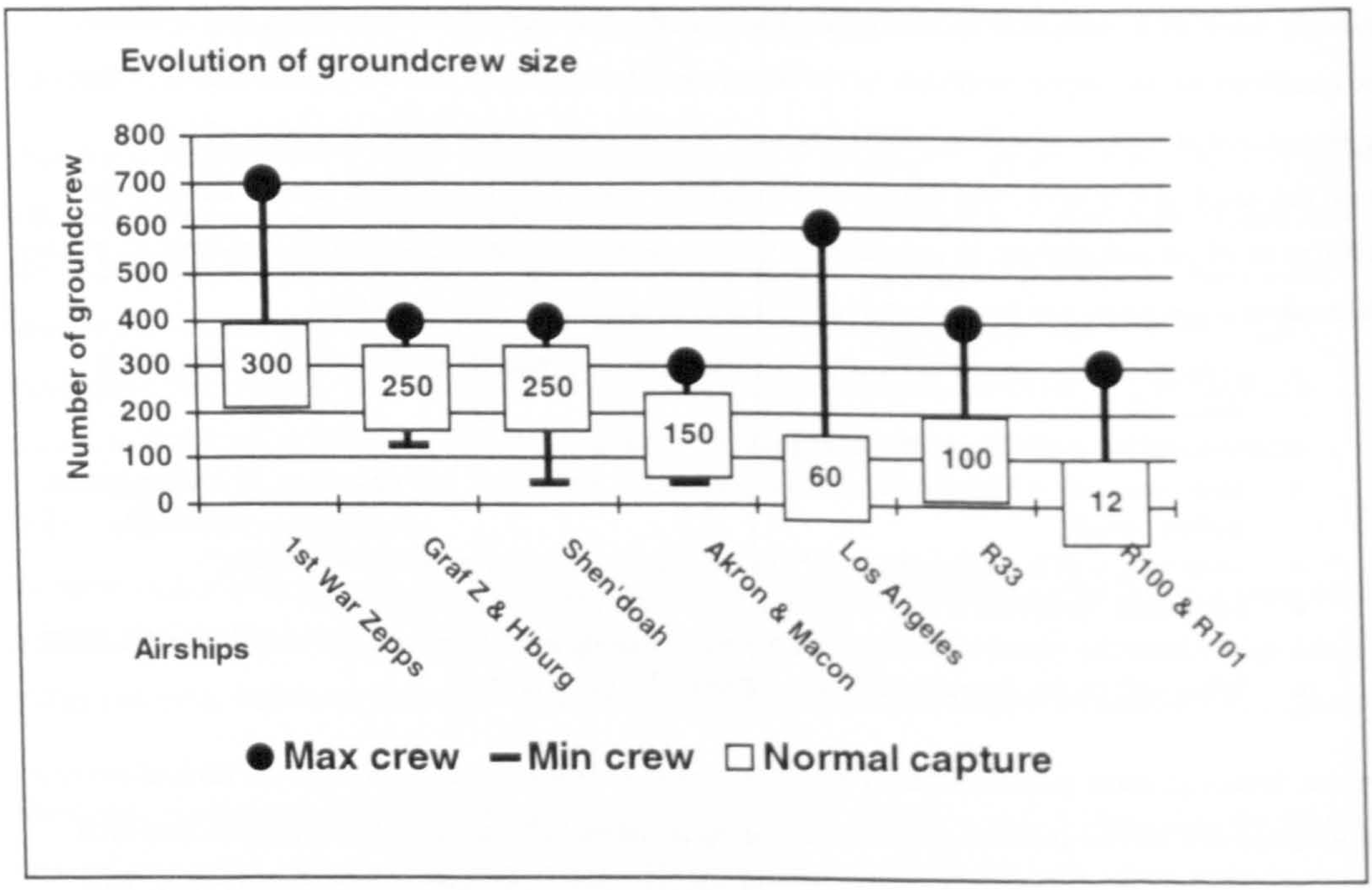

Figure 9.1 – Evolution of ground crew size (revised)

Although this chart was prepared in haste, it did serve to show how the numbers of ground crew had diminished over time, as experience was built up in the three major PGVLA-developing countries. The

[1] (LBA, 2000:25)

Cambridge Paper text also pointed up the importance of trials and training, and of using dedicated experimental airships as a factor in reducing ground crew numbers and enhancing cost-effective GH:

> "The wide variations in the crew numbers for *R33* and *Los Angeles* can be explained by the fact that both were relatively long lived airships which were used as test beds for much experimental work that included mooring trials and crew training. The result was their groundcrews reduced in numbers as lessons were learned." (Camplin & Schaefer, 2002)

However, the chart did not show very clearly the advances made over the German system, in reducing the numbers, by both the British High Mast and the American Mechanical Handling systems. Their progress can be better visualised if essentially the same, but slightly updated data, is redrawn as a different chart.

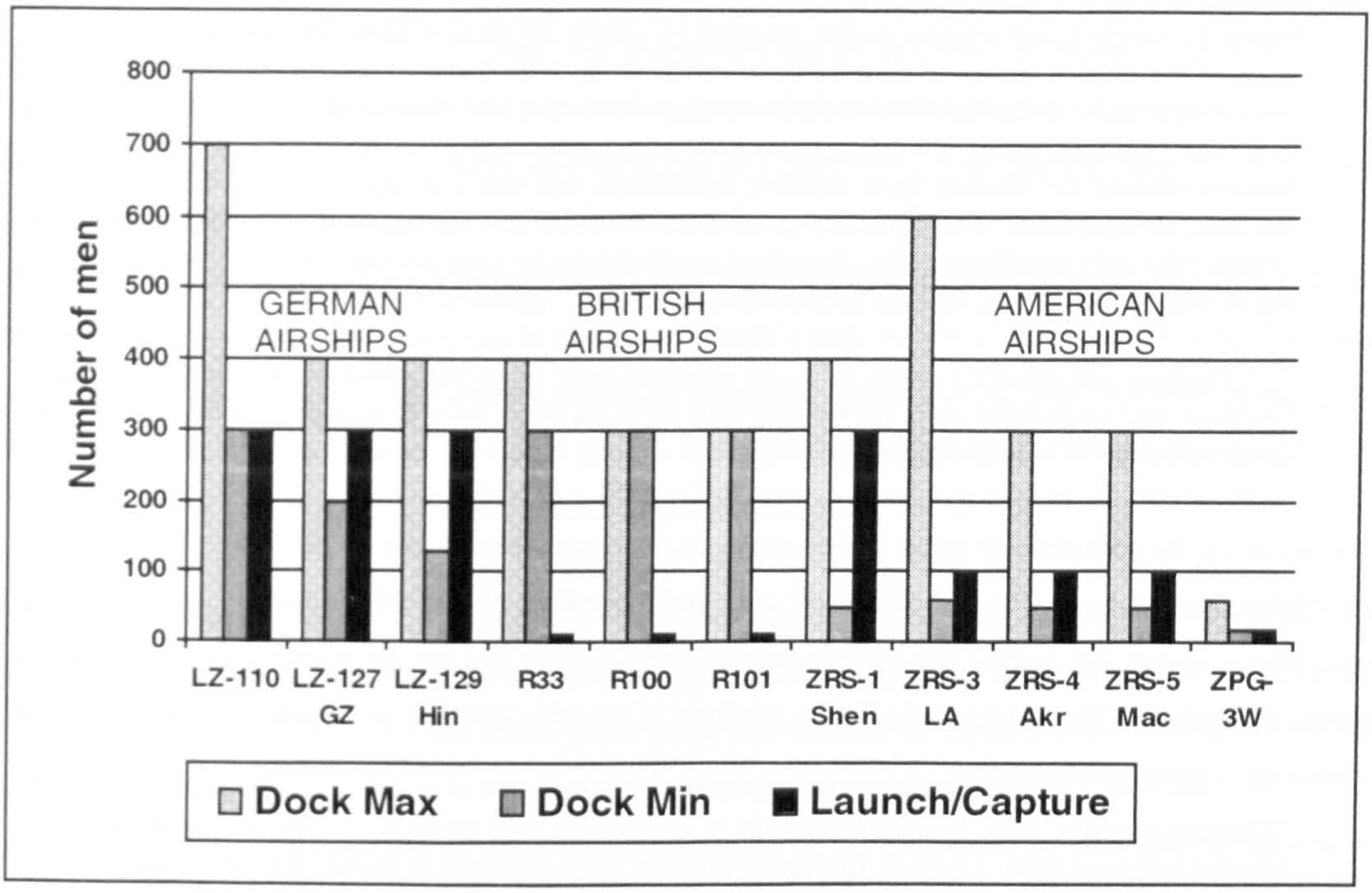

Figure 9.2 – Progress in ground crew size reduction

The numbers used in preparing these charts were derived from the numerous quotes that had been discovered and collected in the course of the HR project. These are a few examples of them - in an approximate chronological order with **[GC emphasis thus]**:

> "Ground-handling parties for the small SS ships numbered between **fifty or sixty men**, even in calm conditions." (Mowthorpe, 1999:21)

> "During the tests [of Pulham mast] the airship [R24] lay out continuously for four weeks … **Only four men at a time** were needed to look after the airship, and do the necessary gassing and ballasting." (Pratt, 1920:82)

> "The number of men required to handle and operate a ship is commonly believed to be large, but with the aid of most primitive mechanical appliances a 500-ft rigid has been safely secured to the mooring mast with the assistance of **only six men on the ground**." (Cave-Browne-Cave, 1920)

> "The man power required to handle a rigid airship on the ground and get her into a shed is out of all proportion to the object attained, as even under the calmest conditions a body of upwards of **300 men** … must be kept standing by whenever a flight or landing is expected …" (Pratt, 1920)

> "In the late afternoon of 4 September [1923] … *ZR-1* was walked out for the first time. This demanding operation required **420 sailors**, marines, and station civilian employees." (Althoff, 1990:28)

> "When the airship [the *Graf*] was over the field ... Yaw lines ... were drawn out to port and starboard by thirty men each, while twenty more on each side pulled the ship down with spider lines ... When the airship reached the ground, fifty men held the control car rails and twenty held those of the after car. With thirty men in reserve, the ground crew totalled two hundred men." (Dick & Robinson, 1985 : 70)

> "*Mooring crew.* At the high mast 10 to 12 men have sufficed thus far. With vertical control added, this number may have to be increased to 16 or 18 men. No stub mast has yet been equipped for a full mechanical mooring, and therefore the number of men required by the present temporary combined manual and mechanical system cannot fairly be compared with the 10 to 12 men in the high-mast crew." (Rosendahl, 1931a)

> "During the period that the ship is being "walked" across the landing field, [using the "Bolster beam"] a single handling-line spider, manned by about 30 men, is used on each side of the stern of the ship. A group of about 12 men walk along with the after taxiing wheel to help it over rough spots in the field and to hold the ship down if it becomes light. These men also assist in holding the ship while it is being connected or disconnected from the beam. They perform no function during the hauling up or docking operations, and this may truly be said to be entirely a mechanical operation, since the only personnel involved are the eight men on each side who connect the side handling cables, the group mentioned who connect the lower fin support, the three winch operators, and the locomotive operator." (Bolster, 1932:116/7)

> "... Landing and mooring of the *ZPG-3W* required only 10 to 18 personnel in the ground crew. Docking and undocking were performed with 11 to 12 men; takeoff required approximately the same number ..." (GAC/NASA, 1977:53) [1]

However, as can be seen there is some inconsistency in these numbers. This is in part due to the wide range of dates covered and also to the different aims and prejudices of the various authors. Nevertheless, there is also evidence that behind this there is another myth lurking that has great import for NGVLAs. It concerns the reality of the claims made for the numbers of ground crew that were used with the American mechanised system. For example:

> "German airships were walked in and out of their sheds, and manhandled on the ground by trained teams of men. Three or four hundred men were required to handle the larger airships. Only with the "*Hindenburg*" and "*Graf Zeppelin II*" did the Germans use mechanical handling equipment - a travelling mooring mast. The U.S. Navy needed 157 men to ground handle the "*Los Angeles*," but with the complete mechanical equipment devised for the "*Akron*" **a dozen men could do the job.**" (Robinson, 1973) **[GC emphasis]**

This final statement is interesting because, if true, it would appear that one of the great bugbears of GH – i.e. the large numbers of ground crew required for the big ships - had indeed been solved by the US Navy in the early 1930s. However, if, as stated, "a dozen men" were sufficient to handle the *Akron*, when it made its final (and fatal) flight from Lakehurst Naval Air Station (NAS) in 1931, then the question has to be asked - why, six years later, in May 1937, at that same NAS, a ground crew which reportedly comprised "92 naval personnel and 139 civilians" [2] was awaiting the *LZ129* "*Hindenburg*," for what was anticipated to be a perfectly normal and routine landing?

Even allowing for the fact that the *LZ129* was a foreign airship; that it was bigger than the *Akron*, and that the Americans were taking the opportunity to conduct an expansive crew training programme, the provision of more than sixteen times as many men as is stated to be actually necessary, would seem to be somewhat extravagant.

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[1] NB – There is only one paragraph on the subject of GH in this 58 page report

[2] Knight, 1938 : Sect III, 4

It must be noted that this was not, as is also commonly believed, the *Hindenburg's* "maiden voyage to America." It was indeed its "first flight to *North* America of that year" (1937) but the ship had already flown once to South America (in April) and had made ten landings at Lakehurst the previous summer.[1] All of these had been conducted without serious incident,[2] and thus the landing of *LZ129* at Lakehurst was a well-rehearsed event. Either a dozen men could do the job or they could not. But the fact that there were more than 200 people standing on the ground underneath the *LZ129* on the day of its final conflagration would suggest that these personnel were not merely supernumerary observers but were active participants with vital and necessary work to do. This needs to be investigated.

The accepted answer is that the Germans, and specifically the all-powerful Dr. Hugo Eckener, were "not happy" with the American system and preferred to ignore the essentially British "flying moor" and to land, as they had always done, directly into the hands of a large body of disciplined men. However, here again, as in all matters concerning GH, the devil really is in the details, and the interesting question is what exactly were the Germans unhappy about? Was it that the systems were too new, and untested, or that the airship was too long wavering in mid-air, controlled only by ropes, cables and winches? It cannot have been an objection to mechanisation in general because the Germans, at their own state-of-the-art home base at Frankfurt, used an 'A' frame mast to hold the airship nose, while rail-mounted 'laufkatzen' trolleys ensured the mooring lines held the tail central during entry and exit of the shed.

Whatever Eckener's reason, and regardless of the low-mooring system's true reliability, there is evidence that the numbers claimed for it by the Americans are suspect and that they never ever got it down to "a dozen men." Firstly there is Bolster's statement in the above listed examples, (Bolster, 1932:116/7). This yields at least 70 personnel but is in rough accord with this statement made in the following year:

> "About 50 men can handle the ship [*Akron*] in and out of the hangar with the present equipment. The ship's crew can do most of the maintenance work in the hangar. ... We had 77 men on the *Akron*, but we flew only two thirds at a time."(US Congress, 1933 : Wiley, 64/5)

These figures are, however, themselves thrown into doubt by a report that turned up in the CargoLifter Library and which is believed to have come from the University of Akron archives. This document is a photocopy of a typed report entitled simply "Ground Handling of Rigid Airships." It is signed by Emmett J. Sullivan, dated 15th February 1935, and it reveals that at the end of their development programme, the Americans were actually using more than one hundred men to ground handle the last of their PGVLAs - *ZRS-5 Macon*. Here are some pertinent quotes from this document:

> "Since qualifying as a Naval Aviator (Airship) I have been assigned duties involving ground handling of rigid airships. Accordingly, it is felt that I am more competent to offer constructive criticism in reference to this particular phase of the airship problem. ... The exposition is brief and gives consideration only to those items which, in my opinion, are outstanding deficiencies in our present system of ground handling." (Sullivan, 1935)

> "It is my opinion that the outstanding difficulty in our application of the three wire system is in the method used in handling the yaw guy lines. ... The existence of contact between the ground and a large portion of the yaw line [when mooring is in progress] has been the cause of most of our troubles in mooring. ... The Mooring Officer's principle difficulty has usually been ... in transmitting orders to both units in time to obtain coordinative [*sic*] response." (Sullivan, 1935)

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[1] In her short life *LZ129* made a total of 63 flights of which 36 were Atlantic crossings to either Lakehurst or Rio de Janiero.

[2] On one occasion the *LZ129* was slightly damaged and had to be squeezed into the NAS Lakehurst shed for repair.

"An ideal riding-out car is one which can under all conditions of weather provide a reliable means for holding down the stern; and at the same time, not interfere with the freedom of movement of the airship as she swings in azimuth. ... An airship, riding at a circular track with its stern secured to such a heavy mobile ground attachment unit, is subjected to unnecessarily large bending loads in starting, stopping, and changing speed." (Sullivan, 1935)

"... the method used in securing the "X" frames to the Macon was crude of design, and unwieldy. Too much time was consumed and too much confusion and trouble has been occasioned in employment of the current method." (Sullivan, 1935)

"Manually Handled Spider Groups: Aft ... these parties have not contributed a perceptible bit of worthwhile effort in handling the ship. It is suggested that such dead weight be discarded ... and in so doing cut down the ground crew by some seventy men." (Sullivan, 1935)

"Ground Crew Under Proposed System - No. Men ... **TOTAL 28.** ... Ground Crew Under Present System - No. Men ... **TOTAL 115.**" (Sullivan, 1935) [GC emphasis]

"... I feel that we are now prepared to completely scrap manual handling and inaugurate an improved system of mechanical handling. ... it appears more desirable to handle a ship by mechanical means with a small thoroughly indoctrinated ground crew than to place the ship at the mercy of a heterogeneous army of poorly trained hands and feet." (Sullivan, 1935)

Considering that Sullivan's report is dated three days after the *ZRS-5 Macon* crashed into the sea, thereby abruptly terminating the US Navy's large airship project, it seems most unlikely that the Americans ever succeeded in this last stated aim, and that Sullivan's suggested improvements remain today as they were at the time, simply a frustrated, state-of-the-art wish list. They are, nonetheless, written by a real expert.

However it is fairly clear that if the first of the new generation of super-large airships ever does get off the drawing boards then it is going to require a ground crew that is proficient in a large number of diverse skills, and for this reason alone, certainly in the early days, it will inevitably involve large numbers of people. Whether, thereafter, the accumulation of NGVLA GH experience in the field, will ever allow these tasks to be condensed in the future so that the dream of employing one multi-talented, "thoroughly indoctrinated" super-person to do everything can be realised, remains to be seen.

Bearing in mind that there are 24 hours in the day, then a crew of 12 will inevitably become 36 if they do 8 hour shifts. Moreover, allowing for sickness and holidays means that 48 will be a more realistic likely total. Thus, perhaps, when calculating their ground crew numbers, the NGVLA teams, instead of trying to modify HTA ground-handling practices, should turn to the Maritime world and ask the wealthy and cost-conscious oil companies how many men they use to berth, and to moor, their super-tankers and VLCCs?

9.3.2 Who was in command?

From the very start of airship ground handling there have been problems with the hierarchy. More importantly, for the NGVLAs, the historical records reveal that there is a very great risk of disaster occurring when authority is usurped by those whose knowledge of LTA vessels is either minimal or dominated by preconceptions; as is the case today with regard to blimps. Here are examples of both cases:

"Evidently it would be a mistake to place the air-ship [1st flight of 1st airship from Paris in 1898] at a [starting-off] point suitable for an ordinary balloon without motor and propeller. And yet it was there that I did place it, not by my own will, but by the will of the professional aeronauts who came in the crowd to be present at my experiment. In vain I explained that by placing myself "up stream" in the wind with relation to the centre of the open space I should inevitably risk precipitating the airship against the trees before I had time to rise above them ... All was useless. The aeronauts ... could not admit of its starting under other conditions than those of a spherical balloon ... As I was alone against them all I had the weakness to yield. I started off from the spot they indicated, and with a second's time I tore my air-ship against the trees, as I had feared I should do." (Santos-Dumont, 1904:78/79)

"When, upon arrival [from France in October 1910], the *Lebaudy* was being docked in the shed at Farnborough, the Air Battalion officer in charge of the landing party of 160 Guardsmen and Sappers noticed as the balloon approached the entrance that the opening was a little too low, and halted the landing party ... A big crowd of soldiers and civilians from far and near had collected ... and the excitement at the arrival of the large airship was intense. An enthusiastic spectator, believed to be an officer of high rank in uniform, shouted to the landing party to go on, which they did. The envelope impinging upon the top of the doorway was punctured, and the airship collapsed on the ground ... It transpired that the over-all height of the airship was 10 ft greater than the makers had specified." (Broke-Smith, 1968:43)

Although this latter was an isolated incident it did foreshadow what was to come, particularly within the British airship community, which was plagued from the start by indecision and inconsistency. This confusion in both planning and action continued through First World War and became almost endemic right throughout the chain of command at every level.

"The reason why the Royal Navy had so few rigid airships in commission at the time of the [1918] Armistice was that policy and design underwent constant refinements. This left the manufacturers without consistent experience, reusable dies, jigs and parts, and without a stable work force skilled in the mass-production of a standard design. ... every new ship or group of vessels had to have Cabinet approval, and this provided further delay." (Higham, 1961:146)

This deep seated lack of trust, and the failure to delegate authority, may have been caused by insecurity that stemmed from a lack of knowledge. It was certainly in total contrast to the confident system practised by the far more knowledgeable and experienced Germans.

"It is often said that the Germans are rigid, hide-bound bureaucrats who are logical to the point of self-destruction. But their procedures in [First World War] airship procurement gave the lie to this, and also make British methods look even worse. Whenever a major procurement decision had to be made, a conference was called at the Admiralty in Berlin. In the chair would be the admiral commanding the dockyards, of which the aeronautical section of the Navy was a part, surrounded by his technical experts. He would be joined by Captain Strasser, the operational commander, and a few of his captains, and representatives of the airship constructional firms. The admiral acted as chairman and was empowered to make final decisions after hearing what each group had to say. When the conference broke up, the constructors went away with a fairly clear idea of what they were to do, and were then left alone to get on with it." (Higham, 1961:147)

But the confusion in Britain was not limited to procurement, design and construction, it also affected the operational chain of command and this seems also to have been strongly influenced by friction between the various military and civilian services that got involved.

"... if airships were to have any future at all that future would be bedevilled by the rivalry between the Admiralty and the Air Ministry. Within months of the end of the [First World] War ... it was agreed that the Admiralty was still to be responsible for the design and for the employment and housing of airship personnel but the size of the airship establishment was to be fixed by the Air Council after receiving recommendations from the Admiralty. The training, discipline and welfare of airshipmen was to be in the hands of the Royal Air Force. Although it was accepted that those who flew **and maintained** airships were Royal Naval personnel, once they were qualified for promotion ...they were then to be transferred to the Royal Air Force and thus inevitably to aeroplanes. The origins of this confused and ludicrous situation ante-dated the Armistice. For example, it had been decided that 'no Court of Inquiry could be convened until its findings were known because whose responsibility it was to convene one was determined by the findings." (Morpurgo, 1972:85) **[GC emphasis]**

Thus the seeds for fundamental misunderstandings as to who should take orders from whom, within the hierarchy of officers who came to take their places in the control cars of the British rigid airships, were long-sown and deep-rooted. Furthermore there is clear evidence that the British had not properly sorted things out even at the abruptly terminated end of their large airship programme in 1930, as is shown by these extracts from memos held at the PRO [1] (Higgins, Colmore, et al, 1930).

> Extract from File 522050/30 - The R100
> "The airship R100 is to make a voyage to Canada next month ... Major G.H. Scott who had charge of R34 when she made her voyage to America ... in 1919, will be in command of R100."
> +++++++
> Attached note from S.9
> "It is stated in the above cutting from the "Times" of 12th inst., that Maj. Scott will be in command of R100 during the forthcoming voyage to Canada. Will you please say whether this is correct, and what will be the posn., of S/Ldr Booth (or F/Lt. Irwin)? ["Captains" of R100 and R101 respectively] Sanction to the issue of a command allowance to these officers was obtained on the ground of the responsibility involved in the command of an airship particularly when in flight (see encs 9A and 10A). We then understood that Maj. Scott would not be in charge of the ship as in earlier flights. ... Dated F.P. 14.4.30 Signed F.G.C. Young"
> ++++++
> Attached responses to above: "18 - With ref to minutes 16 &17 both S/Ldr Booth and F/Lt. Irwin will be in charge henceforth and will carry out the duties and responsibilities as Captains of their respective ships. As far as the forthcoming Atlantic flight is concerned, S/Ldr Booth will be in command of R100 but Maj. Scott will also be on board. It has always been the intention that Maj. Scott should accompany the ships on their preliminary long distance flights in view of his past airship experiences would prove invaluable should difficulties be encountered in event of emergency. On this occasion however he will be onboard in an advisory capacity ... Signed R.N.B. Colemore, DAD RAW 2.5.1930"
> +++++++
> Memo dated 28.7.30 to D.A.D. from J.H. AMSR
> "R100 Atlantic Flight - Booth has been appointed Captain. He must exercise command and be responsible for the airship. In the unlikely event ... circumstances make it necessary for Maj. Scott to take command of the airship then you should formally authorise him to take over from Sqn. Ldr. Booth and report in due course that this has been done and give reasons. ... You [i.e. Colemore as Director of Airship Development] will no doubt settle the route and times of departure and intended times of landing with Maj. Scott who can give the necessary instructions to the Captain of the Airship. During the flight I want Maj. Scott to watch and advise as to the general conduct of the flight and not to have any executive responsibility unless specifically authorised by you. Signed John Higgins"
> +++++++
> Memo dated 28.7.30 to Press secretary (through D.A.D.) from J.H. AMSR
> "It would appear that the press generally are under the impression that Maj. Scott will command R100 on her Atlantic Flight. THIS IS NOT THE CASE and I should like the position to be made clear before R100 starts. R100 on her Atlantic Flight will be commanded by Sqn. Ldr. R.S. Booth AFC and Maj. G.H. Scott CBE AFC will be on board in his capacity as Assistant Director for Flying. Wng. Cmdr. R.B.B. Colemore OBE will be on board in his capacity as D.A.D. and will represent the Air Ministry while R100 is in Canada."

Although it appears from this that things had finally been sorted out by the time of the *R100*'s flight to Canada, in August 1930, in fact, the records show that on this voyage the problem actually took a new turn and it was far from resolved by the time the *R101* set off for India on October the 5th.

> Notes dated 24.10.30
> "Notes regarding the respective position of Maj. Scott Assistant Director of Airship Development (Flying) and the captains of R100 and R101 on flights to Canada and India. Press notes show Scott as "one of the officials from Cardington and seemed to imply that he was merely a passenger and had no responsibility for the flight but ..." [Scott says] "if anything happens on the flight I will be held responsible." [Furthermore] Scott was "rather hurt by the impression which had been formed in Canada that he had been superseded by Booth." Signed C.P. Robertson [RAW Press Officer]"

[1] PRO : AIR 5/13

Here then is an example of a problem which was plainly never solved satisfactorily by the British. It is even conceivable that this lack of a clearly understood chain of command, and the consequent confusion as to area of responsibility, might have contributed to the *R101* disaster. Obviously it will never be known who was in the control cabin at the time of the crash, let alone who was giving the orders. Nevertheless, in the light of the above memos it is revealing to speculate how, for example, the helmsman on *R101*, would have reacted if given simultaneous but contradictory orders by Irwin (the less experienced "Captain") and Scott (the more senior and more experienced officer who officially had "no authority").

Moreover, it must not be forgotten that such confusion has just as much potential to cause a disaster on the ground. If the NGVLAs are to avoid such problems then their ground and flight crews will need to know exactly who is in command at every stage of operations, and this will include all the GH procedures, as well as change-over to and from flight. A clearly defined procedure for the hand-over of responsibility will at the very least have to be established for each of these transitions to and from GH:

- Undocking - hand-over from either inflation or maintenance crew
- Re-docking - hand-over to either maintenance or deflation crew
- Release - hand-over to flight crew
- Capture - hand-over from flight crew

To give the British some credit, it does appear that by 1930 they had at least sorted out the chain of command and the hand-over of responsibility for these vitally important GH transitions. The historical records contain many references similar to this one:

> "... when the airship [*R100*] has been hauled down to a height of 500 feet the main winch is stopped until both the yaw guys are coupled and hauled taut. The Mooring Tower Officer now assumes responsibility and control of operations." (Meager, 1970:156)

Plainly it would be quite useful as a starting point for the NGVLAs to know the exact details of this hand-over and doubtless detailed research could uncover them. However, it lies beyond the scope of this present investigation to research the full extent of all the responsibilities and of the established hand-over points, complete with confirmatory signals and fall-back alternatives, that were used and proven, at every level of the PGVLA hierarchies, at the end of their development programmes in Germany, Britain and America. Nevertheless, it is certainly true that the US Navy had established who was in command by the time they came to be operating their large cold-war-blimps - although they still had some get-out clauses:

> "General Instructions ... Responsibility. 1.4 Landing – Primary responsibility for the safety of the airship during landing belongs to the Ground Handling Officer (GHO) when the airship handling lines are firmly in the hands of the ground handling crew. The pilot is responsible for complying with signals of the GHO ... Whenever, due to shifting winds, gusts, parted handling lines or other reasons, the airship lines are no longer firmly held by the ground handling crew, the primary responsibility, by necessity, shifts to the pilot. ... 1.5 Take-off – During take-off operations the primary responsibility for the safety of the airship is the Ground Handling Officer's until the handling lines have been released ... If, after unmasting, because of adverse conditions, the ground crew lose control of the airship, primary responsibility will revert to the pilot ..." (US Navy, 1958:1)

> "1.6 Wherever conditions or circumstances indicate that the safety of airship's men or equipment may be jeopardized by proceeding with scheduled ground handling operations, it shall be the responsibility of the GHO to advise the officer scheduling the operation. Under such conditions or circumstances, the GHO may decline to assume responsibility for the consequences if ordered to proceed ..." (US Navy, 1958:1-2)

> "Prudential Rule – 1.8 In obeying and construing the procedures outlined herein, due regard shall be given to all special circumstances which may render a departure from these procedures necessary to avoid immediate danger." (US Navy, 1958:2)

These however are rules for airships that behave like HTA craft and whether the NGVLAs will be able to adapt to this regime is in considerable doubt. To this author it seems more likely that something approaching the old rigid airship systems will prove better suited and ultimately safer, even though this will entail the reinstatement of a Mooring Mast Officer, along with clearly defined powers and areas of responsibility. Consequently, the current accepted role and overarching authority of the pilot in relation to the GHO will have to be re-examined and modified accordingly. There are sound practical reasons for this belief, as evidenced by this "rediscovery" made by the British MOD during their latest evaluation of the *Skyship 600* as a possibly useful device:

> "It became apparent that when the airship was in the hands of the crew, the pilot had less influence over the dynamics of the vehicle than the ground crew." (Martyn & Brown, 1996)

The same will be true in the future even if the human ground crew is replaced by winches or purpose built-machines. Furthermore, if such review is undertaken, then the NGVLA developers would be well advised to keep in mind the airship's nautical roots and again to look to the sea for inspiration when seeking to redefine the roles and responsibilities of those officers and ranks of men within the chain of command that must link the airborne to the ground-based without any misunderstandings.

> "Unlike an aeroplane, airships, especially the huge Zeppelin-type rigids, have a great affinity with sea-going ships, especially sailing ships. Taking them in and out of their sheds, mooring to the mast, are reminiscent of guiding a ship to her harbour berth or dock. ... Controlling an airship crew, whether three or twenty-three, demanded similar qualities to that of a captain and his ship's crew." (Mowthorpe, 1999:xv)

> "On all ships, the man who really runs the vessel is the First Officer: his is the most effective daily authority on the ship, that which is most active. The mate, as he was known in the days of sail and even for much of the age of steam, is the one who must ensure that things are shipshape, that they get done, that the ship and its gear are in good running order, that the cargo is efficiently loaded and discharged, and that the crew is under control and doing its job." (Mostert, 1974:136)

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10 POTENTIALLY USEFUL IDEAS

The history of LTA flight is long, and as this investigation has revealed, many of the problems that afflict airships in general and which will have to be addressed if future development of the NGVLAs is to proceed, can be traced right back to the very earliest days of the very first airships. If, as is the case, these intractable problems have withstood, for more than one hundred years, the combined and focussed attention of literally thousands of people, (some of whom are proven to have been exceptionally clever), then the author, who is not an engineer and who makes no claim to be one, has no illusions that he is about to offer any sudden or satisfactory solutions to them.

Nevertheless, in the course of this research, many and various claimed solutions have come to light. Some are obviously daft. Some are from people who plainly do not know what they are talking about and some are for problems that do not, and never have existed. (For examples see **Appendix G - GH Patents**) However, there are also some that do appear to be worthy to further investigation. These range from ideas put forward by experienced engineers, (who for one reason or another were unable to prove or pursue their plans), to Patented concepts from knowledgeable companies, (which were left incomplete or only partially tested), to visionary imaginings (which were simply beyond the technology of their day, but which now, (or perhaps soon) may be realisable).

Limited space does not allow for more than a few of these suggestions to be examined here, but readers seriously intent on pursuing NGVLA development might like to bear in mind that they represent only the tip of an ice-berg, and there are plenty more unrealised plans, untested schemes, incomplete trials, unfulfilled wishes and dreams where these came from. The author does not seek to promote or endorse (with one exception) any of the examples given below. They are chosen merely to demonstrate the variety of topics and diversity of potential sources wherein such information may be found.

10.1 Innovations and untried concepts

Firstly there are ideas concerning the airships themselves. For example, it seems that plans were made for bigger and better blimps, in both Britain and America, at the end of their respective major developmental eras, centred as they were on the First and the Second World Wars.

> "Note - On September 11, 1917 an Admiralty conference decided they (*North Sea* class) should be superseded by the K-class, but these ships were never built." (Higham, 1961:118)

> "The [Goodyear] GZ-16 proposal: Outline specification OS-135 was issued 16 April 1954 for a "barrier airship" ... Due to the size of 2,800,000 cubic feet, the proposal was comparable in size to the rigid airship *USS Los Angeles*. ... GZ-16 reached the car mock-up stage ... Eventually, the GZ-16 was abandoned as too expensive ..." (Shock, 1994:III-32/3)

Whatever these designs were, they represent the wishes, ideals and cumulative experiences of the two most expert nations, as they were recorded immediately after the completion of their independent programmes of intensive non-rigid airship development. Anyone contemplating building a large pressurised airship in the future would be well advised to see whether any designs or drawings from either of these projects have survived and, if so, to take a good hard look at the detail of them, before starting from scratch with their own sheet of blank paper.

Other innovative schemes have been concerned with ways of housing the airship:

> "One fascinating proposal [for solving the lack of sheds problem], made by Sir Robert MacAlpine, was to dig enormous tunnels into convenient hillsides, so creating safe shelters which could easily be enlarged as required. Neither this nor a similar proposal to use dry docks temporarily roofed over was ever implemented, however." (Abbott, 1989:110)

> "Earlier in the year [1916] it had been thought that some ships might be built in dry-docks, which could easily have been roofed over. This was a step halfway between the normal erection sheds and the tunnels proposed by Sir Robert MacAlpine. The discussion on this question was however, short-lived as it was discovered that the papers had been lost." (Higham, 1961:143)

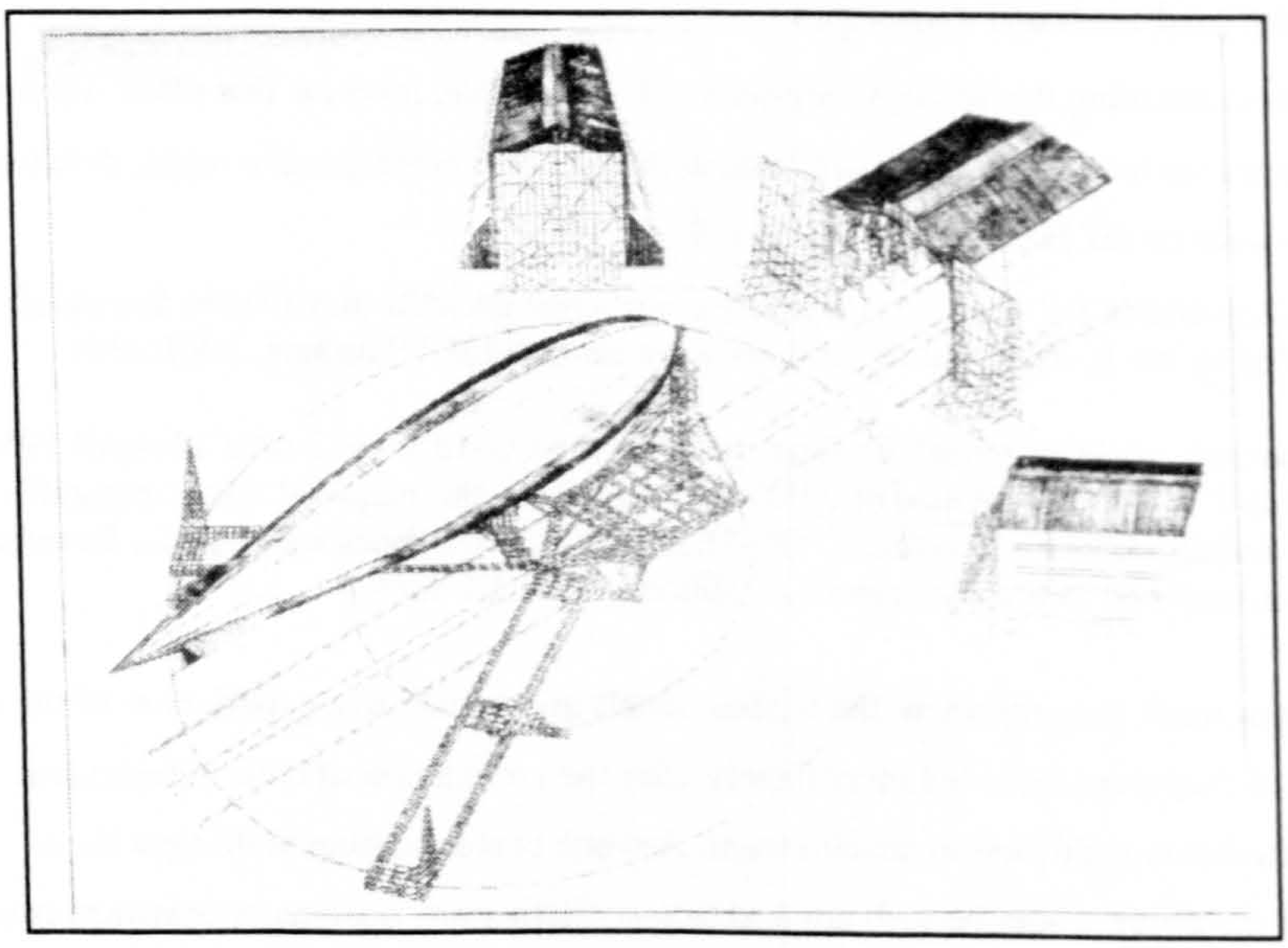
Considering the progress that has occurred in the interim, in the construction and maintenance of enormously large maritime vessels, such as "Supertankers" and VLCCs, there would seem to be some scope for the future utilisation by the LTA community of their even larger, and perhaps now disused or out-grown, dry-docks and other mooring and support facilities.

> "At the end of 1972, there were still only twenty-one repair docks in existence to handle them [VLCCs] … By 1976, it is estimated about forty-two large docks throughout the world will serve them …" (Mostert, 1974:52)

Similarly there would seem to be opportunities deriving from progress with the excavation of large holes in the ground and the creation and maintenance of vast, subterranean chambers (i.e. the Channel Tunnel) that are now regarded as commonplace by the mining, earth-moving and tunnel-building industries.

Alternatively, there have been many schemes for very large airship mooring facilities that are purpose built. One of the most famous is Commander Sir Charles Dennistoun Burney's cradle - as described and pictured in his book "The World, The Air and The Future."

> "Mooring and Docking raft … The ship is moored at a mooring mast in the usual way, and as soon as this has been done, a number of claws are mechanically operated and clasp the ship firmly about the centre line. When the ship is securely held in these claws, the whole structure embracing the mast, claws, and ship, is run into the shed on rails." (Burney, 1929:235)



Burney and his Airship Guarantee Co., actually applied to patent this idea in October 1928, (British Patent No. 310,104 - Improvements in or relating to Means for Berthing Airships) although there is no evidence that they ever tried to build it. Nor is there such evidence for the German idea of combining a hangar and a mooring mast, which appeared in the British Patent Office a few months earlier. Siemens – Schuckertwerke GmbH were granted British Patent No. 256,924 for "Improvements in or relating to Means for Anchoring Airships" on 10 February 1927, having previously gained Patent protection in Germany in 1925. An excerpt from their description explains the concept – "*... The ship is brought in to a mast on a rotatable hangar, and is lowered by the nose to... enable it to be run into the hangar...*"

However, the idea of sliding the airship up and down the mast had also occurred to the Americans:

BRITISH PATENT SPECIFICATION - 256,778

Application date : Aug. 5, 1925 No. 19,724/25.
Complete Accepted : Aug. 19, 1926.
COMPLETE SPECIFICATION

Improvements in Methods of and Apparatus for Mooring Airships

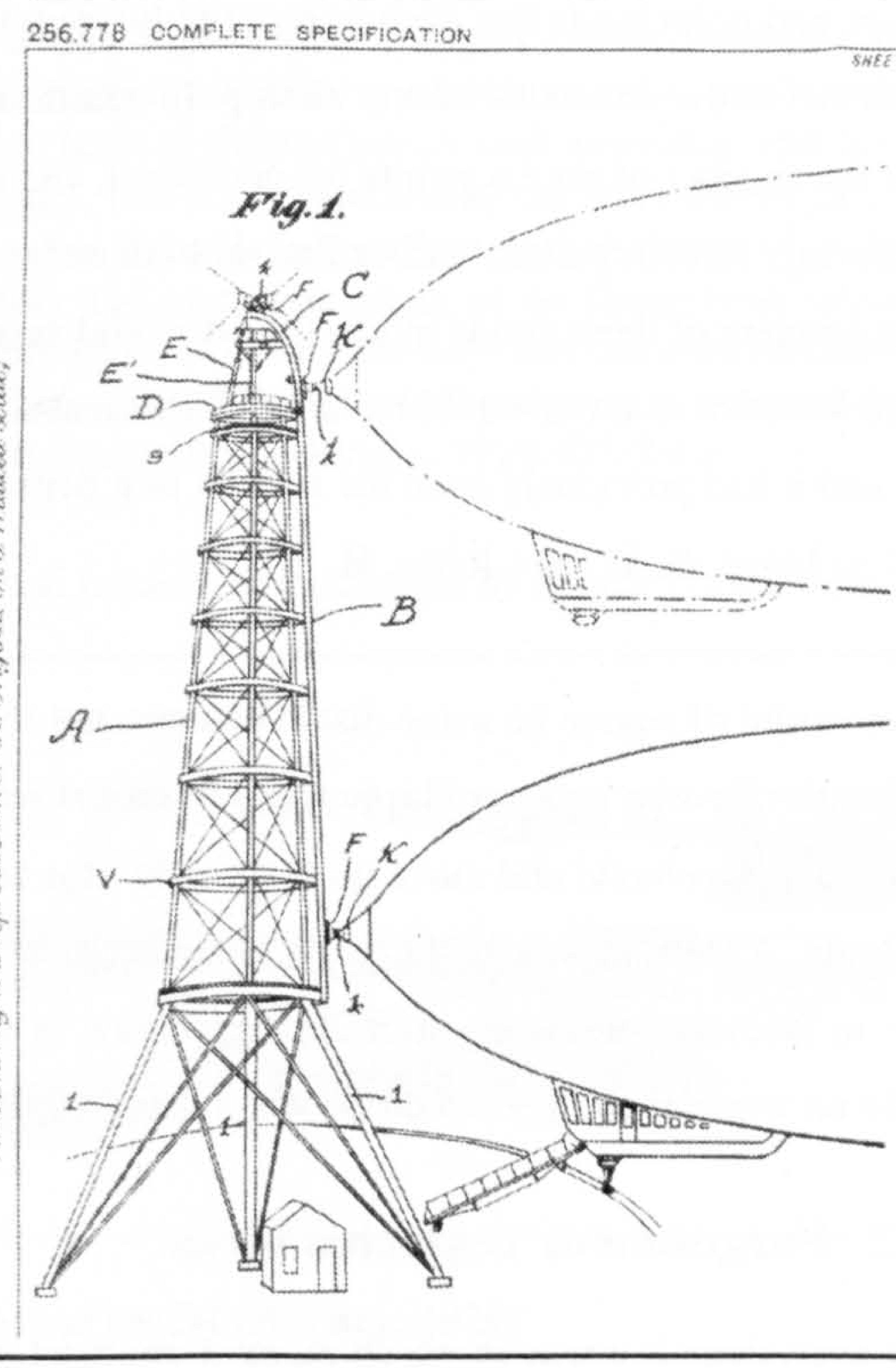
Communication from AIRCRAFT DEVELOPMENT CORPORATION, a corporation incorporated under the laws of the State of Michigan, United States of America, having a place of business at General Motors Corp. Bldg., Detroit, Michigan, United States of America.

I, ALFRED ERNEST WHITE, A.I.Mech.E., Fellow of the Chartered Institute of Patent Agents, a subject of the King of Great Britain, of the firm of White, Langner, Stevens & Parry, of Jessel Chambers, 88-90, Chancery, Lane, London, W.C.2, Chartered Patent Agents, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement : -

"This invention relates to a method of and apparatus for mooring airships. Among the particular objects are to provide better facilities for the practical operation of bringing the ship's nose to a secured relation to the mast and then to permit the swing of the ship completely around the mast if desired or at will and with great facility move the mooring connection down the mast for the purpose of allowing the airship to assume a lower position even to the extent of berthing the ship in contact with the ground. ...

... In my [primary] Specification No. 255,510, I set forth the method and apparatus for the lowering of an airship from the top of a mast by means of a rotating guide. My present invention involves additional developments that may be used in that connection or may be independently used, or may be used in conjunction with modified masts or mooring tower construction.

Some of the practical elements of this invention involve a guide rail running down the side of a mast, which may either be fixed with a rotating mast, or may rotate on retaining connections completely around a fixed mast - but connected with the upper end of the rail is a continuation or horn preferably articulated, which curves from a vertical to a horizontal position over the axis of the mast. For connecting the bow of an airship to the mast by the usual cone on a cable extending from a nose spindle, I provide a complementary cone or flower pot which is supported in a carriage and provide for the easy adjustment of the carriage from the apex of the horn and its ready manipulation to slide down the horn and to the vertical guide rail permitting any desired change in elevation of the airship. ..."



A tower on this principle was actually built (and paid for by Henry Ford) at Detroit Airport, Dearborn, Michigan, USA in the 1920s (See Thaden, 1926). It was 210 feet high and, although three different airships moored to its masthead on separate occasions, the most interesting and innovative part of the tower, the "vertical railway" was never actually tested with an airship attached to it. It remains an extremely interesting idea.

But why stop at only one mast? A US Navy Lieutenant whose name is synonymous with the most advanced mechanised system ever realised for ground handling large airships, Calvin Bolster - inventor of the "Bolster Beam" as used by the *Akron* and *Macon* – suggested at the peak of his career that two masts might be better.

> "Although the author [Bolster] has vividly pointed out the disadvantages of any stern handling structure with solid parts extending high above the ground, there is one such alternative which has been given serious attention. This is a single stern mast on which the stern of the ship would be moored somewhat similarly as the bow is on the bow mast. In this case, our studies have shown that the stern attachment could possibly be worked out so that it permits some relative motion and so that, in case of breakaway, the stern could swing clear of the structure. Then the mast need not be collapsible. Of course a mutual fore-and-aft tow system with provision for ample permissible relative motion or an efficient and reliable servo-drive equipment must again be worked out. Neither solution seems to offer insurmountable difficulties. A stern mast equipment requires some strengthening of the stern of the ship which investigations have shown would not necessarily be prohibitive in weight. … a single stern mast … is considered to be an excellent alternative to the beam. … It has the important advantage, that it removes all handling stresses from the lower fin." (Bolster, 1932:118/9)

A stern mast would also mean that the airship structure would be held in tension all the time it was moored. This would seem to be a considerable advantage as it would automatically remove the high stresses and point loads that derive from the fulcrum inevitably created whenever and wherever any GHE is attached to the underside of any airship. In addition, and co-incidentally, such a system would provide twice the number of access points for personnel, and it would also allow for the supply, and/or monitoring, of both ballast, and/or fuel, at both ends of the ship, simultaneously. This would make replenishment of these fluids quicker, as it would save pumping them the full length of the ship; and it would be safer, as there would be two independent supply systems. However, this idea was not Bolster's own and it had previously been the subject of a British Patent (GB 187,036) granted on the 16th October 1922 to Johns, G. W. and Johns, H. E.

There would of course be some disadvantages, not least the fact that a stern mast for an NGVLA, would necessarily have to be a very large and substantial structure, but would nevertheless, on occasion, be required to accelerate and move quite quickly - for instance if a strong wind were to shift its direction suddenly. A stern mast would also be an obstruction during flight ops, and it would need a second ground crew to facilitate attachment to it during capture, or when mooring, but the operational problems are really no worse than they would be when using a more conventional beam or a "dolly."

10.2 Forgotten or neglected ideas

However, there is a way in which many if not most of the more serious GH and mooring difficulties for the NGVLAs might seemingly be fairly easily alleviated. It is a system that was used with considerable success in the airship's earliest days, although, until very recently it has been rather neglected.

"In order to avoid any crashes to the ground, such as other inventors had had, he [Count Zeppelin] built a floating airship shed on Lake Constance, and planned to make his trial flights over the water. In many such details, Zeppelin showed a thoroughness of preparation and a realization of the difficulties involved, which counted a lot towards his ultimate successes." (Hylander, 1931:143)

"In duplicating the turning, the airship [Count Zeppelin's *LZ-1*] suddenly dropped at the nose, and in spite of all preventative measures the front end of the airship dropped into the lake. After the bow struck the water, which fortunately absorbed much of the shock, the forward car settled to the surface ...The cause of the accident was a leak of gas ... Had the accident taken place on land, the results would have been much more disastrous." (Hylander, 1931:148)

The idea of mooring on, and of test-flying a prototype large airship over, water was given up by Zeppelin in 1909, after the natural-fibre ropes, and anchoring systems then available, had proved unable to cope with the sudden storms that blew up on Lake Constance. However, the advantages of the idea did not escape the entrepreneurial eye of Commander Sir Charles Dennistoun Burney some twenty years later.

"The central idea of the new conception is to enable an airship to alight at unprepared places instead of making fast at a specifically constructed mooring mast, and the actual problem that has to be solved is to keep the ship under dynamic control by means of her rudders and elevators, until such time as the vessel is securely held and no longer in danger of being blown over by a side wind. I doubt if it is possible to do this with any system operated on land. If however the scene of operations is moved to the water, a means of solution soon presents itself. Under the midship part of the vessel, two long floats are constructed upon the same lines as the hulls of the present flying boats, only much larger. These floats are fitted with ballast tanks upon their lower side, and are fixed to the hull of the ship as far apart in the transverse direction as possible. At the same time the section of the ship is altered from the standard circular section to an elliptical section. ... the ship will alight on the water in exactly the same manner as a flying boat. The ballast tanks in the boat hulls will then be automatically filled with 120 tons of water by means of scoops, and as soon as they are full, the ship can be stopped, and will float stably on the boat hulls. The ship can then be moored to a buoy in exactly the same way as a marine vessel, and will lie approximately head to wind. ... For a temporary stop, passengers can be embarked and taken off by boats, ... Under normal circumstances it would be necessary to valve gas in order to bring the ship down from her 2,000 feet flying level to the surface. A ship, provided with floats as described, can be driven down by her engines, this not only allowing her to conserve gas, but automatically giving her the ability to resume her flying height without the discharge of ballast. In other words, the airship is given the mobility and ease of handling of the flying boat, whilst retaining her advantages of great range and buoyancy. I do not see how this can ever be done upon unprepared land; and therefore the airship, like the flying boat, becomes a water vehicle and not a land vehicle insofar as her bases are concerned." (Burney, 1929:237-240)

Burney seems even to have got as far as flying some test models, as evidenced by pictures in his book.

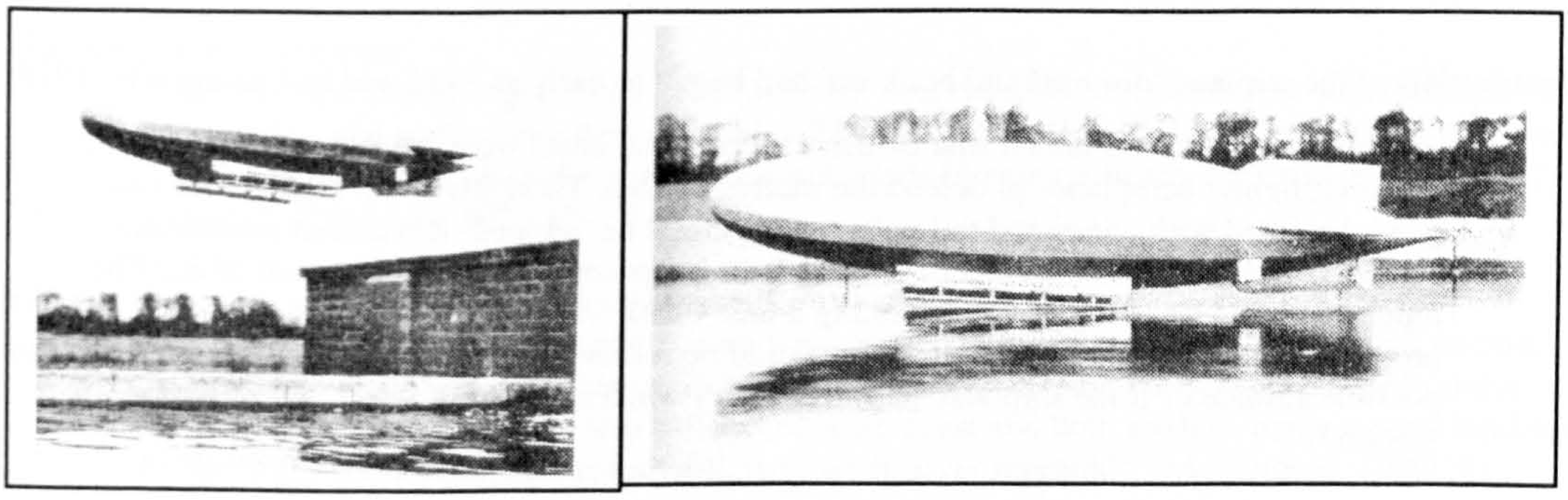


Figure 10.1 – Burney's elliptical model (Burney, 1929)

This idea reappeared and was further tested by Goodyear in 1930, and in 1931, when experiments were made with water-landings and take-offs using full-size blimps fitted with a variety of different floats. The work was picked up again in 1939 when the US Navy tested floatation gear on the blimp J-4, and it was studied in even more detail when they let a contract to Goodyear (Chaffe, et al, 1946) for a programme of further testing in 1946.

More recently, in 2000, a radio-controlled UAV scale model, somewhat similar in appearance to that pictured in Burney's book, and named the "Skykitten" was successfully flown on several occasions from an artificial, purpose-built lake at Cardington by the Advanced Technologies Group. Thus far no-one seems to have found any really serious reason why this idea should not work just as well with airships of any size, and having been proven in the past, this system is one that the author would seek to endorse and to promote as a serious solution to the prototype NGVLA GH problems.

> "On 9th May [1918] the airship [blimp *NS.3*] alighted on the sea in order to hail a trawler ... On a subsequent occasion she again alighted on the water during towing trials with the destroyer HMS *Vectis*. These showed that the airship could be towed safely at some 20 knots and that it was possible to transfer personnel or other items." (Abbott, 1989:76)

> "The water takeoffs and landings created no problems in themselves. In fact water landings by rigid airships continued infrequently through the Arctic flight by the Graf Zeppelin in 1931. It is felt that water landings and moorings are perfectly feasible for any future airship program on the surfaces of large protected bodies of water such as bays, lakes and wide rivers. Loading and off-loading cargo to boats and barges can be accomplished easily, and water landings are ideal from the standpoint of ease in ballasting airships as unlimited amounts of water ballast are immediately available." (Walker, 1975:298)

A further progression of the idea of extending the comparison between AIR-ships and WATER-ships was also actively pursued in the form of "tugs" to assist with manoeuvres such as take-off and landing (equivalent to marine ships leaving and entering harbours). Most of the necessary systems were even tested and proven by all three of the PGVLA countries as part of a another long neglected programme - an equally alien concept which, although it strikes terror into the heart of modern HTA pilots, was accepted as perfectly normal practice in the 1930s by the USAF.

> ">Question – You made a number of airplane flights in the *Akron*? >Answer – Yes, sir. ... >Q – How many would you say? >A – Some 350, that is 350 landings aboard the ship. >Q – How many on the *Los Angeles* did you make? >A – I made approximately 130. >Q – So you have a good deal of experience with the airship and with the airplane? >A – Yes; more experience with the airplane than the airship. I have had perhaps 800 hours in flight aboard an airship. ... >Q – What position did you occupy? >A – I was senior aviator in charge of the airplane unit which was attached to the airship [*Akron*]." (US Congress, 1933 - Harrigan :163)

British trials of the airplane 'drop-off and hook-on' had begun as early as 1915 and had matured by 1918:

> "Senior airshipmen at Pulham [the British experimental base] were not only concerned with releasing fighter aeroplanes to defend the mother airship. Thoughts about engine-cars and gondolas fitted with wings and tail units, which could be 'slipped' if required were under consideration. Maj Boothby, CO of RAF Pulham proposed: 'That the centre car of *R.23* be replaced by a large aeroplane, constituting a unit which will normally contribute to the propulsive power of the airship but which could be released if it was required to attain maximum possible altitude or if the ship was seriously heavy when required to land'." (Mowthorpe, 1999:67)

Obviously, such a system would also work in reverse, allowing extra self-propelled weight to be added in the case of a light landing, thereby negating the need to vent helium from a superheated ship at the end of a long voyage. Also, it should not be forgotten that it was standard practice for *Akron* and *Macon*, (who by the 1930's had seen the mechanisms for hooking and dropping aircraft honed to commonplace reliability), to attach their cargo of four spotter aircraft, after they had taken-off. This procedure enabled them to start their missions with much more fuel than would otherwise have been possible, and were it to be adopted for the NGVLAs, hooking on of light aircraft would allow them to exchange crew members, or pick up spare parts, without either bringing the entire airship to a standstill, or diverting it from its course and thereby delaying its mission.

> "For large rigids a static takeoff from a mast is best. Additional payload up to 10% of the gross static lift of the airship can easily be flown aboard by hook-on plane once the airship is at cruising altitude and speed." (Walker, 1975:308)

10.3 Successful failures

However, the fact that this once widely accepted procedure has now fallen so far into disuse that it is all but forgotten means that suggestion of its re-introduction is viewed with incredulity by many of today's pilot's and regulators alike. And here is another big problem which the NGVLAs will have to face - even with procedures which in their day were well-tried and tested, and proven to be successful, there will be resistance to adopting them simply because they are so far removed from what today is considered standard or safe practice.

Nevertheless, there have been numerous trials of ideas, both for airship systems and their GH procedures, that have apparently been very "successful" but which, having been tried once, and seemingly proven, are then abandoned, or at least are not tried again for decades. Examples of these lost (and sometimes found again) ideas include (with **GC emphasis**):

Vectored thrust:

> " ... in the British Army airship '*Gamma*'. ... the engine power could be used to augment or reduce lift as well as providing a reverse thrust capability. The experiment [in 1910] was **successful** and '*Gamma*' could lift off and land without the need for any provision except a small handling party." (Howe, 1999:304)

The "metalclad" hull construction:

> "One small, but very **successful**, experimental metal-clad airship, the ZMC-2, belongs to the US Navy, and has now been in service for almost six years." (Burgess, 1935:57)

Using gaseous fuel:

> "Interestingly, the most **successful** rigid airship "*Graf Zeppelin I*", minimised the need for venting hydrogen by using a fuel having the same density as air." (Howe, 1999:297)

The floating mooring mast:

> "The very first British rigid, No. 1, the "*Mayfly,*" was designed to float on the water moored to a mast, and ... did so for three days from May 22 through May 25, 1911 ... The mooring trial was considered a **success** when the airship rode out winds blowing a steady 36½ mph gusting to 42-45 mph." (Robinson, 1973:177)

Blimps landing on an aircraft carrier (Britain):

> "During the summer of 1918 experiments were carried out with the Royal Navy's new aircraft carrier HMS '*Furious.*' Two Zeros, SSZ.59 and SSZ.60 operating out of RNAS East Fortune rendezvoused with HMS '*Furious*' off the Scottish coast and both airships made several landings on her flight-deck. Although **successful**, they were never repeated." (Mowthorpe, 1999:38)

Rigid ship landing on an aircraft carrier (USA):

> "The '*Los Angeles*' moored to the ship '*Patoka*' immediately after having made a **successful** landing on the aircraft carrier USS '*Saratoga*' without the benefit of a mooring mast." (Howe, 1999:307)

Indeed the "*Patoka*" itself seems to have done the job it was designed for perfectly well, but it has never been copied, and there have been numerous other interesting "one-hit wonders" which have had successful trials, and even operated for prolonged periods in the field. They include rotating sheds, mobile mooring winches (or "Mules") and the "Bolster Beam" all of which were said in their day to be "solutions" but none of which have propagated very far from their point of origin. Quite why so many apparently successful ideas have fallen by the wayside lies beyond the scope of this present investigation. However, part of the problem is that none of the past Airship Development projects really got far enough down the line to establish much of an infrastructure.[1] A glance at the records reveals a succession of prototypes and partly completed projects that had the plug pulled at a critical moment or which were forced to change tack before they were really ready. But there are more than financial and political risks facing the NGVLAs.

10.4 The risks of pioneering

While some of these aforementioned unproven, long forgotten, or neglected, ideas may seem a little far-fetched, it is nevertheless necessary to keep an open mind when starting from today's almost total lack of knowledge as to how the big rigid airships of the past actually behaved. This is, particularly so when evaluating suggestions, put forward by those who had considerable first-hand experience of the PGVLAs, and when trying to judge the suitability of such schemes for possible application with an unprecedented prototype aircraft - as the first of the NGVLAs will inevitably be.

By its very nature, pioneering, in any sphere of human endeavour, is a risky business, and it is important to remember that many things we take for granted today only exist because their originators took big risks and got away with it. In some cases, these risks, were enormous, and by today's standards, unacceptable. However, it is hard to see how the NGVLAs can make much progress without taking any risks at all. Therefore, it is the author's opinion that if the NGVLAs are ever to become a reality then some sacred cows will have to be slaughtered. Particularly those which reside in the dominant world of HTA flight rules and the all-powerful totalitarian mind-set that seems to result whenever there is strict and unbending adherence to Health and Safety Regulations. If the NGVLAs are seriously intent on pioneering new fields within the world of aviation then some risks will have to be taken and the resultant triumphs and disasters from trying out innovative, and perhaps even weird, old and new GH ideas, will have to be lived with – always assuming that the regulatory authorities can be brought to see the light.

> "Moreover, it must be recognised that the number of ideas submitted to the authorities is too often out of all proportion to those which do prove feasible. After any considerable deluge of these inventor's fantasies, officials become incapable of discrimination and are apt to regard all, except those which modify or amend something with which they are familiar, as the work of a lunatic." (Higham, 1961:9)

If ever there was an organised system for throwing babies out with the bath-water then this is it. However, it is clear that the PGVLA archives do hold a wealth of material and that this offers much food for thought to any NGVLA developers who have the courage to challenge the preconceptions that currently prevail in the modern HTA dominated world of aviation.

[1] With the exception of the DELAG

11 CONCLUSIONS

There are two sets of conclusions that can be drawn from this investigation – those from the collection phase of the project and those from the analysis of the information that was collected.

11.1 Conclusions from the CargoLifter historical research project

The primary purpose of this study was to demonstrate that historical research or more specifically the analysis of historical airship activities is a necessary and effective way of minimising the risks inherent in the development of any next generation very large airships because it offers a reliable source of practical information based on past experience. Such material can be used to mitigate the danger that is threatened by the lack of suitably trained or experienced very large airship personnel and to help fill, or bridge, the knowledge gap that was identified at the start of this work. The method selected to prove the importance of historical research and the effectiveness of the analysis of historical airship activities was by means of four stated aims, the conclusions to which are as follows.

The first aim was to define the fundamental ground handling problems that are generic to all airships and to identify any unresolved issues that were encountered by the previous generation of large airships and which are specific to very large airships in particular. In **Section 7**, it was concluded that there are six fundamental and unavoidable ground handling problems that are generic to all airships regardless of size or type. Three of these problems are physical in nature, in that they stem from the basic structure of the airship and/or the laws of physics, and three are operational, being rooted in the practicalities of human usage of lighter-than-air vehicles. In **Section 8**, it was shown that there are indeed a large number of serious issues encountered by previous airship developers that remain either unsolved or which have large question marks against them. The conclusion is that historical research has allowed these to be identified and that all of those listed will have to be addressed somehow if a new generation of very large airships is ever to be successful in the future.

The second aim was to expose and correct some of the myths that have proliferated since the demise of the previous generation of very large airships and to find answers to some of the difficult ground handling questions that arose at CargoLifter. These resulted directly from a lack of suitably experienced personnel and such questions will inevitably present themselves again as a serious obstacle to any future very large airships development programmes. In **Section 9**, it was shown that historical research can help to identify and to dispel some of these myths and, while it cannot of itself overturn or undo the damage done by them to the image of airships generally, both in the public mind and within the heavier-than-air community, it can at least provide real ammunition for those intent on correcting such erroneous information. Moreover, this work has shown that it is possible by carefully targeted investigation and analysis, to actually answer some of the difficult questions, and to provide sufficient information regarding others, for the risk posed by them to be better understood and thereby diminished.

The third aim was to unearth projections, plans and potentially useful ideas concerning the ground handling of very large airships that have been lost or forgotten and which are lying neglected in archives. **Section 10** has shown that there is indeed an enormous fund of untried and untested ideas hidden away, and many of them are of enormous potential benefit to next generation very large airships, provided that the context in which they were devised and the reason for their abandonment is properly understood. The conclusion is that historical research can thus protect next generation very large airship designers from repeating past mistakes and thereby unwittingly "re-inventing the wheel."

The final aim of this investigation was to suggest a strategy and establish guidelines for anyone in the future who seeks to develop a very large airship for any purpose. In view of the diverse nature and complexity of ground handling in general, and of the intricacies engendered by the different types and theoretically possible hybrid airships that may be envisaged, to say nothing of the bewildering number of possible specific uses for which they may be intended, these guidelines will be given as part of the recommendations that follow this section. The conclusion is that historical research does allow such guidelines to be established.

11.2 Conclusions from analysis of information collected

The conclusions from the analysis of historical airship activity are that, firstly, there has never been a totally successful all-weather mooring system for very large airships although in terms of achievement and reliability, the high mast mooring pioneered by the British and adapted by the Americans onboard the *Patoka* in the 1920's and 30's seems to have come as close to it as the rather different systems currently in use today by the very much smaller modern blimps. Simply rebuilding updated versions of the 1930's designs would probably work for future very large airships, considering that better stress calculations are available today with stronger, more reliable materials. There is also an improved understanding of the weather and a greater ability to monitor and predict localised meteorological phenomena.

However, the uncomfortable fact remains that in terms of proven reliability, as defined by number of cycles of use in the field, the only really successful ground handling system for very large airships was that devised by the Germans for their First World War Zeppelins. That such a labour-intensive, people-dependent, system is impractical in the modern world, both financially and in terms of safety, is beyond doubt - but as this study has revealed, for very large airships, the German ground handling system is undeniably the state of the art. It is an order of magnitude ahead of the rest, having been used thousands of times, against the hundreds of all other systems, and anyone intent on developing the next generation of very large airships must be aware that this is so and that the previous generation never really got beyond the prototype stage.

Moreover, those who follow in this path should not assume that answers to the ground handling problems revealed by this investigation are going to be easily solved by mechanical or by any other automated means. Engineers have been working on some of these problems for more than 200 years without success. This does not mean that they are necessarily permanently insoluble, but neither can they simply be ignored in the hope that they will go away.

And finally, this investigation has also revealed that although there is a wealth of historical data dealing with the flight aerodynamics of previous generation very large airships, there is very little that deals directly with ground handling, and what there is cannot readily be incorporated quantitatively into "modern" analytical methods.

Furthermore, while it appears that at the time of the previous generation of very large airship development programmes, some wind tunnel work and considerable mathematical analysis was carried out for the in-flight performance - and that much of this remains valid[1] today - apart from the seminal work carried out by Roxbee Cox (later Lord Kings Norton) in 1929, (see **Chapter 5.4.2.**) the author could find few scientific studies, or mathematical analyses, of airships when they were either in contact with the ground or in a moored state.

Moreover, as far as ground handling is concerned, all the work for this investigation has not unearthed any material that involves wind tunnels or water tank tests for scale model airships that were either approaching, or very close to, or being manoeuvred on, the ground. It is thus evident that all the previous generation large airship ground handling testing was done empirically. Therefore, unlike in flight, for ground handling there is no basis of experimental data that might be made available for use by next generation airship ground handling system designers. Doubtless a major reason why this is so is because of the complexity that stems from the number of unquantifiable variables involved in the ground handling procedures - as detailed in **Chapter 2.5.** However, the straight-forward difficulty of scaling when modelling such large, fragile and slow moving aircraft should not be underestimated. Whereas in flight it is relatively simple to separate the buoyancy and the aerodynamic forces, in the case of ground handling it is the combination of them that must be precisely replicated and the scaling laws make this impractical.

In considering a scale model for ground handling, the main issues would be to accurately represent:

- The airship's ever-changing buoyancy and effects of solar heat, rain, inversions, etc. on internal lift.
- The turbulent and sheared flow of the natural wind close to the ground in both intensity and scale.
- The effects of flow around large fixed protruding structures such as the shed, mooring mast, etc.
- The aerodynamic forces of drag, lift, moments, etc.
- The forces due to acceleration and mass, including the 'added' mass of the air displaced.
- The way movement relative to the ground is affected by the constantly changing air speed
- The airship's power systems (including vectorable thrust, engine ramp up and ramp down times, etc)
- The elastic forces in mooring ropes and cables, combined with the flexibility and strengths of the airship structure, mooring mast, etc.
- The dynamics, stiffness and damping of the impacting bodies (a rigid airship meeting a rigid tower would produce an infinitely high impact force).

As an example, a 1/100th scale wind tunnel model of a 100 m long, 120 ton airship, would, because it's mass is related to the cube of the linear scale, require a model of 1 m in length with a mass of the order of 0.1 kg. This would obviously be very difficult to achieve but could, perhaps be done by a pressurised model in the style of a toy helium balloon. However modelling any meaningful on-board power systems for it would be very difficult and would be further complicated by the fact that the acceleration forces depend on movement relative to the ground, and the wind components (turbulence, etc) would have to be modelled separately. The aerodynamic scale parameter, (Reynolds number,) could never be represented

[1] For list of selected works on this topic in Bibliography see Appendix B

and artificial flow control methods would have to be used instead. This is unlike modelling of the cruise condition where acceleration is so low that steady state can be represented.

Of course, moving to testing in water would change the situation, but it would bring its own problems (the model would now have a mass of about one tonne and need to approach the mast, or enter the shed, at micro-metres per hour), and it would not affect the fundamental problem of using scale models - namely the fact that an airship's buoyancy, aerodynamics and acceleration all scale by different factors.

Thus, if large airships are to undergo a renaissance in the near future, then a great deal of scientific work remains to be done and that associated with ground handling offers a particularly urgent and difficult challenge. It is the author's opinion, given the complexity of large airship ground handling, and regardless of the present or future sophistication of computer assisted modelling, that the only way to accomplish this work, and to obtain any seriously useful experimental data, will be to restrict the variables and reduce the number of iterations that will be required. Moreover, the only viable means of achieving this, and of establishing a manageable and/or affordable research programme that has some basis in fact, is by means of historical research and the constant referral back to the real events and actual circumstances that were encountered by the previous generation of very large airships.

However, if a new generation of very large airships is going to succeed then these problems will have to be addressed somehow, and unless a satisfactory and workable solution is found for the ground handling of the next generation very large airships then their chances of success are slim.

> "Man after man – some experimenting in darkness and stumbling on valuable truths, others scientifically searching after the answers to their problems in well-equipped laboratories – has set his mind and his hands to this problem of sailing in the air. The result is seen today. In the past Montgolfiers and Charles, Giffards and Renards, Santos-Dumonts and Zeppelins; in the future – who? Unless the knowledge of the past is handed on to those who will take the places of the workmen in this world of tomorrow, much will be lost." (Hylander, 1931:305)

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12 RECOMMENDATIONS AND GUIDELINES

12.1 Recommendations

- In order to avoid both re-inventing the wheel, and falling into the computer-assisted-endless-design trap, the NGVLA developers should adopt the Hochstetler/CargoLifter proposal of 1998. This was for a three-pronged strategy that combined a properly structured programme of archival research with a programme of instruction from ex-US Navy blimp personnel (in order to capture as much as possible of relevant old techniques and science) in conjunction with a series of empirical experimental trials (in order to verify such scientific data as does exist and also to fill in, by the most reliable means possible, the gaps in this neglected area of aviation science that have arisen since the PGVLA programmes were terminated). Computer simulations would then play a properly controlled roll in testing specific theoretical parts, and/or sequences, of the model-to-full-size-scale-up programme, and in planning each stage of the project. Thus design teams should start small and build a sequence of ever bigger airships as their personnel skills and experience allow, and as the confidence of the regulatory authorities and of the general public increases. A planned programme of rebuilding both rigids and large blimps is needed to regain knowledge that has been lost and in order to learn from past experience. HR reveals clear evidence that VLAs are best developed empirically, and allowing them to follow an evolutionary path of step by step development has been shown to be the safest and the most cost effective way to proceed.

  > "...the official report of the *R-38* disaster which proved that she was an engineering experiment on the part of British engineers who had tried to build a huge craft before they had learned how to construct small ones successfully. Their *R-33* and *R-34* had been copied from Zeppelins. **It is one thing to make a copy and quite another problem to jump into larger sizes involving new types and formulas."** (Lehmann & Mingos, 1927:323) **[GC emphasis]**

  > "By 1918, RNAS Pulham, at this period an experimental as well as an operational station, was looking into the possibilities of mooring-masts. Many small masts were erected, old SS non-rigids being used to solve the various problems. Later that year, up to four airships could be seen at any one time, permanently moored for weeks on end, evaluating different systems." (Mowthorpe, 1999:64)

- From the start of their projects, the NGVLA developers should adopt a holistic view of their airships. The physical structures, together with the GH systems and all operational procedures that are vital to the safe and cost effective operation of them must be regarded as a single entity. To this end, the NGVLA developers should consider extending HR to problem areas other than GH, where PGVLA experience may be of benefit, and, for example, to apply the techniques involved in this investigation to the design and construction of the airships themselves.

- It is important to breakaway from the current horizontal landing and take-off methods that have become so predominant and which are deeply ingrained in the public consciousness as a result of the small modern blimps' ability to use derivations of the HTA systems. Whatever is built as a learning tool for the NGVLAs, its primary objective should be to investigate the pros and cons of adopting the old "vertical" operational methods that were proven by the PGVLAs, and thus to move all personnel involved as quickly up the learning curve as possible.

- The prototype NGVLAs should be developed in accordance with naval practice and under maritime regulations. All test flights should start from, and be conducted over, water until such time as the structure is proven, the operational procedures are established, and both flight and ground crews are experienced and proficient. Flights onto land, and the integration of the NGVLAs into HTA airspace, should be treated as further separate projects, which are extensions of normal operations, and the additional difficulties (and dangers) of achieving them should be recognised - as it was in the earliest days of airship development:

  > "Zeppelin ... lands on Terra firma. - On Tuesday last the "Zeppelin" [*LZ 3* (*Army Z1*)], made a successful landing on the ground. Hitherto, the Zeppelin craft have always descended upon the water, and this had been held to be a disadvantage of this type of airship. The craft, with Count Zeppelin at the helm, came down to within about eight feet of the earth, when it was held down by soldiers. Some of the steering planes were damaged by striking a tree, and they had to be removed." (Flight, 1909)[1]

- The terminology of the NGVLA constituent parts, and of the operational and construction procedures, must be firmly established, and all areas of responsibility clearly defined. This is especially important with regard to the seniority, precedence and hand-over of authority within the design, construction and operational hierarchies. In order to save time, confusion and disappointment, these usages and relationships, along with ownership of all equipment, must be agreed internally between all departments involved in the development, before design of the prototype NGVLA commences. This internally agreed terminology also needs to be accepted and agreed externally by all regulatory authorities prior to construction and certification.

- The material concerning the PGVLAs that is currently held in numerous disparate libraries and archives in Germany, Britain and America must be catalogued and cross-referenced so that the NGVLA engineers can learn quickly and efficiently whether their ideas have any precedent. Ideally a publicly accessible, world study centre dedicated to all facets of LTA flight should be established, in combination with a museum of artefacts from the PGVLAs. These should be housed at a single site, where the NGVLA developers can have access to documents, drawings, conference papers, books, pictures, patents, and etc., for all shapes and sizes of balloons and airships, including past attempts to hybridise them with HTA craft.

12.2 Guidelines for a VLA development strategy

The fourth aim of this thesis was to give guidance to potential NGVLA developers and to suggest a strategy based on the lessons of history in order to minimise the risks inherent in future large airship projects.

The following suggestion is thus made by the author on the basis that it is his firm belief that it will be absolutely necessary, on grounds of cost and safety if nothing else, for those who will design and operate any future large airships, to relearn much of the forgotten knowledge and to regain some proficiency in proven VLA techniques *before* they begin to experiment with brand new GH ideas or to attempt unprecedented feats such as LEP manoeuvres.

[1] NB - this event did not take place until some nine years after the first flight of Count Zeppelin's first airship *LZ1*

Moreover, this lost knowledge and skill can only be regained by a measured and carefully planned process of accretion, moving progressively in stages, from the small blimps of today to ever larger airships, as the ground and flight crews' abilities grow. However, it must be emphasised that the strategy outlined below, would only be fully necessary in cases where an NGVLA development project is intending to be wholly or largely dependent upon procedures that have never ever been attempted or undertaken by large airships of previous generations. There is no doubt that airships, in themselves, can be made to function. The danger comes from unproven assumptions, such as, for example, that they can be used to pick up and transport heavy loads cost-effectively.

Attention also needs to be drawn to the fact that, although the science of large airship development and operation has lain dormant for some 60 plus years, much has happened in other fields of human endeavour that is either directly applicable, or potentially of considerable use to anyone intent on updating the subject. An example of this is given at the end of **Appendix B** where the hydrodynamic theories that underlie the development of modern submarines can be seen to have much in common with very large airships. Similarly for the moored airship, where much wind-tunnel, and other theoretical and experimental work that has been conducted on buildings and large ground based structures since the termination of the PGVLA programmes, can be expected to offer much that will save time and money for NGVLA development teams. One or two works pertaining to this have thus also been included in the Bibliography of this investigation.

However, as a result of this study, and based on the forgoing conclusions and recommendations, it is suggested that anyone intent upon the construction of any very large airship in the future, and regardless of the airship's intended purpose, should allocate, within their development programme, a considerable amount of both time and resources to the completion of two distinct but interacting research projects. These are:

- Firstly, to conduct a properly funded, in-depth study of the historical material held in LTA archives, bearing in mind that there are 2 angles from which to view the subject – the designer's and the operator's. This study should be done in a proper professional manner, preferably by a team of experienced historical researchers, in order to ascertain:

  a) whether the intended NGVLA project, or anything approximating it, has been previously attempted, and, if it has, then why it (or they) failed, or alternatively, if it has no direct historical predecessor, nor precedent, then whether there are any reasons given in the records as to why those past projects which might be adjudged closest in size, or scope, or in operational capability, to the intended project, were not so used, and why they too eventually failed or are not still operating today;

  and,

  b) whether there have ever been in the past any GH equipment or operational techniques that were proven in the field, which are not in use today, but which might be applicable to the intended project, and which if resuscitated might save either time, or money, or improve groundcrew safety or otherwise minimise the risks of the NGVLA development programme;

  and,

c) whether there have ever been any plans or proposals put forward by experienced personnel for similar or related schemes to that intended, or for improvements to relevant GH equipment, or for other interesting suggestions and ideas that have never previously been tried or tested, (perhaps for political reasons, or due to financial restrictions, or because of the limited technological capabilities of their day,) and thus which may have been forgotten or overlooked, but which now might be achievable, or are at least worthy of further investigation.

- Secondly, to carry out a properly structured, concurrent programme of empirical testing in order to establish the viability of their intended VLA GH systems at a small scale. This would simultaneously extend the team's "in-house" knowledge and build up individual skills and experience in manageable, incremental steps. Moreover, if this test or trials programme were to be run in parallel with the archival study, then relevant discoveries from HR could be confirmed or tried out affordably at a small scale. Such a programme would thus allow:
    - construction teams to learn fast by experiment;
    - GH and flight teams to feed back real results to the designers;
    - designers to innovate with the confidence that they are not re-inventing the wheel, and
    - the regulatory authorities, or those in charge of certification, to know with a degree of confidence that they were not simply being "rail-roaded" into rubber stamping a *fait accompli* that has no precedent.

The author's suggestion for one such incremental test programme that would move by degrees from today's level of knowledge, progressively into unknown territory, as it might be applied in the case of an unprecedented weight-lifting airship, is appended here. It would begin with small models, and step-up, where possible, by use of extant equipment, and the application of already proven procedures, while allowing for the incorporation of some previously known but now forgotten, (or neglected,) ideas. Thus:

- Use a small UAV or flying model to perfect the GH and LEP procedures, indoors, in still air – i.e. practice and perfect the precise-point-pick-up (PPPU) and the precise-point-put-down (PPPD) at small scale with something like an egg. This will determine, with minimal financial risk, that the project idea does not contravene the laws of physics and is a viable proposition. It will also begin to build the practical skills of the operators (pilots and ground crews).

- Feed data to computer model and make projections to predict behaviour and the implications of the chosen procedures in real weather conditions and at full size, and to suggest experiments, improvements and/or modifications accordingly. This will allow the designers, theoreticians, programme planners, et al, to think outside the box, to make radical changes without such constraints as certification and to make early estimates of the likely costs of the finished project.

- When a workable procedure, which all departments are happy and familiar with, has evolved and the operators are proficient at it, then introduce variables such as pre-determined artificial gusts of wind and measured temperature changes inside the controlled environment to mimic the real world. This will define what physical systems the full-size airship structure needs in terms of propulsion, thrusters, winches, &c., and what GHE is necessary to support it and enable it to conduct the chosen LEP. It will also further increase the skills of the operators.

- Refine the physical and computer models accordingly.

- Involve the regulatory authorities. Agree incremental development programme that will give confidence to all parties and allow for ultimate incorporation of certified NGVLAs into today's highly regulated and restricted airspace.

- When operators are skilled in chosen procedures take the UAV model and its GH system out of doors and repeat the LEP procedures in progressively worse, real weather conditions. This will test the accuracy of the computer predictions and build confidence of operators and regulators.

- Continue to refine the computer models with real data from the miniature scale trials and use them to make predictions for full size trials.

- It is strongly recommended that the media are not involved and press conferences are not called at least until this "small scale" stage is complete. This will mean that operators are skilled in control of the models and can demonstrate them without embarrassment, that at least some of the early models are expendable and can be used for publicity, that designers are free to make drastic changes along the way without the public humiliation of an apparent U-turn, that the costs of the project are kept to a minimum, that team confidence is kept at maximum and that the regulatory authorities are relaxed and conversant with progress and plans.

- Start full size trials with a real, weight lifting, person-carrying, airship - such as the hot air ship devised for and used during the "Radeau de Cimes" project - and try out the chosen procedures in calm conditions.

- Compare results of full-size trials with computer predictions and feed real data back to improve the computer model.

- Repeat the trials with a series of full-size, helium-filled, modern blimps, starting with a small *Lightship* that has no vectored thrust and comparing it with a larger *Skyship* that has increased hovering capability. This will reveal what systems the VLA pilots actually need in terms of vertical/lateral/reverse thrust, as opposed to what the designers think they will need, and allow for integration of ideas from experienced blimp operators. It will also allow an input of ideas, suggestions and/or criticisms from experienced blimp pilots and ground crews.

- Also conduct trials of vertical take-off and landing from a mooring mast with an available aircraft and infrastructure e.g. *Zeppelin NT* landing vertically to the "Hydramast" or similar mechanical GH system.

- Then open up construction process by building an updated copy of a US Navy *ZPG*, or similar proven large blimp[1] such as an *M-ship*, to regain lost construction and operational techniques. This should be a standard blimp with x fins and no vectored thrust to give performance as close as possible to its predecessors. Test flights and trials of this blimp will allow comparison of actual and theoretical performance with known performance of forebears and should aim to achieve full certification. This ship will finally become available for crew training and promotional work.

- Followed by a second similar blimp, but with a new configuration, perhaps adding vectored thrust to facilitate vertical landing, LEP, etc. This will enable the two designs to be compared in reality and a decision as to the desirable configuration for a large scale modern design to be made with confidence. The changes and innovations incorporated into the second ship will allow the certification process to take a further small step forward and success in this will increase the crew training and promotional possibilities available with perhaps a ship dedicated to each.

- Then build an updated copy of a proven small rigid airship, such as the "*Bodensee*" which was of similar size to the biggest of the US Navy's blimps. This will be a big and expensive step but by this time a fully operational assembly plant, with a partially skilled workforce will be available. The preceding work on the blimps will by this time also have provided a pool of partially experienced designers and operators, thereby reducing the risks in building such a prototype. An old proven design built of improved modern materials would allow verification of performance against the historical records. This data would further improve the computer models of even larger airships for the future and would allow a decision as to whether a rigid or a non-rigid airship was the most suitable for the intended NGVLA.

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[1] "The *ZPG-3W* required 120,000 square feet of drawings, 4,800 pages of handbooks and 26,000 pages of reports. There were 102,000 hours of static tests, 130,000 man-hours for the flight test program, and 40,000 man-hours on the engine test stands. ... The Goodyear project number was GZ-17. Engineering effort consisted of 1.56 million man-hours; there were 378 engineers assigned at the peak in March, 1956." (Shock, 1994)

- Then go back to sea. Basing the large blimps and new small rigid at a water-based facility would allow all crews and designers to experiment with, and verify the claimed advantages for, some of the systems such as those envisioned in **Section 10.** This would facilitate planning for a new generation of even larger airships that might be allowed to operate as prototypes only from and over water, thereby alleviating much of the pressure on the regulators and removing some of the media attention by reducing the foreseeable threat of an accident affecting the public.

- By this time there would be sufficient knowledge and expertise available to then realise one of the Goodyear plans for a *GZ-13* or a *GZ-16* type blimp - something that is much bigger in size than the *ZPG.* These blimps were designed during the US Navy blimp programme in the 1950's but neither of them was ever built. (Shock, 1994:III-32)

- Compare actual weight-lifting performance of similar sized rigid and non-rigid airships and begin to experiment with a full-size Load Exchange Procedure as tested by the small UAVs at the start of the NGVLA programme.

Such a test programme would plainly not be cheap. Neither would it be risk free, but it would be a lot less expensive and far safer than jumping into the darkness and starting straight out to assemble a full sized, theoretically conceived, weight-lifting, NGVLA directly from the drawing board (or from CAD software). Furthermore, if it is argued that such an incremental trial programme would of itself be either prohibitively expensive, and/or too risky to be allowed, or that current certification and/or regulatory requirements would prevent or disqualify it, then the whole idea of building the NGVLAs can simply be forgotten, because the historical records clearly indicate that the costs and risks at full scale are going to be immeasurably greater.

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APPENDIX A : THE FUNDAMENTAL PRINCIPLES OF AEROSTATICS

THE ATMOSPHERE

The US Navy pilots of large rigid airships were taught that:

> "Aerostatics is really a branch of thermodynamics and in its specialized aspects is based on general thermodynamic laws. Atmospheric air (as well as the ordinary lifting gases) throughout the range of conditions which we are interested in acts as an almost perfect gas, following Boyle's law and Charles's law with a high degree of exactness." (US Navy, 1927 : II-6-18)

From which it follows that:

> "The volume of a gas varies with the absolute temperature and the pressure : this consequently affects the density.
> Let V = volume of gas in cu ft.
> Let T = absolute temperature of gas.
> And let p = absolute pressure in lb per sq ft.
> Then; combining the laws of Boyle and Charles,
>
> $$\frac{pv}{T} = \text{a constant}$$
>
> where T = (ordinary temperature + 461) for Fahrenheit deg.
> T = (ordinary temperature + 273) for centigrade units." (Lewitt, 1925 : 23)

However, as is well known and understood in all fields of aviation, the atmosphere is an ocean of gas that is constantly in motion. This makes accurate time-based calculation all but impossible, and, as a consequence the conditions of a theoretical "standard atmosphere" have been internationally agreed. Here is the CAA's definition of the International Standard Atmosphere or ISA as it is more commonly known:

> "ATMOSPHERE, INTERNATIONAL STANDARD
> An atmosphere defined as follows:-
> the air is a perfect dry gas;
> the temperature at sea-level is 15 ° C;
> the pressure at sea-level is:
> $1.013250\times10^{5} N/m^{2}$ (29.92 inches Hg) or (1013.2 mbar)
> the temperature gradient from sea-level to the altitude at which the temperature becomes -56.5 ° C is:
> 3.25 ° C per 500 m (1.98 ° C /1,000 ft);
> the density at sea-level, ρ_0, under the above conditions is
> 1.2250 kg/m^3 (0.002378 slugs/ft^3)"
> (CAA : CAP 471, 1979: Chap. Q1-2 Definitions : 4)

And just to keep an eye on reality:

> "The highest pressure ever recorded (reduced to mean sea level) was 1076.2 mb at Irkutsk in Siberia, ... The lowest ever was 886.8 mb on a boat 400 miles E of the Philippines. The highest pressure recorded in Britain in the last 100 years [i.e. prior to 1979] was 1054.7 mb, and the lowest 925.5 mb." (Welch, 1979 : 36)

THE WEIGHT OF ATMOSPHERIC GASES

Thus it is the case that:

> "The air, like other matter has weight. A column of air weighing nearly half a ton rests on the head of each one of us." (Cook, J.G. undated : 10)

And, it therefore follows that under ISA conditions, the density of other atmospheric gases can also be defined, and the two that are most commonly used in lighter-than-air flight can be compared with air:

Air (dry) - 1.2250 kg/m^3
Hydrogen - 0.0846 kg/m^3
Helium - 0.1693 kg/m^3

Therefore:

> "Hydrogen has half the density of helium, while natural coal gas has about nine times the density of hydrogen and four and a half times the density of helium. The three gases – hydrogen, helium, and natural coal gas – have net lifts per thousand cubic feet at sea level of about 70, 65, and 29 pounds respectively." (Overs, 1981 : 22)

In metric terms these translate as:

Lift of hydrogen	(70 lbs per 1000 ft^3) = 1.121 kg per 1 m^3
Lift of helium	(65 lbs per 1000 ft^3) = 1.041 kg per 1 m^3
Lift of coal gas	(29 lbs per 1000 ft^3) = 0.464 kg per 1 m^3

These are by far the lightest gases that are available for LTA flight and therefore:

> "All balloons and airships up to present time have used as their lifting gas hot air, hydrogen (either commercially pure or as coal gas), or helium. Other lifting media proposed from time have ranged from hard vacuum (De Lana, 1670 and Edgar Rice Burroughs, 1950's) to superheated steam (Pabst, 1970)." (Mowforth 1991 : 22)

Moreover, because any gas filled body, such as a balloon or an airship, is entirely surrounded by a denser fluid medium, namely the air, it must follow that it will be subject to the Principle of Archimedes.

ARCHIMEDES PRINCIPLE

> "When a body is immersed in a fluid, it appears to lose weight by an amount equal to the weight of the fluid displaced. This apparent loss of weight by a body is really the upward thrust on the body caused by the fluid." (Lewitt, 1925 : 22)

Which means that, contrary to that which is commonly believed:

> "The true source of buoyancy is the surrounding air and not the confined gas. If the gas could be removed, leaving a vacuum, without collapse of the container, the lift or buoyancy of the airship would be increased by an amount equal to the weight of gas abstracted." (Recks, 1977)

And thus:

> "It should be clearly understood that no actual lifting power is obtained from the gas, its only function is to counteract the external pressure of the atmosphere on the structure ... [and] The hydrogen actually presses radially outwards on all parts of the bag, with a greater pressure at the base ..." (Lewitt, 1925 : 22/27)

This is true for all balloons and airships regardless of type, size or structure.

THE THERMAL PROPERTIES OF LIFTING GASES

While it is commonly believed that there is little to choose in terms of lift between "dangerous" hydrogen and "safe" helium, from the point of view of the balloon or airship pilot, there is a great deal of difference, as the two gases have very different thermal properties. This becomes apparent when an LTA craft moves vertically through the natural pressure gradient of the atmosphere. Thus:

> "... rapid ascent allows little heat transfer from the surroundings into the contained gas as it expands and thus cools. The cooling rate is different for each of the gases. The reduction in gas temperature during the ascent is continuous. The net increase in positive buoyancy, (as when dropping a quantity of ballast) will thus be reduced differently for each gas during the climb. These reductions in buoyancy are significantly different and are related to the lapse rate of each gas and the lapse rate of the surrounding atmosphere. The lapse rate is the change in temperature for each gas for each 1000 feet change in altitude. The United States Standard Atmosphere has a lapse rate of 3.6° F for each 1000 feet of altitude below a level of about 36,000 feet. If a balloon containing a gas is raised rapidly upward through the atmosphere and is allowed to expand without superpressure, the reduction in temperature for each gas is as follows:

Hydrogen	5.4° F
Helium	7.3° F
Methane	3.9° F

Since the lapse rate of the atmosphere itself is 3.6° F per 1000 feet, balloons inflated with these three gases will supercool by a value equal to the lapse rate of each gas, minus the lapse rate of the atmosphere as follows:

Hydrogen	1.8° F
Helium	3.7° F
Methane	0.3° F

Methane having a lapse rate nearly equal to that of the atmosphere, supercools very little during a rapid ascent compared to helium and hydrogen." (Overs, 1981 : 24/5)

Which means that in practical terms balloons filled with different gases will behave differently:

> "...during ascent below pressure altitude, the methane balloon will rise with only a small change in buoyancy while the helium balloon will tend to arrest its own rise as the helium supercools." (Overs, 1981 : 25)

Naturally the same thing will happen in reverse following a rapid descent with the result that:

> "The lift of a balloon filled with helium will, after a rapid decrease in altitude, exhibit more false lift than will balloons inflated with either hydrogen or methane. The false lift will dissipate over a period of time, but can cause the pilot some degree of confusion." (Overs, 1981 : 25)

This false lift is known as "superheat" and there are two causes of it that an LTA pilot needs to be aware of - that caused by the aforementioned change of altitude (adiabatic heating), and that induced by solar radiation (solar gain). When it comes to very large airships the combination of these physical properties of the atmosphere can have dramatic effects upon the buoyancy of a vessel, although these may be exacerbated, or mitigated by the design and physical structure of any specific LTA craft.

> "In an airship of the rigid type, the hydrogen is protected from the heat of the sun by the outer cover and air space, and will not necessarily be the same temperature as the atmosphere."
> (Lewitt, 1925 : 23)

BUOYANCY CONTROL AND EQUILIBRIUM

Nevertheless, it is the case for all LTA craft that:

> "... a ship whose buoyancy or total lift is in excess of its weight will rise, and will continue to rise until it reaches an altitude at which the weight of air it displaces is just equal to the total weight of the ship, including the weight of the hydrogen. At this altitude a condition of equilibrium will be established. ... If ... the weight of the ship is decreased by a discharge of ballast, the ship will rise higher until the weight of air displaced is correspondingly decreased ; a new state of equilibrium is then reached. Thus it follows that for every discharge of ballast the ship will rise into less dense air." (Lewitt, 1925 : 24)

GENERAL EQUATION OF MOTION FOR A FREE BALLOON

Moreover, the foregoing can also be expressed in mathematical terms:

"The general equation of motion of a free balloon may be most readily expressed by the following form:

$$K\left(w-\frac{dz}{dt}\right)^2 - m\frac{d^2z}{dt^2} + cz + F = 0$$

Where:

z = vertical distance above given reference altitude
m = total mass of the balloon including the mass of the gas and the hydrodynamic "virtual mass"
K = the overall resistance coefficient of the balloon in question
w = the speed of the vertical air current in which the balloon is placed
c = a thermal constant whose magnitude depends on the volume of the balloon and the difference between the temperature gradient of the outside air and the adiabatic rate of change in the temperature of the contained gas per unit change of altitude.
F = any arbitrary unbalancing force such as that due to discharge of gas or ballast, or radiation or conduction of heat.
t = time from the position where z = 0."

(Upson & Chandler, 1926:14/15)

GENERAL EQUATION OF MOTION FOR FREE BALLOON WITH INITIAL VELOCITY

"For the case where the balloon has an initial velocity

$$z_2 - z_1 = \frac{m}{K}\log\left(\frac{1+e^{2bt_2}}{e^b(t_2-t_1)(1+e^{2bt})}\right)$$

Where: z_1 and z_2 = the initial and final positions and
t_1 and t_2 = the initial and final times respectively
Measured from the point where v = 0

For a balloon of some other size, K above will vary as the two-thirds power of the volume and m and c directly as the volume. K, m and c (approximately) also vary directly as the air density for different temperatures and pressures." (Upson & Chandler, 1926:14/15)

PRESSURE HEIGHT OR STATIC CEILING

However, there is a maximum altitude to which any given balloon (or airship) will rise in any given set of circumstances. This is known as the pressure height or static ceiling:

"The height to which the ship will rise depends on the ratio of excess buoyancy over weight.
Let B = total buoyancy of ship in tons, based on lift of hydrogen as 68 lb per 1,000 cu ft.
Let W = total weight of ship in tons, which consists of weight of hull, fabric, engines, fuel, ballast and crew.

Then, percentage of lift used = $\frac{W}{B}\times 100$

The curve in Fig. 21 gives the altitude to which the ship will rise, the base representing $\frac{W}{B}\times 100$ and the vertical ordinate representing the altitude in feet. This curve is approximate only, it being plotted for normal temperature and pressure, but it is accurate enough for practical purposes." (Lewitt, 1925:25/26)

THE EFFECT OF BAROMETRIC PRESSURE ON LIFT

In order to demonstrate how some of this theoretical work impacts upon the planned next generation of very large airships (NGVLAs) it is revealing to take as the basis of an investigation two large airships - one real one from the past, and one that has been proposed as a theoretical concept - and to compare the effects that one aspect of Aerostatic theory has on them when they are moored.

The real example is *LZ130 "Graf Zeppelin II"* (the last and largest of the previous generation) and, for the theoretical example of the planned next generation it is convenient to use the published dimensions that were envisioned for the *CargoLifter CL160.*[1] These dimensions are for an early version of the *CL160* and were later revised, but they are adequate to give an idea of the magnitude of the resultant effects.

Table A.1 - Dimensions of LZ130 and CL160

	LZ130 "Graf Zeppelin II"	*CL160 "CargoLifter"*
Volume	200,000 m^3	550,000 m^3
Length	245 m	260 m
Diameter	41.1 m	65 m
Speed	82 mph (131 km/h)	125 km/h
Engine power	4200 hp	8,000 hp

If Archimedes Principle is now applied to these two moored airships, (and for simplicity measurement is transferred to S.I. units) then the different amount of lift that each of the two fixed volumes will yield can easily be calculated. Furthermore by keeping the temperature constant and varying the pressure it can be seen how the lift will change as the barometric pressure changes. Thus, for the purposes of this investigation it is assumed that these airships are moored in a temperature controlled environment at sea-level and that they are fully inflated with 100% pure hydrogen.

Furthermore it is also assumed that:

[1] Everding & Reich "Neue Entwicklungen in der Luftschiffahrt - Table 5" in Meyer, Meiners, Post, et al. 2000 : 234)

- the airships are permanently supplied with fresh gas so that they always remain totally full,
- they have pressure relief valves so that the gas in them is never pressurised above atmospheric pressure,
- the temperature of the gas contained within them is constant and uniform throughout each,
- the gas temperature in each is identical with the ambient air surrounding them,
- the humidity of both the gas and the ambient air are also identical, and that
- the ambient air surrounding them conforms exactly to the International Standard Atmosphere.

Given that the first and smaller of the two examples *LZ130 "Graf Zeppelin II"* had a volume of 200,000 cu m then the total theoretical lift can be determined thus:

If the weight of air (dry) at ISA is 1.2250 kg/m^3 then 200,000 cu m of displaced air will weigh 245,000 kg and if the weight of Hydrogen at ISA is 0.0853 kg/m^3 then 200,000 cu m of hydrogen weighs 17,060 kg. Therefore, under ISA conditions, *LZ130*, filled with hydrogen has a theoretical gross lift of 227.94 tonnes.

However, if all else remains constant but the atmospheric pressure drops from ISA 1013 mb to 970 mb then the airship's lift will be similarly decreased and *LZ130* lift will equal 227,940 / 1013 × 970 = 218,264.36 kg or 218 tonnes.

Conversely if the atmospheric pressure were to rise to 1040 mb then the lift would increase and *LZ130* lift will equal 227,940 / 1013 × 1040 = 234,015.39 kg or 234 tonnes.

Thus it can be seen that any potential mooring system for the hydrogen-filled *LZ130* can expect to have to deal in extremis with some 15 tonnes of variation in lift (234 - 218 kg = 15,751.03 kg). This difference will be caused solely by changes of the barometric pressure between 970 and 1040 mb and is regardless of whether these variations are due to fluctuations of the ambient pressure over a period of time at one location or, perhaps, to transferral of the mooring system to a new operational base at a different altitude.

> "The atmospheric pressure is due to the weight of the column of air above, and will consequently decrease at higher altitudes. As a decrease in pressure means a decrease in density, the weight of air displaced by the ship decreases as the altitude increases; the lift of the ship will therefore, decrease at higher altitudes." (Lewitt, 1925:24)

THE EFFECT OF SIZE ON BUOYANCY

Turning now to a theoretical airship, which is equal in size to the dimensions proposed for the *CL160*, it will be found that when filled with hydrogen at ISA there would be a gross theoretical lift of 626,835 kg. Furthermore this figure would vary with changes of barometric pressure to yield 600227 kg of lift at 970 mb and 643,542.34 kg at 1040 mb, resulting in a range of some 43 tonnes (43,315.34 kg).

In reality this figure can be expected to be somewhat reduced because it has been found impossible in practice to fill any airship with a 100% pure gas. Consequently, it would be more accurate to assume a 95% pure gas which naturally enough will only generate 95% of the lift. Also, it seems currently unlikely that the regulatory authorities will permit hydrogen to be used as the lifting gas for the prototype NGVLAs and it is therefore interesting to note that doing the same sums again with 95% helium yields a calculated difference in lift due to changes of barometric pressure of some 38 tonnes (38,116.71 kg).

It can thus be seen that, in order to simply accommodate variations of barometric pressure between 970 mb and 1040 mb, any mooring system for an NGVLA of similar size to the *CL160* will need to have access to at least 30 tons of ballast to counteract the potential changes in the airship's lift from this cause alone. While this is not by any means an enormous number, it is a significant weight and it cannot be ignored. It is certainly far more than ground crew personnel can be expected to move by hand on a regular basis as is currently the case for today's small blimps.

By way of comparison, one of the larger of the modern blimps, the *Skyship 600*, has a volume of 6600 m^3 and thus displaces 8085 kg of air under ISA conditions. This then gives: Helium = 1,117 kg : Lift = 6,967 kg at ISA : Lift at 970 mb = 6,672 : Lift at 1040 mb = 7,152 : Resulting in a Difference of 480 kg. Thus barometric change is scarcely noticed in the course of today's blimp operations. Added to which:

> "Pressure changes are usually slow – often less than half a millibar per hour ... in most meteorological contexts, a pressure fall of about 3 mb/h is considered to be rapid – such a fall would normally be indicative of the speedy approach of a vigorous depression." (Wallington, 1982:14)

THE EFFECT OF WATER VAPOUR ON LIFT

However, in the real world there are further complications:

> "The density of clean dry air at the pressure of 1,000 mb and temperature 290° K (17° C) is 0.001201 grams per cubic centimeter. The formula for calculating the density of moist air at the pressure of p mb and temperature T° K is
>
> $$0.001201\left(\frac{p-\frac{3}{8}e}{1000}\right)\frac{290}{T}$$
>
> where e is the vapour pressure of the water in the air in millibars. This shows that density increases with pressure and decreases with temperature, and also that if the proportion of water vapour is reduced, the air pressure and the temperature remaining the same, the density increases. Thus in general wet air weighs less than dry air." (Sutton, 1962:203)

And furthermore, an airship that is filled with a moisture laden gas and submerged in *dry* air will generate more lift than one that is filled with a *dry* gas and submerged in *wet* air. Investigation of this however, depends on knowing something of the nature of water vapour.

> "Pure water vapor cannot exist under standard conditions; however, its specific weight can be calculated from theory.
>
> $$\gamma_{W0} = 0.7620 kg/m^3$$
>
> Adjusting for an average temperature of 29.4°C gives
>
> $$\gamma_W = 0.7252 kg/m^3$$." (Jones & Thach, 1995:80)
>
> Where: "γ_{W0} = specific weight of water vapor at STP, and
>
> γ_W = specific weight of pure water vapor." (Jones & Thach, 1995:77)

It also depends on the rate at which water vapour is transmitted through helium retaining membranes.

> "In a previous paper[1] it was reported that humidity in both the helium and the ambient air affects buoyant lift and that water vapour penetrates modern laminated aerostat hull material rather well. Since water vapor is lighter than air it provides additional lift when the helium is moist. On the other hand, moisture in the outside air reduces the air density and decreases lift. Analysis shows that when the water vapor content of the helium is the same as that in the outside air, there is no net effect on lift, although there is an effect on gas volume." (Jones & Thach, 1995:77)

However, calculating the exact buoyancy of any particular airship at any specific moment is an enormously complex subject,[2] that is governed by the size and surface area of its gas cells. But some idea of the scale of the effect humidity will have on the lift of the NGVLAs can be estimated from work carried out on the TCOM 71M™ aerostats. These are 71 metres long, have a helium volume of 10,246 m^3 and a material surface area of 4,280 m^2.

> "It is apparent that [following inflation of a TCOM 71M aerostat with "initially-dry" gas] the water vapor pressure in the helium increased approximately as predicted ... approaching that of the outside air in about 10 days." (Jones & Thach, 1995:79)

In this case the rate of water vapor transmissivity was found to be "0.0165 kg/m^2-hr at 29.4°C" and although this number may seem small it cannot simply be ignored by the NGVLAs because:

> "Study will show that the effect of humidity on the lift is the greatest under conditions that otherwise tend to make the lift of an airship the least. The larger we build airships the greater the attention we must pay to humidity effects." (US Navy, 1927:II-24)

This effect will be most strongly felt by any NGVLAs that are intended to carry loads between the tropics and higher and colder latitudes (where, incidentally, condensation and liquid water accumulation within the gas chambers will also become a further problem!). Humidity ingress will also affect the lift of any newly inflated airship, where gas has been freshly de-compressed from cylinders - or vaporised from a liquid state - and will thus contain very little any moisture initially.

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[1] Jones, S.P., "Tethered Aerostat Performance Modeling," AIAA paper 86-2567-CP, October 1986.

[2] For a method of correcting airship lift equations by inserting humidity values see US Navy Rigid Airship manual, 1927 : II-24/25, paragraphs 50-53.

AEROSTATIC RULES OF THUMB

While Aerostatics theory is not exceptionally difficult to understand it is nevertheless a complex subject and it is widely misunderstood largely because many of the concepts are not encountered elsewhere within modern aeronautical engineering. There are however some simplified "rules of thumb."

"HELIUM - AEROSTAT RULES

Constants: (with all other factors equal)

1. The lift of an aerostat varies with a change in volume.
2. The lift of an aerostat varies with a change in barometric pressure.
3. The lift of an aerostat varies with a change in temperature
4. The lift of an aerostat varies with a change in humidity.
5. The barometric pressure decreases approx.1-in [2.5 cm] for each 1000 ft of altitude.
6. The temperature will decrease approx. 1-degree of Fahrenheit for each 300 ft ascent.

Changes:

7. The lift of gas increases as barometric pressure increases, and decreases if pressure decreases.
8. The lift of a fixed volume of gas decreases if the atmospheric temperature increases, and increases if the temperature decreases.
9. The lift does not change due to a change in barometric pressure, if the gas is free to expand.
10. The lift decreases as the Atmospheric humidity increases, for a fixed volume of gas.
11. The lift does not change when air and gas temperature change in equal amount, if the gas is free to expand.
12. An aerostat in equilibrium at any altitude will be in equilibrium at the surface, providing there is no superheating of the gas.
13. An aerostat rising from the surface in equilibrium will be in equilibrium at any altitude below pressure height, providing no weight is lost and there is no superheating.

Numbers : (if the gas is free to expand)

14. The gas volume will increase approx. 1% for each 375 ft [114.3 m] of altitude.
15. The gas volume will increase 1% for every 5 F-degrees [2.8°C] of temperature.
16. The gas volume will increase 1% for every 5 F-degrees [2.8°C] of superheat."

(Rechs, 1977)

"FORMULA FOR LIFT

$$L = \frac{As\,x\,Pp\,x(1 - Sg)x\,Ts}{Pp\,x\,Ps}$$

Where: As = Standard air density (.0765) : Sg = Specific Gravity of He gas (Sg of helium is normally 0.1381, but varies slightly by source) : Pp = Present barometric pressure (Where 'Present' means true readings at a specific altitude above Mean Sea Level - MSL) : Ps = Standard Pressure (29.92) : Tp = Present Temperature : Ts = Standard Temperature (59)."

(Rechs, 1977)

THE IMPACT OF TEMPERATURE ON GROUND HANDLING

The effects of adiabatic heating and externally induced super-heating (or super-cooling,) due to solar radiation and changes of air temperature, are well documented because they play a large part in the flight operations of all airships. However, it is important to note that the effects of super-heating can be exacerbated on the ground when, for example, an airship is moved out of a heated hangar on a winter's day, or is held still on its moorings on a calm, summer's day when without any "wind chill" the airship can "cook up" and any excess lift that is generated must be dealt with by the mooring system.

Moreover, from the GH perspective, whereas the appearance of solar-generated superheat is fairly predictable for it occurs while the airship is static, the ramifications for GH from adiabatic heating are in some ways more complicated. By definition the airship is arriving from flight, and has thus been in motion. When it is brought under control and held still, the airship may well be positively buoyant but the proportion of lift resulting from its rapid descent will not be apparent until it has cooled and the time taken for this is dependent upon the radiative properties of the specific airship and the weather on the day in question. Consequently, the ground crew must plan for any ballast that is initially loaded on to the hot airship to be removed again as the airship cools or for this temporary excess lift to somehow otherwise be accommodated by the mooring system.

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APPENDIX B : AERODYNAMICS AND HYDRODYNAMICS

AERODYNAMICS

The branch of Aerodynamic Science that applies to large airships has been somewhat neglected. Little work was done on the subject between the seminal paper of Lord Kings Norton (Roxbee Cox, 1929) and the investigation at Cranfield Institute of Technology (Gomes, 1990). Thus:

> "The aerodynamics of the airship, particularly in transient flight conditions, - turning, briefly climbing or diving, flying through gusts – are far less well understood than the corresponding phenomena for the aeroplane and the helicopter." (Mowforth, 1991:27)

Moreover, apart from the obvious fact that far greater effort has been applied to the study of heavier-than-air behaviour, since the demise of the large rigid airships some 60+ years ago:

> "The origins of this ... rest with the ancient spectre of Scale Effect." (Mowforth, 1991:27)

SCALE EFFECT

The problem stems from the fact that all airships are large and they fly slowly.

> "Unfortunately, a model of a subsonic aircraft under test in an atmospheric wind tunnel can accurately reproduce the flow pattern over the full-size vehicle at its true flight speed only if:-
> (i) the product (size x speed) is the same for both, and
> (ii) the airflow velocity over the model is too slow to introduce compressibility effects, i.e. it is less than about 900 km/h (560 mph)
> - so to generate an accurate representation of the flow pattern over an airship 200 m (660 ft) long flying at 100 km/h (63 mph), using a 1/100 scale model 2.0 m (6.6 ft) long, condition (i) above would require the model to be tested in an airstream at 100 x100 =10 000 km/h (6 300 mph), or about 8 times the speed of sound, and this would be somewhat beyond the limits prescribed by condition (ii)." (Mowforth, 1991:27)

While techniques do exist for increasing the Reynolds (Re) number and reducing air viscosity by means of high-pressure and low-temperature wind-tunnels, these are costly and there has thus far been little incentive to apply them to airships. Thus the usual practice is still to carry out model tests:

> "...at more manageable speeds and [then apply] suitable corrections for scale effect; but [for large airships] the process of correction has always been a difficult one, becoming more so for cases other than those of steady flight at small angles of attack, mainly because of the limited pool of existing experimental data. Most of this data was gathered during a period when wind tunnels were too small to accommodate, without serious flow distortion ... airship models large enough to offer accurate measurements with the apparatus available..." (Mowforth, 1991:27)

Nevertheless, a large body of work has been produced over the years and much from the time of the previous generation of very large airships (PGVLAs) remains of value today. Here are some examples:

> "... if an airship model is placed in a wind tunnel so that it is free to turn about its c. g., it is found that it will increase its angle of inclination to the air stream up to about 40°, then steady down and remain in a stable equilibrium at about that angle. That is, at great angles of inclination the pressure on the leading side near the stern ... becomes so great as to neutralize the other moments. However, up to about 40° the model is unstable. Therefore, it can be said, that an airship, regardless of its length, rigid or non-rigid, is in general aerodynamically unstable in all planes ... Thus a light ship tends to dive and a heavy ship tends to climb ; also if ship yaws off its course it tends to increase the yaw." (US Navy, 1927 : III-7)

> "Proper stream lining makes it possible to reduce the total resistance of an envelope form to a remarkable degree, the resistance of the best hulls being less than 5 per cent of the resistance of flat plates of like projected area." (US Navy, 1927 : III-22)

TYPES OF FORCE ACTING ON AN AIRSHIP

> "The aerodynamic forces acting on airships may conveniently be divided into drag and transverse forces." (Burgess, 1927)

> "Forces - a) inertial effects of its own mass, b) steady wind, c) atmospheric turbulence" (Howe, 1999)

"Transverse forces may be divided into two kinds: a) forces imposed through the rudders and elevators to control the direction and altitude, and to balance inequalities of weight and buoyancy; b) forces resulting from gusts when flying in rough air." (Burgess, 1927 chap 5. : 68)

"The dynamic forces on the hull are small in comparison with the static forces, excepting those due to turning, and usually are not very important." (Lewitt, 1925 : 59)

ADDITIONAL MASS OF ENTRAINED AIR

"The basis of Munk's theory is that the additional mass of air carried along by the motion of the airship is the same around any short length of the hull as around an equal length of an infinite cylinder of the same cross-sectional area, with a correction factor equal to $k_2 - k_1$ to allow for the difference between an infinite cylinder and an ellipsoid of finite *L/D*." (Burgess, 1927 : 89)

SKIN FRICTION

"It is known that the resistance of a body moving in a fluid is proportional to the square of the linear dimensions and to the square of the velocity.[1] Some of this resistance is due to the skin friction of the body, and the remainder to head resistance, but the latter causes eddies in the fluid, and is eventually lost in friction. The frictional resistance of an airship cannot be accurately calculated from the coefficient of friction of the doped fabric. The resistance of the ship can only be treated as a whole, and must be obtained from the **known resistance of existing airships. [GC emphasis.]**

Let C = capacity of airship in millions cu ft.

V = maximum velocity of ship in miles per hour.

k = the resistance coefficient found experimentally

Then, total resistance = a constant $\times C^{\frac{2}{3}}V^2$

And, as the horse-power is proportional to resistance × velocity,

Total horse-power required = $kC^{\frac{2}{3}}V^3$

From which, $k = \dfrac{\text{maximum horse-power}}{C^{\frac{2}{3}}V^3}$." (Lewitt, 1925 : 236)

However, the characteristics of airships in flight really lie outside the scope of this investigation, and in view of the fact that there is not space here to do justice to the large body of work concerned with this complex subject, those seeking further enlightenment are referred to the Bibliography and specifically to the works of: Cheeseman, 1999; Cook, 1999; Gomes, 1990; Gibson & Laming, 1975; Von Kármán & Troller, 1940; Abbot, 1931; Anon, c1930; Anon. (undated 7); Roxbee Cox, 1929; US Navy, 1927; US Government, 1941; Harrold & Browning, 1968.

EFFECT ON GROUND HANDLING

Unlike the Aerostatic forces that are constantly at work on an airship from the time it is inflated until its eventual deflation, the Aerodynamic forces play a relatively, and perhaps surprisingly, small part in airship GH operations. From the ground handling (GH) perspective, the problems caused by Aerostatics need to be addressed constantly, day and night, summer and winter, regardless of whether an airship is inside or outside the hangar, whereas those caused by Aerodynamics are only applicable when an airship is out of doors and really only become a problem when there is a strong or gusty wind blowing. As a consequence, there are only four areas where Aerodynamics really has any impact on GH. These are:

- Undocking in a side wind
- Realignment with shed for re-docking
- Mooring
- Launch and Capture

Considerable work was done both theoretically and in terms of practical experimentation during the golden era of the previous generation of very large airships (PGVLAs) and much of this work remains as state of the art today. Although, undocking/re-docking and launch/capture are all transitory procedures that in ideal circumstances would last only a few minutes in each case, and thus occupy a very small percentage of the GH time, it was found that these were in fact among the most dangerous time. Whereas those affecting the behaviour of the airship when attached to its mooring mast - such as "kiting" "surging" and "dutch roll" - were in many cases more annoying than dangerous.

[1] "See Author's [Lewitt] text-book on Hydraulics (Pitman)."

Again this is an enormously complex and extensive subject that requires detailed explanation for which there is not space in this study. Nevertheless here are some items of interest from the archives:

FIN DESIGN EFFECT ON MOORING

"It was found from experience that R.29 was over stable, it being very difficult to turn, and that R.33 was under-stable ..." (Lewitt, 1925 : 219)

"When the ship is moored by the nose to a mast, the forces in the structure will depend on the wind velocity which is liable to reach the maximum speed of the ship, in which case the pull on the nose will equal the total engine thrust." (Lewitt, 1925 : 69)

HEADWIND AT MAST

"The resistance of an airship may be found, providing the maximum speed and horse-power are known, by equating the work done per second by the engines to the work done per second against the resistance.

Let R = total resistance of ship at full speed in tons.
V = maximum speed of ship in miles per hour.
H.P. = maximum horse-power of engines.

Then, work done per second against resistance = work done per second by engines

$$2240R \times V\frac{88}{60} = \text{H.P.} \times 550$$

$$R = \frac{\text{H.P.} \times 550 \times 60}{2240 \times V \times 88}$$

Most of the resistance is due to the skin friction of the hull the remainder being due to head resistance and resistance of cars." (Lewitt, 1925 : 60)

SIDE WIND FORMULA

"A number of formulae have been derived for finding the side wind pressure on an airship, but the one that appears to agree with service conditions is Formula No.1.

Side pressure = 0.00143 × $SV^2(1+Kr)$ + pressure on vertical fins.

Where

Side pressure = pounds
V = wind mi./hr. [mph]
S = area of lateral plane = sq ft.
r = fineness ratio.

When

r = 2 to 4 $K = 0.01$
r = 4 to 8 $K = 0.02$
r = 8 to 12 $K = 0.03$

Pressure on vertical fins = 0.003 × (pressure area sq ft) V^2.
The foregoing is at standard density of = 0.00237 slugs/cu ft." (US Navy, 1927 : III-17)

EXAMPLE OF USE OF US NAVY FORMULA NO.1:

"Problem: Find resistance of [*LZ126*] *Los Angeles*, axis perpendicular to a 10 mi./hr. wind.

Lateral area = 46,800 sq. ft.

V in mi./hr. $r = \frac{658}{90} = 7$ approx.

D = 0.00143 × 46,800 × 100 (1 + 0.02 × 7).
D = 0.00143 × 46,800 × 100 (1.14) = 7,629 lbs.
Fin and rudder area = 2,400 sq ft approx.

$R = K\rho SV^2 = 0.03 \times 2{,}400 \times 100 = 720$ lbs.

Lateral resistance bare hull	7,629 pounds
Lateral resistance of fin and rudder	720 pounds
	8,349 pounds

Or general formula for this ship [*LZ126*] is F = 83.49 V^2.
V in M.P.H.
F in pounds" (US Navy, 1927 : III-17)

NUMBER OF CREW NEEDED FOR GH OF *LZ126 USS LOS ANGELES*:

"If each man on the windward side has an effective lateral pull of 45 pounds (from test run on spring balance in hangar) then

$$\text{Number of men} = \frac{8{,}349}{45} = 186 \text{ men required on windward side}$$

To just hold the ship [*LZ126 USS Los Angeles*] in an exactly steady wind (no inertia forces due to gusts to overcome)." (US Navy, 1927 : III-17)

THUMB RULE FOR [*LZ-126/ZR-3*] *U.S.S "LOS ANGELES"* ONLY

"Number of men required = KV^2 where K = some constant

$186 = K100$

$K = 1.86$, call it 2

Thumb rule. Number of men required = $2V^2$ for *Los Angeles.*

V = wind, M.P.H." (US Navy, 1927 : III-17)

There is also much that is of interest to large airship designers in the theoretical work that was done on submarines during the 1940's, 50's and 60's at a time when very little work was being done on airships and also on behalf of the oil industry concerning their large supertankers (e.g. Wayne & others, 1997).

HYDROSTATICS

"FIRST PRINCIPLES OF FLOTATION: To naval architects the hydrostatic properties of vessels floating on the water surface represent a fundamental part of their stock in trade, and that familiarity readily reads across to submarines on the surface; the hydrostatic properties of submerged submarines are less familiar to naval architects in general, but they can identify the parallels without difficulty. For most other engineers the subject of hydrostatics may not be so familiar." (Burcher & Rydill, 1994 : 25)

HYDRODYNAMICS

"A submerged submarine has freedom to move in all directions that constitute the six degrees of freedom which, in naval architecture, are termed surge, sway and heave for bodily translations along the three axes of the vessel (namely, longitudinal, athwartships and vertical) and are termed roll, pitch and yaw for the angular rotations about those axes. Although there is usually some interaction between the motions, it is often a sufficient simplification to treat them in uncoupled groups. (Fig.8.2) When that applies, surge (the change of speed of the submarine in the direction of its longitudinal axis) is treated as a single, independent motion related to the powering and resistance of the vessel; the motions in the horizontal plane, i.e. sway (the sideways movement) and yaw (the rotation in heading) are treated as coupled pair; the motions in the vertical plane, i.e. heave (the up and down movement) and pitch (the angular attitude) are also treated as a coupled pair; and roll (the rotation about the longitudinal axis) is treated as single, independent motion, even though it is closely related to the turning motion." (Burcher & Rydill, 1994 : 153)

"**Motion control.** Looking at the motions in the coupled groups described above, the customary approaches to their control are as follows:

(a) Surge: This motion is the outcome of the variation between two longitudinal forces, the thrust of the propulsor and the resistance of the vessel to the forward motion. When the submarine is proceeding, sufficiently deep, on a level path at constant speed, the forces are equal and opposite, but if it changes course and/or depth the other motions will alter the resistance and a speed variation will result. Control of surge is not usually attempted, but could be effected by changing the propulsor RPM.

(b) Yaw and Sway: The means of control of this coupled pair is by rudders at the after end of the submarine. Rudder operation effects control of heading or rate of turn by causing the vessel to take up an angle of yaw; sway is a consequence of yaw and generally no attempt is made to control it directly.

(c) Pitch and Heave: It is the freedom of a submerged submarine to move in the vertical plane that differentiates it from the surface ship, for which the pitch and heave motions are relatively small and determined by surface waves and the hydrostatics of the ship's waterplane. In submarines, the means of control of this coupled pair is usually by two sets of control surfaces known as hydroplanes, one set forward and one aft. With that approach, it is possible to control pitch and heave independently. In older, slow speed, submarines it was common practice, in manual control, to have two planes men, one to each set of hydroplanes, with the forward planesman controlling the depth of the submarine and the after planesman controlling pitch angle. As we shall see later in this chapter there is sound logic in the practice at slow speeds, though at higher speeds the need for separation of control in that way diminishes and then coupled control can be taken over by the after hydroplanes alone, the forward hydroplanes being zeroed.

(d) Roll: It is not usual to provide control of roll in submarines, unlike many surface ships in which roll stabiliser fins are employed. In submarines, any asymmetric moment tending to cause roll is countered by the hydrostatic restoring moment due to the centre of gravity being below the centre of buoyancy." (Burcher & Rydill, 1994:153/4)

"As the submarine approaches the water surface it may encounter the effects of wave action which generate disturbing forces tending to cause it to heave and pitch; there will also be suction forces on the hull due to is proximity to the surface while underway." (Burcher & Rydill, 1994:155)

EQUATIONS OF MOTION OF A SUBMARINE

The following should be compared with the similar Equations of Motion for airships in Cook, 1999:76.

"**Conventions. 8.4** Although it is not our intention to go very far into the theory of submarine dynamics, it is desirable for a general understanding to provide ... some preliminary discussion of the form of the equations of motion of a submarine. We do not go into their derivation, which can be found in a suitable textbook. To that end it is necessary to define sthe axes and coordinate system employed for the purpose and these are illustrated in Fig 8.2. The set of axes commonly used is aligned to the longitudinal, vertical and athwartships geometry of the submairine, assumed to be moving in three dimensions in hydrosapce, the centre of the set beign either at the geometric centre of the boat, or more conveniently, at its centre of gravity. This choice of axis system overcomes some of the problems of coupling between the various motion componenets, though it does lead to other complications as regards forces such as gravity which are related to a spatial set of axes." (Burcher & Rydill, 1994 : 157/8)

"**The surge equation** – $m\,u = X_{\mathrm{P}} + X_{\mathrm{U}} + X_{\mathrm{M}} + X_{\mathrm{A}}$

This shows that the rigid body mass of the submarine times its acceleration in the direction of its longitudinal axis is equal to the sum of the forces acting on it in that direction. These forces comprise: the propulsor thrust; the hydrodynamic resistance appropriate to its motion in the direction of its longitudinal axis; the summation of additional drag forces arising from any lateral motion which might be occuring; and the hydrodynamic forces associated with accelerated motion in the direction of its longitudinal axis, commonly known as the 'added mass' term.

Horizontal plane equations – $m\,(v^{\cdot} + rU) = Y_{\mathrm{V}} + Y_{\mathrm{V}^{\cdot}} + Y_{\mathrm{R}} + Y_{\mathrm{Cont}}$

and

$I_{zz}\dot{r} = N_{\mathrm{V}} + N_{\mathrm{R}} + N_{\dot{\mathrm{R}}} + N_{\mathrm{Cont}}$

The first of these equations relates the product of the rigid body mass and its sideways acceleration to the summation of the hydrodynamic forces acting on the hull in the sideways direction. The second equation relates the product of the rotary inertia of this rigid body about a vertical axis through the centre of gravity and its angular acceleration in yaw to the summation of the horizontal moments of the hydrodynamic forces acting on the hull.

Vertical plane equations - $m\,(\dot{w}^{\cdot} - qU) = Z_W + Z_\theta + Z_{\dot{W}} + Z_{\mathrm{Cont}}$

and

$I_{yy}q^{\cdot} = M_W + M_Q + M_\theta + M_{\mathrm{Cont}}$

The first of these equations relates the product of the rigid body mass and its acceleration in the vertical direction to the summation of the hydrodynamic forces acting on the hull in that direction. The second equation relates the product of the rotary inertia of the rigid body about a horizontal axis through the centre of gravity and its angular acceleration in pitch to the summation of the vertical moments of the hydrodynamic forces acting on the hull, augmented in this case by the hydrostatic restoring moment due to the departure of the axis of the submarine from the horizontal.

Roll equation – $I_{XX}\phi^{\cdot} = K_V + K_R + K_\phi$

This relates the product of the rotary inertia of the rigid body about its longitudinal axis and its angular acceleration in roll to the summation of the athwartships moments acting on the hull due to the hydrodynamic forces arising from the other motions, augmented in this case by the hydrostatic restoring moment due to the departure of the submarine from the vertical." (Burcher & Rydill, 1994 : 158/9)

CONTROL REVERSAL IN SUBMARINES

"As speed is reduced, however, the pitch effectiveness term reduces in magnitude and at sufficiently low speeds the angle of pitch due to after plane operation can be less than the drift angle caused by the plane force. At such low speeds, when and upward force is applied by the after planes, the boat will pitch down but the dominant effect will be a bodily upwards movement. At some intermediate speeds there will be a circumstance in which an after plane force will cause a pitch angle which exactly matches the drift angle and then the submarine will be unable to change depth even though pitched. (Fig.8.8). This is known as the 'critical speed', at which after planes are ineffective for changing depth, and then forward planes become necessary. ... The change of after plane control effectiveness at the critical speed is sometimes known as the 'Chinese effect". The critical speed is typically around two knots or so and its significance lies in the fact that as it is approached with reducing submarine speed, the effectiveness of the after planes in controlling depth is progressively reduced." (Burcher & Rydill, 1994 : 168/9)

"It should be noted that with after planes the direction of the control force is in the opposite sense to the resultant pitch angle and the heave velocity component is in the opposite direction to that in which the pitch angle drives the submarine. With forward planes on the other hand, because they are forward of the neutral point, the control force is in the same sense as the pitch angle it causes, whilst the heave velocity component is in the sme direction to that in which the pitch angle drives the boat. However, because the neutral point is forward, it is not possible to get the forward planes sufficiently ahead of the neutral point for good control effectiveness. Nevertheless, owing to the Chinese effect, forward planes are essential to good slow speed contrl at depth – and necessary for control at periscope depth, as they greatly assist rapid depth changing when a submarine dives from or close to the water surface." (Burcher & Rydill, 1994 : 169)

CONTROL REVERSAL IN AIRSHIPS

"The game becomes even more interesting at low speed when for example the elevators raised to initiate climb, may be struggling to get the tail down and the nose up against the opposition of the ship's pendulum stability. Below a certain critical speed - usually between about 15 and 30 km/h (10 and 20 mph) - the downward force on the elevator becomes greater than the dynamic lift induced by the resulting upward tilt of the hull, so that the net effect is descent rather than ascent. A simplified explanation of the phenomenon is offered with Figure 20. Even at speeds above this '"control reversal" range the tail must be depressed before the ship can begin to climb, the required "dip" being more pronounced at lower speeds. This would have posed some interesting problems for the long, slow early Zeppelins when manoeuvring near the ground, had they not been ingeniously furnished with separate elevators near the bows to lift the nose, instead of lowering the tail, to initiate climb. These bow elevators had, however, a destabilising effect and could lead to "porpoising" at higher speeds: they were consequently phased out as cruising speeds increased and as ground handling strategies were developed to cope with low-speed movements at ground level." (Mowforth 1991 : 32)

In conclusion, it should not be overlooked that when moored to a mast an airship most closely resembles a building - albeit one that can weathervane into wind. Consequently, there is also much work that has been done in the field of building research on the aerodynamics of structures that are close to the ground and study of the aerodynamics at low-level, and the effects of airflow on lightweight structures can be found in such papers as: Davenport, 1963a & 1963b; Harris, 1963 & c.1969; Scruton, 1963; Shellard, 1963; Sonntag, & Hoff, 1922.

APPENDIX C : CONTENTS LIST OF TAR 1ST DRAFT

WITH AUTHOR'S ASSESSMENT OF MATTERS RELATING TO GROUND HANDLING HIGHLIGHTED THUS

Transport Airship Requirements

Draft 1 - 12th January 1999

submitted by:

Luftfahrt-Bundesamt, Division M, Certification and Environmental Protection, Herrman-Blenk-Strasse 26, D-38108 Braunschweig

Information:

- units (transformed into metric system (SI); "uneven" values are rounded where useful
- A question mark (?) indicates an item "to be discussed"

6. Durchführungsverordnung zur Bauordnung für Luftfahrtgerät (6. DV LuftBauO-LFLS):

AIRWORTHINESS REQUIREMENTS FOR TRANSPORT CATEGORY AIRSHIPS

INTRODUCTION

These Airworthiness Requirements for Transport Airships originally base on the report "Airship Design Criteria" of the US Department of Transportation, Paper No. FAA P-8110-2, change 1, dated July 24, 1992. These criteria were applicable to airships certificated in the normal category that had a total seating configuration of 10 seats or less. The criteria were referenced in Advisory Circular (AC) 21.17-1, "Type Certification-Airships", as an acceptable means for the type certification of conventional, non-rigid airships.

By amending the FAA criteria, airworthiness requirements for the type certification of airships in the categories Normal or/and Commuter were provided. The numbering system of FAA part 23 was introduced. However, these requirements for normal and commuter category airships were not published to date and therefore are not legally effective.

With the upcome of several large airship projects a code for Transport Category Airships (TAR) is inevitable. The above mentioned code was upgraded to the level of JAR-25 were applicable, plus using few elements from JAR-27 and JAR-29. Units were transformed into the metric system were applicable and rounded sensibly.

In the run up to this draft close and fruitful cooperation between the Airworthiness Divisions of RLD (NL) and LBA (D) was experienced and still is. Due to the pressure of time for both NAA's it was agreed to share the work load by the RLD focusing on rigid airships and the LBA on non-rigid airships. However, this draft code might give the impression that the rigid design has not enough been taken into account. The apparent emphasis of the semi-rigids is due to an already submitted application to the LBA and therefore the rulemaking has progressed much further. It goes without saying that rigids will catch up very soon with the TAR then fully embracing both design philosophies.

The following consolidated draft is mainly based on the following documents and papers:

- **Airworthiness requirements for normal and commuter category airships -** (8. DV LuftBauO-LFLS; to date not legally effective)
- **LBA-Supplements to Transport Airship Requirements (TAR) -** Introducing modified paragraphs of JAR-25, JAR-27 and JAR 29 were applicable
- **Concept for modern Airworthiness Requirements for the Large Airship category -** P.L. van Daalen, RLD/LW May/June 1998
- **Preliminary Comments from RLD/Airworthiness Div. -** J.P. Veeze, E.R. de la Rambelje, P.L. van Daalen, RLD/LW October/Dezember 1998
- **A Review of LBA Airworthiness Requirements - Applicable to the CargoLifter Airship -** N. J. Mayer 21. October 1997
- **Comments Large Transport Category Airships -** Gritzbach, Hagenlocher, Mandel, ZLT January 1999

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AIRWORTHINESS REQUIREMENTS FOR TRANSPORT CATEGORY AIRSHIPS

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FLIGHT CHARACTERISTICS - § 141 General;

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APPENDIX D : INFLATION AND ASSEMBLY OF U.S. NAVY BLIMPS

(This list gives some idea of the number of detailed procedures that are involved in the construction and inflation of a pressurised airship of any size and is recommended as the basis of such procedures for anyone contemplating an NGVLA of this type. Most of the tasks listed here will have to be accomplished at some stage in the inflation process.)

SEQUENCE OF EVENTS
Extracted by GC from

Goodyear Aircraft Corporation K-Type Airships – Erection Manual (June 1944)

(NB - This manual assumes blimp envelopes are tested and inspected by the manufacturer prior to delivery.)

Preparation

- General - Inspect, weigh and arrange in order all component parts.
- Space - Inspect and sweep clean the deck area, check vertical height clearance.
- Equipment - Inspect all ladders, cranes, ropes, work platforms, ground sheets, and special tools.

First Air Inflation

- Laying out the Envelope - Remove envelope from its box, spread envelope out while pumping in a little air to prevent fabric pressing together.
- Suspension of Starboard External Catenary Curtain - Fold starboard side of envelope up with cranes to expose external catenary curtain car attachment points on the airship belly, pump in more air to ease access for riggers.
- Installation of Accessories
- Pressure Glands - check all small manometer holes are plugged.
- Tying Off the Helium and Air-to-Helium Sleeves - make all sleeves air tight.
- Light Sleeve (Inspection window) - check rubber plug installed.
- Gas-tight Links (Internal suspensions) - riggers enter envelope and work in teams to install gas-tight fittings in the sleeves through which the internal suspension cables will pass.
- Attachment of Strap Cables (Internal suspensions) - internal suspension straps installed and adjusted to maximum lengths, tensioning straps locked-off with wire and metal parts covered in padding.
- Installation of Gas-tight Fittings for Rip Cords - Rip lines installed and coiled ready for attachment.
- Tying off the Sleeve for the Superheat Gas Element - Instrument entry sleeve tied off.

Second Air Inflation

- Laying out the Envelope - Starboard side lowered and envelope re-positioned, tunnel structure inserted beneath envelope to permit air from electric blower to enter via helium valve hole.
- Laying out the Internal Suspensions - Increase air fill as the riggers attach internal suspension cables, cables require careful adjustment to prevent excessive envelope tensions during the inflation process.
- Attachment of Rip Cords to Rip Panels - Rip cords attached to forward and aft rip panels and tied to correct lengths as air fill proceeds.
- Superheat Meter-Gas Element - Temperature difference indicator suspended in position.

Preparation for Helium Inflation

- Removing Air from the Envelope - Remove tools and equipment, reverse blower and suck out all air, adjust position of envelope as it deflates to align top and bottom centrelines and centralise on floor space.
- Net and Ballast - Connect helium fill sleeve, spread net over envelope to its marked centre line, lay out net in squares, check net lengthways fit with envelope, place 250 sandbags along each side of envelope.
- Helium Valves - Fold back net and envelope to reveal valve holes, insert clamp rings, ensure valves are set to open at correct pressures, seal the valve clamps, insert the valves, attach temporary valve guards, turn envelope and net back flat again.
- Control Surfaces
    - Preliminary Preparation - Prior to inflation inspect the control surfaces, ensure breather holes are open, set surfaces upright on padded blocks, secure from being blown over with guy lines, attach movable control surfaces and check hinges, bearings, etc. check elevator angle indicator is zeroed, fit counterbalance bungees, attach stay cables and base straps, attach control cables and reeve through tunnels etc. attach surge cables, attach handling slings and guide slings.
    - Attaching Surfaces to Envelope prior to Helium Inflation
        - Attachment of Upper Vertical Surface (Top fin) - Lift top fin with crane and suspend over base patch on envelope, adjust slings so forward end is higher than rear, secure chafing pads, lower onto envelope and connect base straps, secure surge cables and wrap adjusters to protect envelope, attach temporary brace cables, check all cables have sufficient slack for inflation, secure rudder hard over to prevent swinging.
        - Attachment of Horizontal Surfaces (Elevators) - suspend from cranes and move to position alongside the envelope clear of the deck, lift slack of envelope and secure top surge cables, set forward end of elevators 3 feet higher to balance propeller thrust, wrap adjusters etc., connect base straps on top side only, connect fore/aft brace cables allowing slack as for top fin.
- The Car (Preliminary Preparation) - Car should arrive anchored to a cradle, car should be made as complete as possible prior to its attachment to envelope.
    - Car prepartion checklist tasks include :
        - Check clamping bands on damper valves.
        - Install temporary cap on air-to-helium air chamber.
        - Install temporary wood panel floor boards to protect permanent surfaces.
        - Secure chafing strips and pads to car frame and any parts that may contact envelope.
        - Fit thimbles to car suspension cables.
        - Attach internal suspension shackles.
        - Check fuel lines and tanks, align hoses for envelope attachments.
        - Inspect seals, springs and hinges of damper and air chamber flap valves.
        - Test and calibrate gauges and instruments.

    - Inspect control wheels, keys, shunt cables and tensioning devices.
    - Inspect all control cable sheaves and fairleads, replace if necessary.
    - Complete radio and other electrical installations.
    - Inspect pitot and purity tubes for leaks and condensed moisture, fill liquid manometers.
    - Service engines, do not attach propellers, run auxiliaries if desired.
    - Oil and clean the damper valve springs and cables.
    - Check elevator position indicator circuit.
    - Check all other installations such as, door safety bars and catches, car vents, slip tank releases, tank suspensions, hand pumps, etc.
- Check the mooring cone in the mast cup for fit and locking of lugs.

Helium Inflation

- The Handling of Helium - Count cylinders and record temperatures and pressures, check manifold safety relief valve.
- The Volume of Helium Required - Estimate desired fill level considering seasonal temperature variations, calculate volume of gas required.
- Taking Helium
    - Inflating the Envelope with Helium - Check communication link between helium supply and hangar, inflate from nose to tail, use 6-7 men standing on envelope to control the gas bubble, 4-5 men on each side to adjust the sandbags, maintain nose up position, ensure internal suspension cables do not become tight, (this manual details the US Navy method of effecting repairs to envelope if fabric is torn by excessive suspension cable tension during inflation), fill until top vertical fin touches envelope, use cranes to raise tail fins keeping pace with inflation, adjust fin brace cables as envelope fills, keep fabric taut and free from folds, roll up deck cloths as envelope rises and remove to store when envelope leaves the ground.
    - Preparation and Attachment of Accessories during Inflation.
    - Inserting the Airline Frames into the Airlines - Insert airframes into the ballonets via manholes and valve sleeves, tie off sleeves.
    - Internal Suspension Sleeves - Inspect ISS and tie off fore and aft cables temporarily.
    - Inserting the Propeller Guards in the Apertures - Insert guards and lace in temporarily.
    - Attachment of Temporary Liquid Manometers - Tie temporary manometers to starboard curtain catenary ring, connect rubber tubes to corresponding valves.
    - Installing the Temporary Air Valves - Install temporary valves in forward and aft ballonet manhole sleeves, remove helium inflation tube and tie off inflation sleeve, adjust sandbags so that envelope is on an even keel, set temporary air valve pressures to suit seasonal variations.
    - Inflating the Air Ballonet - Check helium fill is complete and close valves, connect air blower and increase pressure, inspect ballonets by removing temporary valves and entering via manhole sleeves, estimate and record amount of air in ballonets.
    - Purity Tests - Test purity of helium and record in log.

Rigging the Ship

- The Envelope
    - Installation of Propeller Guards - Set helium to working pressure, lace PGs into apertures permanently, position PG covers and lace loosely, decrease envelope pressure, tighten laces, increase to working pressure and seal laces with cement.
    - Installation of Pitot Tube bracket - Lace three bracket legs to envelope, inflate fabric tunnel by blowing air, pull rubber tube through tunnel with pre-installed string, bond brackets, seal tunnel against moisture.
    - Installation of Remote indicating compass - Wire up electrical connections, fit transmitter and seal laces, check proper flying trim, adjust and calibrate.
    - Installation of Superheat Air Element - Lace into position, pull wires through tunnel, bond air element after car is attached.
    - Suspension of M.A.D. Basket - Attach with cord suspensions, pull electric wire through tunnel to car.
    - Installation of Helium valve Accessories - remove temporary guards and install bridges, install valve shields on aft side, lubricate and connect control cables, check control cables orientation and function.
    - Attachment of Fiddle Bridge (Major controls) - lace into position, prepare surge cables for tensioning after major control lines have been strung and tensioned, bond electrical connections, allow slack to compensate for envelope stretch.
    - Suspending the Superheat Gas Element - secure blocking cord and shock absorber, open helium sleeve and hoist SGE into position, tie off sleeve and make gas-tight, tuck sleeve inside envelope and secure patch.
    - Attachment of Lower Vertical Fin to Envelope - Check tension of top and side fin temporary stay cables, align LVF with its base straps, attach safety guide ropes, hoist into position against envelope (>6 men), connect and tension temporary stay cables to hold fin firmly in place, adjust fin position with base straps and surge cables.
    - Installation of Airline Frames - Lace into designated shoes inside ballonets, tension bungees at ends of air curtain, allow for frame movement at pressure height, attach bonding wire and leave enough slack for later adjustment.
    - Installation of Nose cone and battens - Prepare battens and cables, move inflation net aft of envelope batten patches, bolt temporary stub battens to nose cone, attach piston and universal joint to nose cone, raise nose cone into position with crane and lace temporary battens in place, lace cone permanently, attach all battens and lace permanently, attach batten cables, cement sealing strip over lacings.
- The Car
    - Positioning - Disconnect hangar blower sleeves, tie off temporary damper and air valve sleeves, adjust sand bags until envelope is high enough to clear air valve stems above the car, move car into position, place work stage around car, "Bag" envelope down and adjust car position to align with suspension sleeves.
    - Attaching the Car to the Envelope
        - Attachment of External Suspension and tighten all external suspension and surge cables, ensure distance from side catenary curtains is equal both sides, check turnbuckle alignments.
        - Attachment of Internal Suspension pressure, bag envelope down so that all internal suspension cables can be reached and connected to suspension eyes on car frames, ensure turnbuckles are started in unison in correct orientation.
        - Attachment of Damper Valve and Air Sleeves - remove temporary sleeves for damper valves and air valves, pull valves sleeves over valves, tighten and lock clamping bands.

- Forward and Aft Internal Suspensions - Tie off sleeves in airline for forward and aft internal car suspensions.
- Removal of temporary Liquid Manometers - Fill and adjust manometers in car, disconnect pressure tubes from temporary manometers and reconnect to car manometers.
- Removal of Temporary Air valves - Remove temporary air valves from ballonet manholes sleeves and tie off sleeves, connect hangar blower sleeve to air intake duct on car, attach blower sleeve from air intake to LaDel Blower, ensure LaDel Blower is not operated when hangar blower sleeve is connected to air intake duct.

- Removal of Net
  - Ballasting - Add ballast weight to car according to seasonal temperature variations, check envelope still at reduced pressure, remove half the sandbags from the net, lower remaining sandbags to floor, increase envelope pressure to medium, remove remaining sandbags from the net, increase envelope pressure to full.
  - Removing the Net - Ensure airship is in trim, secure fore and aft handling lines to mooring cleats, hoist a rigger in bosun's chair to attach three crane lines to net front edge, raise crane lines in unison and roll net back to centre line, repeat procedure for tail section, after whole net has been moved to transverse centreline rigger connects slings around whole net on each side of centre, three cranes in unison lift net and carry it forward off the airship, net is lowered to floor and stored away.
- Car suspensions
  - Weigh off
    - Static Lift - weigh off to determine static lift, add suspended sandbags to nose to compensate for bow mooring unit not yet installed, calculations should include other uninstalled and additional items such as car skid.
    - Attachment of Plumb bob Chains - Ballast car down again, adjust skid to make car floor level, attach plumb bob chains to nose and tail on centreline, equalise chain heights by blowing air between ballonets.
    - Differential Pressure - Read and record differential pressures between gas and each ballonet, pressures should be close to equal for internal suspension adjustments.
  - External suspensions
    - Tensioning the Cables - Adjust external suspensions to equalise distance from catenary ring to car frame on both sides, draw catenary curtain taut, ensure seam above catenary curtain is straight.
    - Use of Crank Type Come along - use crank type "come-along" to draw catenary ring to suspension eye on car frame when turnbuckles are taken up, ensure hook of "come-along" does not snag internal suspension sleeves where cables are attached.
    - Tensioning the Forward and Aft Surge Cables - Tension cables to locate car centrally on envelope, ensure air and damper valve sleeves are not too tight, safety wire and tape all external suspension turnbuckles, wrap felt strips around catenary rings to prevent chafing, tape and lash all thimbles, sew felt strips over suspension hook cables on all car frames.
  - Internal suspensions
    - Desired tensions - Cable tensions will change proportional to car weight, establish theoretical car weight for given gas fullness and operational intentions, weigh off airship and determine total car load, determine differential pressures of air vs. gas for fore and aft ballonets, consult inflation factor charts and graphs to calculate desired cable tensions, interpolate and apply correction factors for abnormal inflations.
    - Tensioning of Internal Suspensions - adjust turnbuckles to tension IS cables to their desired theoretical tensions beginning at fore or aft end of car, retension and adjust as necessary until desired tension is established, maintain airship in trim at constant gas pressure throughout the process, remove twists from suspension sleeves.
    - Safety-wiring the Turnbuckles - double lock wire all turnbuckles, tape and tie down felt sleeves over turnbuckles, check suspension cable sleeves for leaks, cement covers over the sleeves.
- Final adjustment of Control Surfaces
  - Desired Theoretical tensions - adjust Fin Brace Cables during inflation, (cable tensions are given in shed test report for each airship).
  - Final Adjustment of Horizontal Surfaces - attach measuring chains of equal lengths to surfaces, connect #1 and #4 temporary stay cables to suspension points and adjust until fin is close to desired plane, check inclination with chains, position base with surge cables and base patches, use "come-alongs" and "hand-take-ups" to adjust stay cables until they are correctly loaded and the surfaces are level athwartship, maintain envelope pressure, adjust winches on "hand-take-ups" to obtain desired tensions, attach #2 and #3 permanent stay cables to respective finger patches, measure all cables, ensure all turnbuckles in "one-half-up" position to permit adjustment, make up permanent cables to replace #1 and #4 temporary cables, attach permanent cables before temporary cables are removed, adjust all stay cables to within tension tolerances, tighten surge cables of horizontal fins and secure with knots near finger patches, wrap knotted cables with tape, safety wire all turnbuckles and cotter key all bolts and pins.
  - Final adjustment of Upper Vertical Surface - drop plumb line from overhead envelope top centreline just aft of rudder, slacken all stay cables, position base forward end of fin with base straps, tighten #1 temporary stay cable slightly, ensure fin is plumb vertical and #4 temporary cable remains slack, adjust aft base straps and check alignment with centreline, tighten #4 temporary stay cables to desired tension, tighten #1 temporary stay cable to desired tension, check alignments, attach and adjust permanent stay cables as for horizontal surfaces.
  - Final adjustment of lower Vertical Surface - copy procedure for upper fin except that temporary stay cables cannot be made slack due to the weight of the fin, keep stay cable tensions equal on both sides of fin, adjust final tensions in same manner as for upper fin.
- Installation of Bow mooring Unit
  - Assembly of bow mooring Disc prior to Installation - Assemble component parts including, thrust washer, cylinder, "spider", housing spacer, pulley cables etc. and ensure cables are correctly reeved through their sheaves and re-assembled with turnbuckles in correct orientation.
  - Installation of Bow Mooring Disc (or "spider") - Lubricate compression spring, insert into spindle (piston), connect spider to nose cone by fitting cylinder over the piston, attach safety stay cable, shackle batten cable to pulley cable, connect vernier links to batten link connector, connect turnbuckle, tension batten cables and double wire lock all turnbuckles, grease all bearing surfaces.
  - Installation of mooring cone - bolt "flower pot" to the end of cylinder extension.
  - Installation of Yaw lines - attach yaw lines to the splice ring on cables leading from mooring lugs on bow mooring disc as per blueprint.

- Installation of Accessories Prior to Final Tests and Inspection
    - General - terminate all electrical connections on wires running from envelope to car in their respective junction boxes, ensure adequate slack in each wire, lace running lights onto envelope, cement sealing strips over lacings and make water-tight, connect pitot tubes ensuring sufficient slack under car fairing.
    - Attachment of Helium Valve Controls – connect valve control cables to pilot's instrument panel (the method of terminating these Bowden cables is detailed, it includes insertion of grease to prevent moisture penetration and how to leave sufficient slack to allow for adjustment as the envelope stretches).
    - Vent loop installation – check and insert vent loop into aft airline appendix, lash in place, wrap and tape metal parts.
    - Installation of Car Fairing – Clean and prepare the 8ft long sections, degrease the attachment strips, keep airship in constant trim, tie fairing temporarily to check alignments prior to permanent lacings, tension panels to remove wrinkles, use different lace stitches according to grommet hole alignments, apply five coats of cement allowing for drying times, seal with tape, put patches on all conduits that pass through car fairing to make watertight, paint sealing strips.
    - Outside attachment of Rip Cords – fit rip lines and secure against fluttering.
    - Attachment of Air-to-Helium Sleeve – remove temporary caps from duct, attach sleeve to duct with gummed strip and metal clamp band, attach red warning tags to helium sleeves.
    - Final adjustment of Major controls – After fins have been aligned and during measurement of control cables, establish connections through aft end of car, (the method is detailed and includes setting of tensions and adjustments).
    - Removing Skid from the Car – Ballast car to allow for weight to skid, disconnect skid suspension cables, weigh off light to allow removal of skid, extend landing gear and re ballast, carry out final weigh-off to determine static lift, check and record additional or missing items of standard equipment on board during weigh-off.
    - Installation of Bombardier's window – Fit window. Note - This window can be installed earlier but may be damaged because the opening is often used in gaining access to the car during the rigging process.
    - Installation of the Propellers - bond Propeller Guards directly to structural frame of car, lubricate all parts and slide propellers onto prop shafts, secure, tighten and check. Note – Manual assumes correct propellers already balanced.
    - Installation of the Drag rope – Coil drag rope and attach to cable leading from stern mooring lug at aft of car, insert rope in box and ensure rope is free to fall when door opens.

Final Pre-flight Tests and Inspection

- General – Check all installations and rigging complete, test all parts and assemblies, check for chafing and safe tying.
- Helium and Air Valves – Pressurize envelope until relief valves open automatically, adjust settings to desired pressures.
- Slip Tanks - Remove covers and temporary safety devices.
- Fuel Dump Tanks – Check valve performance, check control cable connections and freedom of movement, inspect all fittings and check for leaks.
- Air chamber – Open dampers and check air chamber for leaks.
- Motors
    - Main engines – Run motors, check all functions (as per checklist).
    - Auxilliary motors – Test air blowers and electric generators.
    - Fuel Line - Check for leaks as fuel is taken on board, check hand pumps, check oil pumps.
- Major controls – Operate controls and ensure all correct, inspect tensioning devices.
- Airspeed Indicator – Blow through pitot tube to check indicator.
- Helium Tell-tale Mechanism - Set control panel lights, allow for valve seepage close to max pressure.
- Elevator Indicator – Check for neutral and orientation.
- Miscellaneous Items to be checked – List includes:
    - Electrical bonding and lighting circuits.
    - Instruments and Radio.
    - Fire extinguishers.
    - Landing gear – extend and retract, check tyre and cylinder pressures.
    - Handling line and drag rope releases.
    - Car vents and controls.

The Shakedown Flight

- General – The flight is made for the purpose of further checking the operation of all parts and equipment under actual flying conditions. It establishes the operational characteristics of the airship as a whole. Flight should be carried out according to instructions of officer in charge.
- Customary Checks to be made during SF:
    - Operation of major and minor controls.
    - Maximum rate of ascent and descent and auxilliary blowers.
    - Maximum air speed.
    - Fuel consumption against RPM.
    - True airspeed.
    - Radio communication.

Appendix

- Special Tools and Equipment
- List of Emergency spare Parts kit

APPENDIX E : GLOSSARY (SAMPLE PAGES) [1]

INCOMPLETE GLOSSARY OF AIRSHIP GROUND HANDLING TERMS

(as defined by previous authors - see References and Bibliography)

Note: English spelling has been used for consistency

(eg. Center becomes Centre, Manoeuvre replaces Maneuver, Utilised instead of Utilized, etc.)

A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*A*

ACCIDENT - An occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage. (NTSB 830.2) (FAA, 2001)

ADIABATIC HEATING - When a gas is compressed, its temperature rises, owing to the work done on it. (The opposite is true when the gas expands.) With hydrogen the temperature of the gas changes approximately 5°F per 1000 feet of ascent or descent; with helium the adiabatic temperature change is somewhat over 7°F per 1000 feet. When landing, adiabatic heating of the gas could make the airship lighter than it otherwise might be. (Robinson & Keller, 1982)

ADIABATIC PROCESS - A change in pressure and temperature (and therefore in density) of a substance is said to occur adiabatically if no heat enters or leaves the substance during the process. If a volume of air at 1,000 millibars pressure and 170° C temperature were suddenly expanded so that its pressure fell to 900 millibars, its temperature would fall simultaneously to about 80° C. (Sutton, 1962)

AERODROME - any area of land or water designed, equipped, set apart or commonly used for affording facilities for the landing and departure of aircraft and includes any area or space, whether on the ground, on the roof of a building or elsewhere, which is designed, equipped or set apart for affording facilities for the landing and departure of aircraft capable of descending or climbing vertically, but shall not include any area the use of which for affording facilities for the landing and departure of aircraft has been abandoned and has not been resumed; (CAA CAP 393 Art. 118: Sect 1/95 August 1995)

AERODROME CONTROL SERVICE see CONTROL SERVICE, AERODROME

AERODROME FLIGHT INFORMATION UNIT see FLIGHT INFORMATION UNIT, AERODROME

AERODROME OPERATING MINIMA see OPERATING MINIMA, AERODROME

AERODYNAMIC - A shape that streamlines or generates lift from the movement of air flow around it. (Recks, 1997)

AERODYNE - A vehicle sustained in flight by aerodynamic forces generated by the forward motion of the vehicle through the air. Conventional aeroplanes and gliders are aerodynes. (Mowforth, 1991)

AEROLOGY - Old term for study of the weather. Meteorology.

AERONAUT - One who operates or travels in a balloon or airship. (Ventry & Kolesnik, 1982)

AEROPLANE – 1. Aeroplane or airplane; 2. Cody kite (used by Cody); 3. Any aerodynamic lifting surface. (Walker, 1971)

AEROSTAT - A device supported in the air by displacing more than its own weight of air. (FAA, 2001)

AEROSTAT - An aircraft, filled with a gas lighter than air, or hot air, which is supported in flight mainly from the buoyancy derived from the surrounding air. Balloons and airships are aerostats, as well as balloonists, who are also called aeronauts. (Kirschner, 1985)

AEROSTAT - Any lighter-than-air craft, not necessarily navigable; this includes kite balloons. (Kinsey, 1988)

AEROSTATIC - The branch of science dealing with mechanical properties of gases in equilibrium, and the equilibrium of bodies held up by them, like balloons and other lighter-than-air (LTA) vehicles. Aerostation - is the science connected with LTA vehicles not provided with motive power. It is, by use of the balloon, a logical application of the Archimedes' principle. (Kirschner, 1985)

AEROSTATICS - Branch of pneumatics dealing with the equilibrium and pressure of air and gaseous fluids, and of solid bodies immersed in them. (Ventry & Kolesnik, 1982)

AEROSTATION - The practical use of aircraft receiving lift from gas or hot air. (Kinsey, 1988)

AIR LOADING see LOADING, AIR

AIR, AMBIENT - Air surrounding the outside of a balloon envelope. (FAA, 2001)

AIRCRAFT - A device that is used or intended to be used for flight in the air. (FAA, 2001)

AIRCRAFT, PRESSURISED - means an aircraft provided with means of maintaining in any compartment a pressure greater than that of the surrounding atmosphere; (CAA CAP 393 Art. 118: Sect 1/103 August 1995)

AIRCRAFT, SMALL - means any unmanned aircraft, other than a balloon or a kite, weighing not more than 20 kg without its fuel but including any articles or equipment installed in or attached to the aircraft at the commencement of its flight; (CAA CAP 393 Art. 118: Sect 1/104 June 1996)

AIRDOCK - Name coined by Goodyear for giant hangar built for construction of Akron & Macon. (Ventry & Kolesnik, 1982)

AIRPORT - An area of land or water that is used for the landing and takeoff of an aircraft. (FAA, 2001)

AIRSHIP - A power-driven, lighter-than-air aircraft. (CAA, CAP 471, 1979)

AIRSHIP - A powered aerostat with dirigibility. (Recks 1977)

AIRSHIP OR AIR-SHIP – 1. Airship; 2. Any self-propelled aircraft; airship or aeroplane; aerial vehicle. (Walker, 1971)

ALBEDO The fraction of the incoming radiation which is diffusely reflected. Some typical values are: fresh snow, 0.7 to 0.9; fields and woods, 0.02 to 0.15; whole Earth, including clouds, 0.34 to 0.45. (Sutton, 1962)

ALTIGRAPH - Old name for BAROGRAPH

AMBIENT AIR see AIR, AMBIENT

ANCHORAGE – Boating – a general term that refers to moorings and the bending of cordage (by means of hitches) to various attachments; climbing – a safe belay point. (Budworth, 2004)

ANCHORING POINT see POINT, ANCHORING

ANCHORMAST/ ANKERMAST - A solid construction of a specified height to which the reinforced nose cone of an airship is attached to provide secure all-weather mooring. (Cargo OSG 01)

ANEMOMETER - An instrument for measuring wind speed. (Sutton, 1962)

ANOMALY - The difference between the value of a meteorological element, such as temperature, at a given time and place and its average or climatic value at the same place. (Sutton, 1962)

ANTICIPATED OPERATING CONDITIONS see CONDITIONS, ANTICIPATED OPERATING

ANTIFREEZE - Alcohol was invariably used in airship engine cooling systems. Glycerine was used in water ballast sacks by the Germans until shortages required the use of a substitute, calcium chloride, whose damaging corrosive effects on duralumin were not at first realised. American airships used alcohol exclusively in water ballast sacks. (Robinson, 1973)

[1] A full list can be obtained from the author

APPENDIX - Bottom of gas chamber of a gas balloon. Usually a fabric sleeve through which the balloon is inflated and which can be tied shut when balloon is moored. It is released to hang open when balloon takes off (See APPENDIX BRIDLE) allowing excess gas to escape as the balloon ascends above its pressure height. See NECK. (Upson & Chandler, 1926)

APPENDIX BRIDLE - A number of thin cords attached to a ring of patches around the neck of a gas balloon. These hang down in a cone to join a single cord or rope which may be tied to the load ring to hold down the bottom of the balloon and prevent it from "parachuting" in the wind. The same cord is usually made long enough to serve as the appendix opening cord. For this use a breakable thread is tied around the appendix and around a strand of the bridle cord. It is broken open at the start of the flight by a sharp pull on the appendix cord. (Upson & Chandler, 1926)

APPLICANT - A person applying for approval of an Airship or any part thereof. (CAA CAP 471, 1979)

APPROACH TO LANDING see LANDING, APPROACH TO

APRON - means the part of an aerodrome provided for the stationing of aircraft for the embarkation and disembarkation of passengers, for loading and unloading of cargo and for parking; (CAA CAP 393 Art. 118: Sect 1/97 August 1995)

ARAMIDES – The first commercial manmade (synthetic) fibres doe not met when heated. Their high cost limits them to specialized applications. (Budworth, 2004)

ASSUMED HANDLING INFORMATION see HANDLING INFORMATION, ASSUMED

ATMOSPHERE - The air which surrounds the Earth. (Kirschner, 1985)

AVIATION - The branch of science, business, or technology that deals with any part of the operation of machines that fly through the air. (FAA, 2001)

AXES OF AIRCRAFT - Three fixed lines of reference, usually centroidal and mutually perpendicular. The longitudinal axis in the plane of symmetry, usually parallel to axis of the propeller, is called the longitudinal axis; the axis perpendicular to this in the plane of symmetry is called the normal axis; and the third axis perpendicular to the other two is called the lateral axis. In mathematical discussions, the first of these axes, drawn from front to rear, is called the X axis; the second, drawn upward, the Z axis; and the third, running from right to left, the Y axis. (Burgess, 1927)

AXIAL CABLE - A stranded wire cable running through the gas cells from bow to stern of the ship, and connecting the wire bracing of all the main rings at their centres, reducing the loads on the framework if there was an inequality in pressure between adjacent cells. (Actually the axial cable was not continuous; each gas cell contained a 10-meter segment which was attached to the centre bulkhead wiring of the main rings.) A Schütte-Lanz patent, the axial cable (Zentralverspannung) was introduced in the Zeppelin L 30. (Robinson, 1973) The Shenandoah was the only U.S. rigid airship so equipped. (Robinson & Keller, 1982)

AXIAL GANGWAY - In some of the later and larger rigid airships, the axial cable was replaced by an axial gangway. A girderwork structure running from end to end of the ship, the axial gangway served the same structural purpose as the axial cable, while permitting riggers access to gas valves and gas cells. "Graf Zeppelin" was the first with a gangway through the gas cells, though this was below the centre line of the ship. R 100 had an axial girder but this was too small to serve as a gangway. "Hindenburg" and "Graf Zeppelin II" had axial gangways. (Robinson, 1973)

B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*B*

B.E.2c TYPE - Body of aeroplane rigged to SUBMARINE SCOUT or "S.S." blimp (Admiralty, 1917)

BABIES - Nickname for small types of British airship (Middleton, 1920)

BACKING WIND - Changes direction in a counter-clockwise fashion. A change in the opposite direction is called a VEER (Sutton, 1992)

BACKSTAY - A STAY to keep a MAST from leaning (raking) forward. Can be either fixed or running. (Snyder, 1989)

BAG, THE - The gas cell of an airship or the envelope of a gas balloon. (US Navy)

BALANCED RUDDER - A control plane hinged more or less centrally to relieve the pilot of the full loads when in action. (Kinsey, 1988)

BALANCING PLANE - Aileron; separate aerodynamic surface for control of roll. (Walker, 1971)

BALLAST - Any substance, usually sand or water, carried in a balloon or airship and intended to be thrown out, if necessary, for the purpose of reducing load carried and thus altering aerostatic relations. Water is the only suitable ballast for rigid airships. (Burgess, 1927)

BALLAST - For upward control of a gas balloon. Usually sand in canvas bags weighing about 30 lbs [13.6 kg] (UPSON & CHANDLER, 1926)

BALLAST - Expendable mass - usually water or sand - discarded by an aerostat to reduce its weight when necessary. (Mowforth, 1991)

BALLAST - To enable the airship to ascend to higher altitudes, or to compensate for gas loss or increased loads on the ship owing to rain or ice, water ballast was carried, distributed along the keel in rubberised bags (Graf Zeppelin) or metal tanks (Hindenburg). (Dick & Robinson, 1985)

BALLAST - Though the German naval airships briefly carried sand in 110 lb. sacks early in 1917, water was the usual form of ballast. (Robinson 1973)

BALLAST - In American rigid airships water was the invariable form of ballast. (Robinson & Keller, 1982)

BALLAST - A movable, usually expendable counterweight to a lighter-than-air craft's lifting gas. Sand or metal shot is commonly used by gas balloons; water has been the preferred agent in rigid airships. Small sand-filled bags weighing twenty-five to thirty-five pounds are commonly used to "weigh off" (or balance by static equilibrium) most pressure airships. In an emergency ballast is anything with weight that can be separated from the vehicle. Ballast may be dropped by an airship to compensate for lost lifting gas, to counter adverse aerodynamic loads or to ascend more quickly than by use of propulsion or aerodynamic pressure on the hull or fins. (Topping & Brothers, 2001)

BALLAST - Droppable ballast carried, water for rigid airships, and either sand or water for non-rigids and balloons. Dropping ballast enables a ship to ascend, or to compensate for gas loss or increased loads. (Ventry & Kolesnik, 1982)

BALLAST - A quantity of weight used to compensate for changes in lift. (Rechs, 1997)

BALLAST BOARD - Indicated the amount of water ballast at various locations throughout the ship. (Dick & Robinson 1985)

BALLAST SACKS - Most of the ballast was carried along the keel in rubberised fabric sacks holding 2,200 lb. of water. Fourteen of these, arranged in pairs, were in the Los Angeles when she was delivered. Toggles in the control car were pulled by the elevator man to empty them as necessary with the time being taken with a stopwatch (in ten seconds 400 lb. of water would be released). The officer of the watch was responsible for keeping a running record of how much ballast had been released, and from which locations. (Robinson + Keller 1982) The big sacks drained completely in 60 seconds. In some of the later ships, water ballast was carried in tanks rather than bags. In "Hindenburg" each ballast tank contained 5500 lb. of water. (Robinson, 1973)

BALLONET - Compartment of variable volume constructed of fabric ... ...

**** END OF SAMPLE FROM 54 PAGES ****

Appendix F : Comparison of Airship Classes by Length

Identity No.	Name	Length ft	Length m	Type	No. in class
USN-H	USN H-1	95	29	Blimp	
RNAS SS	SS	110	34	Blimp	
RNAS SSZ	SS.Zero	143	44	Blimp	
USN-L	USN L-type	148	45	Blimp	
ZMC 2	METALCLAD	149	45	Rigid	1
USN-E & F	USN E-type	162	49	Blimp	
USN-B	USN B-type	163	50	Blimp	
RNAS SST	SST	165	50	Blimp	
USN-DN-1	USN DN-1	175	53	Blimp	
USN-G	USN G-type	192	59	Blimp	
SK 600	Skyship 600	193	59	Blimp	
USN-C & J	USN C-type	196	60	Blimp	
COASTAL	RNAS C-type	196	60	Blimp	
USN-D	USN D-type	198	60	Blimp	
C-Star	C-Star	218	66	Blimp	
TC-13	US ARMY TC-13	235	72	Blimp	
NT-07	Zeppelin NT	246	75	Blimp	3
USN-K	USN K-type	251	77	Blimp	
USN ZP2/3K	USN ZP2K	256	78	Blimp	
NS	North Sea Type	262	80	Blimp	12
USN ZSG4	USN ZSG-4(ZP4K)	267	81	Blimp	
RS 1	US ARMY RS 1	285	87	Semi-rigid	1
USN ZS2G	USN ZS2G-1(ZP5K)	285	87	Blimp	
PL 6 & 7	PARSEVAL 6	301	92	Blimp	2
USN-M	USN M-type	302	92	Blimp	
HMA-5 PL20	PARSEVAL 20	304	93	Blimp	
HMA-4 PL18	PARSEVAL 18	312	95	Blimp	
USN ZPN	USN ZPN-1/ZPG-1	325	99	Blimp	
N 4	ITALIA	341	104	Blimp	1
USN-ZPG 2	USN ZPG2 /2W	341	104	Blimp	
N 1	NORGE	348	106	Semi-rigid	1
PL 25	PARSEVAL 25	369	112	Blimp	
M IV (b)	GROSS-BASENACH	395	120	Blimp	1
403 feet	**XXXXXXXXXXXXXX**	**403**	**123**	**XXXXXX**	**XXXXX**
ZPG 3W	USN ZPG3W	403	123	Blimp	4
LZ 2	ZEPPELIN	413	126	Rigid	3
M IV (c)	GROSS-BASENACH	417	127	Blimp	1
T 34	ROMA	420	128	Semi-rigid	1
LZ 1	ZEPPELIN	420	128	Rigid	1
LZ 120	BODENSEE	426	130	Rigid	2
SL 1	SL 1	430	131	Rigid	1
LZ 4	ZEPPELIN	446	136	Rigid	3
LZ 10	SCHWABEN	459	140	Rigid	3
GZ 16*		463	141	Blimp	(not built)
LZ 7	DEUTSCHLAND	472	144	Rigid	2
SL 2	SL 2	472	144	Rigid	1
LZ 11	VIKTORIA LUISE	485	148	Rigid	2
SL 3	SL 3	500	152	Rigid	3
No.1r	MAYFLY	512	156	Rigid	1
No.9r	R 9	520	158	Rigid	1
LZ 17	SACHSEN	520	158	Rigid	6
LZ 26	Z XII	528	161	Rigid	1
SL 6	SL 6	532	162	Rigid	2
No.23.r	R 23	535	163	Rigid	4
R 80	R80	535	163	Rigid	1
R 27	R 27 (23 X class)	539	164	Rigid	2
LZ 59	L 20	561	170	Rigid	12

Identity No.	Name	Length ft	Length m	Type	No. in class
LZ 41	L 11	561	171	Rigid	22
SL 10	SL 10	570	174	Rigid	10
R 31	R 31	615	187	Rigid	2
R 34	R 34	639	195	Rigid	1
R 33	G-FAAG	643	196	Rigid	1
LZ 62	L 30	645	197	Rigid	36
SL 20	SL 20	650	198	Rigid	3
LZ 126	ZR 3 - LOS ANGELES	656	200	Rigid	1
ZR 1	SHENANDOAH	680	207	Rigid	1
R 38	ZR 2	690	210	Rigid	1
LZ 112	L 70	694	212	Rigid	2
R 36	G-FAAF	695	212	Rigid	1
R 100	G-FAAV	709	216	Rigid	1
R 101(a)	G-FAAW	720	219	Rigid	1
LZ 114	L 72 - DIXMUNDE	741	226	Rigid	1
LZ 113	L 71	743	226	Rigid	1
LZ 127	GRAF ZEPPELIN	777	237	Rigid	1
R 101(b)	G-FAAW	777	237	Rigid	1
ZRS 4	AKRON	784	239	Rigid	2
LZ 129	HINDENBURG	803	245	Rigid	2
R 102*		814	248	Rigid	(not built)

* (not built)

APPENDIX G : LIST OF GH PATENTS

British Patent applications relating to Ground Handling 1900 – 1940

NB – THIS LIST IS NOT EXHAUSTIVE
and
ENTRIES ARE IN APPROXIMATE CHRONOLOGICAL ORDER OF APPLICATION

GB 123 24 AUG 1908
Clement, A. **Aerial machines with aerostats ... Anchoring; collision buffer fittings**
... semi-rigid, keel, gas partitions, baffles with holes, retractable steering planes, mooring cables,

GB 157,198 22 AUG 1913 Not accepted
Basenach, N. **Anchoring**
... Airships are anchored in direct contact with the ground at a point on the keel frame or front gondola below the front part of the airship... The elevator of the airship is set to keep the rear end raised.

GB 115,260 (6042/17) Ap 28 APR 1917 Gr 29 APR 1918
Saunders, Ltd; Porter, S.E.; Goatley, F. **Improvements in Landing Runners for Airships and other aircraft**
...a pneumatic cushion or buffer for use on aircraft... comprises an inner inflatable tube contained in a flexible but inextensible jacket secured to the framing of the craft and provided with a shoe.

GB 128,979 Ap 08 SEP 1917
Aeronautical Instrument Co., and Brewer, G. **A pressure relief device for balloons**
... comprises a sleeve in communication with the balloon and normally held in position by elastic cords, and increase of pressure above a predetermined amount causing the sleeve to expand and tear of a ripping patch to a greater or lesser extent by pulling a cord.

GB 130,691 14 MAR 1918
McKechnie, Sir J. and Vickers, Ltd.; **Cars and cabins - shock of landing, deadening; floats, arrangement of**
... One or more pneumatic buffer bags are secured to the underside of the car by a water-tight fabric covering so as to provide a space of considerable volume around the bag to support the car on water. The bag is held in position by cords secured to flaps. Rubbing cords are provided on the covering.

GB 131,072 (6533/18) Ap 17 APR 1918 Gr 21 AUG 1919
McKechnie, Sir J., and Wallis, B. N. and Vickers Ltd, of London
Improvements in or relating to the Mooring of Lighter-than-air Aircraft
... the aircraft is moored to the mast by means of a ball and socket device the socket member of which comprises a number of spherical segments adapted to open and to close upon the ball member when the latter enters the socket, one of the said members being carried by the upper end of the mast while the other is securely attached to the nose... A mooring rope passes through or alongside of the ball...

GB 147,162 20 JUL 1918
Goodyear Tire & Rubber Co., and Upson, R. **The nose of a dirigible or like balloon is strengthened**
... to prevent caving-in by means of a metal plate spaced from the envelope and secured by screws to the outer clamping-ring of the battens. The battens are similar to those usually employed but terminate at the periphery of the metal plate instead of meeting at a common point. They are clamped between the rings by bolts.

GB 125,003 (13,227) Ap 14 AUG 1918 Gr 10 APR 1919
Masterman, E.A. **Improvements relating to Mooring Devices for Lighter-than-air Air Craft**
...mooring devices for lighter-than-air aircraft designed to enable such aircraft to be moored in the open without wind screens or other protection against the effect of wind... the aircraft is moored to the upper end of a vertical mast, ropes carried by the mast being attached when the craft is moored at points near the nose... symmetrically disposed on either side of the vertical longitudinal central plane

GB 142,573 (3535/19) Ap 13 FEB 1919 Gr 13 MAY 1920
Hasler, Henry Neville of RAF East Fortune, Edinburgh **Apparatus for Mooring and/or Handling Airships**
... an apparatus for mooring... doing away with airship sheds at "port" of call, for commercial airships, and also dispensing with a large number of men at present necessary to take an airship out of its shed... consists of a turntable provided with a conical projection or a rotating pivot only, said turntable which floats in gimbals... whole being mounted on a triangular platform... moved on caterpillars

GB 166,206 (3981/19) Ap 18 FEB 1919 Gr 11 JUL 1921
Watt, William Hutcheon of RAF Airship Station, Pulham, Norfolk
Method of Maintaining Angle of Trim of an Airship Moored to a Mast
...consists of three or more inverted rails (a number could be laid at various distances to allow for different sizes of ships) set in the ground at various radii from the centre of the mast and encircling same. A series of bridles... are made fast to the holding down positions on the keel, and set up on tackles to a ball swivel securing ball bearing rollers clipping the rails, and free to run on them...

GB 140,197 08 MAR 1919
Birkbeck, T. E. **Anchoring**
... A dirigible is secured to a mooring arranged directly underneath the envelope and free to adjust itself under the influence of wind pressure on the envelope to a position end-on to the wind. The mooring device... comprises a lattice girder or beam carried by two frames mounted on bogies arranged to run on two circular rails so that the beam occupies a radial position.

GB 145,834 (7714/19) Ap 27 MAR 1919 Gr 28 JUN 1920
Glazebrook, Sir Richard T and Frazer, R. A. and Simmons, L. F. G. of the National Physical Laboratory, Teddington
Improvements in Mooring for Airships and the like
... to employ three mooring cables of equal lengths connected at one end to a common swivel or connection upon the airship and at their other ends to three fixed bollards on the ground at the apices of an equilateral ground base... with an adequate reserve of buoyancy ... the point of connection with the airship remains fixed and... disadvantages will be obviated... one or more swivelling pulleys...

GB 137,235 11 JUN 1919
James, A. P. **A topping-up valve for supplying gas to balloons**
... comprises a rigid close-ended tube with side perforations covered by a rubber tube secured at one end. A hose passing through a cover is led to the car. After passing the valve, the gas enters the envelope by way of a rigid cone and a collapsible tube, perforated on its lower side, which normally lies-flat upon the bottom of the envelope.

GB 146,852
DE 22 JUN 1919
Riedinger Ballonfabrik Augsburg Akt.-Ges., **Captive balloons; cars; - Anchoring and Tow Lines**
... The anchoring cable and the car of a captive balloon are connected to the envelope through systems of looped cords with interposed rollers or similar members so that, for all ordinary attitudes of the balloon, the forces pass approximately through the same points on the longitudinal axis of the balloon. The rigging is designed so that, when the balloon is being hauled in and the nose consequently dips...

GB 152,729 & 152,730 10 JUL 1919
Roots, J.D. **Aerial ways and guides**
... Grooved wheels secured to an airship fore and aft on each side engage two laterally arranged aerial ropeways, the airship running between the ropeways. The wheels are preferably arranged in pairs, with the wheels of each pair staggered and engaging one above and the other below the rails... Rudders may be provided at each end of the airship to relieve the ropeway of lateral wind stresses...

US 1,351,931 (321,526) Fi 04 SEP 1919 07 SEP 1920
Ullmann, Emanuel S. of New York City, USA **Apparatus for Mooring Airships**
... to provide means whereby such an airship, having arrived at a stopping place, may be easily moored to the ground in an expeditious and secure manner, and released in order to renew or resume its journey... if an appreciable degree of wind prevails at the time, considerable difficulty is experienced in mooring the airship to the ground... requiring the services of a great number of men...

GB 162,135 (5658/20) Ap 25 FEB 1920 Gr 28 APR 1921
Moehl, Steffen of London **Improvements in the Construction of Mooring Masts for Airships and the like**
... On or near the top of a self-supporting tower of reinforced concrete, steel or other suitable material should be fixed on or several circular horizontal rails with centres in axis of tower. On these rails a construction forming the head of the mast and suitable for the mooring of the airship should be guided... it is able to turn freely round the axis of the tower and to withstand forces in all directions.

GB 163,172 09 MAR 1920
Cave-Browne-Cave, T.R. and Rope, F.M. **Anchoring**
... In mooring gear for airships, of the type in which a cone or other coupling, within which a fitting at the bow of the airship can be locked, is resiliently mounted on a turntable on a mast-head, the cone or other coupling can be angularly adjusted in a vertical plane, and means are provided for indicating the lift exerted by the airship on the mast.

GB 164,561 (9511/20) Ap 01 APR 1920 Gr 16 JUN 1921
Ullman, Emanuel Salomon of New York City, USA **Improvements in or relating to Apparatus for Mooring Aircraft**
... to provide means whereby such an airship, having arrived at a stopping place, may be easily moored to the ground in an expeditious and secure manner, and released in order to renew or resume its journey... there is provided a device for mooring aeronautical machines comprising a fixed support having a mooring member pivotally mounted thereon... to which the mooring ropes of an airship may be...

GB 169,938 01 APR 1920
Ullmann, E.S. **Anchoring; Landing places**
... Dirigibles are moored by ropes secured to wheeled trollies running beneath circular and radial tracks on the ground so that the dirigible can swing round in the wind or be moved radially into hangars. Series of plates are secured to concrete blocks in the ground so as to leave concentric circular slots and radial slots. Channel members are secured beneath each slot to support four-wheeled trollies...

GB 170,839 28 OCT 1920
Luftschiffbau Zeppelin Ges., and Merz, L. **Improvements relating to Nacelles for Lighter-than-air Aircraft**
... An engine gondola, which is just large enough to contain the engine only, may be pulled against the side of, or into, the body of an airship for repairs or when not in use. The gondola is suspended from the body of the airship by cables and may be pulled into position by removing a pivot and hauling on a rope by a winch.

GB 178,568 (2652/21) Ap 20 JAN 1921 Gr 20 APR 1922
DE 400367 : US 1,448,088 : FR 539576 : IT 235880 : ES 87397
Scott, G. H. **Improvements in Mooring Masts and Mooring Gear for Airships**
... wherein a mooring fitting on the bow of the ship is coupled to a resiliently mounted mooring fitting on the mast-head with the aid of a mooring cable... an uprising lever carrying the mooring mast fitting at its upper end is mounted on the fixed mast-head with facility of a limited listing movement in any direction... under the restraining action of resilient means or of the tension of the mooring cable.

GB 162,280 (11,797/21) Ap 25 APR 1921 Gr 25 MAY 1922
DE 23 APR 1920
Luftschiffbau Zeppelin GmbH, and Jaray, Paul **Improvements relating to Alighting Gear for Lighter-than-air Aircraft**
... Shock absorbers, applications of; land wheels – For use when starting or alighting, and to facilitate the handling of airships on the ground, wheeled frames holding elastic nets are detachably and elastically secured to the gondolas of an airship. The frame has two pairs of swivelling wheels and an elastic net for engaging the undersurface of the car or car-buffer. The frame is secured to the car...

GB 179,439 (13,803/21) Ap 17 MAY 1921 Gr 11 MAY 1922
DE 400367 : US 1,448,089 : FR 540016
Scott, G. H. **Improvements in Masts and Mooring Gear for Airships**
... relates to improvements in mooring mast gear for airships of the type wherein the fitting on the bow of the ship is coupled, with the aid of a mast wire of the like, to a fitting carried at the upper end of an uprising lever mounted on the masthead with facility of limited listing movement in any direction, about a neutral point under the restraining action of resilient means or of the tension of the mast wire ...

GB 187,036 (19,251/21) Ap 16 JUL 1921 Gr 16 OCT 1922
Johns, George William and Johns, Harold Edgar **Improved means for Mooring Airships on Open Ground**
... An airship is moored at both ends by means of a fixed mast and one or more moveable masts working on a concentric track, the masts having means for raising and lowering the airship to enable passengers and goods to be transferred to and from the gondolas directly by means of lifts working through the floors.

GB 182,792 (18,270/22) Ap 04 JUL 1922 Gr 05 NOV 1923
DE 08 JUL 1921
Luftschiffbau Zeppelin GmbH **Anchoring Devices for Airships**
... A pyramidal frame secured beneath an airship has a ball member adapted to be secured in a socket on the ground or on a scaffolding so that the airship can swing in the wind. The frame also carries a beam which is adapted to rock within limits about a pivot and is provided with castor wheels to enable the airship to be moved into and out of its shed.

GB 183,469 (19,768/22) Ap 19 JUL 1922 Gr 11 OCT 1923
DE 20 JUL 1921
Luftschiffbau Zeppelin GmbH **An Anchoring Device for Airships**
... Trucks of the kind used for moving an airship into or out of its shed are rigidly secured beneath the front and rear parts of the airship, and the front truck is pivotally secured to a point on the ground, the rear truck, which is loaded sufficiently to prevent it from being lifted during wind gusts, running upon an asphalted or cemented track concentric with the anchoring point.

GB 205,059 03 OCT 1922
Chenu, A. J. J. **The Lifting Gas of an Airship is Purified (1)**
... by passing it through a closed circuit containing a purifier which comprises an apparatus for liquefying any air contained in the lifting gas. The purifying apparatus may be carried on a motor truck. The impurities may be replaced by additional lifting-gas which may consist of Dowson gas after the elimination of the carbon-monoxide. The lifting-gas... is circulated from one gas chamber to another...

GB 208,511 15 DEC 1922
Chenu, A. J. J. **The Lifting Gas of an Airship is Purified (2)**
*... The gas purifying arrangement described in the parent Specification [*GB 205,059*] is modified by the provision of reservoirs for the impure and the purified gases respectively, thus enabling the purifying treatment and the movement of the gases to and from the receptacle to be effected in separate stages by branching the conduits to open into the receptacle at several points... by substituting...*

GB 212,882 12 MAR 1923
Luftschiffbau Zeppelin Ges. **Reinforced Nose Cone for Mooring Aerostats**
... An airship has a cone-shaped or pyramid-shaped framework at its front end to take mooring stresses, the greater part of the frame-work being within the streamlined covering. The re-entrant angle between the projecting part of the frame and the covering may be rounded off by a fillet.

US 1,478,747 (645,291) Fi 14 JUN 1923 25 DEC 1923
Kinyoun, Floyd H. of Omaha, Nebraska **Airplane Starting and Landing Device**
... comprising a turn table having an endless belt mounted thereon and guidable in triangularly shaped trackways. The turn table is provided with an electric motor for driving the endless belt on which the airplane rests; the motor also forming means by which the turn table can be turned to various positions for receiving or launching an airplane.

GB 222,310 24 SEP 1923
Uhlendahl, P. **Landing places, docks, and launching ways**
... An airship landing-place and shelter comprises a chamber capable of receiving the airship, mounted on a stage capable of being lowered into a pit and having sections of rail which, when the stage is raised, join with rails on the adjacent ground to form a circular track on which the chamber may be rotated to set it in a suitable direction for the wind... side-walls... are adapted to fold down...

GB 223,746 (27,220/23) Ap 30 OCT 1923 Gr 30 OCT 1924
Richmond, Vincent Crane and Scott, George Herbert **Improvements in or relating to the Ballasting of Airships**
... To maintain the trim of an anchored airship automatically during loading and unloading, groups of tanks are connected to a pipe which has an open end and is kept continuously supplied with water from the mooring-tower so long as any variation of trim is likely to occur. As the orifice rises or falls the tanks, commencing at the rear group, fill or discharge...

*** END OF SAMPLE FROM 10 PAGES ***

APPENDIX H : WHO WAS WHO (DRAFT OUTLINE)

Knowing Who was Who allows quoted opinions to be evaluated for bias and extent of knowledge at time of writing

BIOGRAPHIES OF SIGNIFICANT AIRSHIP PERSONNEL

(NB - This is a first draft outline of the intended list as provisionally compiled at time of CargoLifter's demise)

Arnstein, Karl of Goodyear-Zeppelin
Bolster, Calvin - inventor of Bolster Beam for docking Akron and Macon
Booth, Ralph - Captain of R100
Brereton, Christopher Francis of Armstrong Whitworth, (Sir W. G.) & Co Ltd,
Burgess, C.P. author of Airship Design
Burney, Sir Denistoun - Founder of Airship Guarantee Co, and R100
Campbell - Designer of R38
Cave-Browne-Cave, T.R. - engines of R101
Coleman – Director of Airship Development (D.A.D.) at Royal Airship Works, Cardington
Collins - R101 Certification
Davis, F. W. of Cleveland Bridge & Engineering Co., Ltd.
Dick, Harold - US representative on board LZ 127
Dresel, Admiral - of US Navy
Dürr, Ludwig of Luftschiffbau Zeppelin GmbH
Eckener, Dr Hugo - the doyen of large airships
Forlanini, Enrico - Italian constructor
Frazer, R. A. of the National Physical Laboratory, Teddington
Fritsche, Carl B of Aircraft Development Corp., Detroit
Fulton, Garland - of US Navy
Glazebrook, Sir Richard T of the National Physical Laboratory, Teddington
Hall-Brown, Archibald of Babcock & Wilcox Ltd
Hasler, Henry Neville of RAF East Fortune, Edinburgh
Helma, Paul of Goodyear-Zeppelin
Hollick, F.W. of Babcock & Wilcox Ltd
Jaray, Paul of Luftschiffbau Zeppelin GmbH
Johnston, Ernest - navigator of R100 and R101
Jones, Edwin Walter of Babcock & Wilcox Ltd
Kenworthy - of US Navy
Krell, O. - designer of Berlin revolving shed
Lehmann, Ernst - Graf Zeppelin Captain
Lillienthal, Otto - pioneer of flight
Loeser, Oscar Jnr of United States Navy
Maitland - British innovator
Masterman, E.A. - designer of early mooring mast
McKechnie, Sir J. of Vickers, Ltd.
Meager, George - Officer of R100
Merz, L. of Luftschiffbau Zeppelin Ges.,
Moffett - US navy Admiral responsible for Akron and Macon
Neon - Anonymous critic of rigid airships
Nobile, Umberto - doyen of Italian semi-rigids
Norway, Neville Shute - author and member of R100 design team
Pratt, H.B. - R100 design team
Richmond, Vincent Crane of Royal Airship Works, Cardington
Riedinger Ballonfabrik Augsburg Akt.-Ges.,
Rope, Michael of Royal Airship Works, Cardington
Rosendahl, Admiral Charles Emery – US Navy Commander of Lakehurst NAS
Roxbee Cox, Harold (later Lord Kings Norton) of Royal Airship Works, Cardington,
Schnitzer, Beno of Luftschiffbau Zeppelin GmbH
Scott, George Herbert of Royal Airship Works, Cardington
Settle, Tex - US Navy
Simmons, L. F. G. of the National Physical Laboratory, Teddington
Southwell, Professor
Spanner - author and Critic of Rigid airships
Strasser, Peter - Commander of German Navy First War Zeppelin Fleet
Thaden, Herbert V. of Aircraft Development Corp., Detroit
Thompson, Lord Christopher Bird - Minister of Aviation who died on R101
Upson, R. of Goodyear Tire & Rubber Co., - designer of ZMC2 Metalclad
Usbourne, Neville - British pioneer airshipman
Ventry, Lord - editor of Airship magazine
Wallis, Barnes Nevil – British National Icon, designer of R100 and R80
Watson, Wilbur J. of Goodyear-Zeppelin
Watt, William Hutcheon of RAF Airship Station, Pulham, Norfolk
White, Alfred Ernest pp. Aircraft Development Corporation of Detroit, Michigan, USA.
Williams, T.B. - author of Airship pilot No 28
Zeppelin, Graf Ferdinand von - inventor of rigid airships

APPENDIX I : CHRONOLOGICAL LIST OF EVENTS (SAMPLE PAGES)

(INCLUDING FIRST AND LAST FLIGHTS)

- SECTION 1 – EUROPEAN AIRSHIPS (pages 1 – 7)
- SECTION 2 – BRITISH AIRSHIPS (pages 7 - 11)
- SECTION 3 – AMERICAN AIRSHIPS (pages 11 - 14)

Section 1 - EUROPEAN AIRSHIPS

1776		Joseph Priestley's *Experiments on Different Kinds of Air* published		France
1782		First experimental hot air balloons flown - Joseph Montgolfier	Annonay,	France
1783	05 Jun.	First public demonstration of unmanned hot air balloon - Montgolfier Bros.	Annonay,	France
	27 Aug.	First public demonstration of unmanned hydrogen-gas balloon - Prof. Charles	Paris	France
	23 Sep.	First tethered passenger rides in a captive hot air balloon - Joseph Montgolfier	Paris	France
	21 Nov.	First human free-flight (hot air) - Pilatre de Rozier & Marquis d'Arlandes	Paris	France
	21 Nov.	First pursuit of hot air "Montgolfiere" balloon on horseback – Duc de Chartres	Paris	France
	01 Dec.	First human free-flight in hydrogen gas filled "Charliere" – Prof. Charles	Paris	France
	03 Dec.	Design for a ballonet to control airship pressure published – Lt. J. Meusnier	Paris	France
1784		Design for fully formed airship driven by co-axial propellers - Lt. J. Meusnier	Paris	France
	10 Jan.	Ascent of first giant balloon, *Le Flesselle* – Montgolfier Bros.		France
	22 Feb.	First unmanned balloon to cross the English Channel (Sandwich to Warneton)	England/France	
	25 Feb	First human free-flight in a "Montgolfiere" in Italy – Paolo Andreani	Milan	Italy
	04 Jun.	First free-flight by a woman in a "Montgolfiere" – Madame Thible	Lyons	France
	15 Jul.	First ascent of cylindrical "airship" balloon with ballonets – Duc de Chartres	Paris	France
	19 Sep.	First 150 mile flight in cylindrical "dirigible" – Robert Bros. & Colin Hullin	Paris/Bethune	France
1785	07 Jan.	First human flight across the English Channel – J-P. Blanchard & Dr Jeffries	Dover/Calais	
	15 Jun.	First flight of hybrid "Montgolfiere/Charliere" – de Rozier & Romain	Boulogne	France
1786	18 Jun.	First night-time flight in a balloon – Tetsu Brissy		France
1789		First plans for "fish-shaped" dirigible or navigable balloon – Baron Scott	Paris	France
1791	18 Sep.	First balloon display at a state occasion – Proclamation of new Constitution	Paris	France
1794	26 Jun.	First military use of a gas balloon *L'Entreprenant* - J-M-J. Coutelle Battle of Fleurus		France
1797	22 Oct.	First successful parachute descent from a balloon – Andre-Jaques Garnerin	Paris	France
1798	21 Oct.	First free-flight on horseback under a cylindrical balloon – Tetsu Brissy	Versailles	France
1812		First design for rigid keel to stiffen pressure airship – Leppich/Russian Govt.	Germany/Russia	
1820		Aluminium isolated as a rare metal		
1831		Proposal for metal hull vacuum balloon – Marey Monge		
1834		Regular passenger transport flights proposed London/Paris – Comte de Lennox	Paris	France
1835		*Eagle* airship propelled by oars goes on public exhibition – Comte de Lennox	London	England
1836	07 Nov.	First long-distance international flight (480 miles/772 Km) – Monck-Mason et al.	London/Nassau	
1843		Rigid spherical balloon of copper sheet built but not flown – J-F. Dupuis-Delcourt		France
1848-1849		Demonstration of dropping 'aerial torpedos' from balloons – Henry Coxwell	Berlin	Germany
1849	Jun.	First aerial bombardment – Austrian Armed Forces	Venice	Italy
1850		Streamlined model clockwork airship demonstrated flies indoors – Pierre Jullien	Paris	France
		Man-powered "locomotive balloon" with propellers tested – Bell	London	England
1851		Proposal for large cylindrical rigid airship built of iron – Prosper Meller	Bordeaux	France
1852	24 Sep.	First flight of mechanically powered (steam-engine) airship – Henri Giffard	Paris	France
1863	19 Aug.	Graf Ferdinand Zeppelin's first ascent in a captive balloon	St Paul MN	USA
1870	23 Sep.	First Air Mail delivered by balloon escaping from Siege of Paris – J. Duruof	Paris	France
1872	02 Feb.	First flight of airship with 8 men working hand-cranked propeller – Dupuy de Lome		France
	13 Dec.	Trial ascent of Lenoir gas-engined balloon with tractor propeller – P.Haenlein	Brunn	Moravia
1873		Patent for rigid airship with separate gas cells – Spiess	Paris	France
1877		Proposal for vertical-axis airscrews to control airship climb/descent – Graf Zeppelin	Germany	
1881	08 Oct	Trials of first electrically powered dirigible balloon – Tassandier Bros.	Auteil	France
1884	09 Aug.	First aerial circuit by electric-powered airship *La France* - Renard & Krebs	Chalais-Meudon	France
1885		Metal covered rigid airship with variable volume proposed – Konstantin Ziolkovski		Russia
1886		Patent for steel rigid airship – Boyman		
		Aluminium becomes commercially available		
1888	12 Aug.	First flight by petrol-engined aircraft – Woelfert & Daimler	Seelberg to Kornwesthein	Germany
1891-1899		Concept of large rigid airship begins: men, money and materials sought – Graf Zeppelin		Germany
1892		Casein wood-glue cement (*Kaltleim*) invented and patented -		Switzerland
		Metal-covered airship proposal published after wind-tunnel tests on model – K.E.Ziolkovski		Russia
	23 Aug.	Contract signed for supply of first all-metal aluminium airship – David Schwarz	Vienna	Austria
1893		Swiss Military Ballooning begins (Hildebrandt, 1992)		Switzerland
1895	31 Aug.	Patent application for multi-cell large rigid airship – Graf Zeppelin		Germany
1896		First successful elongated Drachen kite-balloon– von Parseval & von Sigsfield	Berlin	Germany
1898	20 Sep.	First successful flight of small pressurised airship *No.1* – Alberto Santos Dumont	Paris	France
1899	17 Jun.	Construction of first multi-cell rigid airship (*LZ1*) begins – Graf Zeppelin	Manzell	Germany
1900		First use of oxygen on balloon ascent to 35,500 ft – Berson & Süring		Germany
	01 Jul.	Inflation of *LZ1* completed in 12 hours – Maj. Sperling	Manzell	Germany
	02 Jul.	First trial flight of first rigid Zeppelin *LZ1* on Lake Constance – Graf Zeppelin	Manzell	Germany
	15 Nov.	Fourth and last trial flight of *LZ1* – Graf Zeppelin	Manzell	Germany
1901	30 Apr.	First rigid airship *LZ1* broken for scrap	Manzell	Germany
1902		Stratosphere discovered by using sounding balloons - Teisserenc de Bort		France
	19 Oct.	Deutsch Prize for flying round Eiffel tower won by airship *No.6* – Santos Dumont	Paris	France
	13 Nov.	First flight of practical semi-rigid pressure airship *Le Jaune* – Lebaudy Bros.	Moisson	France

*** END OF EUROPEAN SAMPLE OF 7 PAGES ***

Section 2 – BRITISH AIRSHIPS

1766		Hydrogen gas discovered by Henry Cavendish	England
1776		Joseph Priestley's *Experiments on Different Kinds of Air* published	France
1783	04 Nov.	First unmanned gas balloon flight – Count Zambeccari	Cheapside, London/Waltham Abbey
	25 Nov.	First public demonstration of gas balloon – Count Zambeccari	Moorfields, London/ Petworth
1784	17 Aug.	First human free-flight in a "Montgolfiere" in Great Britain – James Tytler	Edinburgh Scotland
	15 Sep.	First human free-flight in a "Charliere" in England - Vincenzo Lunardi	London England
	12 Nov.	First flight in a "Charliere" by an Englishman – James Sadler	Oxford England
1784 cont.	30 Nov.	First scientific observations from free-flying balloon – Blanchard & Dr Jeffries	London England
1785	07 Jan.	First human flight across the English Channel – J-P. Blanchard & Dr Jeffries	Dover/Calais
	29 Jun.	First ascent of an "English female aerial traveller" – Mrs Sage	London
1802	21 Sep.	First parachute descent from a balloon in England – Andre-Jaques Garnerin	London England
1803		"*Treatise on the use of balloons in Military Operations*" published – Maj. Money	
1810		Proposal for fish-shaped balloon - Sir George Cayley	England
1811	07 Oct.	Flight speed of 112 miles (180 Km) in one hour recorded – James Sadler	Birmingham England
1816-1817		First serious attempt to construct a dirigible balloon – John Pauly & Durs Egg	London England
1817		Proposal for airship with separate gas-cells - Sir George Cayley	England
	22 Jul.	First aerial crossing of the Irish Sea - Windham Sadler	England/Ireland
1821	19 Jul.	First balloon flight using coal gas – Charles Green	London England
1828		Trail rope introduced to assist gas balloon landings – Charles Green	England
1834		Regular passenger transport flights proposed London/Paris – Comte de Lennox	Paris France
1835		*Eagle* airship propelled by oars goes on public exhibition – Comte de Lennox	London England
1836	07 Nov.	First long-distance international flight (480 miles/772 Km) – Monck-Mason et al.	London/Nassau
1848-1849		Demonstration of dropping 'aerial torpedos' from balloons – Henry Coxwell	Berlin Germany
1862	05 Sep.	Record altitude balloon ascent to 30,000 feet (9144 m) – Coxwell & Glaisher	England
1866		The (Royal) Aeronautical Society of Great Britain founded	London England
1868		First aeronautical exhibition in England at Crystal Palace	London England
		Helium first detected in light from the sun – Sir Norman Lockyer	England
1878		South Africa Boer war observation balloons	
1879		First British military aircraft (gas balloon *Pioneer*) built	England
		War Ministry Balloon School founded – Col. Templer	Chatham
1883		First military gas balloon made of goldbeater's skin (*Heron*) – Capt. Templer	Chatham England
1884		First portable gas cylinders for compressed hydrogen introduced – Capt. Templer	Woolwich England
1891		Balloon School moved to new premises	Aldershot
1895		Helium gas discovered on Earth – Sir William Ramsay	England
1900			
1901		(Royal) Aero Club of the United Kingdom founded – C.Rolls & Hedges-Butler	London England
1902	22 Sep.	First flight by powered airship in Britain Crystal Palace/Eastcote - Stanley Spencer	London England
1904	05 Sep.	First flight of *Willows No.1* blimp (with swivelling propellers) – E.T.Willows	Cardiff
1905		Modified *Willows No.1a* blimp makes many flights - E.T.Willows	Cardiff
	22 Jul.	First and only flight of *The Barton* blimp – Dr F.A.Barton	London England
	30 Sep.	*Willows No.1* blimp flies for 2 hours	Cardiff
1906		Modified *Willows No.1a* blimp makes more flights - E.T.Willows	Cardiff
1907		(circa) E.T.Willows Patent for swivelling propellers	London England
	10 Sep.	First flight of goldbeater's skin pressure airship *Nulli Secundus*– Col.Templer	Farnborough
	05 Oct.	*Nulli Secundus* cross-country flight and forced landing – Col.Capper & S.Cody	London England
1908		Construction of small experimental Army blimp *Baby* – Col.Capper	Farnborough
	Jul.	First flight of *Nulli Secundus II* - Col.Capper & S.Cody	Farnborough England
	Sep.	*Nulli Secundus II* dismantled	Farnborough England
1909		*Baby* blimp enlarged and modified and renamed *Beta I* – Col.Capper	Farnborough England
	26 Nov.	First flight of *Willows No.2* blimp – E.T.Willows	Cardiff
1910		First flight of Army blimp *Gamma*	
	26 May	First flight of *Beta I (ex-Baby)* blimp – Col.Capper	Farnborough England
	06 Aug.	*Willows No.2* blimp starts cross-country overnight flight – E.T.Willows	Cardiff
	07 Aug.	*Willows No.2* blimp completes 10 hour overnight flight – E.T.Willows	Cardiff/London
	16 Oct.	*Clement-Bayard II (Dail Mail)* blimp : 1st cross-channel airship flight	France/London England
	26 Oct.	*The Lebaudy (Morning Post)* blimp cross-channel delivery flight	France/Farnborough England
	29 Oct.	First flight of renamed *Willows No.2* blimp *City of Cardiff* – E.T.Willows	London England
	04 Nov.	*City of Cardiff (Willows 2)* blimp crosses English Channel – Willows & F.Gooden	England/France
	28 Dec.	*City of Cardiff (Willows 2)* blimp arrives in Paris after delays for repair and weather	Paris France
1911		*Clement-Bayard II* enters service with British Army	London
	22 May.	Vickers *No 1. Mayfly* rolled-out for mooring trials in Cavendish Dock	Barrow-in-Furness England
	24 May	*Mayfly* completes first mooring out trials on floating mast - Vickers	Barrow-in-Furness England
1912		British order *Astra-Torres* from France	London England
		British purchase *Parseval (P.18)* from Germany	London England
		Willows No.4 blimp constructed with swivelling propellers – E.T.Willows	Birmingham England
		First flight of Aircraft Factory *Delta* blimp – Col.Capper	Farnborough England
	12 Feb.	First flight of Aircraft Factory *Gamma I* blimp – Col.Capper	Farnborough England
	Jun.	*Gamma I* blimp modified to become *Gamma II* blimp – Col.Capper	Farnborough England
	18 Jul.	Admiralty purchase *Willows No.4* blimp : renamed *HMA No.2*	Birmingham England
1913		*Parseval (P.18) (HMA No.4)* delivered	Farnborough England
		RBF *Beta I (ex-Baby)* blimp rebuilt to become *Beta II* – Col.Capper	Farnborough England
	12 Jun.	First flight of *Astra-Torres (HMA No.3)* blimp - Col.Capper et.al.	Farnborough England
	19 Jun.	Admiralty places order for rigid airship *Vickers No.9r*	London England

*** END OF BRITISH SAMPLE FROM 5 PAGES ***

Section 3 – AMERICAN AIRSHIPS

1793	09 Jan.	First human free-flight in gas balloon in USA – J-P. Blanchard	Philadelphia
1834		First human-carrying gas balloon to be built of goldbeaters' skin – Louis Lauriat	USA
1839	27 Apr.	First use of a Ripping Panel to rapidly deflate a balloon - John Wise	USA
1861		First successful portable hydrogen generator developed - Thaddeus Lowe	USA
		First successful aerial reconnaissance from captive balloon – La Mountain	Fortress Monroe USA
	18 Jun.	First electric telegraph message transmitted from captive balloon – T. Lowe	Columbia Armoury USA
	03 Aug.	First captive ascent of observation balloon from a ship *Fanny* – La Mountain	James River USA
1863	19 Aug.	Graf Ferdinand Zeppelin's first ascent in a captive balloon	St Paul Minnesota USA
1868		First American airship *Avitor* built – F. Marriott	California
1903	12 Dec.	First powered, sustained and controlled flight by aeroplane - Wright Bros.	Kitty Hawk USA
1904		First flight of blimp *California Arrow* – Prof. Baldwin	Los Angeles CA.
1905		First flight of blimp *City of Portland* – Prof. Baldwin	Los Angeles
1908		First flight of US Army blimp *Signal Corps 1* – Baldwin	??
1910	15 Oct.	Start of Transatlantic attempt by semi-rigid *America* – Walter Wellman	Atlantic City NJ.
1911		Second Tansatlantic blimp *Akron* built by Goodyear – Mevin Vaniman	Akron OH.
1917	Spring	Construction of first *USNavy blimp DN-1* in floating hangar	Pensacola FL. USA
	20 Apr.	First flight of *USNavy DN-1 blimp (A-1)* - Hans Otto Stagel	Pensacola USA
	29 Apr.	Last flight of *USNavy blimp DN-1*; damaged by inexperienced handling party	Pensacola USA
	24 May	First flight of *USN blimp B-1 (A-235)* - Upson & Kraft	White City, Chicago USA
	29 May	*USN blimp B-1 (A-235)* distance record flight - Upson & Kraft	Chicago/Akron Ohio USA
1918	22 Jan.	*USN blimp B-2 (A-236)* delivered to Navy	Key West USA
	27 Apr.	*USNavy blimp AT-1* completes 25+ hour convoy escort mission	Paimboeuf France
	30 Sep.	First flight of *USN blimp C-1 (A-4118)* – Smith & Hamlen	Wingfoot Lake USA
	Oct.	First flight of training airship *USN blimp E-1 (A-4109)*	Wingfoot Lake USA
	12 Dec.	*USN blimp C-1 (A-4118)* carries and launches Army airplane	Fort Tilden USA
	26 Dec.	*USNavy blimp B-2 (A-236)* completes record duration patrol (40+hours)	Key West USA
1919	11 Feb.	*USN blimp B-15 (A-249)* completes 2 week trial dropping torpedoes	Pensacola USA
	14 May	*USN blimp C-5 (A-4126)* begins Atlantic Ocean crossing attempt	Montauk USA
	15 May	*USN blimp C-5* completes 1,177 mile 1st leg of Ocean crossing	St John's Newfoundland
	16 Sep.	First flight of *USNavy semi-rigid O-1* ("Wop Ship") purchased from Italy	Cape May USA
1920	03 Jun.	*NS-7* blimp training American crews for rigid *R38 (ZR-2)*	Howden England
	07 Jun.	*SSE-3* blimp training flight American crews for rigid *R38 (ZR-2)*	Howden England
	08 Jun.	*NS-7* blimp training American crews for rigid *R38 (ZR-2)*	Howden England
	06 Jul.	*Beardmore R34* completes outward transatlantic flight - G.H.Scott	New York USA
	07 Jul.	*Beardmore R34* moored on 3-wire system for three days	Long Island, New York USA
	10 Jul.	*Beardmore R34* starts return transatlantic flight - G.H.Scott	New York USA
	13 Jul.	First flight of *USN blimp D-1 (A-4450)*	Wingfoot Lake USA
	20 Jun.	*SSE-3* blimp training flight American crews for rigid *R38 (ZR-2)*	Howden England
	28 Sep.	First flight of *US Army C-1 blimp*	Fort Bliss, TX USA
1921	Apr.	First flight of *USN blimp H-1 (Towing airship)*	Wingfoot Lake USA
	09 Jul.	Rebuilt *USNavy semi-rigid O-1* completes 4 days of a/a target glider drop trials	Cape May USA
	05 Dec.	First flight of a helium filled airship *USN blimp C-7 (A-4127)*	Hampton Roads USA
1922	24 Jun.	Contract signed to build *LZ126 (ZR-3) Los Angeles*	USA/Germany
	13 Aug.	Helium inflation of *US Navy ZR-1 (Shenandoah)* begins (13,000 cylinders)	Lakehurst NJ. USA
	16 Aug.	Helium inflation of *US Navy ZR-1 (Shenandoah)* completed	Lakehurst NJ. USA
	31 Aug.	First flight of *USN blimp J-1(A-6111)*	Wingfoot Lake USA
	04 Sep.	First flight of helium rigid *US Navy ZR-1 (Shenandoah)* – Anton Heinen	Lakehurst NJ. USA
	14 Sep.	*US Army C-2 blimp* starts transcontinental flight	Langley Field USA
	23 Sep.	*US Army C-2 blimp* completes transcontinental flight	Ross Field, CA USA
	10 Oct.	*US Army C-2 blimp* starts return transcontinental flight	Ross Field, CA USA
1923	Aug.	*USArmy blimp H-type (A-121/OB-1)* hydrogen replaced by helium	Wright Field OH. USA
	18 Sep.	Rebuilt *USArmy blimp D-3 (A-4453)* airplane/trapeze hook-on trials	Langley Field USA
1924	07 Oct.	*US Navy ZR-1 (Shenandoah)* begins 20 day transcontinental trip	Lakehurst NJ. USA
	09 Oct.	*US Navy ZR-1 (Shenandoah)* begins 2nd leg of transcontinental flight	Fort Worth TX. USA
	10 Oct.	*US Navy ZR-1 (Shenandoah)* reaches Pacific coast: moored to portable mast	San Diego CA. USA
	12 Oct.	Start of first transatlantic flight by *LZ126 Los Angeles* – Hugo Eckener	Friedrichshafen Germany
	15 Oct.	Arrival of *LZ126* after 81-hour trans-atlantic flight - Hugo Eckener	Lakehurst NJ. USA
	15 Oct.	*LZ126 Los Angeles* walked into hangar	Lakehurst NJ. USA
	18 Oct.	Hydrogen from *LZ126 Los Angeles* vented to atmosphere	Lakehurst NJ. USA
	25 Oct.	*US Navy ZR-1 (Shenandoah)* completes transcontinental round trip	Lakehurst NJ. USA
	25 Nov.	*LZ126* formally christened *USS Los Angeles* after valving gas to land 'light'	Washington DC. USA
	15 Dec.	First aircraft hook-on to an airship: *US Army blimp TC-3*- Lt.C.V.Finter	USA
1925		First flight of Goodyear blimp *Pilgrim*	Akron
1926		Design begins of *ZMC-2 "Metalclad"* aluminium alloy airship – R.H. Upson	Detroit, MI. USA
	08 Jan.	First flight of US Army semi-rigid *RS-1*	
1927	11 Jun.	*LZ126 (ZR-3) Los Angeles* begins airplane hook-on experiments	Lakehurst NJ. USA
1928	06 Oct.	US Navy/Goodyear sign contract for *ZRS-4 & ZRS-5*	Washington USA
	15 Oct.	65,000 spectators camp out overnight to see arrival of *LZ127 Graf Zeppelin*	Lakehurst NJ. USA
	20 Oct.	20,000 visitors per day to see *LZ127 Graf Zeppelin* in hangar	Lakehurst NJ. USA
	29 Oct.	*LZ127 Graf Zeppelin* undocked for return passenger flight to Germany	Lakehurst NJ. USA
1929		*LZ127 Graf Zeppelin* flies around the world	Germany/USA
	03 Jul.	Serious aircraft/airship hook-on trials begin *LZ126 (ZR-3)* – Lt A.W.Gorton	USA
	28 Aug.	*LZ126 (ZR-3) Los Angeles* first public demonstration of airplane hook-on	Cleveland OH. USA
	19 Aug.	First flight of *ZMC-2 "Metalclad"* aluminium alloy airship – R.H. Upson	Detroit, MI. USA

*** END OF AMERICAN SAMPLE FROM 4 PAGES ***

APPENDIX J : ACCIDENTS AND INCIDENTS (SAMPLE PAGES)

- SECTION 1 - EUROPEAN ACCIDENTS (pages 1 – 3)
- SECTION 2 - BRITISH ACCIDENTS (pages 3 – 5)
- SECTION 3 - AMERICAN ACCIDENTS (pages 5 – 9)

Section 1 - EUROPEAN ACCIDENTS AND GH INCIDENTS

1784	11 Jul.	First riot by angry crowd at failed ascent – Marquis d'Arlandes & Abbe Miolan	France
1785	15 Jun.	First humans killed in balloon accident – Pilatre de Rozier & Jules Romain	Boulogne France
1819	07 Jul.	Fatal accident during firework display from gas balloon - Madame Blanchard	Paris France
1863	19 Oct.	Crash of the *Geant* balloon	France
1893		*Schwarz 1* aluminium airship irreparably damaged during inflation – D.Schwarz	Volkhov Russia
1897	12 Jun.	First airship fatalities after petrol engine ignites hydrogen – Woelfert & Knabe Berlin	Germany
	11 Jul.	First unsuccessful attempt to reach North Pole by Balloon – Andree	Danes Island Norway
	03 Nov.	*Schwarz 2* all-metal rigid airship destroyed by landing impact after first ascent Berlin	Germany
1900		First floating hangar *Pendelhalle* breaks from its moorings and strands on shore	Manzell Germany
1902	12 May.	Pressure airship *Pax* bursts in mid-air and kills two pilots – Severo & Sachet	Paris France
	13 Oct.	Two more killed after control car falls from pressure airship – de Bradsky & Morin	Paris France
1905	30 Nov.	Rigid airship *LZ2* damaged during "rollout" from floating shed – Graf Zeppelin	Manzell Germany
1906	17 Jan.	*LZ2:* destroyed by storm after landing on lake shore – Graf Zeppelin	Bodensee Germany
1907		*LZ3* survives undamaged when *Reichshalle* sinks after storm damage	Manzell Germany
	01 Dec.	*Lebaudy La Patrie* torn from groundcrew by storm and blown out to sea	Verdun France
1908	01 Jul.	*Gross/Basenach M1* non-rigid forced landing and deflated in forest	Berlin Germany
	05 Aug.	*LZ4* wrecked by storm after successful emergency landing – Graf Zeppelin	Echterdingen Germany
	25 Aug.	*Lebaudy Republique* wrecked after propeller cuts gascell, 4 on board killed	France
	Nov.	*Gross/Basenach M1* forced landing on water at night in Ostsee and deflated	Wollin Germany
1909	16 Mar.	Tail damaged in first rigid on-land landing *LZ3a (Army Z-1)* – Graf Zeppelin	F'hafen Germany
	07 Apr.	Blimp *da Schio Italia 1* damaged beyond repair in accident	Italy
	30 May	*LZ5* makes intermediate landing to pick up passenger - Ludwig Dürr	Bitterfeld Germany
	31 May	*LZ5* survives impact with pear tree while refuelling on ground – Graf Zeppelin	Göppingen Germany
	01 Jul.	*LZ3a (Army Z-1)* makes several intermediate landings – Maj. Sperling	Germany/France
	03 Aug.	*LZ5 (Army Z-2)* makes several intermediate landings – Graf Zeppelin	Germany
	30 Aug.	*LZ6* makes several intermediate landings for repair – Ludwig Dürr	Germany
1910-1914		DELAG airships completed 1,600 flights and carried 34,000 passengers	Germany
1910	01 Feb.	*Forlanini semirigid Leonardo do Vinci* wrecked by tree branch after forced landing	Pavia Italy
	25 Apr.	*LZ5 (Army Z-2)* destroyed in a storm	Limburg Germany
	13 Jun.	*Erbsloeh* semirigid bursts in mid-air, 5 on board killed – Oscar Erbsloeh	Elberfeld Germany
	28 Jun.	Wreck of *LZ7* on first passenger cruise after tree-top crash – Capt. Kahlenberg	Wallendorf Germany
	08 Sep.	*Yamada No 1* blimp wrecked on landing after first flight – Isaburo Yamada	Japan
	14 Sep.	*LZ6a* destroyed by accidental petrol fire in its shed	Baden-Oos Germany
1911	??	*Yamada No 2* blimp torn from mast by wind – Isaburo Yamada	Japan
		Ruthenberg II semirigid damaged after forced landing due to gas loss	Berlin Germany
	14 Apr.	*LZ8* survives hangar door impact while undocking – Dr. Hugo Eckener	Düsseldorf Germany
	16 May.	*LZ8* wrecked while undocking in cross-wind with passengers – Dr. Eckener	Düsseldorf Germany
	16 Jun.	*Parseval PL5* non-rigid "Sport Luftschiff" burnt during deflation	Munich Germany
	Sep.	*Gross/Basenach Army MIII* destroyed by fire	Germany
1912	28 Jun.	DELAG's *LZ10 Schwaben* destroyed by fire on the ground – W.E.Dörr	Düsseldorf Germany
1913	19 Mar.	*LZ15 (Ersatz Z-1)* destroyed in storm -	
	03 Apr.	Emergency landing of Army airship *Z-4 (LZ16)* at French military base	Luneville France
	12 Jul.	*Veeh* semirigid deflated after forced landing	Cologne Germany
	17 Jul.	Schütte-Lanz *SL1* forced down to ground and wrecked	Prussia
	09 Sep.	First Zeppelin fatalities: Navy airship *L-1 (LZ14)* lost at sea -	Heligoland
	17 Oct.	Second Zeppelin fatalities: Navy airship *L-2 (LZ18)* destroyed by fire in flight -	Berlin Germany
1914	09 Apr.	Semirigid *Forlanini Citta di Milano* hit mountain in squall, split open and burnt	near Como Italy
	13 Jun.	*LZ19 (Desatz Z-1)* destroyed in storm –	
	20 Jun.	*Austrian Army M-III* blimp exploded in flight, 400m high, 7 on board killed	Fischamend Austria
	06 Aug.	*LZ21 (Army Z-6)* shot down by a/a fire –	
	23 Aug.	*LZ22 (Army Z-7)* and *LZ23 (Army Z-8)* both shot down by a/a fire –	
	28 Aug.	Enlarged *LZ20a (Army Z-5)* shot down by a/a fire –	
	08 Oct.	*LZ25* (Army *Z-9*) bombed in shed	Düsseldorf Germany
1915	17 Feb.	*LZ24* (Navy *L-3*) wrecked in forced landing -	Denmark
	17 Feb.	*LZ27* (Navy *L-4*) wrecked in forced landing -	Denmark
	05 Mar.	*LZ33* (Navy *L-8*) shot down by a/a fire -	Belgium
	21 Mar.	*LZ29* (Army *Z-10*) forced down by a/a fire -	St Quentin France
	13 Apr.	*LZ35* (Army) forced down by a/a fire -	Belgium
	17 May	*LZ39 (Army)* survives direct hit in mid-air bombing attack by aircraft	Ostend Belgium
	20 May	*LZ30 (Army Z-11)* burned on ground after blowing away -	Posen Germany?
	21 May	*LZ34 (Army)* forced down by a/a fire -	East Prussia
	07 Jun.	*LZ37 (Army)* shot down by aircraft -	Ghent Belgium
	07 Jun.	*Army LZ38* bombed in shed	Evère
	06 Aug.	*LZ28* (Navy *L-5*) forced down by a/a fire -	Russia
	10 Aug.	*LZ43 (Navy L-12)* damaged by a/a fire over England and burned	Ostend Belgium
	03 Sep.	*LZ40 (Navy L-10)* burned in flight	
	18 Nov.	*Navy SL6* explodes on ground after leaving shed	Seddin Baltic
	19 Nov.	*Parseval PL26* non-rigid burnt in shed	Bitterfeld Germany

*** END OF SAMPLE FROM 3 PAGES ***

Section 2 - BRITISH ACCIDENTS AND GH INCIDENTS

1784		Crowd riot after failed unmanned gas balloon ascent	Chelsea London
1785	12 May	First crash and rescue at sea – Richard MacGuire	Holyhead Wales
1869	28 May	First break-away of a tethered passenger-ride balloon *Captive* – Henri Giffard	London
1902		Dirigible burned	Cosham Portsmouth
1905	22 Jul	*The Barton* blimp wrecked on landing – Dr F.A.Barton	London
1907	06 Oct.	*Nulli Secundus* wrecked by wind when moored out after forced landing	Crystal Palace London
1910	26 Oct.	*The Lebaudy* blimp damaged entering hangar (countermanded order)	Farnborough England
	04 Nov.	*City of Cardiff (Willows 4)* force landed for repair after Channel crossing	Douai France
	28 Dec.	*City of Cardiff (Willows 4)* blimp completes flight after bad weather delay	Paris France
1911	04 May	*The Lebaudy* blimp misses landing party and crashes into cottage	Farnborough England
	May	Vickers *No 1. Mayfly* gas cell deflated by ableseaman Palmer falling through it	Barrow-in-Furness
	22 May.	Vickers *No 1. Mayfly* rolled-out for mooring trials in Cavendish Dock	Barrow-in-Furness
	23 May	*Mayfly* on floating pontoon mooring mast with wind shields - Vickers	Barrow-in-Furness
	24 May	*Mayfly* completes first mooring out trials on floating mast - Vickers	Barrow-in-Furness
	24 Sep.	Modified *Mayfly* wrecked undocking from floating hangar - Vickers	Barrow-in-Furness
1913	Autumn	British Army blimp *Eta* survives 50 mph gale moored in chalk pit	Odiham
1914	14 Aug.	*HMA No.20 (Eta)* damaged in landing after engine trouble aborted sortie	Farnborough
	Sep.	*HMA No.4(Parseval P.18)* blimp replaces propeller blade while on patrol	England/Belgium
	14 Sep.	*HMA No.20 (Eta)* ripped in storm and repaired	Roehampton
	19 Nov.	*HMA No.20 (Eta)* destroyed when blown from moorings into trees after forced landing	Redhill
??		End of *HMA No.18 (Gamma II)* blimp after hull badly damaged in landing accident	?Farnborough
1915	Summer	*Navy blimp SS-17* drifts rudderless across Irish Sea and makes balloon landing	England/Ireland
	05 Aug.	*Navy blimp SS-27* wrecked by collision with church steeple	Marquise ?
	10 Sep.	*Navy blimp SS-10* salvaged and towed ashore by trawler after forced landing in sea	English Channel
	22 Oct.	*Navy blimp SS-18* breaks u/c when landing, ship drifts away and is lost at sea	England/Ireland
	05 Nov.	*Navy blimp SS-22* survives 1,000ft dive in 56 seconds	Anglesey Wales
	11 Nov.	*SS-5* blimp towed to shore by destroyer after forced landing in sea	England
	22 Nov.	*HMA No.4(Parseval P.18)* collided with shed in dense fog	Barrow? England
1916	06 Feb.	*Navy blimp SS-34* damaged when shed was blown down	Barrow England
	21 Feb.	Experimental hybrid 'airship-plane '*AP-1* kills pilots – Usborne & Ireland	Kingsnorth England
	12 May	*Coastal C.1* blimp towing trials with light cruiser *HMS Carysfoot*	Harwich England
	09 Jun.	*Coastal C.8* blimp lost at sea, 1 out of 4 crew survived	English Channel
	14 Jul.	*Coastal C.13* blimp wrecked due to defective valve	Kingsnorth England
	23 Jul.	*Coastal C.9* blimp towed ashore by destroyer after balloon landing in sea	Mullion England
	28 Aug.	*Coastal C.16* blimp wrecked after engine failure, landed in sea, crew saved	Berwick England
	03 Sep.	Wooden rigid *Army SL11* shot down by incendiary ammunition	London England
	06 Sep.	*Coastal C.1* blimp refuelling and crew exchange trials from ship	Kingsnorth England
	15 Sep.	*Navy blimp SS-42* pilot survives 100 mile flight with inverted car	Pembroke/Devon England
	24 Sep.	*LZ74* (*Navy L-32*) shot down by aircraft	Billericay England
	24 Sep.	*LZ76* (*Navy L-33*) forced down and burned by crew	Little Wigborough England
	02 Oct.	*LZ72* (*Navy L-31*) shot down by aircraft	Potters Bar, England
	15 Nov.	*Coastal C.17* blimp punctured by broken propeller during grapnel rope trials	Pulham England
	16 Nov.	Newly built *Vickers No.9* damaged control car when leaving shed, rehoused	Barrow England
	28 Nov.	*LZ78 (Navy L-34)* shot down by aircraft	W Hartlepool England
	28 Nov.	*LZ61* (*Navy L-21*) brought down by a/a fire and wrecked	Yarmouth England
	27 Dec.	*HMA No.4(Parseval P.18)* blimp damaged by down gust when landing	Howden England
1917	02 Jan.	*Navy blimp SS-23* landed on beach, held in gale for 3 hours until envelope ripped	Anglesey Wales
	25 Jan.	*Navy blimp SS-23* salvaged after forced landing at sea	Luce Bay Scotland
	16 Mar.	*RNAS SSP-3* blimp wrecked	Faversham England
	21 Mar.	*Coastal C.22* blimp lost at sea due to engine trouble	Pembroke Wales
	23 Mar.	*Coastal C.6* blimp lost at sea due to engine trouble, crew saved	off Lands End England
	14 Apr.	Only recorded accident (explosion) at a Silicol hydrogen producing plant	Pulham England
	21 Apr.	*Coastal C.17* blimp missing on patrol: assumed shot down, no survivors	Pulham England
	23 Apr.	*Navy blimp SS-32a* experimental landing and taxying on water	Barrow England
	23 Apr.	*Coastal C.11* blimp wrecked	Scarborough England
	26 Apr.	*Navy blimp SS-32a* moored at sea	Barrow England
	29 Apr.	*Navy blimp SS-13* salvaged and towed ashore after forced landing in sea	Newhaven England
	01 May	*Coastal C.23* blimp deflated by own top gun puncturing envelope	Folkestone England
	05 May	*Navy blimp SS-32a* wrecked in 30 mph [km]gusts when moored at sea	Barrow England
	05 May	*Navy blimp SS-34* destroyed in gale during mooring trials	Barrow England
	12 May	*Navy blimp SS-39* defective valve caused uncontrolled descent: force landed in tree	England
	16 Jun.	*NS-2* blimp wrecked	Stowmarket England
	11 Jul.	*Navy blimp SS-31* balloon landing after collision with rigid airship shed	Cranwell England
	16 Jul.	*Coastal C.15* blimp deleted as wrecked in towing trials	East Fortune Scotland
	19 Jul.	*Coastal C.11a* blimp burst into flames in flight, 5 crew killed	Humber England
	25 Jul.	*Navy blimp SS-39* broke away from landing party: 1 crew carried up on rope	Cranwell England
	27 Jul.	*Coastal C.1* blimp deflated after breaking away from handling party	Cranwell England
	14 Aug.	*SSZero.2* blimp engine failure, caught fire over funnel of assisting destroyer	English Channel
	12 Sep.	*Navy blimp SS-42a* wrecked at sea after crashing into farm during night landing	Pembroke Wales
	01 Oct.	*Coastal C.26* blimp forced landing 3 miles from base after running out of fuel	Howden England
	27 Oct.	*SSZero.14* blimp drifted across Channel after engine failure, landed in trenches	Montreivil France
	29 Oct.	*Vickers No.9* seriously damaged entering shed in bad weather	Howden England

*** END OF SAMPLE FROM 3 PAGES ***

Section 3 - AMERICAN ACCIDENTS AND GH INCIDENTS

1861	20 Apr.	First failed attempt to cross Atlantic Ocean by balloon – Thaddeus Lowe	Cincinatti OK
1862		Captive balloons under fire hauled down by galloping horses – J.R.Bryan	Yorktown USA
1905		Blimp *City of Portland* lands for 20 mins on roof of Chamber of Commerce	Portland OR.
1906		Blimps *California Arrow* and *City of Portland* burnt in hangar – Prof Baldwin	California
1910	17 Oct.	Transatlantic attempt by semi-rigid *America* ends in sea – Walter Wellman	Atlantic Ocean
1912	02 Jul.	Tansatlantic blimp *Akron* explodes in mid-air on test flight, 3 killed – Vaniman	Atlantic City
1917	Apr.	*USNavy blimp DN-1* car sank on first undocking from floating hangar	Pensacola FL
	29 Apr.	Last flight of *USNavy blimp DN-1*; damaged by inexperienced handling party	Pensacola FL
	Dec.	*USN blimp B-5 (A-240)* burnt after engine fire and release by handling party	Akron(?) OH
1918	25 Apr.	*USNavy blimp T-2* drifted ashore after sea impact during training	Paimboeuf France
	08 Jun.	*USN blimp B-5 (A-240)* hit power lines when landing; rip panel failed	Chatham USA
	10 Jun.	*USN blimp B-3 (A-237)* emergency night landing after rudder in-flight failure	Sayville USA
	16 Jul.	*USN blimp B-12 (A-246)* blown out to sea; rescued 3 days later by steamer	Provincetown USA
	08 Aug.	*USNavy blimp B-4 (A-238)* damaged by loss of rudder post	Cape May USA
	08 Aug.	*USNavy blimp B-13 (A-244)* envelope repaired after seam separated	Montauk USA
	18 Aug.	*USN blimp B-13 (A-247)* damaged undocking in cross-wind when rope broke	Montauk USA
	07 Dec.	*USNavy blimp B-10 (A-247)* envelope damaged and deflated	Cape May USA
1919	23 Jan.	*USN blimp B-20 (A-5257)* lost at sea	Provincetown (?) USA
	11 Feb.	*USN blimp F-1 (A-4348)* ripped and deflated after problems on delivery flight	Catlett VA
	19 Feb.	*USN blimp E-1 (A-4109)* damaged and repaired	Wingfoot Lake USA
	20 Mar.	*USN blimp E-1 (A-4109)* landed safely by instructor after rudder failure	Pensacola FL
	21 Apr.	*USN blimp B-9 (A-243)* envelope badly torn by engine failure	Key West(?) FL
	28 Apr.	*USNavy blimp B-3 (A-237)* slight envelope damage due to engine problem	Rockaway USA
	15 May	*USN blimp C-5* torn from 100-man groundcrew and blown out to sea	St John's Newfoundland
	17 May	*USN blimp C-1 (A-4118)* accidentally deflated	Key West USA
	03 Jun.	*USN blimp C-8 (A-4123)* survives mid-air carburetor fire – Lt R.Paunack	Cape May USA
	01 Jul.	*USN blimp C-8* burnt after emergency landing due to mid-air fin collapse	Camp Holabird MD
	31 Dec.	*USNavy semi-rigid O-1* ripped after engine failure and free balloon landing	Pennsville NJ
1920	13 Jan.	*USN blimp B-19 (A-5467)* envelope torn in strong winds	Chatham USA
	08 May	*USN blimp C-10 (A-4121)* repaired after envelope seam separated	Rockaway USA
	08 May	*USN blimp E-1 (A-4109)* damaged attempting to enter hangar	Pensacola USA
	20 May	*USN blimp E-1 (A-4109)* made land after rip panel failed in-flight	Pensacola USA
	17 Jun.	*USNavy blimp B-1 (A-235)* slight envelope damage by engine problem	Pensacola USA
	Jul.	*USN blimp D-1 (A-4450)* destroyed by fire in hangar	Wingfoot Lake USA
	21 Jul.	*USN blimp C-10 (A-4121)* damaged while covering Americas Cup Race	Jamaica Bay USA
	29 Jul.	*USN blimp C-7 (A-4127)* envelope damaged by impact with hangar doors	Pensacola USA
	30 Sep.	*USN blimp C-6 (A-4125)* became lost in fog and crashed	Laurel Canyon CA
1921	10 Jun.	*USNavy blimp B-3 (A-237)* damaged and repaired	San Diego CA
	08 Jul.	*USN blimp C-3 (A-4120)* burnt in flight; hydrogen ignited by engine spark	Hampton Roads USA
	21 Jul.	*USArmy blimp D-2 (A-4451)* made land after terminal damage by engine failure	Langley Field USA
	05 Aug.	*USN blimp H-1 (Towing airship)* ripped by farmer after flight without crew	Scarsdale NY
	31 Aug.	*USN blimp C-10 (A-4121)* destroyed in hangar fire	Rockaway USA
	31 Aug.	*USN blimp D-6 (A-5972)* destroyed in hangar fire	Rockaway USA
	31 Aug.	*USN blimp H-1 (Towing airship)* destroyed in hangar fire	Rockaway USA
1922		*USArmy blimp D-4 (A-4452)* deflated while attempting to moor to mast	Scott Field IL
	21 Feb.	USArmy semi-rigid *"Roma"* burnt after power line impact: 34 killed	Hampton Roads
	14 Oct.	*US Army C-2 blimp* burnt after hangar door impact ruptured fuel tanks	Brooks Field, TX
1923		*USArmy blimp D-5 (A-4454)* wrecked when punctured during crew training	Scott Field IL
	19 Jan.	*USArmy blimp D-3 (A-4453)* badly damaged undocking from hangar	Aberdeen MD
	06 Jun.	*USArmy blimp TC-1* destroyed by fire	Wright Field OH
1924	16 Jan.	*US Navy ZR-1 (Shenandoah)* breaks-away from mooring mast in gale (78mph)	Lakehurst NJ
	17 Jan.	*US Navy ZR-1 (Shenandoah)* returns to base with damaged top fin and nose	Lakehurst NJ
1925	03 Sep.	*US Navy ZR-1 (Shenandoah)* broke up in flight during storm: 14 killed	Ava, OH
1927	Mar.	*LZ126 (ZR-3) Los Angeles* trapped in hangar for 2 weeks by lack of ground crew	Lakehurst NJ
	25 Aug.	*LZ126 (ZR-3) Los Angeles* pitches 85° and swings 180° on mooring mast	Lakehurst NJ
1928	13 Oct.	*LZ127 Graf Zeppelin* survives fin damage in violent squall in flight	Atlantic Ocean
1929	25 Aug.	*LZ127 Graf Zeppelin* drags tail on ground when taking off	Los Angeles CA
1930	31 Jul.	*R100 (G-FAAV)* hit by extreme turbulence off Canadian coast	Quebec Canada
1932	Jan.	*USN blimp K-1* envelope damaged and returned to Goodyear by rail	Cape May USA
	22 Feb.	*USS ZRS-4 Akron* tail damaged when weathervaning unrestrained	NAS Lakehurst NJ.
	11 May	*USS ZRS-4 Akron* lifts 3 crew men on mooring lines during landing: 2 killed	Camp Kearney
1933	03 Apr.	*Goodyear ZRS-4 Akron* wrecked in Atlantic Ocean in storm	Eastern seaboard USA
	04 Apr.	*USN blimp J-3(A-7382)* deflated at sea after engine problem, 2 crew died	Beach Haven NJ
1934	21 Apr.	*USS ZRS-5 Macon* survives top fin damage during cross-mountain flight	Texas
1935	12 Feb.	*USS ZRS-5 Macon* loses top fin in flight and crashes into sea	California
	May	*USN blimp K-1* envelope returned to Goodyear with 25 foot long tear	Cape May USA
1937	06 May	First deaths of fare-paying passengers in *LZ129 Hindenburg* fire – Pruss et.al.	Lakehurst NJ
1939	May	*USN blimp K-2* damaged and deflated after impact with trees	Lakehurst NJ
1942		One ground crew killed in handling accident	USA
		USN blimp L-2 deflated during practice take-off after impacting trees	Lakehurst NJ
	08 Jun.	*Goodyear G-1 "Defender"(NC-12A)* collided with *L-2* on night trial at sea	Manasquan Inlet USA
	08 Jun.	*USNblimp L-2* collided with *G-1* on secret mission night trial; 12 men died	Manasquan Inlet USA
	Jul.	*USN blimp K-6* wrecked at mast during thunder storm; one ground crew injured	Sth Weymouth USA

*** END OF SAMPLE FROM 5 PAGES ***

APPENDIX K : UNASSISTED LANDINGS (SAMPLE PAGES)

(and rescue from emergency situations)

The following is a list of incidents where airships and/or their crew-members survived ground contact without the use of their "normal" ground-handling systems. It is not a complete list largely because determining what is a "normal landing" in all circumstances for the different types of airship that have existed is far from easy.

For example the British Army had proved before the First World War that their small non-rigids could be sheltered in quarries and behind copses. Owing to shortages of space and man-power the idea was adapted for the larger naval blimps that operated during the war. Mooring-out stations were established about the principal bases and the ships docked and secured in enclaves cut in the lee of woods. All that was required was a handful of men and some "screw-pickets" (ground anchors). The system worked very well and few ships were lost.

But small blimps in wartime are one thing and large rigids in peace are another. Yet even here we find it hard to draw a clear line. The Germans preference for landing their Zeppelins directly into the outstretched hands of the ground crew, who then either held on to it (sometimes for days) or walked it into its shed, means that here too very little equipment or systems were required. The procedure for an airship landing "off-base" and having its ropes and rails held by local villagers until the real groundcrew arrived to take over and "walk it" home is not significantly different from the "normal" on-base one.

In addition, there were occasions when airships were rescued without touching the ground - when they were towed behind boats or even by other airships. For example:

> "The idea of towing airships, rather than kite-balloons, at sea was one of the ways in which the Fleet hoped to be able to make up for the lack of range of British Airships. *Astra-Torres No.3* was towed as early as November 2, 1914, but the experiments were not resumed until March 1916. Then a *Coastal* at Kingsnorth was tried out in this manner, and on May 12th the Admiralty gave approval for *Coastal C.1* to be taken in tow in Harwich Harbour by the light cruiser *Carysfort*. By May 16th the technique had been developed to such an extent that during the picking up of the trail rope a speed of 22 knots was maintained. On September 6th, after experiments at Kingsnorth had developed the necessary techniques, refuelling and the interchange of crew at sea was accomplished from *Canterbury; Coastal C.1* again being the guinea pig. The pick-up was made at 26 knots, but speed was reduced to 12 while the ship was hauled down and the crews swapped over. In normal North Sea weather, it was found that with the blimp riding at 100 feet, one crew man at a time could be exchanged by bosun's chair and 60 gallons of petrol pumped up to the blimp by compressed air in eight minutes." (Higham, 1961)

Whether this was actually done sufficiently often to make it "normal" is not known. How many airships (and lives) that would otherwise have come to grief were actually saved by throwing out a sea anchor and waiting for a boat to tow them to safety will probably also never be known. The point is that trying to sort out the "normal" landing for airships from the "emergency" in a time when holding onto their ropes, or tying them down in the woods and towing them home behind boats was commonplace is not a simple matter. That being said, there clearly were unusual occasions and what follows is a list in chronological order of some of the more notable unassisted landings that have been recorded.

++++++++++++++

AIRSHIP IDENTIFICATION : Nulli Secundus

DATE : 9th - 11th October 1907

AIRSHIP TYPE/SIZE : British Army non-rigid / 112 ft long x 32 ft diam. 85,000 ft^3

INCIDENT : ...her power was insufficient to get her back in the face of the breeze...decided to land in the grounds of the Crystal Palace.... A descent was made in perfect safety. and the vessel was moored to some stakes.... Here she stayed for two or three days...in an exposed position...with only very few men to look after her...the wind freshened, she dragged her moorings, bumped herself on the ground, and did a certain amount of damage to her frame-work, until the sergeant who had been left in charge, seeing that he could not control the tugging monster in such a wind, deflated as speedily as possible, thereby probably saving the airship....

OUTCOME : Airship damaged "solely due to the lack of experience and foresight of those in command."

++++++++++++++++

AIRSHIP IDENTIFICATION : The Patrie

DATE : November 1907

AIRSHIP TYPE/SIZE : Lebaudy non-rigid / 197 ft long x 34 ft diam. 111,250 ft^3

INCIDENT : ...during a flight near Verdun, the motor stopped...drifted with the wind to a village...where she was safely landed and anchored. The following day a strong wind sprang up and, tearing up some of the iron posts to which she was anchored, caused the airship to swing broadside on...then tilted over...and some ballast bags fell out. Thus lightened the vessel rose in the air, and despite the efforts of nearly 200 soldiers who were hanging onto her ropes, she dragged them along the ground until the officer in charge ordered them to let go, considering he was risking their lives....the Patrie rose and...drifted out to sea and was never seen or heard of again.
OUTCOME : Airship blew away. No serious injuries to crew.
++++++++++++++
AIRSHIP IDENTIFICATION : S.M.S. Zeppelin II
DATE : 29th May 1909
AIRSHIP TYPE/SIZE : Zeppelin rigid / 446 ft long x 42.5 ft diam. 530,000 ft^3
INCIDENT :...descended just outside Goppingen, having been in the air for almost 38 hours...coming into sudden collision with a large pear-tree, which tore open two sections of the envelope and smashed the aluminium bows very considerably. Some attributed this accident to a sudden gust of wind, and others to the steersman having failed to notice the tree...worn out with fatigue.... Within 24 hours temporary repairs were carried out on the spot, and...she was enabled...to commence the return journey to Lake Constance.
OUTCOME : Airship flew home with structural damage. No crew injuries.
++++++++++++++++++
AIRSHIP IDENTIFICATION : German Army Airship Zeppelin I
DATE : 29th June to 3rd July 1909
AIRSHIP TYPE/SIZE : Zeppelin rigid
INCIDENT : Airship encountered a heavy storm on a flight from Friedrichshafen to Metz in France. Forced to land 34 miles from start at Mittelbiberach "...and for 98.5 hours the giant vessel was held down by the united efforts of 150 soldiers." Finally on 3rd July airship flew on to Metz covering 225 miles in 8.5 hours.
OUTCOME : Airship and crew survived.
+++++++++
AIRSHIP IDENTIFICATION : German Army Airship Zeppelin III (LZ6)
DATE : 30th August 1909
AIRSHIP TYPE/SIZE : Zeppelin rigid
INCIDENT : On a return trip to Friedrichshafen after a visit to Berlin the airship fought a strong headwind until a propeller broke and tore a hole in the hull. A descent was successfully accomplished and repairs commenced with great difficulty due to the strong wind. "...despite the efforts of a company of soldiers, disaster at one time seemed inevitable. Thirty men were packed like sardines in the rear of the car to weigh it down, while others clung on to it from below. Occasionally these were lifted in a body from the ground, and hung dangling in the air for several seconds at a time. As the front of the car was in danger of being battered to pieces against the earth, a detachment of soldiers was placed beneath it, forming a kind of living spring buffer. By these desperate means the vessel was saved, and the repairs being completed, Friedrichshafen was safely reached on the night of September 2nd ..."
OUTCOME : Airship and crew survived.
++++++++++
AIRSHIP IDENTIFICATION : German Army Airship Zeppelin II
DATE : 24th/25th April 1910
AIRSHIP TYPE/SIZE : Zeppelin rigid / 446 ft long x 42.5 ft diam. 530,000 ft^3
INCIDENT : Following a review by the Kaiser at Homburg the airship fought a strong headwind and made a forced landing near Limburg. It was held successfully overnight but "...on the following morning...despite the efforts of the troops whose services had been requisitioned to hold down the airship, it was carried away by the gale, and wrecked by colliding with some trees at Weilburg. Several of the soldiers who were clinging on to the ropes and cars when the vessel was blown away were dashed to the ground and seriously injured."
OUTCOME : Airship destroyed. Flight crew survived. Ground crew injured.
+++++++++++++++++
AIRSHIP IDENTIFICATION : Zeppelin VII "Deutschland"
DATE : 28th June 1910
AIRSHIP TYPE/SIZE : Zeppelin rigid /
INCIDENT : Flew from her shed near Düsseldorf for a cruise with 21 passengers. Developed motor trouble and ran out of fuel as weather deteriorated. "...and navigation became impossible. The derelict vessel was finally blown into the fir-trees of the Teutoberger Wald, and was wrecked. Happily the disaster was attended by no loss of life or injury, every one of the thirty-three persons on board being safely rescued."
OUTCOME : Airship destroyed. 21 passengers and 12 crew survived without injury.

+++++++++++++++++
AIRSHIP IDENTIFICATION : SL 1
DATE : October 17th 1911
AIRSHIP TYPE/SIZE : Schütte Lanz rigid - 734,500 cu ft - 432 ft long x 60 ft dia.
INCIDENT : SL 1 made her first flight on October 17th 1911. A control cable broke and the ship made a forced landing across the Rhine, lying overnight in an open field while repairs were being made and gas added. Next day the ship took off and after three and a half hours of circling over Mannheim, she returned to the Rheinau shed.
OUTCOME : Airship and crew survived.
+++++++++++++++++
AIRSHIP IDENTIFICATION : SL 1
DATE : April 18th 1912
AIRSHIP TYPE/SIZE : Schütte Lanz rigid - 734,500 cu ft - 432 ft long x 60 ft dia. x ?? ft high
INCIDENT : While approaching to land at noon, a vertical gust slammed the ship down on the ground, damaging all control and water ballast wires, the propellers and gondolas. The shock of the crash threw seven out of 14 crew members overboard and dumped all ballast. Lightened of all this weight, SL 1 no longer under control, ascended to 5,600 feet. Her momentum carried her well over pressure height; considerable gas was lost, the ship became heavy, and since there was no more ballast, SL 1, touched down on the far side of the Rhine. Troops from Mannheim and Speyer manhandled her back to her shed the same day. Old photos show the SL 1 floating several hundred feet in the air at the end of numerous lines; when soldiers reached the Rhine, the lines were made fast aboard a tug boat that took them over.
OUTCOME : Airship and crew survived.
+++++++++++++++++
AIRSHIP IDENTIFICATION : German Army Airship ZIV (LZ.16)
DATE : April 1913
AIRSHIP TYPE/SIZE : Zeppelin rigid (sister ship of Sachsen,)
INCIDENT : Forced down on a French Army drillfield on a factory test flight. The German aviators were most hospitably entertained by the gallant soldiers - but not without reason. Whilst the crew were diverted, French experts hastily photographed and made drawings of the ship and its equipment.
OUTCOME : Airship and crew survived.
+++++++++++++++++
AIRSHIP IDENTIFICATION : British military Astra-Torres - No 3.
DATE : June 12th 1913
AIRSHIP TYPE/SIZE : Tri-lobe blimp -
INCIDENT : On her first flight in England, at 2,000 feet, she buckled in the middle when engine failure caused loss of pressure. She made a forced landing "hinged in the middle with both ends in the air!" After fifteen minutes on the ground the ballonets were once again properly inflated, and she was flown back to Farnborough despite the fact that several cables had snapped and it was not easy to control her.
OUTCOME : Airship and crew survived.
+++++++++++++++++
AIRSHIP IDENTIFICATION : SL 1
DATE : 15th July 1913
AIRSHIP TYPE/SIZE : Schütte Lanz / 131 m length: 18,4 m diameter: unladen weight 21,190 kg
INCIDENT : BREAKAWAY
"By the time the airship was handed over to the army on 30 December 1912, it had made 350 flights and had been in the air for about 120 hours. The end of SL1 began when a fuel line flawed and the airship had to make an emergency landing on the parade ground near Schneidemühl. In a storm the airship was torn from its anchorage and carried some kilometers away until it crashed in a forest on 15 July 1913."
OUTCOME : Airship destroyed. Crew survived.
++++++++++++++
AIRSHIP IDENTIFICATION : Willows (Naval No 2)
DATE : August 20th 1913
AIRSHIP TYPE/SIZE :
INCIDENT : The Royal Engineers airship "Eta" towed the small experimental Willows airship back to the Factory at Farnborough after its engines broke down at Odiham
OUTCOME : Airship and crew survived.

*** END OF SAMPLE FROM 9 PAGES ***

APPENDIX L : AIRSHIP BASES AND FACILITIES (Sample Pages)

Name of Base	Identity of different airships that used base	No. of airships	Ops start	Ops end	Years active	Country
Nordholz	LZ-24(L3), LZ-28(L5), LZ-31(L6), LZ-32(L7), LZ-36(L9), LZ-40(L10), LZ-41(L11), LZ-43(L12), LZ-46(L14), LZ-48(L15), LZ-50(L16), LZ-53(L17), LZ-61(L21), LZ-64(L22), LZ-66(L23), LZ-62(L30), LZ-72(L31), LZ-74(L32), LZ-76(L33), LZ-78(L34), LZ-82(L36), LZ-75(L37), LZ-79(L41), LZ-91(L42), LZ-93(L44), LZ-95(L48), LZ-97(L51), LZ-98(L52), LZ-100(L53), LZ-101(L55), LZ-103(L56), LZ-106(L61), LZ-107(L62), LZ-110(L63), LZ-109(L64), LZ-111(L65), LZ-112(L70), LZ-113(L71), SL-3, SL-4, SL-8, SL-9,	42	1914	1919	5	Germany
Friedrichshaven Riedlepark Navy	LZ-14(L1), LZ-18(L2), LZ-24(L3), LZ-27(L4), LZ-28(L5), LZ-31(L6), LZ-32(L7), LZ-33(L8), LZ-36(L9), LZ-40(L10), LZ-43(L12), LZ-45(L13), LZ-50(L16), LZ-53(L17), LZ-54(L19), LZ-59(L20), LZ-62(L30), LZ-74(L32), LZ-76(L33), LZ-80(L35), LZ-82(L36), LZ-86(L39), LZ-88(L40), LZ-91(L42), LZ-92(L43), LZ-94(L46), LZ-95(L48), LZ-97(L51), LZ-100(L53), LZ-102(L57), LZ-105(L58), LZ-106(L61), LZ-110(L63), LZ-112(L70), LZ-113(L71),	35	1914	1940	26	Germany
Friedrichshaven Riedlepark Zeppelin	LZ-7, LZ-8, LZ-9, LZ-10, LZ-11, LZ-12(ZIII), LZ-13, LZ-15(ZI), LZ-16(ZIV), LZ-17, LZ-19(ZI), LZ-20(ZV), LZ-21(ZVI), LZ-22(ZVII), LZ-23(ZVIII), LZ-25(ZIX), LZ-29(ZX), LZ-34, LZ-35, LZ-38, LZ-39, LZ-47(LZ77), LZ-57(LZ87), LZ-60(LZ90), LZ-65(LZ95), LZ-120, LZ-121, LZ-126(ZR-3), LZ-127, LZ-129,	30	1909	1940	31	Germany
Ahlhorn	LZ-62(L30), LZ-68(LZ98), LZ-72(L31), LZ-74(L32), LZ-80(L35), LZ-75(L37), LZ-84(L38), LZ-86(L39), LZ-88(L40), LZ-79(L41), LZ-91(L42), LZ-92(L43), LZ-93(L44), LZ-85(L45), LZ-94(L46), LZ-87(L47), LZ-96(L49), LZ-89(L50), LZ-97(L51), LZ-101(L55), LZ-105(L58), LZ-107(L62), LZ-110(L63), SL-12, SL-20,	25	1916	1919	3	Germany
Friedrichshafen Löwenthal	LZ-41(L11), LZ-44(LZ74), LZ-46(L14), LZ-48(L15), LZ-51(LZ81), LZ-52(L18), LZ-61(L21), LZ-64(L22), LZ-67(LZ97), LZ-68(LZ98), LZ-72(L31), LZ-78(L34), LZ-84(L38), LZ-90(LZ120), LZ-93(L44), LZ-96(L49), LZ-101(L55), LZ-107(L62), LZ-111(L65), LZ-114(L72), LZ-129, LZ-130,	22	1915	1943	28	Germany
Berlin-Potsdam	LZ-10, LZ-13, LZ-17, LZ-20(ZV), LZ-22(ZVII), LZ-30(ZXI), LZ-34, LZ-37, LZ-42(LZ72), LZ-49(LZ79), LZ-55(LZ85), LZ-56(LZ86), LZ-58(LZ88/L25), LZ-60(LZ90), LZ-63(LZ93), LZ-66(L23), LZ-69(L24), LZ-71(LZ101), LZ-73(LZ103), LZ-77(LZ107), LZ-81(LZ111),	21	1912	1920	8	Germany

Dresden	LZ-13, LZ-16(ZIV), LZ-17, LZ-21(ZVI), LZ-22(ZVII), LZ-25(ZIX), LZ-31(L6), LZ-42(LZ72), LZ-51(LZ81), LZ-54(L19), LZ-56(LZ86), LZ-57(LZ87), LZ-60(LZ90), LZ-63(LZ93), LZ-80(L35), LZ-81(LZ111), SL-4, SL-8,	18	1913	1920	7	Germany
Seddin (Jeseritz) Navy	LZ-28(L5), LZ-36(L9), LZ-58(LZ88/L25), LZ-59(L20), LZ-61(L21), LZ-75(L37), LZ-81(LZ111), LZ-83(LZ113), SL-3, SL-4, SL-6, SL-8, SL-9, SL-14, SL-20,	15	1915	1919	4	Poland
Tondern	LZ-32(L7), LZ-36(L9), LZ-53(L17), LZ-52(L18), LZ-54(L19), LZ-59(L20), LZ-61(L21), LZ-64(L22), LZ-66(L23), LZ-69(L24), LZ-62(L30), LZ-75(L37), LZ-85(L45), LZ-99(L54), LZ-108(L60),	15	1915	1919	4	Denmark
Düsseldorf	LZ-7, LZ-8, LZ-10, LZ-13, LZ-25(ZIX), LZ-29(ZX), LZ-33(L8), LZ-38, LZ-39, LZ-42(LZ72), LZ-47(LZ77), LZ-51(LZ81), LZ-58(LZ88/L25), LZ-63(LZ93), LZ-65(LZ95),	15	1910	1920	10	Germany
Jüterbog	LZ-13, LZ-16(ZIV), LZ-26(ZXII), LZ-42(LZ72), LZ-49(LZ79), LZ-58(LZ88/L25), LZ-77(LZ107), LZ-80(L35), LZ-83(LZ113), LZ-90(LZ120), LZ-102(L57), LZ-104(L59), SL-7, SL-22,	14	1915	1919	4	Germany
Leipzig	LZ-13, LZ-17, LZ-19(ZI), LZ-20(ZV), LZ-21(ZVI), LZ-23(ZVIII), LZ-32(L7), SL-3, SL-6, SL-8, SL-9, SL-11, SL-13, SL-16(E9),	14	1913	1920	7	Germany
Berlin-Staaken	LZ-75(L37), LZ-79(L41), LZ-83(LZ113), LZ-85(L45), LZ-87(L47), LZ-89(L50), LZ-98(L52), LZ-99(L54), LZ-103(L56), LZ-104(L59), LZ-108(L60), LZ-109(L64), LZ-120,	13	1916	1920	4	Germany
Wittmundhaven	LZ-45(L13), LZ-64(L22), LZ-67(LZ97), LZ-73(LZ103), LZ-88(L40), LZ-96(L49), LZ-98(L52), LZ-99(L54), LZ-103(L56), LZ-106(L61), SL-12,	11	1917	1919	2	Germany
Hage (ex-Norden)	LZ-31(L6), LZ-36(L9), LZ-41(L11), LZ-43(L12), LZ-44(LZ74), LZ-45(L13), LZ-46(L14), LZ-47(LZ77), LZ-48(L15), LZ-50(L16), LZ-64(L22),	11	1914	1917	3	Germany
Namur	LZ-39, LZ-44(LZ74), LZ-47(LZ77), LZ-49(LZ79), LZ-51(LZ81), LZ-57(LZ87), LZ-60(LZ90), LZ-63(LZ93), LZ-65(LZ95), LZ-67(LZ97), LZ-68(LZ98),	11	1914	1917	3	Belgium
Baden-Oos	LZ-6, LZ-9(ZII), LZ-10, LZ-12(ZIII), LZ-15(ZI), LZ-16(ZIV), LZ-17, LZ-19(ZI), LZ-20(ZV), LZ-22(ZVII), LZ-23(ZVIII),	11	1910	1915	5	Germany
Mannheim-Rheinau	LZ-60(LZ90), LZ-67(LZ97), SL-1, SL-2, SL-3, SL-7, SL-10, SL-14, SL-15, SL-20, SL-22,	11	1914	1920	6	Germany
Hamburg Fuhlsbüttel	LZ-12(ZIII), LZ-13, LZ-14(L1), LZ-17, LZ-24(L3), LZ-27(L4), LZ-28(L5), LZ-31(L6), LZ-36(L9),	9	1912	1916	4	Germany
Howden, RNAS	No.9, R-26, R-27, R-31, R-32, R-34, R-38(ZR2), R-80, R-100,	9				Britain
Pulham RNAS	No.9, R-23, R-24, R-33, R-34, R-36, R-80, LZ-109(L64), LZ-113(L71),	9				Britain
Wainoden	LZ-58(LZ88/L25), LZ-68(LZ98), LZ-80(L35), LZ-75(L37), LZ-84(L38), SL-8, SL-9, SL-14,	8	1916	1918	2	Germany

Hannover	LZ-26(ZXII), LZ-58(LZ88/L25), LZ-60(LZ90), LZ-63(LZ93), LZ-68(LZ98), LZ-71(LZ101), LZ-73(LZ103), LZ-77(LZ107),	8	1915	1920	5	Germany
Gotha	LZ-9(ZII), LZ-10, LZ-12(ZIII), LZ-13, LZ-16(ZIV), LZ-20(ZV), LZ-21(ZVI), LZ-26(ZXII),	8	1910	1920	10	Germany
Königsberg	LZ-16(ZIV), LZ-19(ZI), LZ-34, LZ-38, LZ-56(LZ86), LZ-57(LZ87), LZ-58(LZ88/L25), LZ-73(LZ103),	8				East Prussia
Cologne Spich	LZ-42(LZ72), LZ-49(LZ79), LZ-60(LZ90), LZ-63(LZ93), LZ-71(LZ101), LZ-73(LZ103), SL-16(E9),	7	1915	1920	5	Germany
Liegnitz	LZ-16(Z-IV), LZ-17, LZ-19(ZI), LZ-21(ZVI), LZ-26(ZXII), LZ-55(LZ85), LZ-34,	7	1913	1920	7	Germany
Cologne	LZ-5(ZII), LZ-9(ZII), LZ-19(ZI), LZ-21(ZVI), LZ-35, LZ-58(LZ88/L25), LZ-63(LZ93),	7	1909	1920	11	Germany
Cardington, RAW	R-31, R-32, R-33, R-38(ZR2), R-100, R-101, LZ-127,	7				Britain
Schneidemühl	LZ-16(Z-IV), LZ-38, LZ-39, LZ-56(LZ86), LZ-71(LZ101), LZ-81(LZ111), SL-1,	7				Poland
Seerappen	LZ-62(L30), LZ-80(L35), LZ-75(L37), LZ-90(LZ120), SL-9, SL-14,	6	1916	1919	3	East Prussia
Frankfurt Rebstock	LZ-10, LZ-26(ZXII), LZ-12(ZIII), LZ-19(ZI), LZ-20(ZV), LZ-22(ZVII),	6	1910	1915	5	Germany
Berlin-Johannisthal	LZ-10, LZ-13, LZ-14(L1), LZ-18(L2), LZ-20(ZV), LZ-24(L3),	6	1911	1920	9	Germany
Friedrichshaven Manzell	LZ-1, LZ-2, LZ-3(ZI), LZ-4, LZ-5(ZII), LZ-6,	6	1899	1910	11	Germany
Allenstein	LZ-16(ZIV), LZ-26(ZXII), LZ-39, LZ-55(LZ85), LZ-68(LZ98), SL-17(E10),	6				Poland
Maubeuge	LZ-26(ZXII), LZ-44(LZ74), LZ-49(LZ79), LZ-58(LZ88/L25), LZ-83(LZ113), LZ-114(L72),	6				France
Lakehurst, NJ	ZR-1, LZ-126(ZR-3), LZ-127, LZ-129, ZR-4, Blimps	5				USA
Szentandras	LZ-51(LZ81), LZ-55(LZ85), LZ-56(LZ86), LZ-67(LZ97), LZ-71(LZ101),	5				Bulgaria
Darmstadt	LZ-44(LZ74), LZ-57(LZ87), LZ-67(LZ97), SL-5,	4	1914	1919	5	Germany
Brussels	LZ-29(ZX), LZ-37, LZ-38, LZ-39,	4				Belgium
Inchannan	R-24, R-27, R-34, R-36,	4				Britain
Poznan (Posen)	LZ-16(Z-IV), LZ-30(ZXI), LZ-39, LZ-49(LZ79),	4				Poland
Walney Island	No.9, R-23, R-26, R-80,	4				Britain
Jamboli	LZ-71(LZ101), LZ-104(L59), SL-10,	3	1917	1919	2	Bulgaria
Zeesen	SL-12, SL-17(E10), SL-21(F2),	3	1916	1920	4	Germany
Barlow Selby	R-25, R-29, R-33,	3				Britain
Kowno	LZ-56(LZ86), LZ-68(LZ98), LZ-90(LZ120),	3				Russia
Metz, Nancy	LZ-9(ZII), LZ-12(Z-III), LZ-16(Z-IV),	3				France
Rome Ciampino	LZ-90(LZ120), LZ-106(L61), LZ-120,????	3				Italy

APPENDIX M : EVOLUTION OF GH INFRASTRUCTURE - ILLUSTRATIONS
(Figures 6.13 to 6.52 from Section 6.4)

PICTURES OF GH EVOLUTION

THE PIONEERS

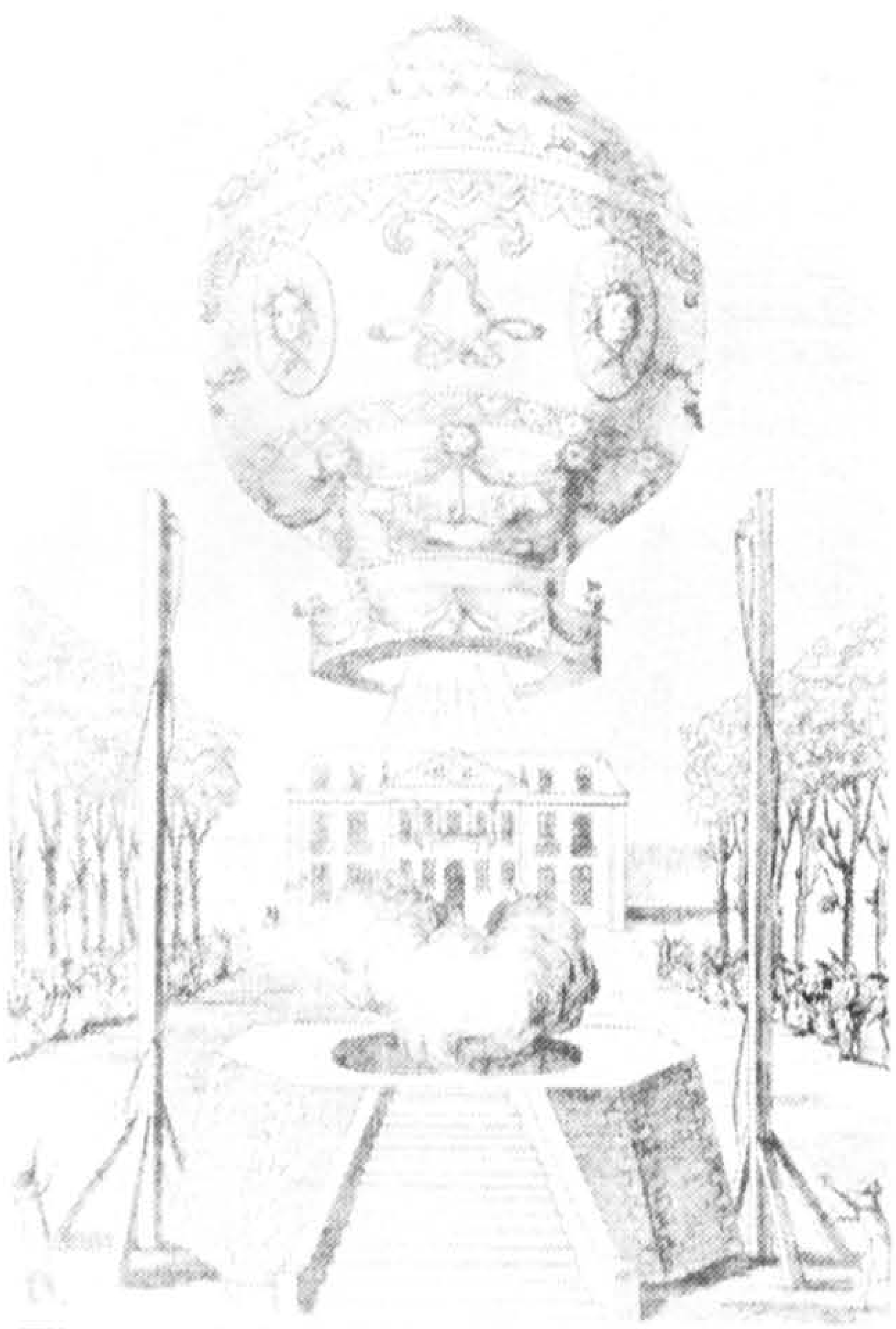

Figure 6.6 – 1783 The first ascent of a manned Montgolfiere

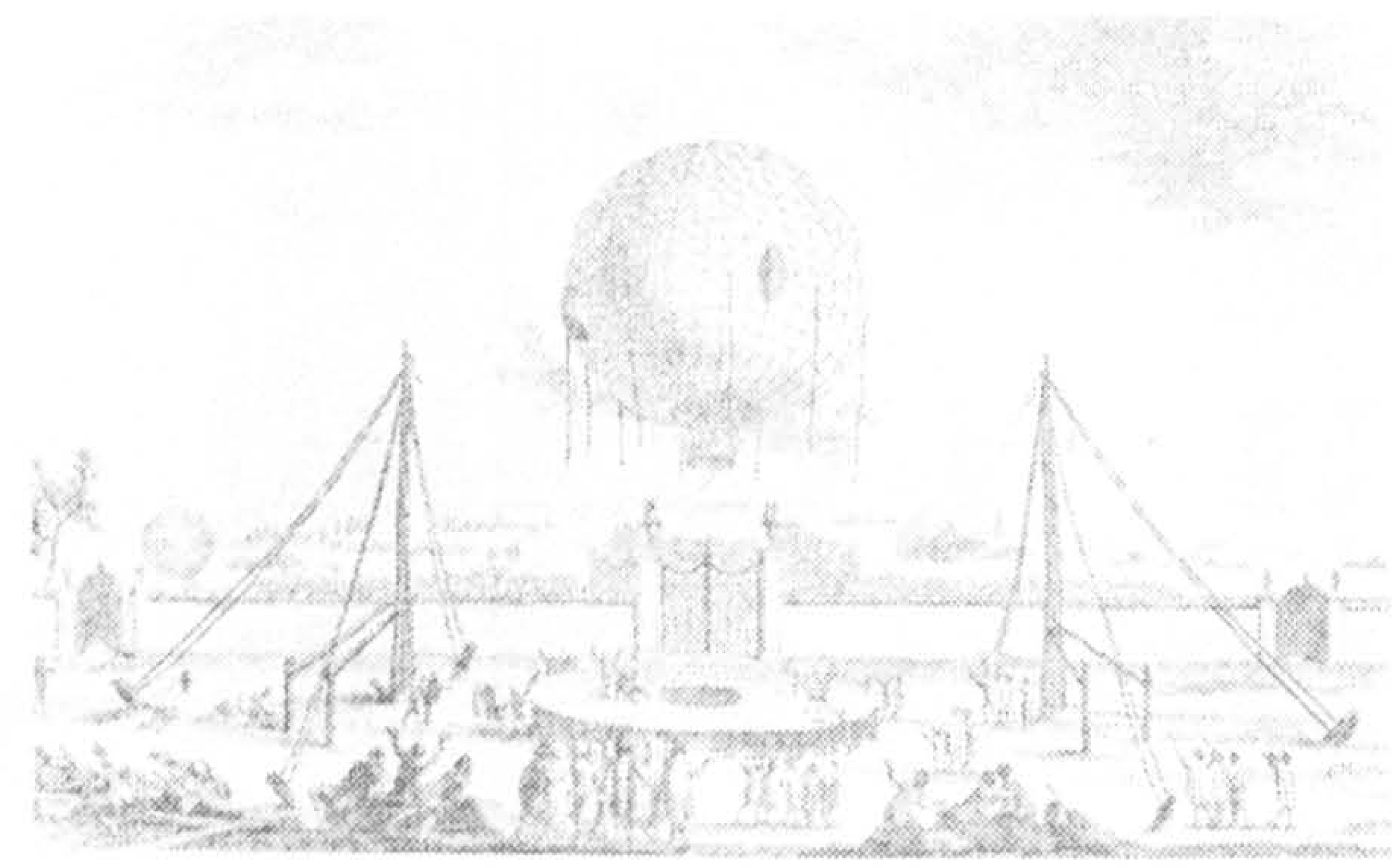

Figure 6.7 – 1784 Andreani ascends from Milan

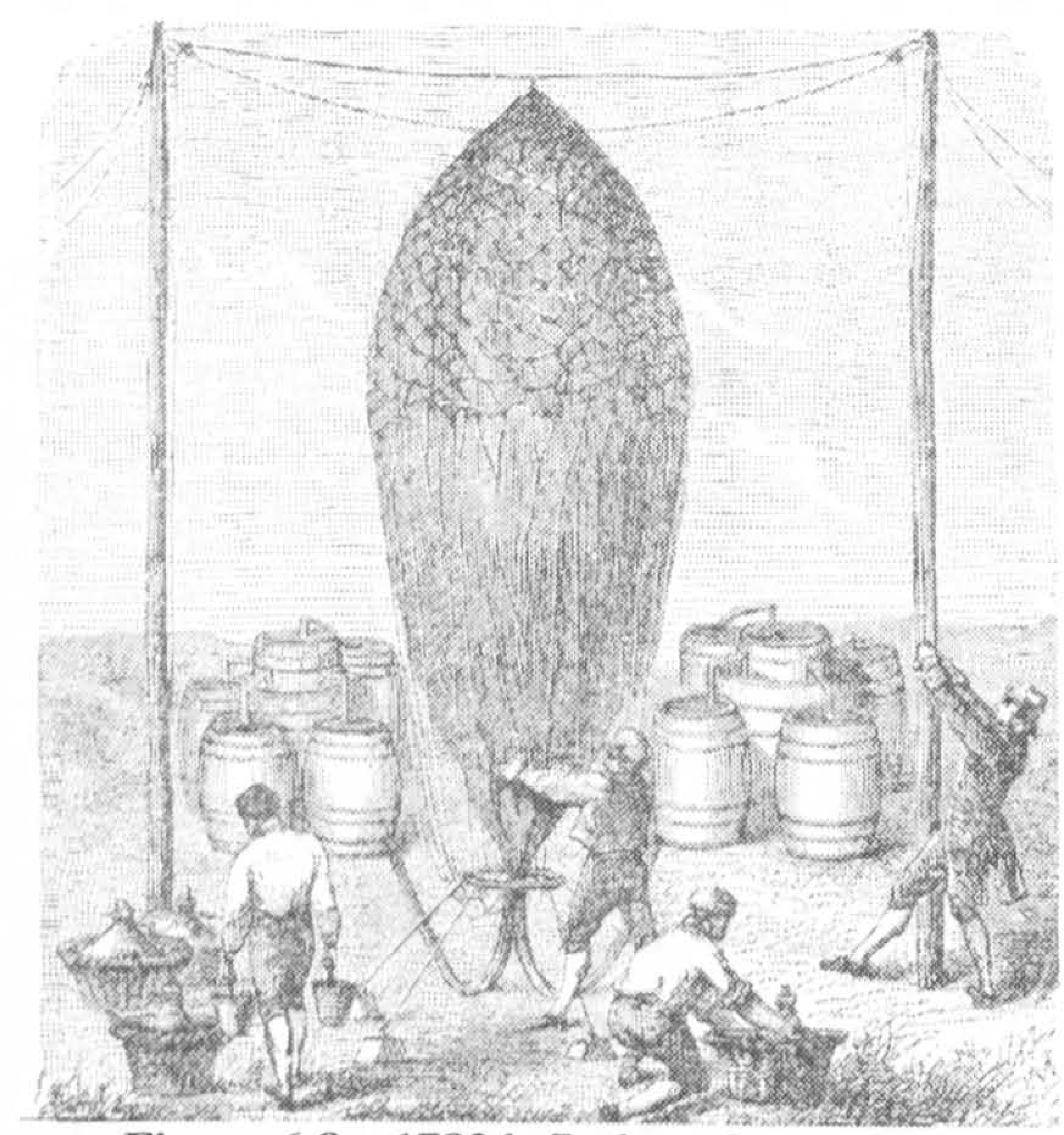

Figure 6.8 – 1783 inflation of a gas balloon

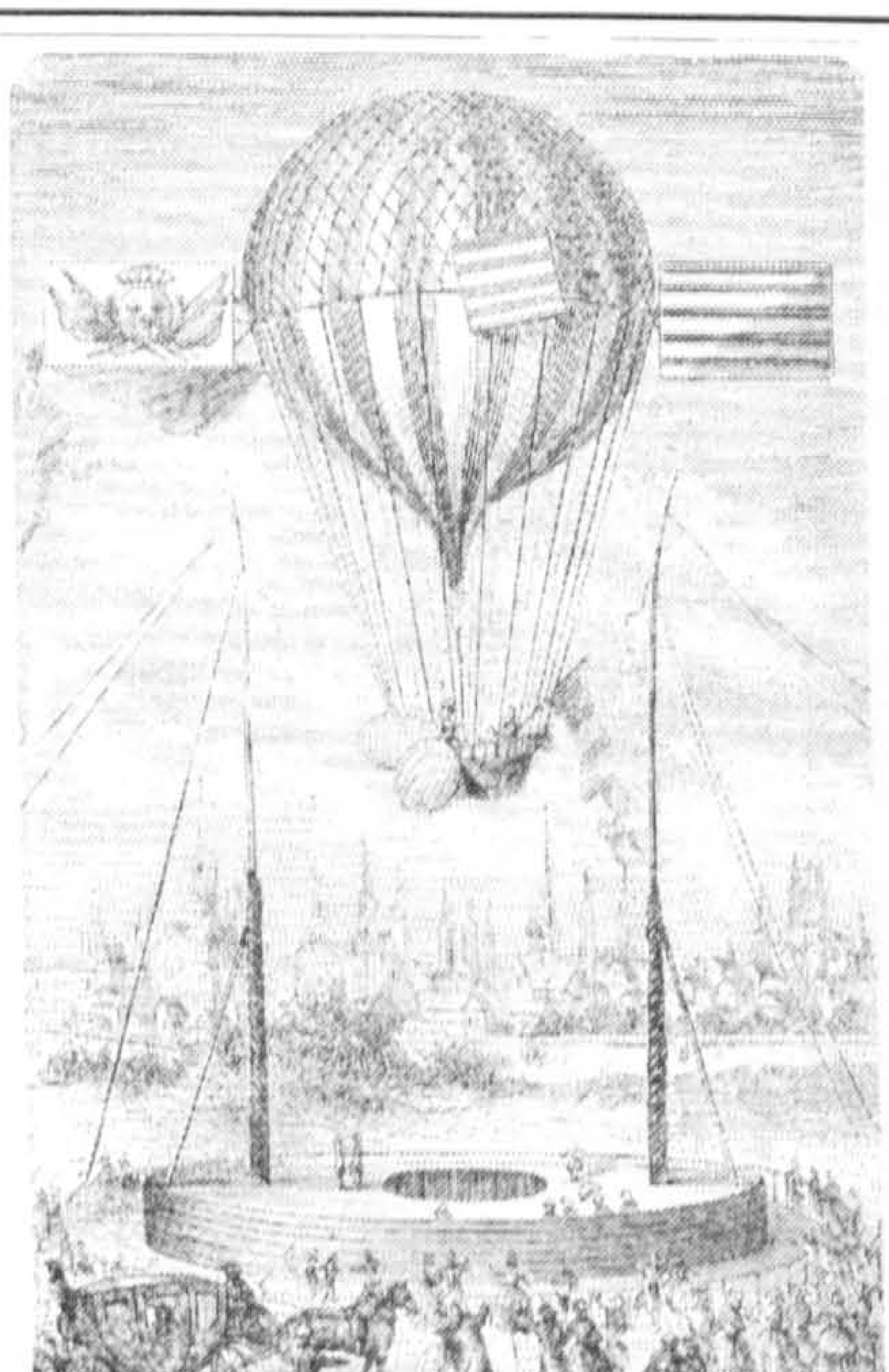

Figure 6.9 - 1784 gas ascent at Dijon

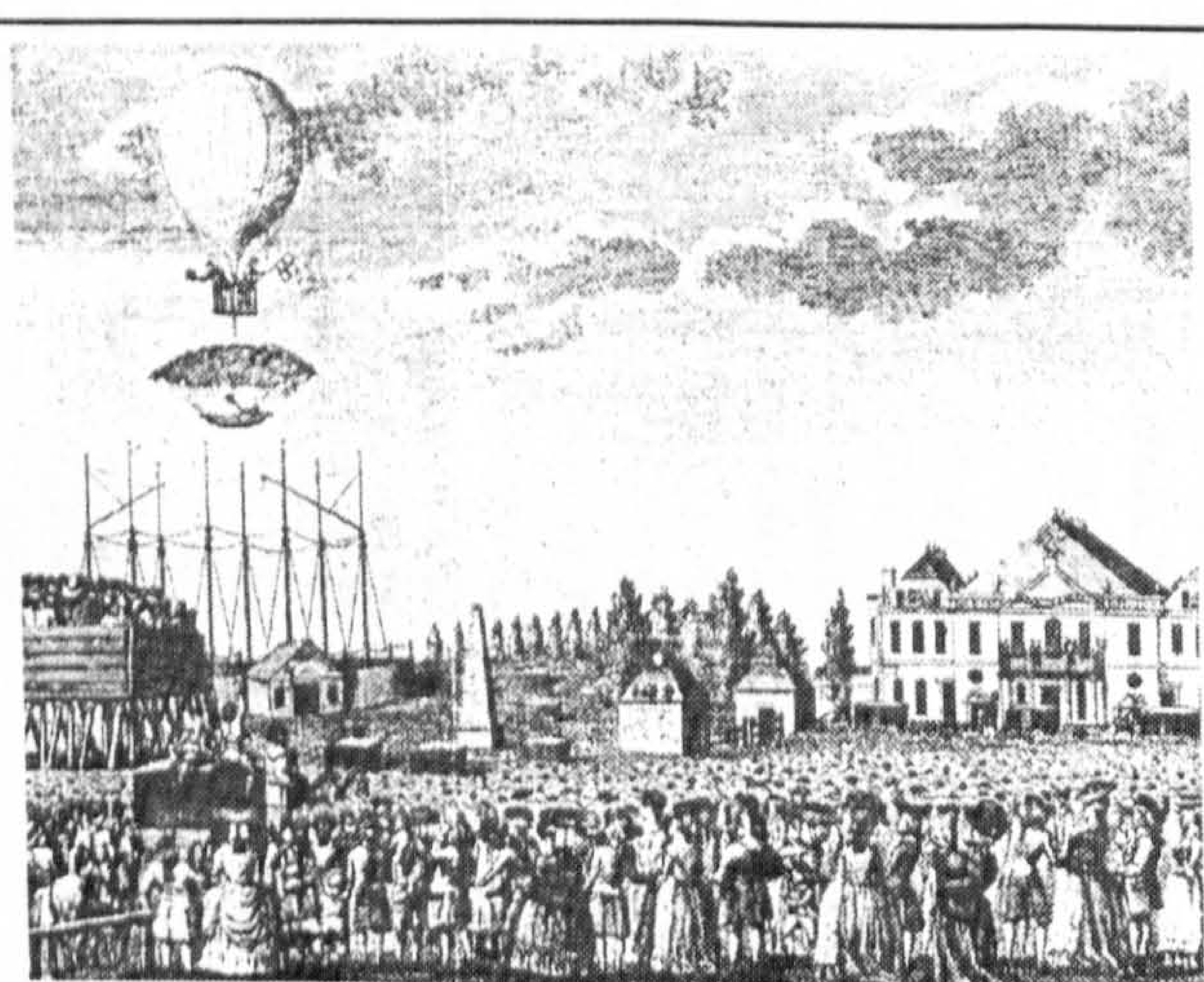

Figure 6.10 – 1785 Mr Amos Arnold's ascent

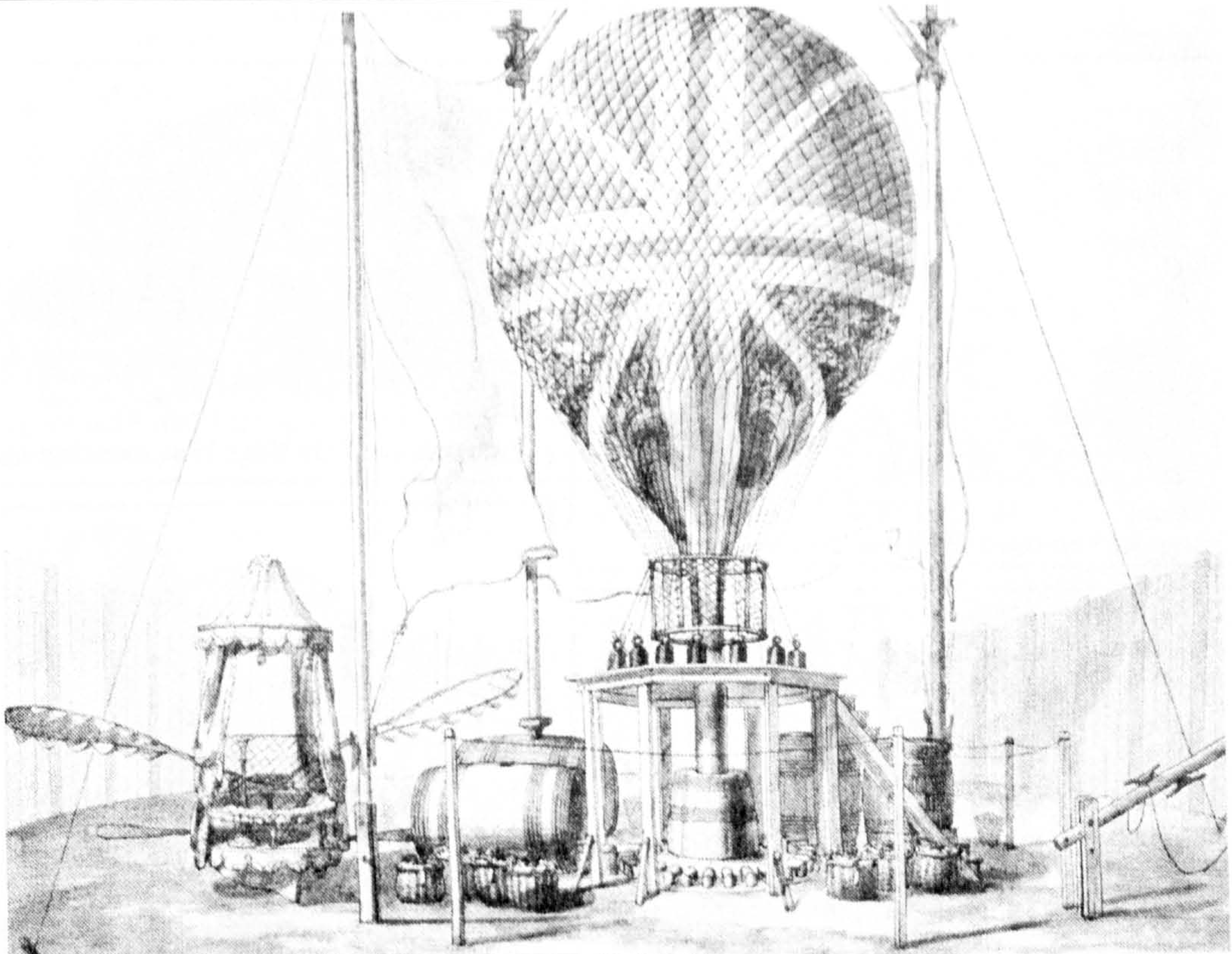

Figure 6.11 : 1785 Inflation of Lunardi's second balloon in St George's Fields

Figure 6.12 :1788 Blanchard/Berlin

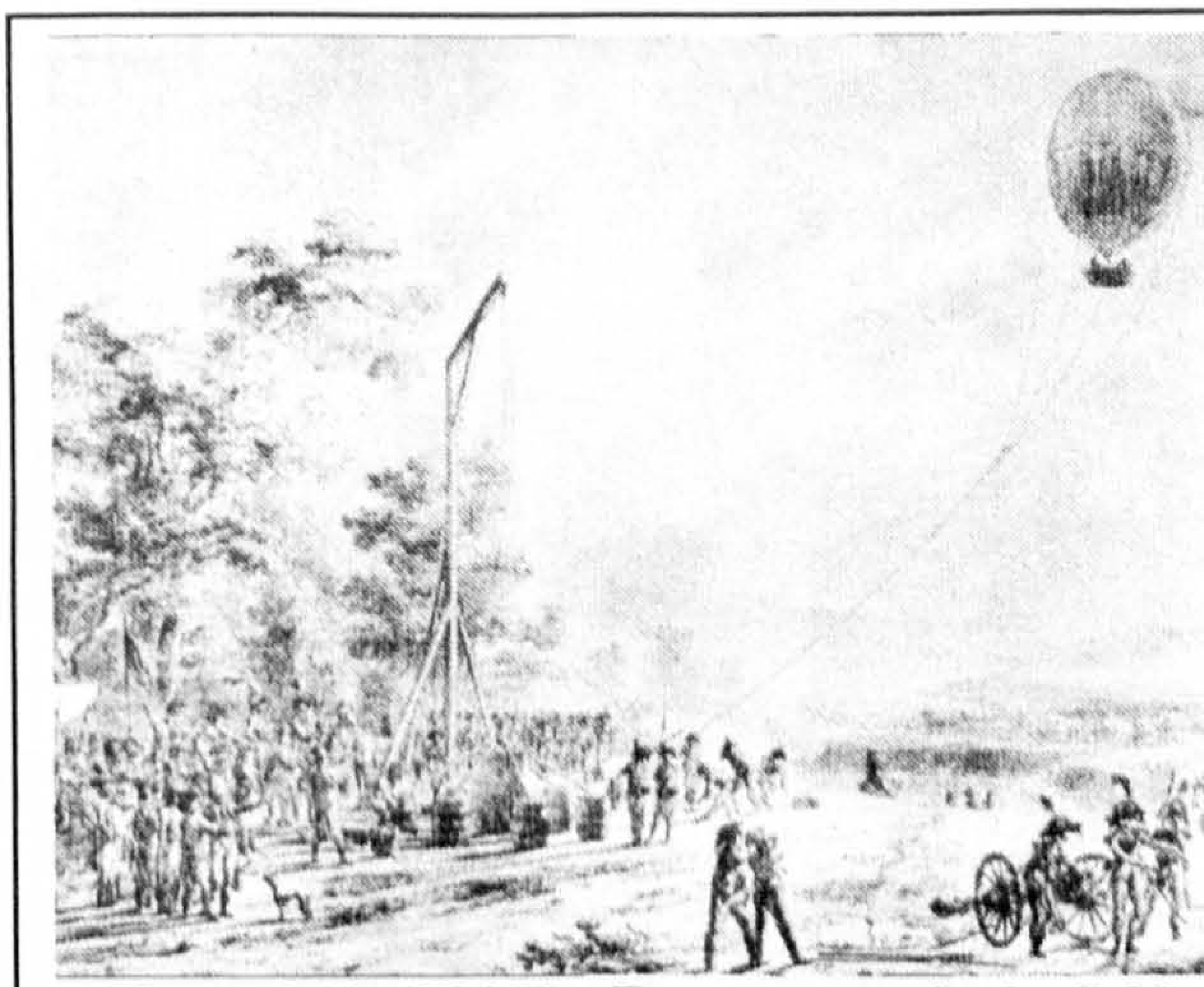

Figure 6.13 :1794 The Entreprenant in the field

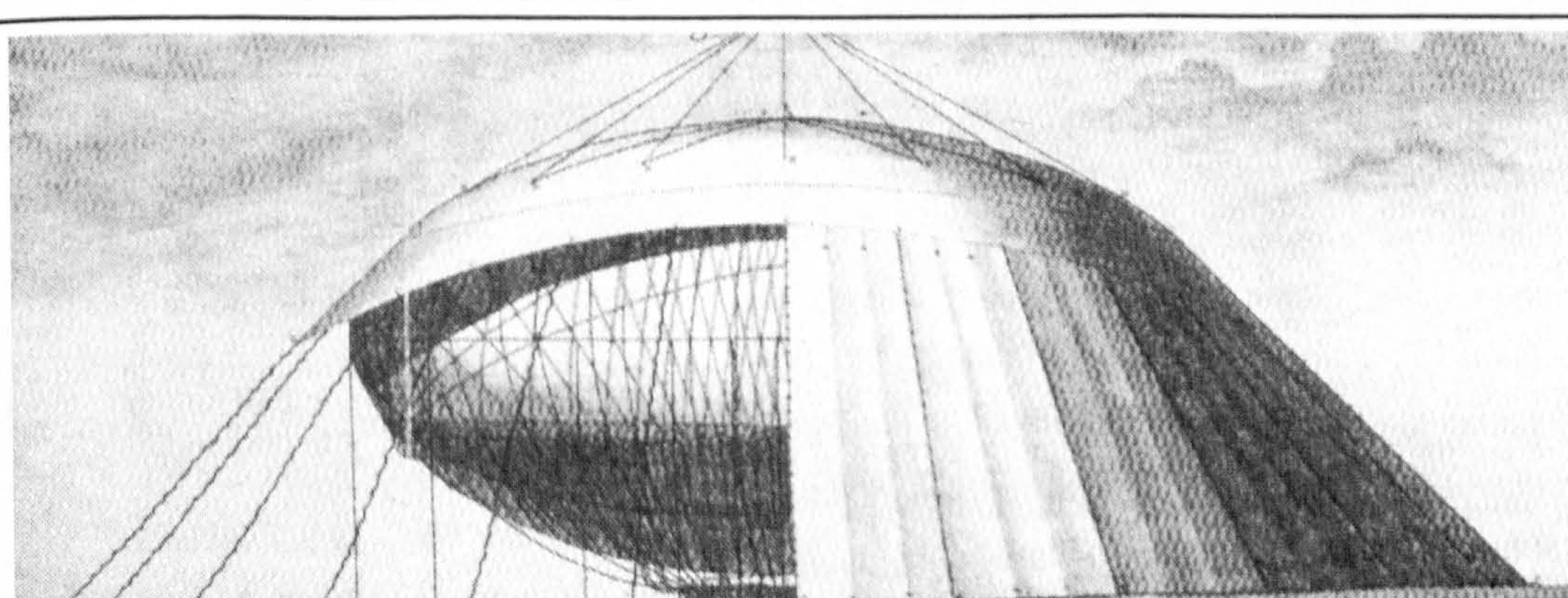

Figure 6.14 :1783 Meusenier's design for an airship tent shelter

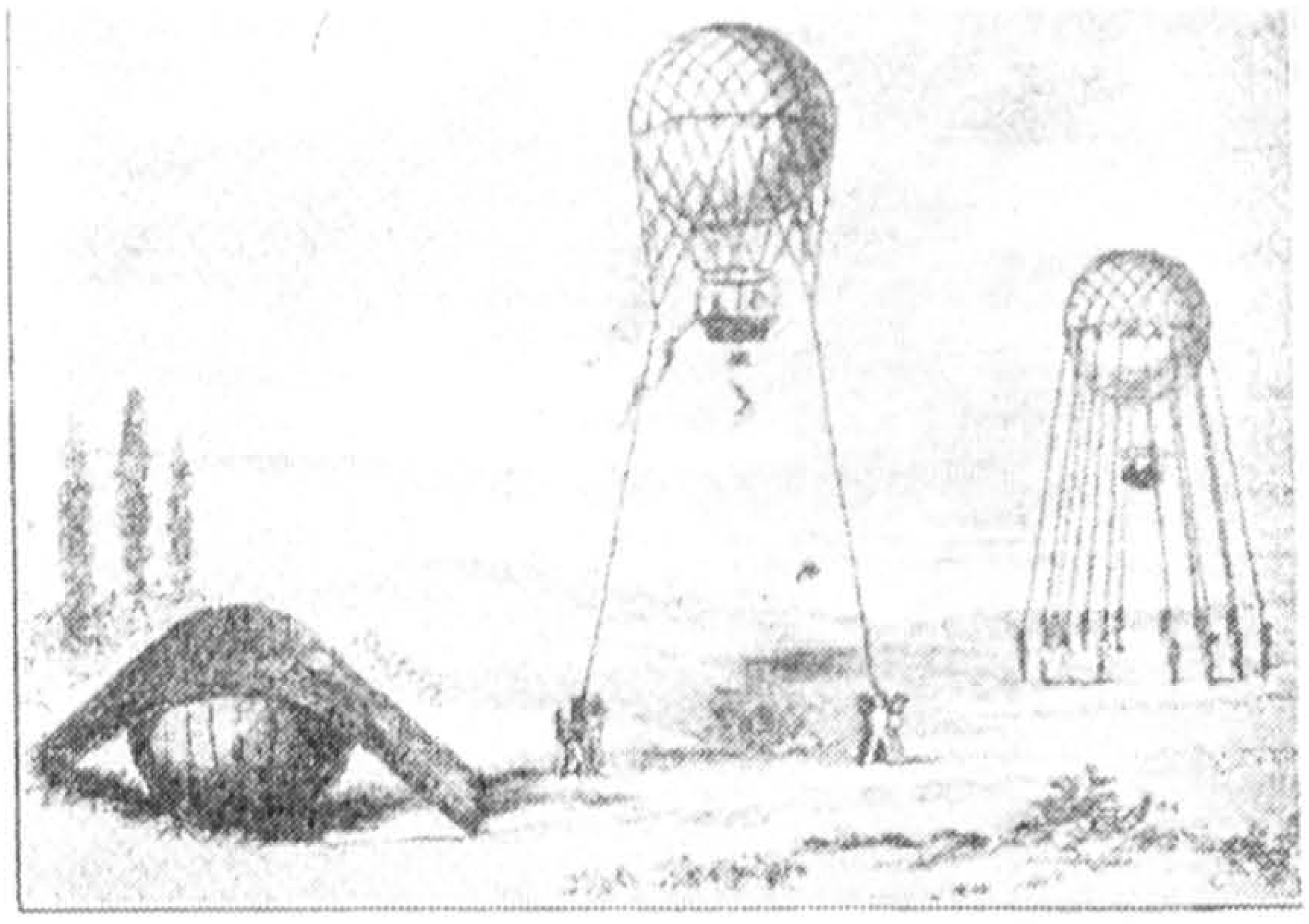

Figure 6.15 : circa 1800 Transport methods

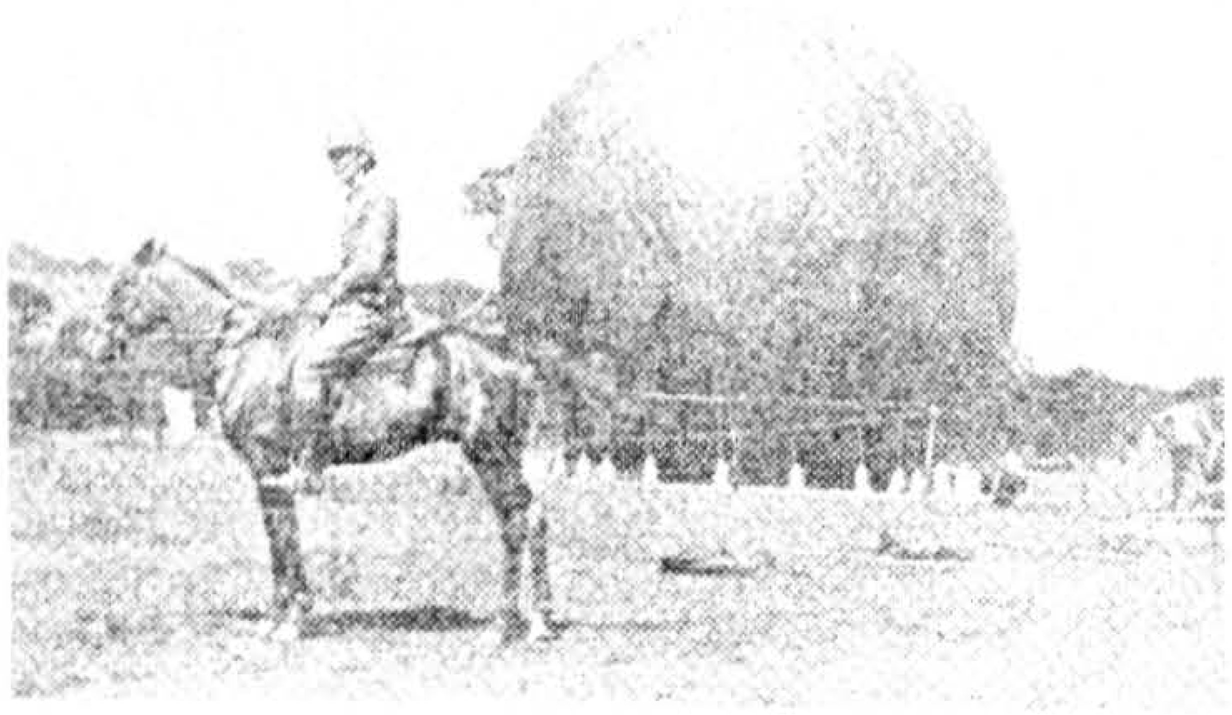

Figure 6.16 :1899 Boer War mooring-out

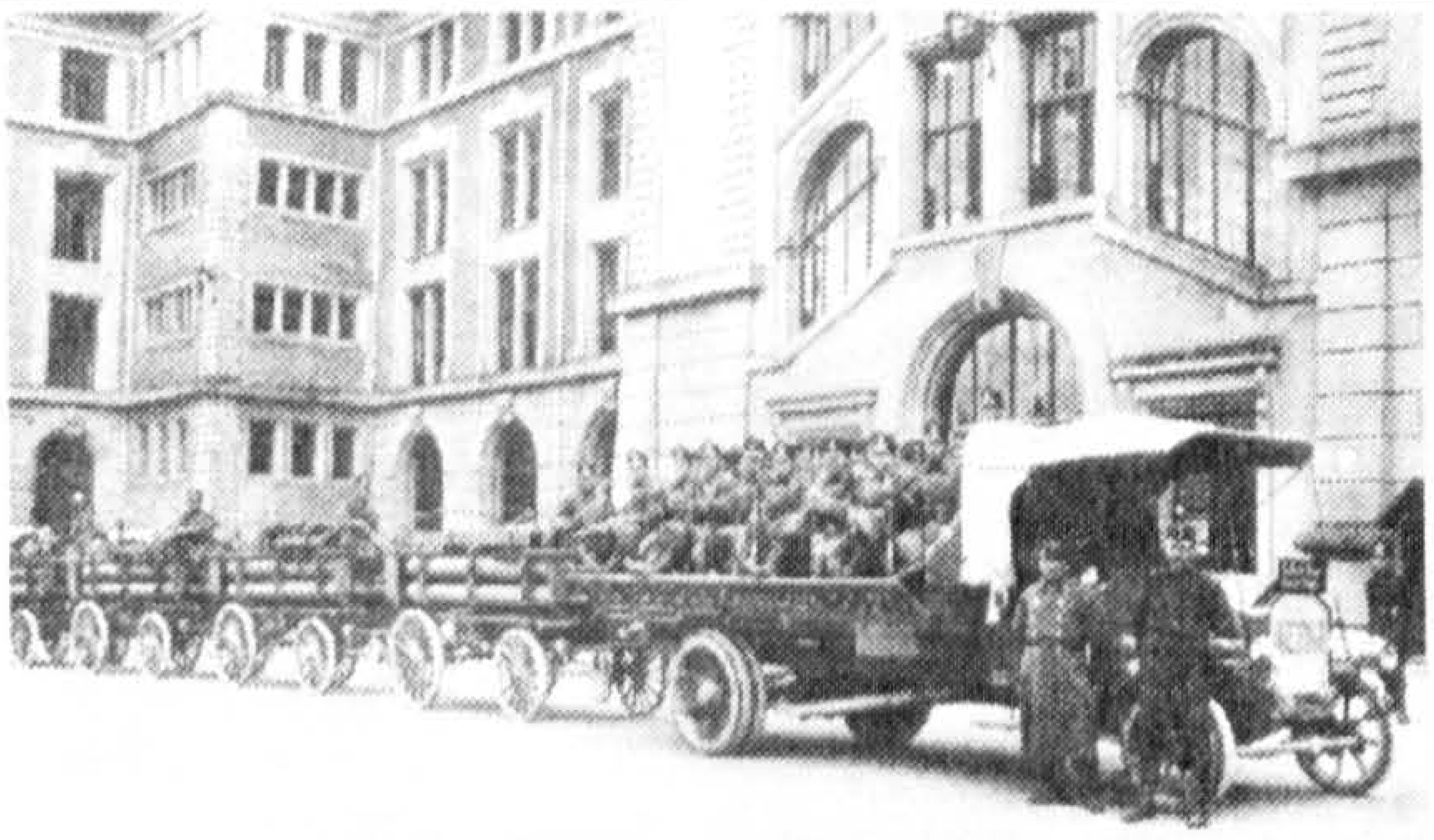

Figure 6.17 :1915 Swiss Army Balloon Troop

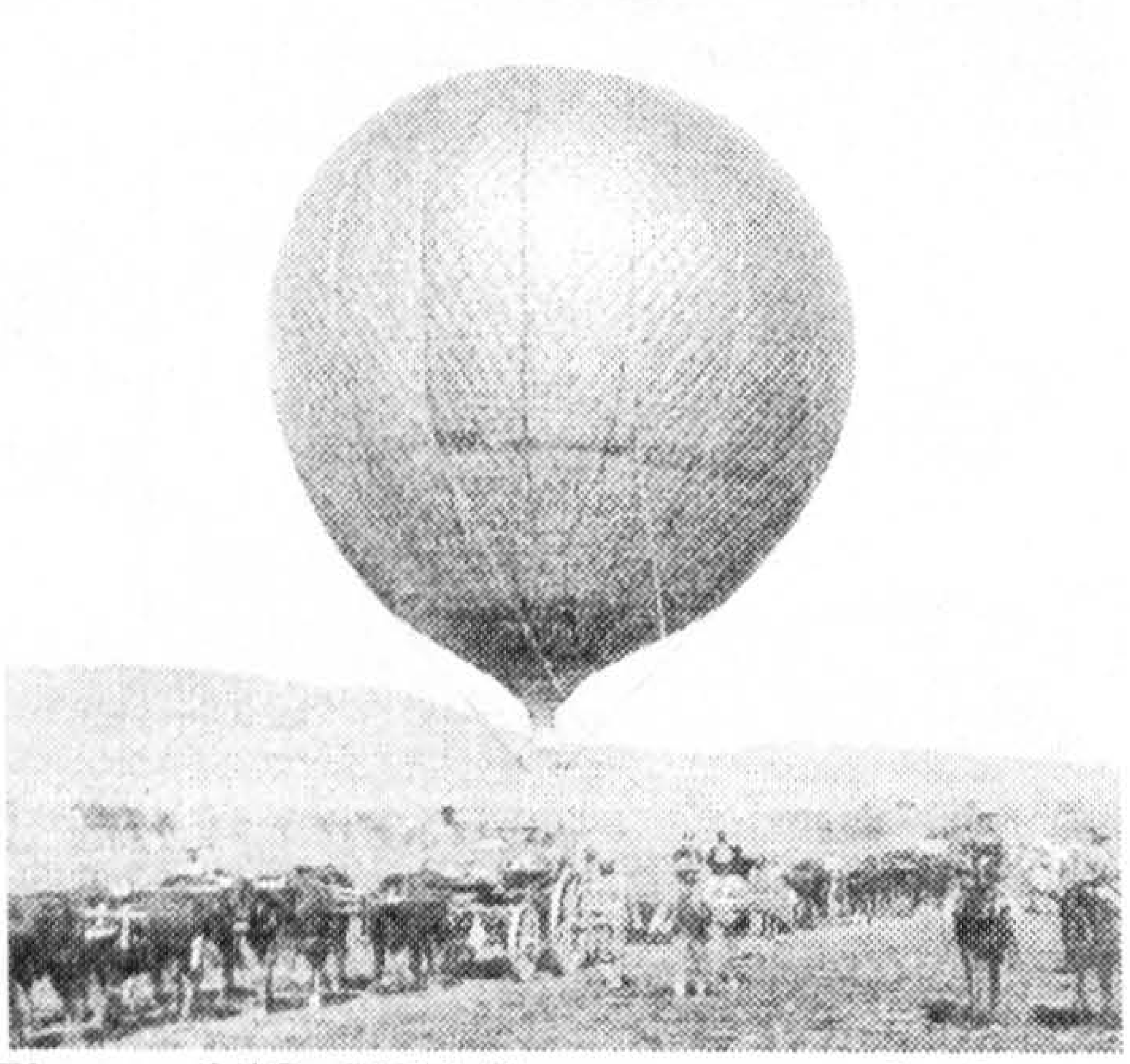

Figure 6.18 :1900 Transport methods

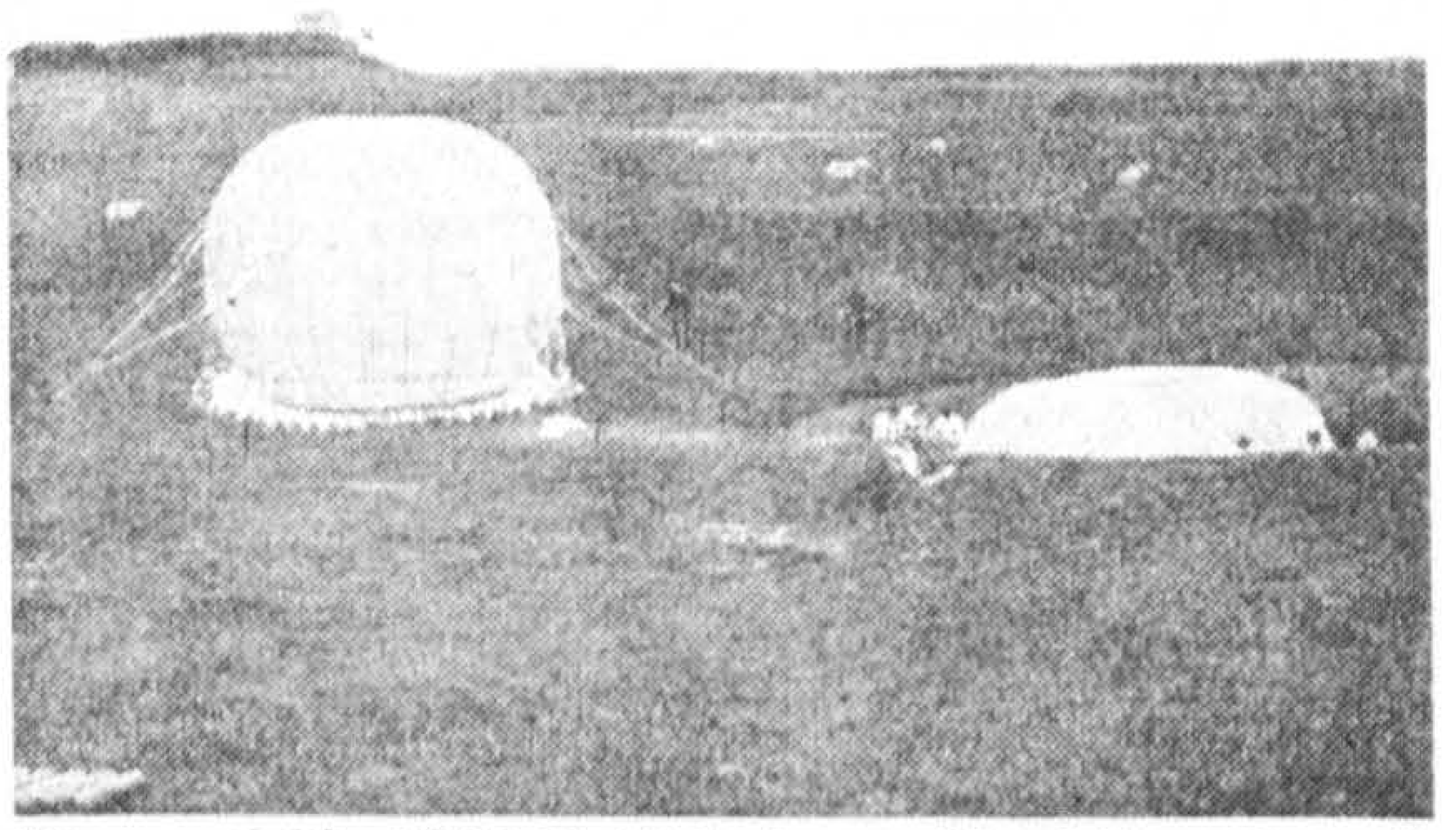

Figure 6.19 :1900 British Army "bedding-down" experiments - note gas cylinders in foreground

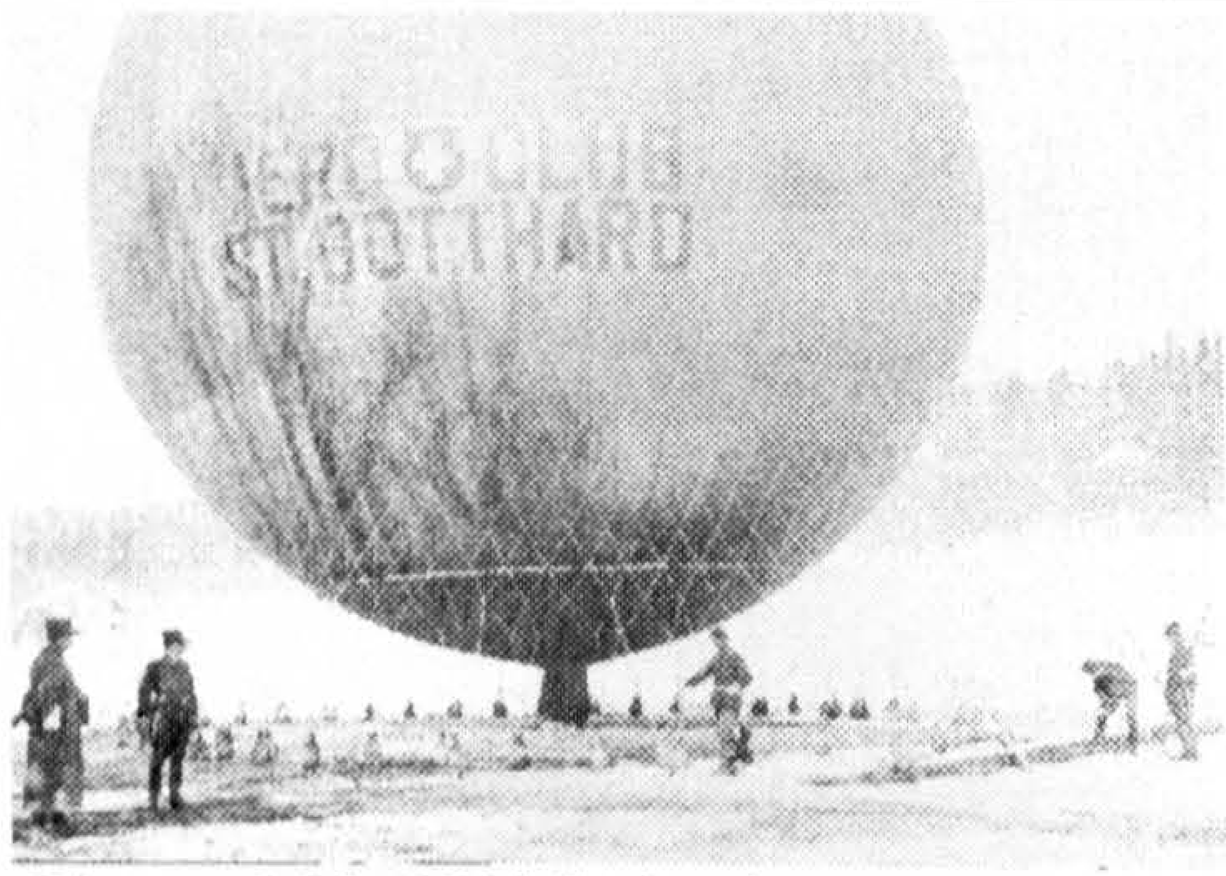

Figure 6.20 :1915 Swiss Army - standard gas inflation with net and sandbags

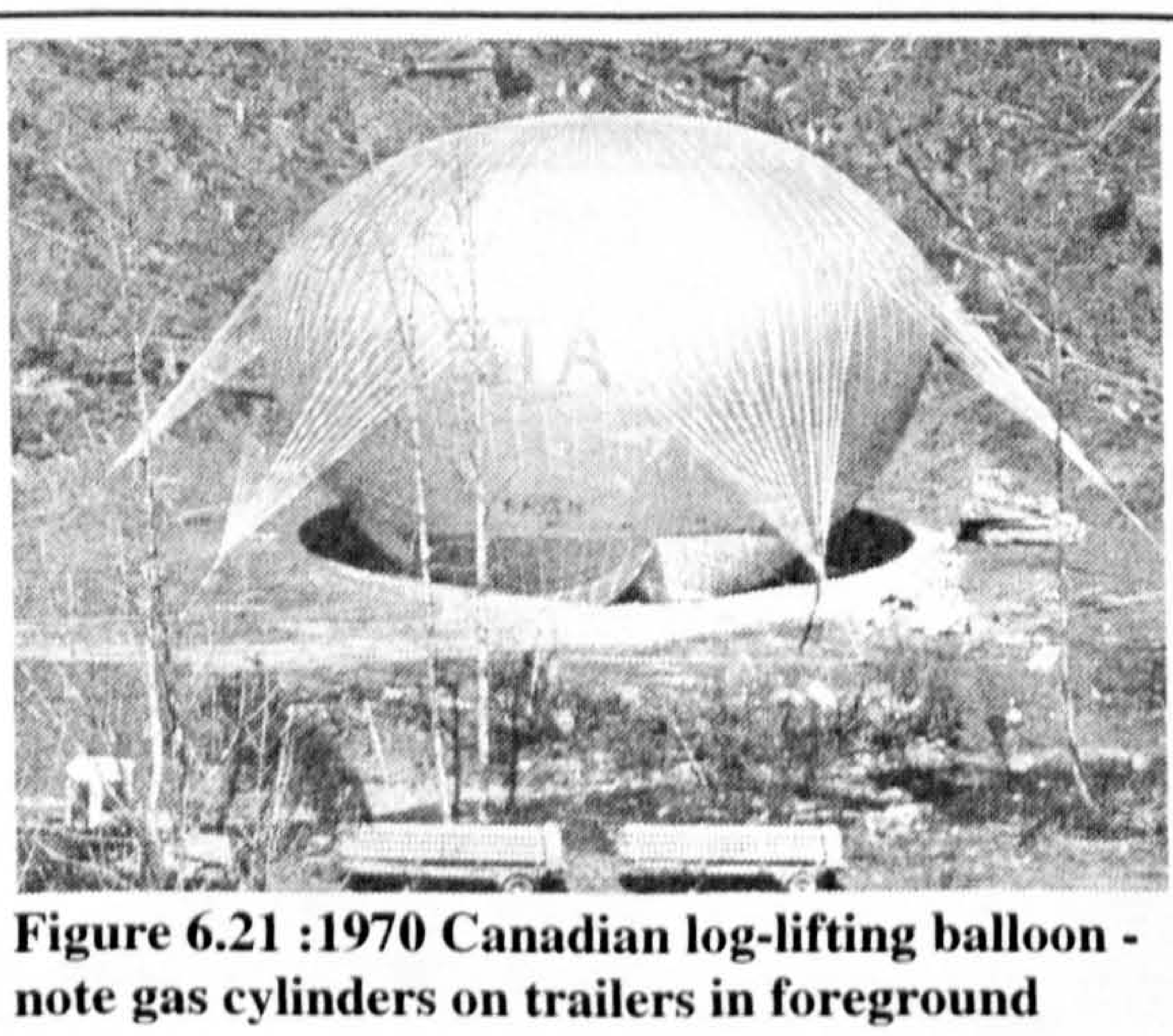

Figure 6.21 :1970 Canadian log-lifting balloon - note gas cylinders on trailers in foreground

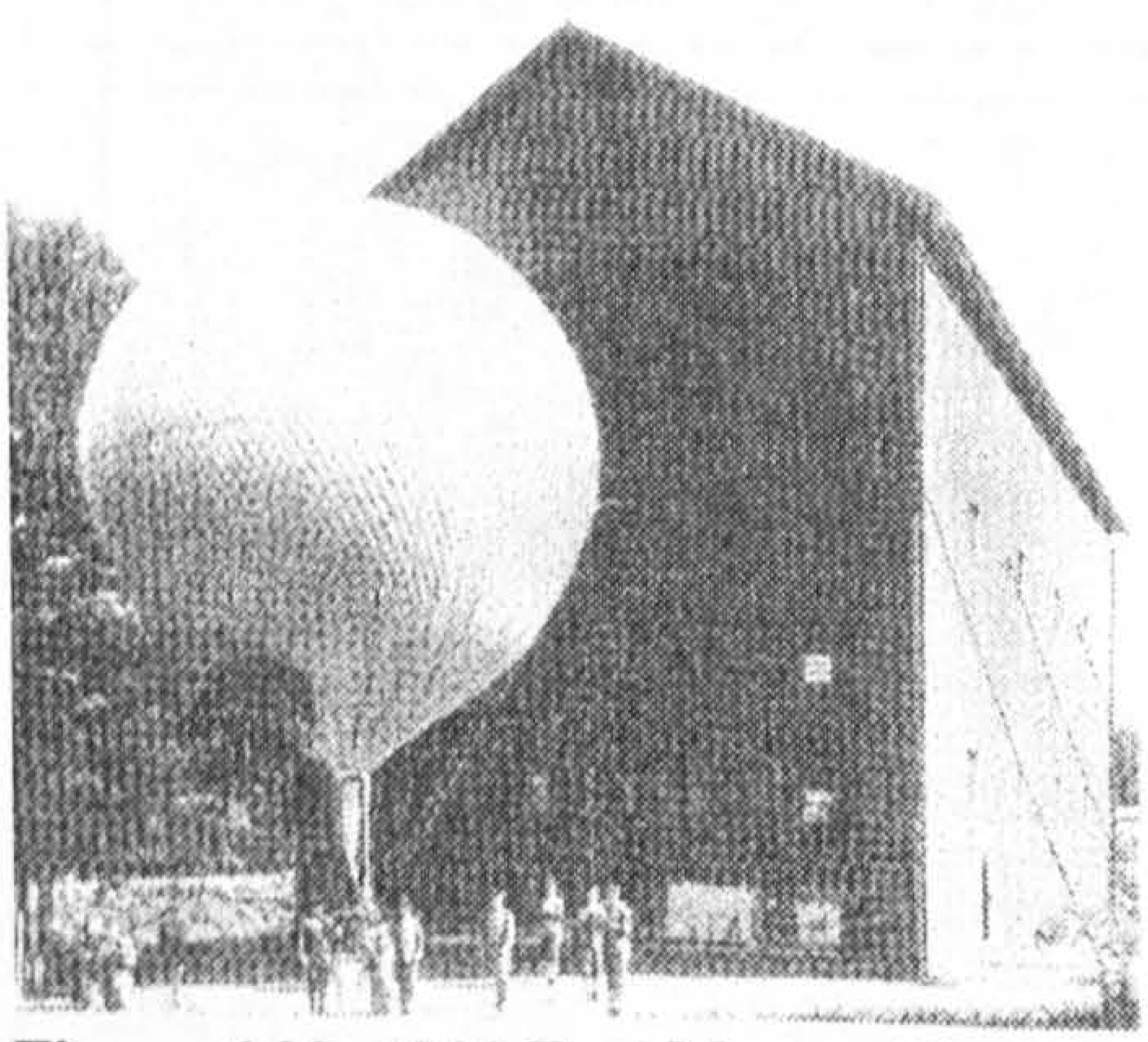

Figure 6.22 :1903 Fort Meyer, Virginia

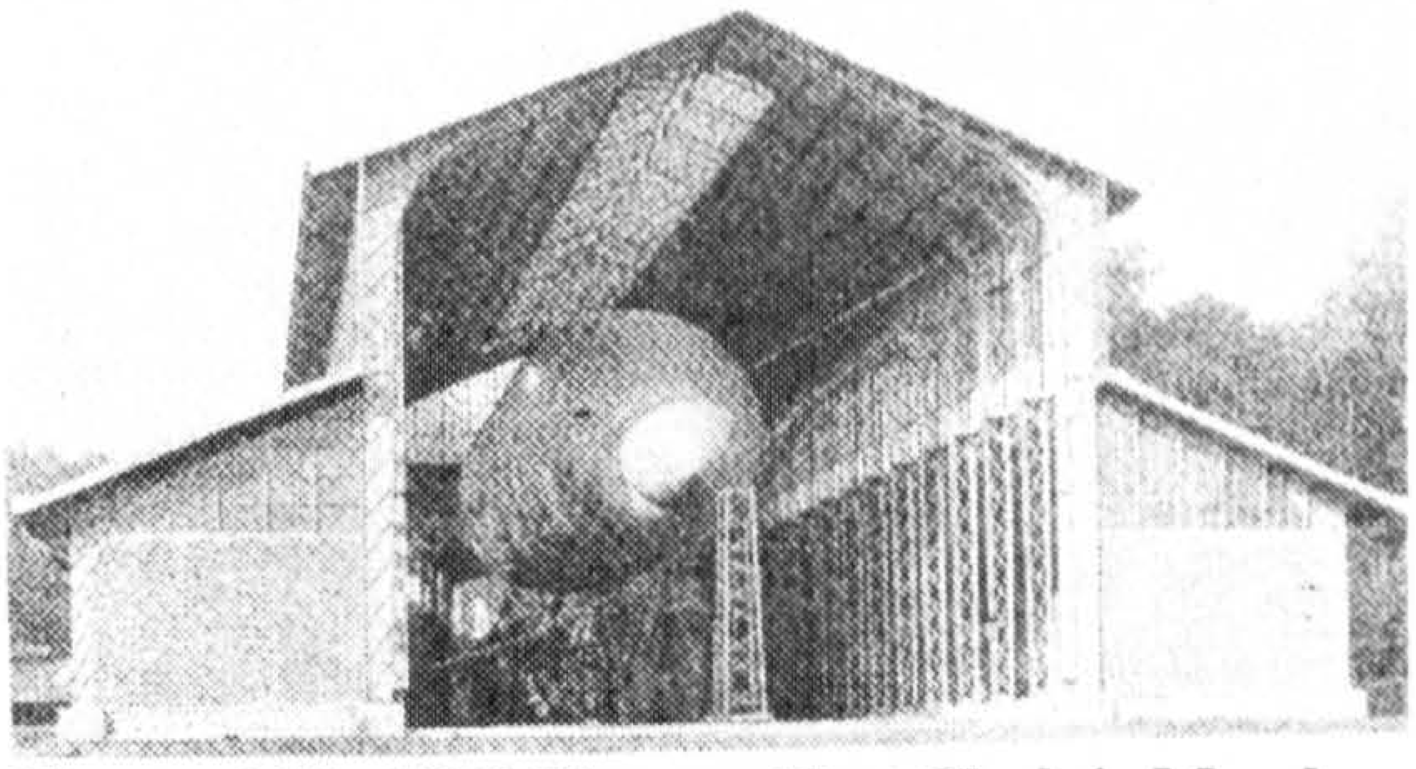

Figure 6.23 :1879 Hangar Y at Chalais Meudon

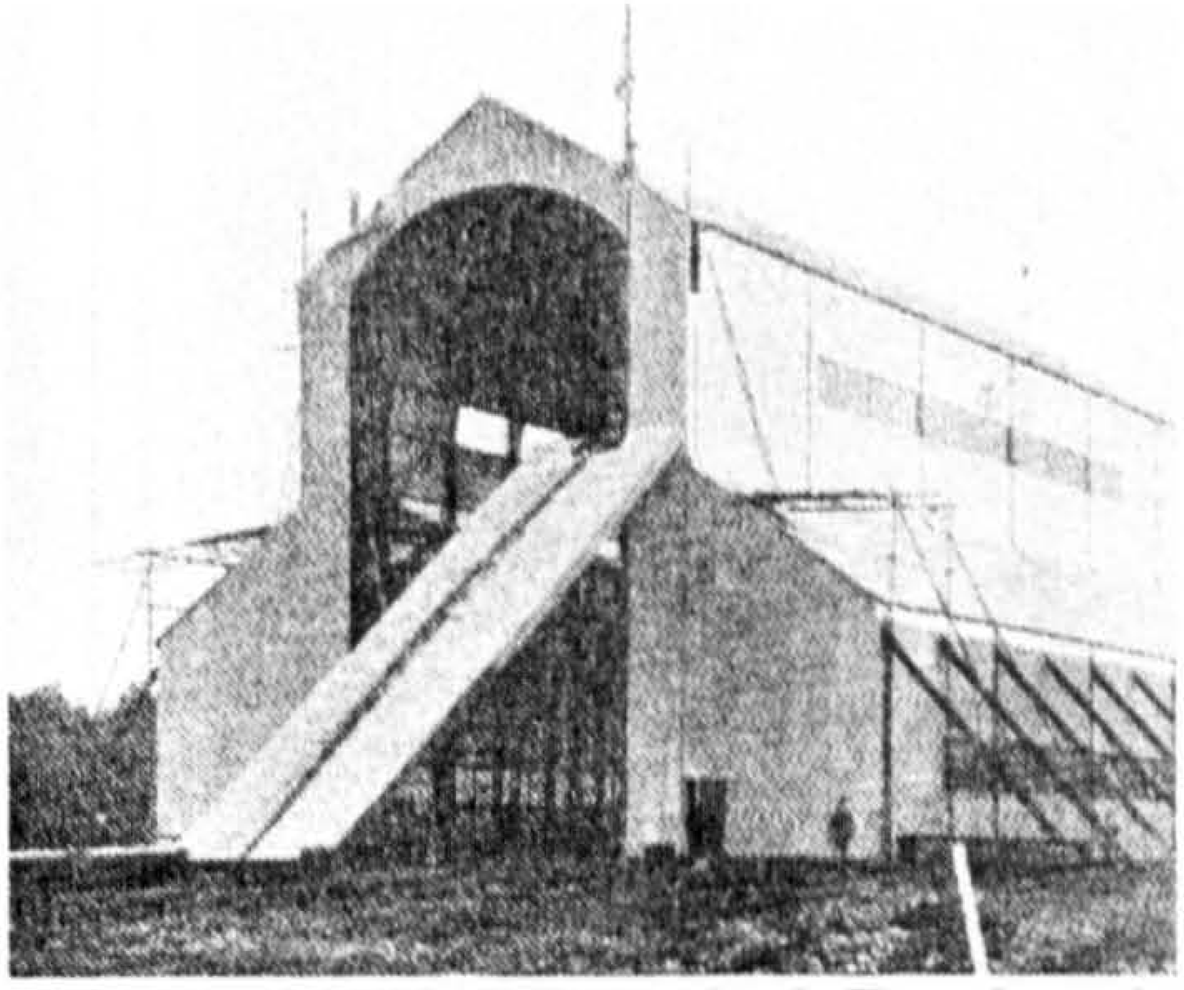

Figure 6.24 :1905 Beta shed, Farnboro'

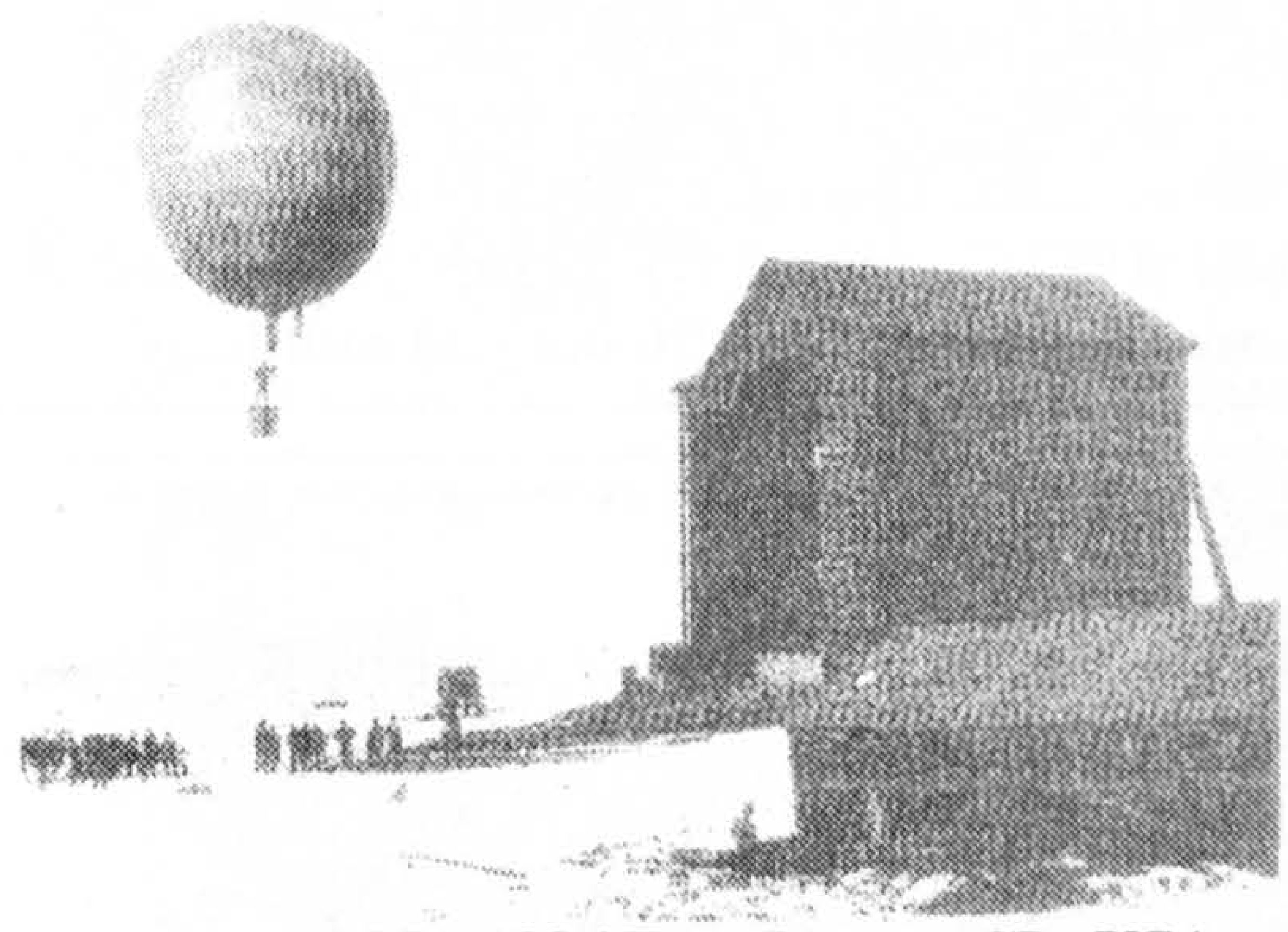

Figure 6.25 :1896 Fort Logan, CL. USA

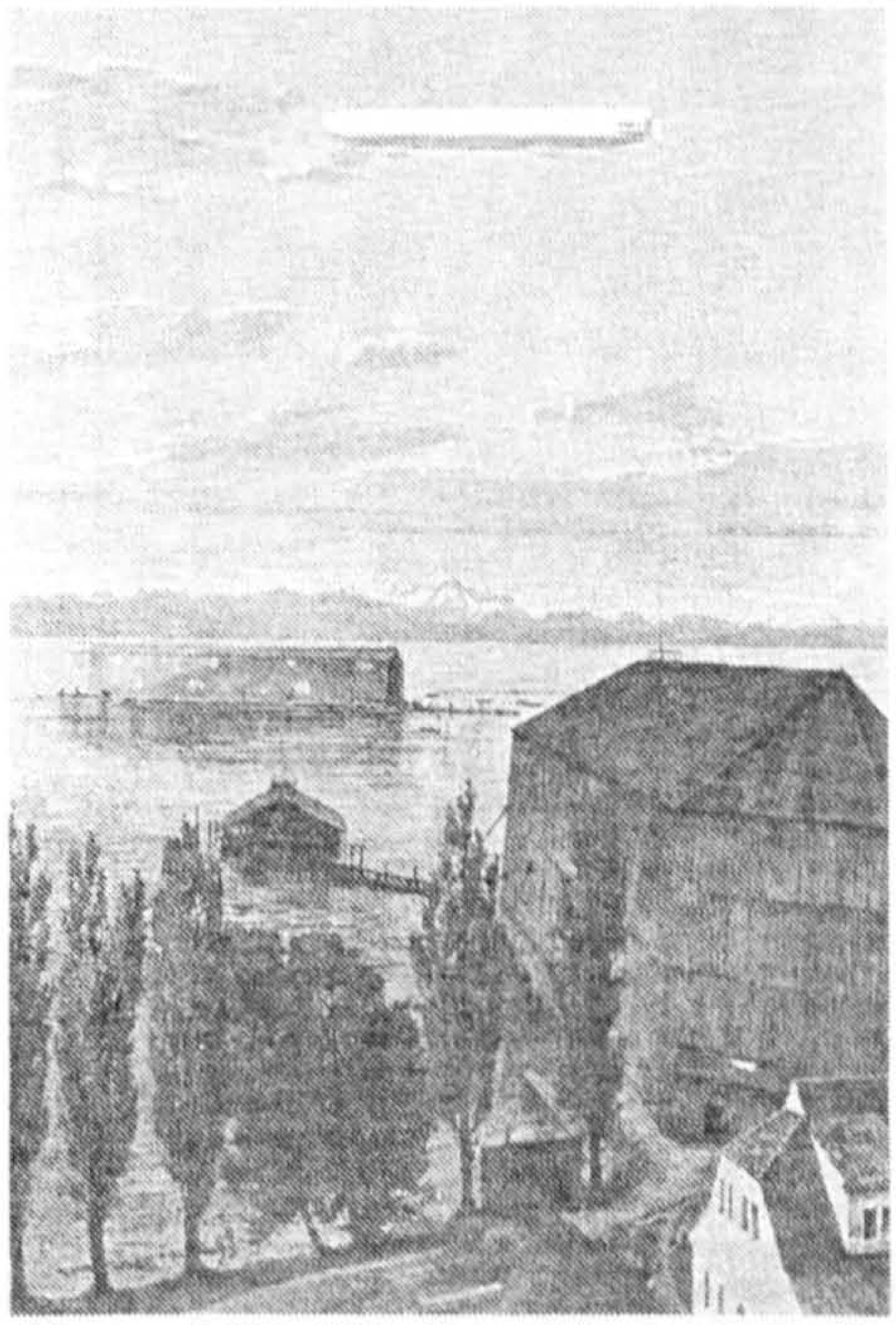

Figure 6.27 :1907 Zeppelin at Manzell

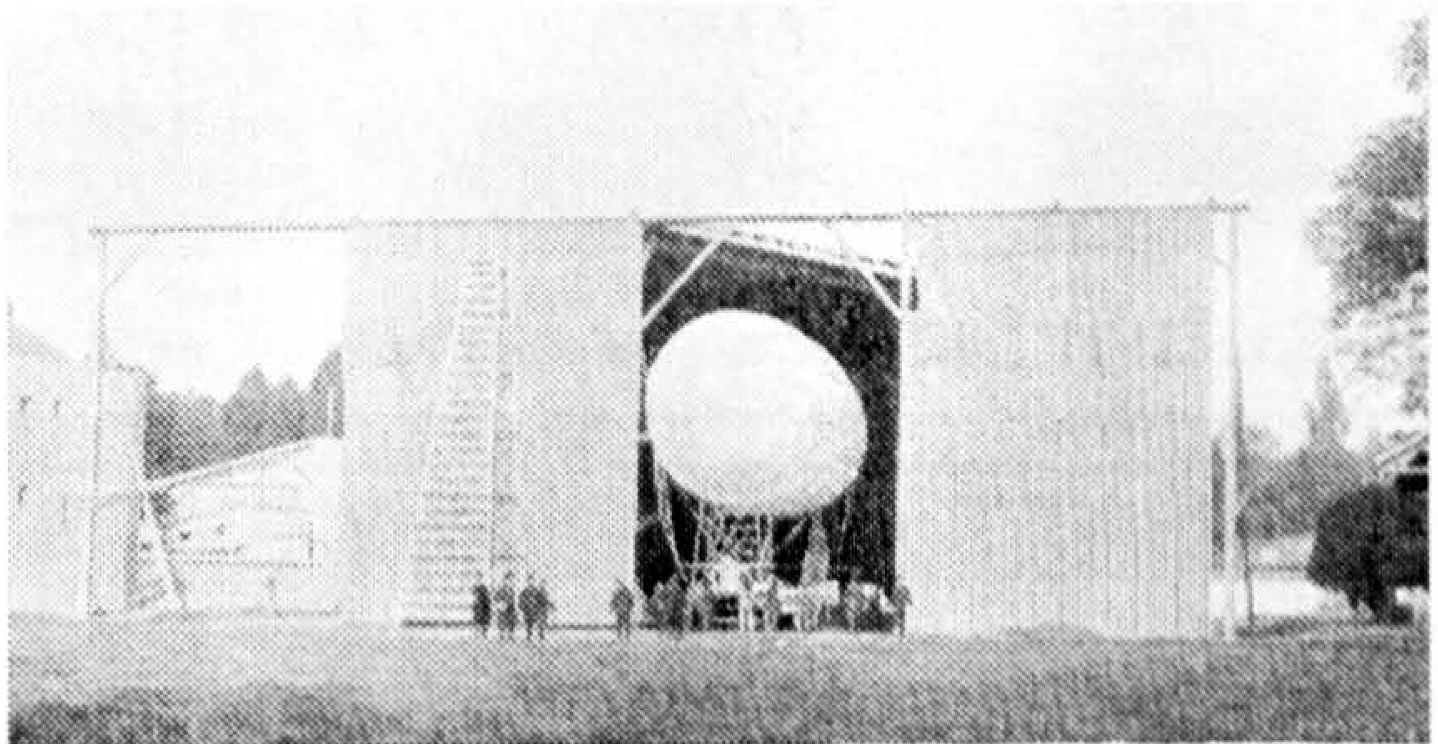

Figure 6.26 :1902 Santos Dumont's 1st Hangar

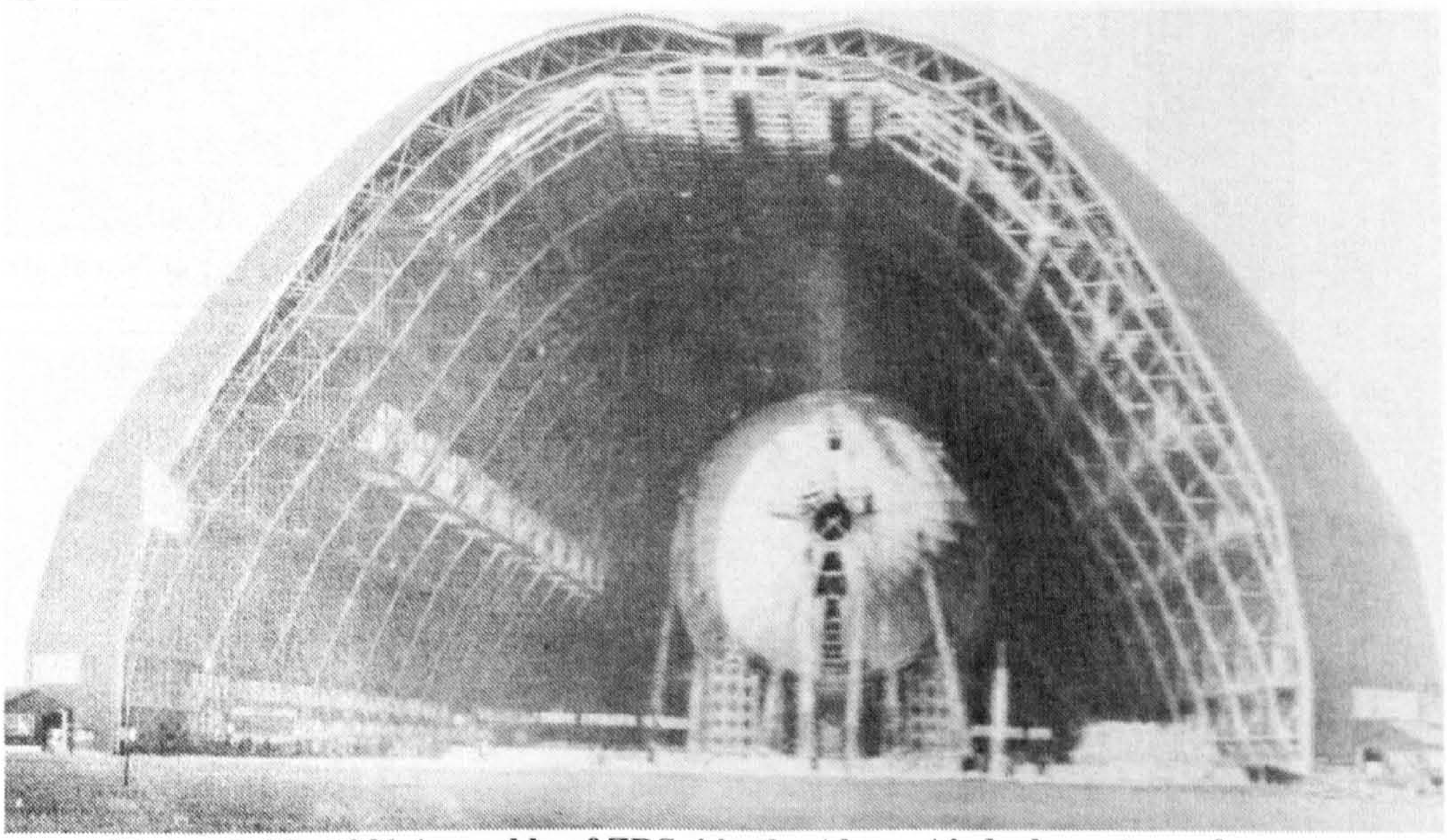

Figure 6. 28 - 1931 Assembly of ZRS-4 in the Akron Airdock - note roof cranes

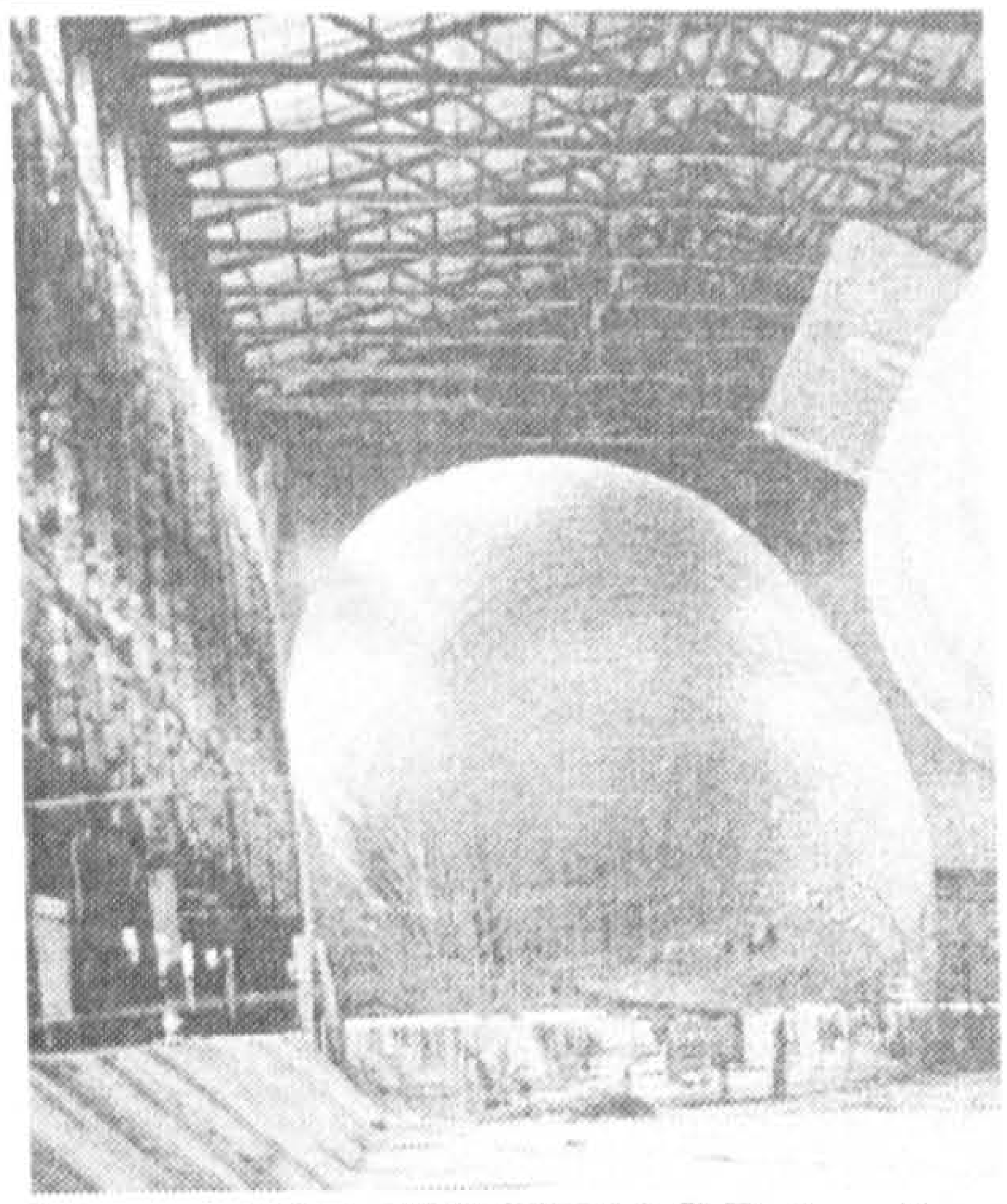
Figure 6.29 :1916 RNAS Polegate

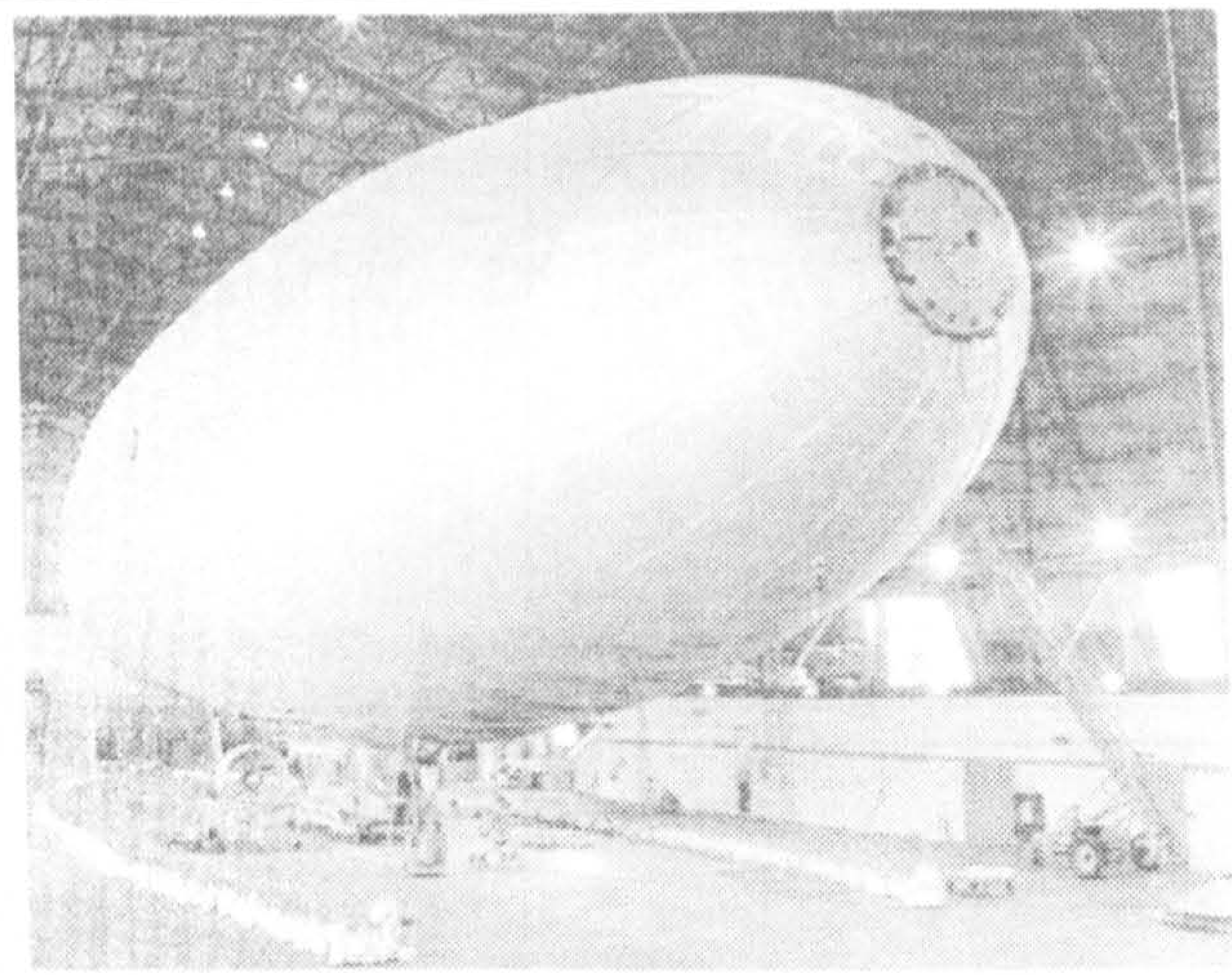
Figure 6.30 :1987 Goodyear GZ 22 inflated in shed as a standard gas balloon with net and sandbags

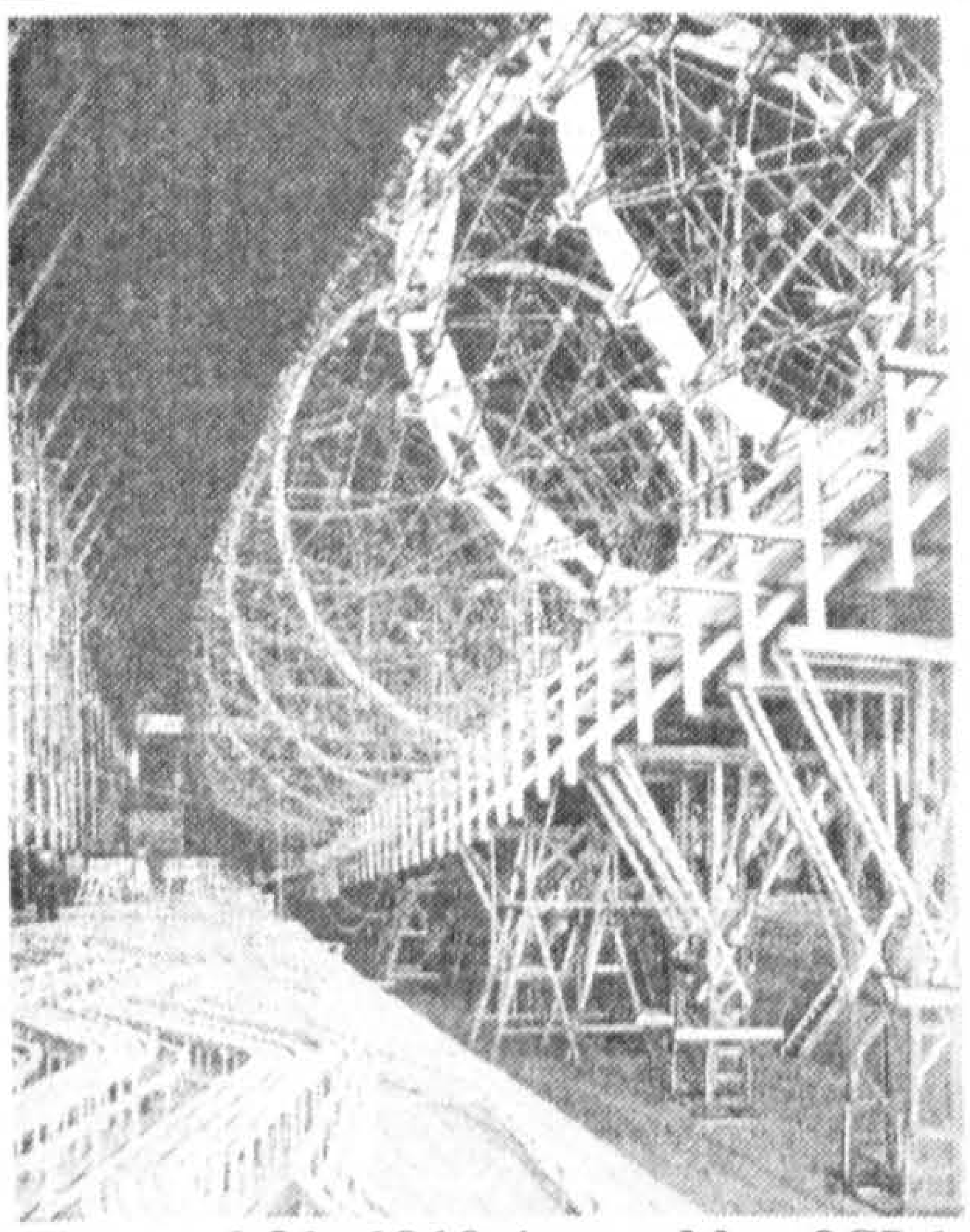
Figure 6.31 :1910 Assembly of SL1

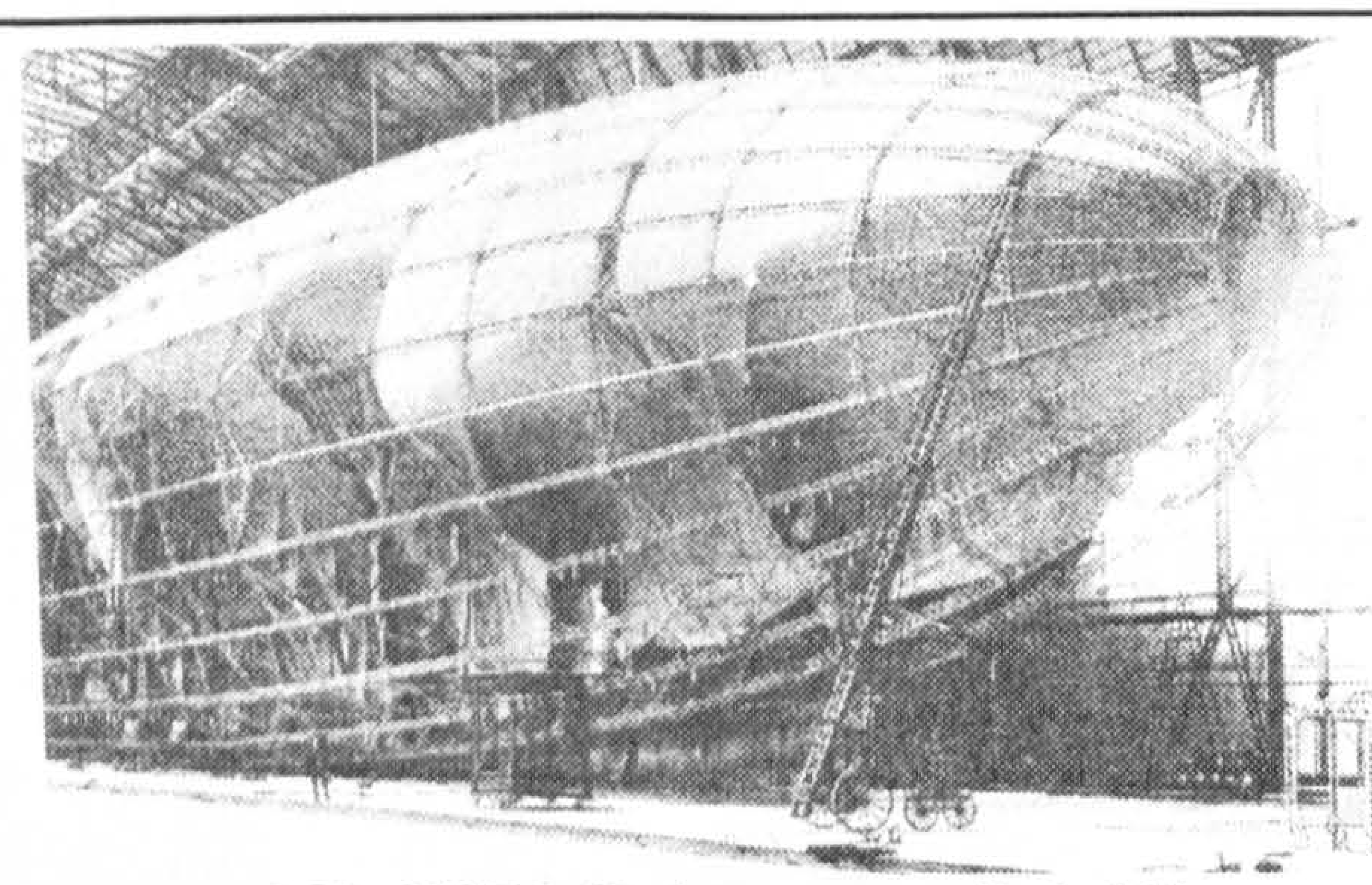
Figure 6.32 :1917 L42 shows gas cells held by nets

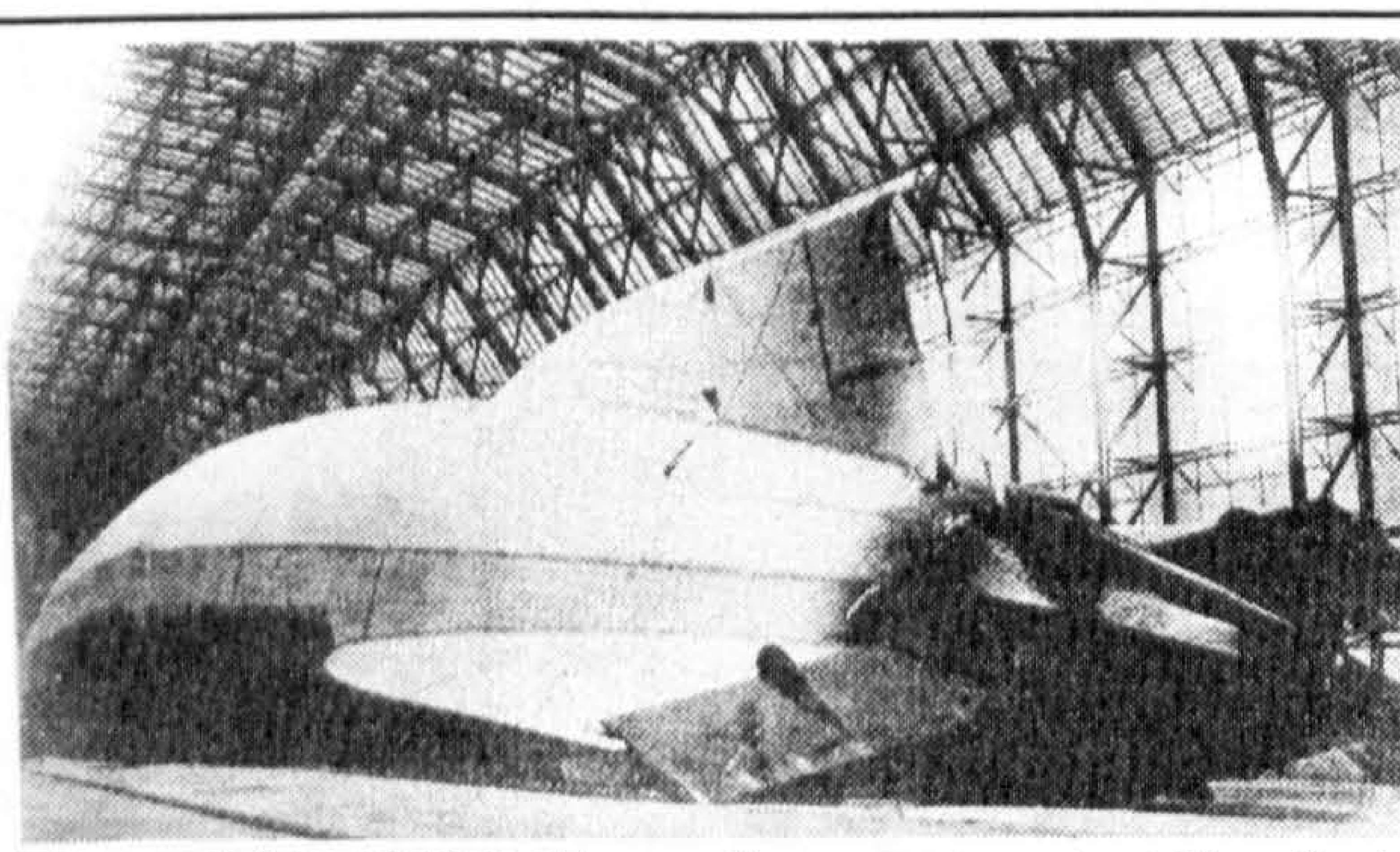
Figure 6.33 :1919 L65 - roof supports cut at Nordholz

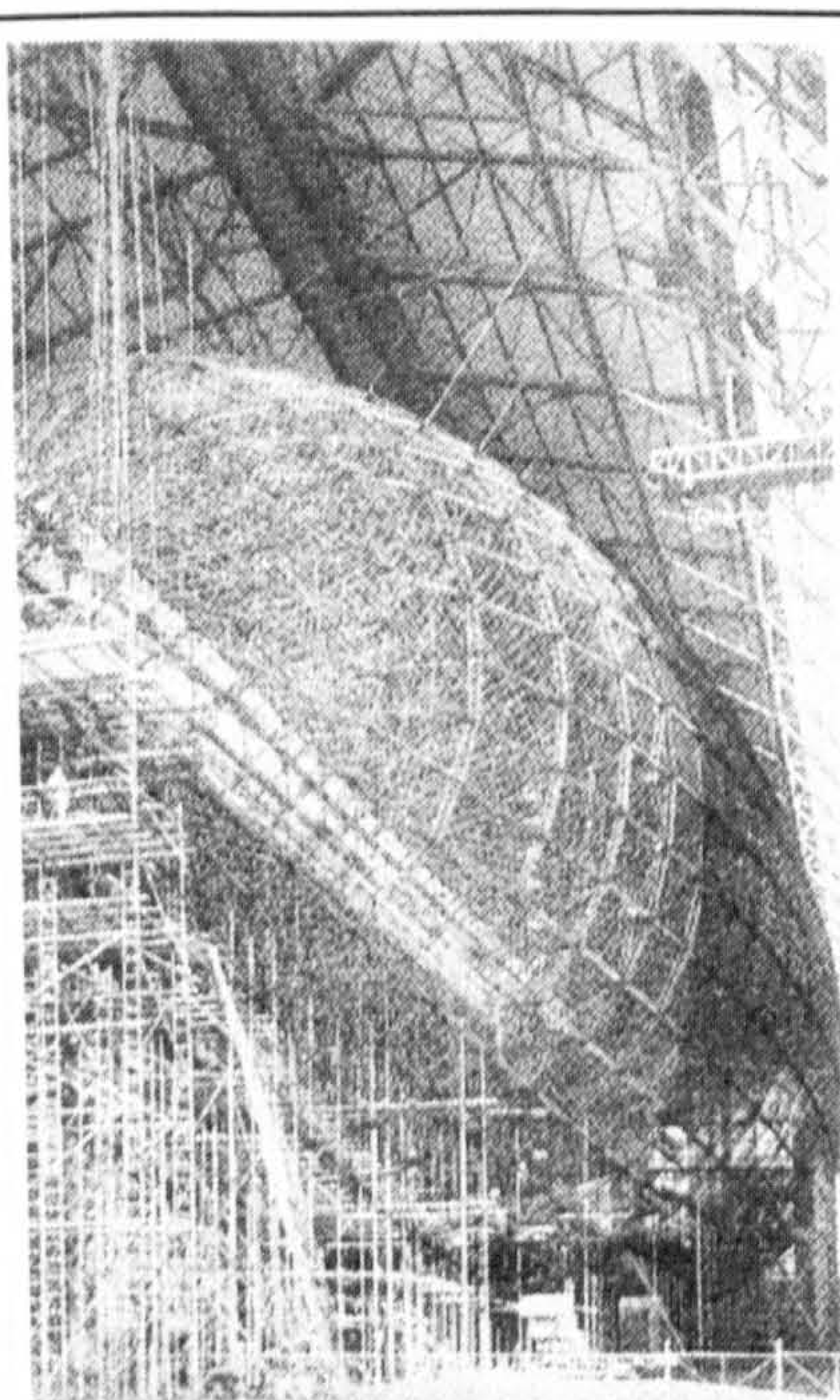
Figure 6.34 :1935 LZ129 F'hafen

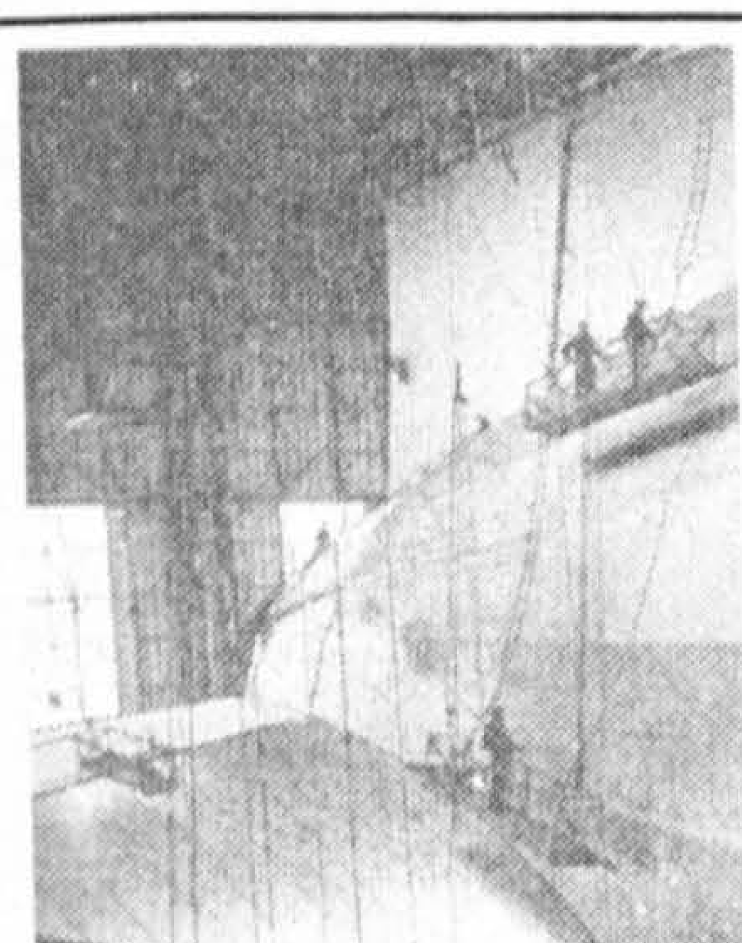
Figure 6.35 :1935 LZ129

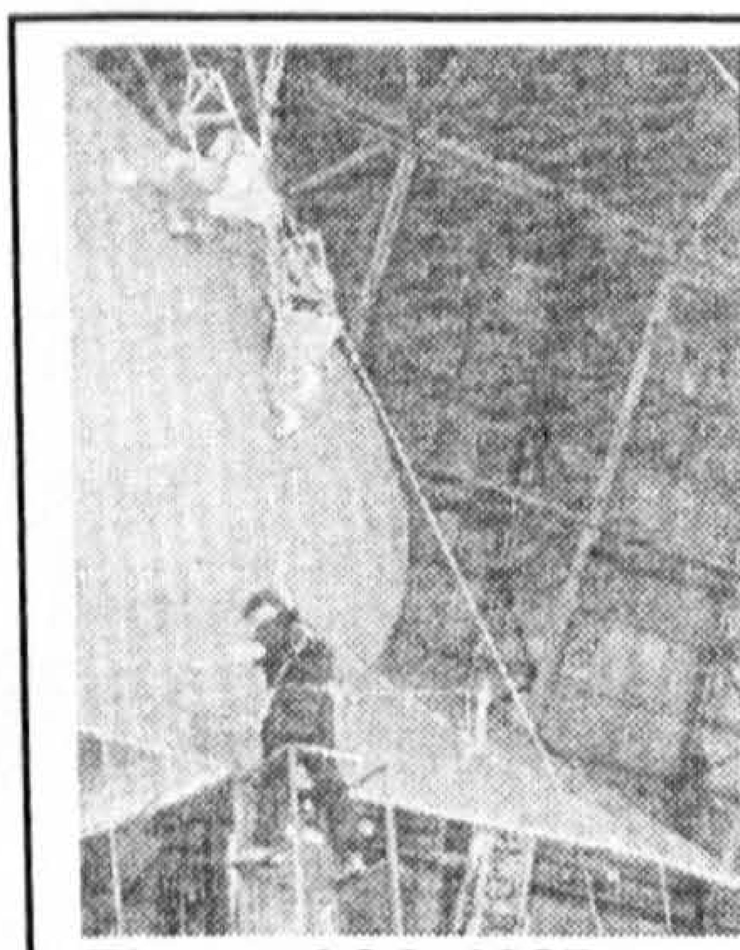
Figure 6.36 :1987 crew work on GZ22 tail fins

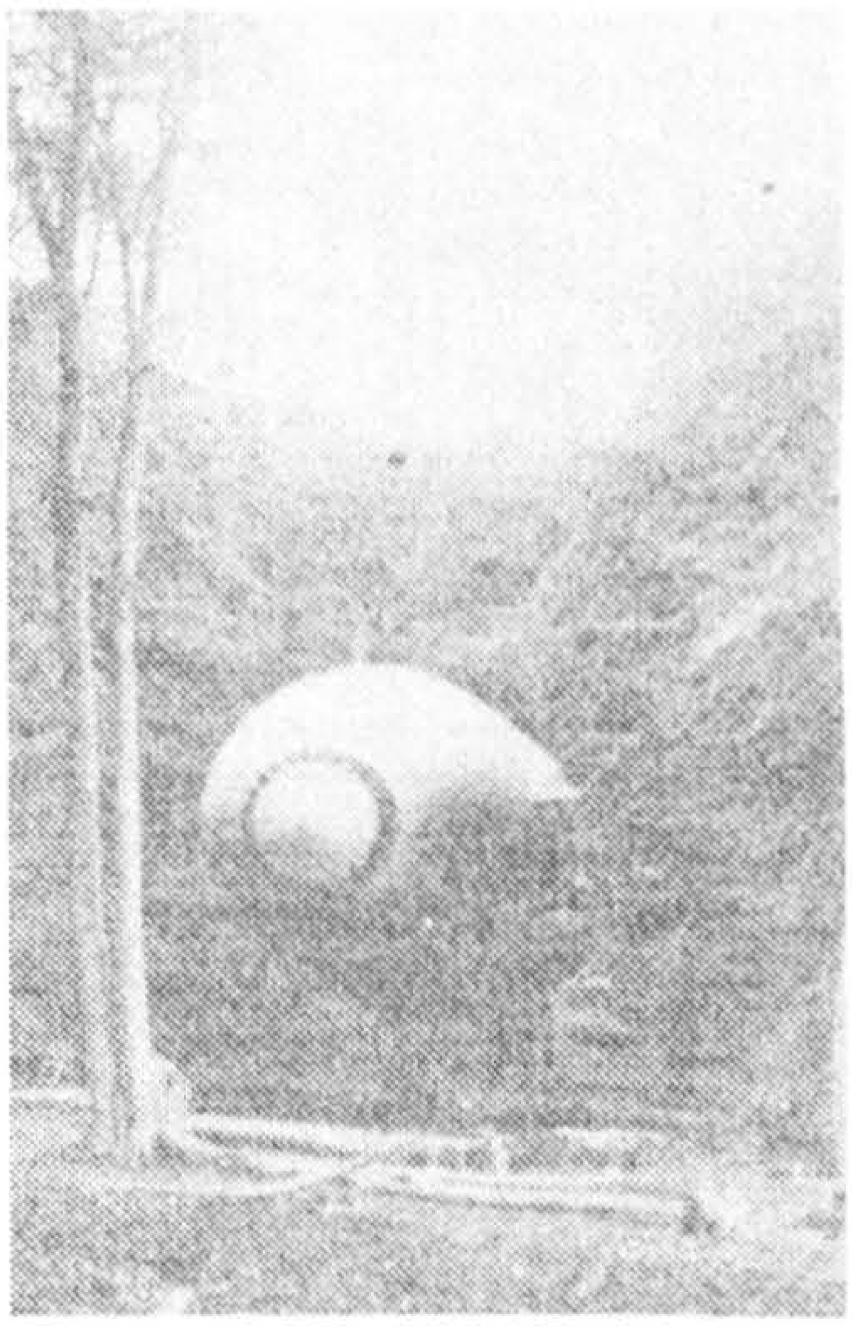

Figure 6.37 :1916 British blimp "mooring out" station

Figure 6.38 :1926 LZ126 at Ford's Dearborn mast with "vertical railway"

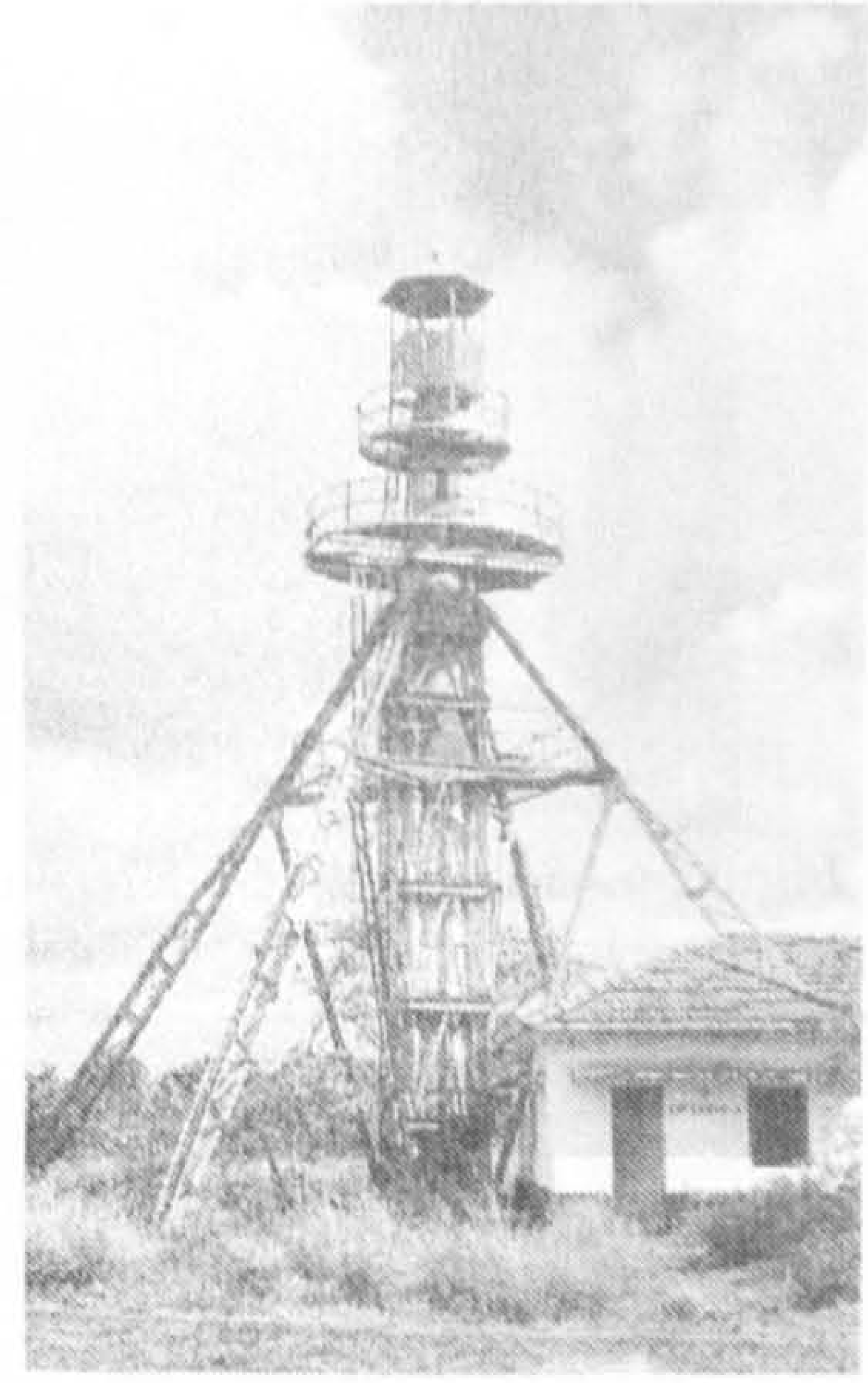

Figure 6.39 :1936 Brazilian "expeditionary" mast used by both LZ127 Graf Zeppelin and LZ129 Hindenburg. This mast is believed to be still extant today.

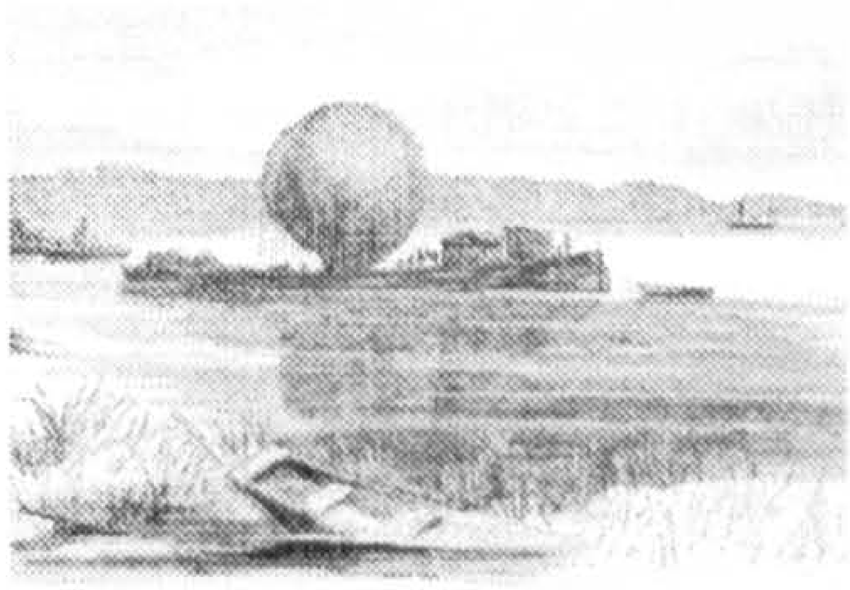

Figure 6.40 :1862 balloon moored on a river boat

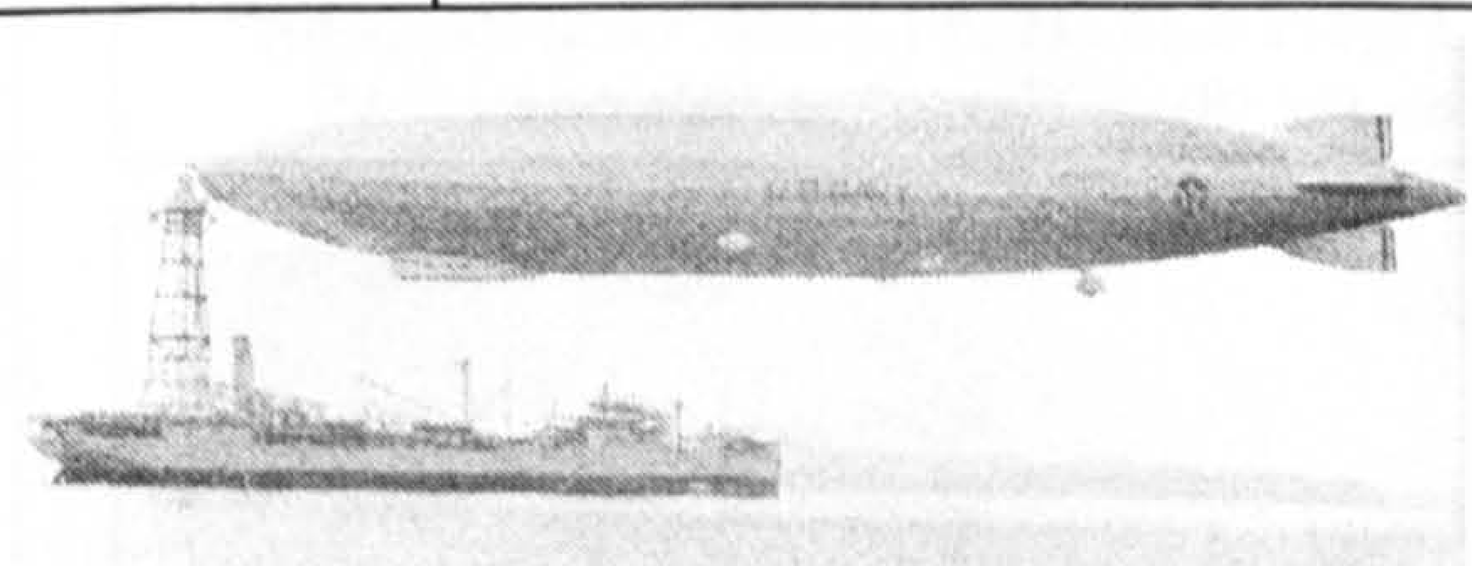

Figure 6.41 :1930 LZ 126 moored to Patoka

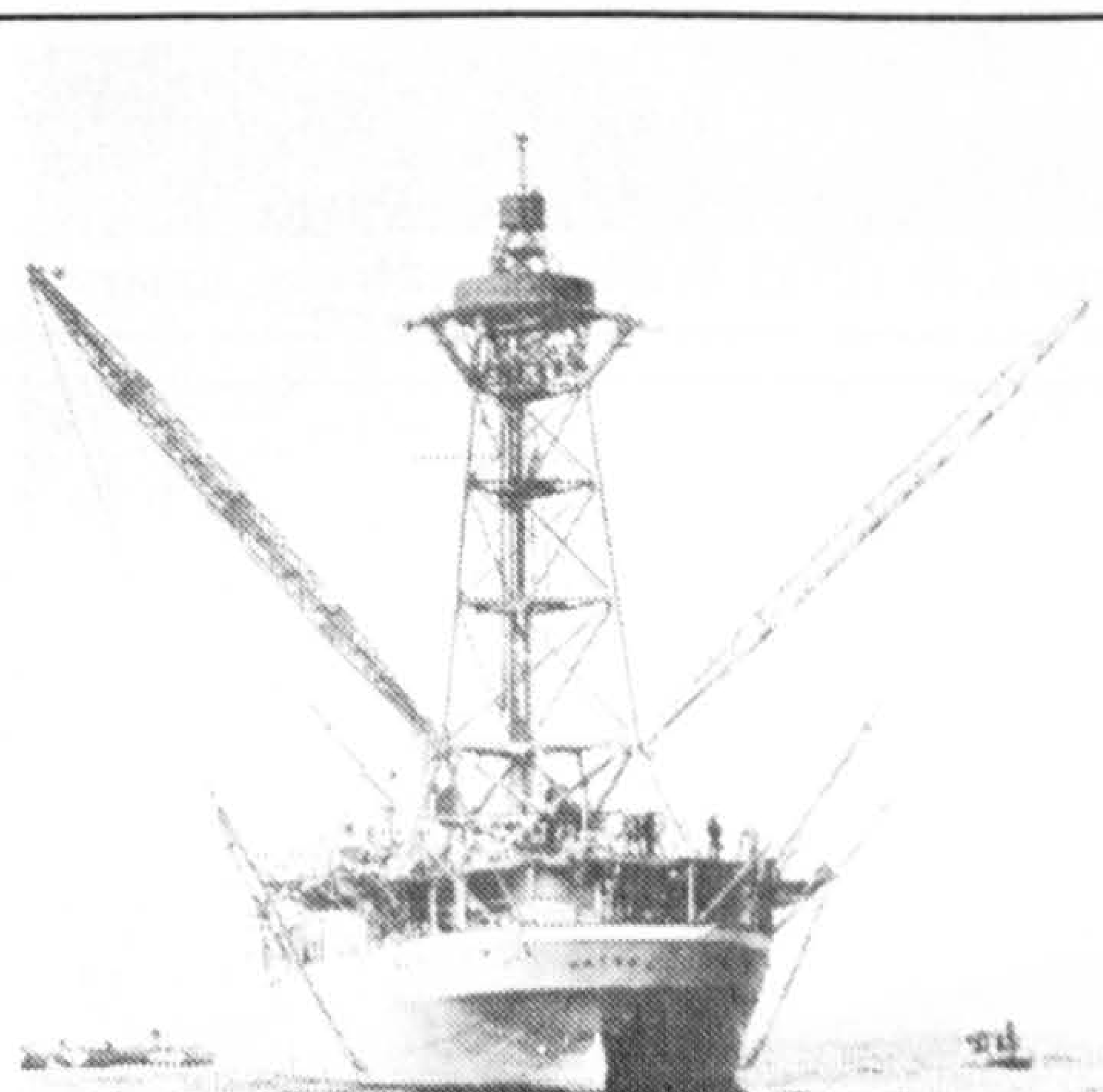

Figure 6.42 :1930 USS Patoka

Figure 6.43 :1935 Loading and access for LZ127 "Graf Zeppelin" passengers

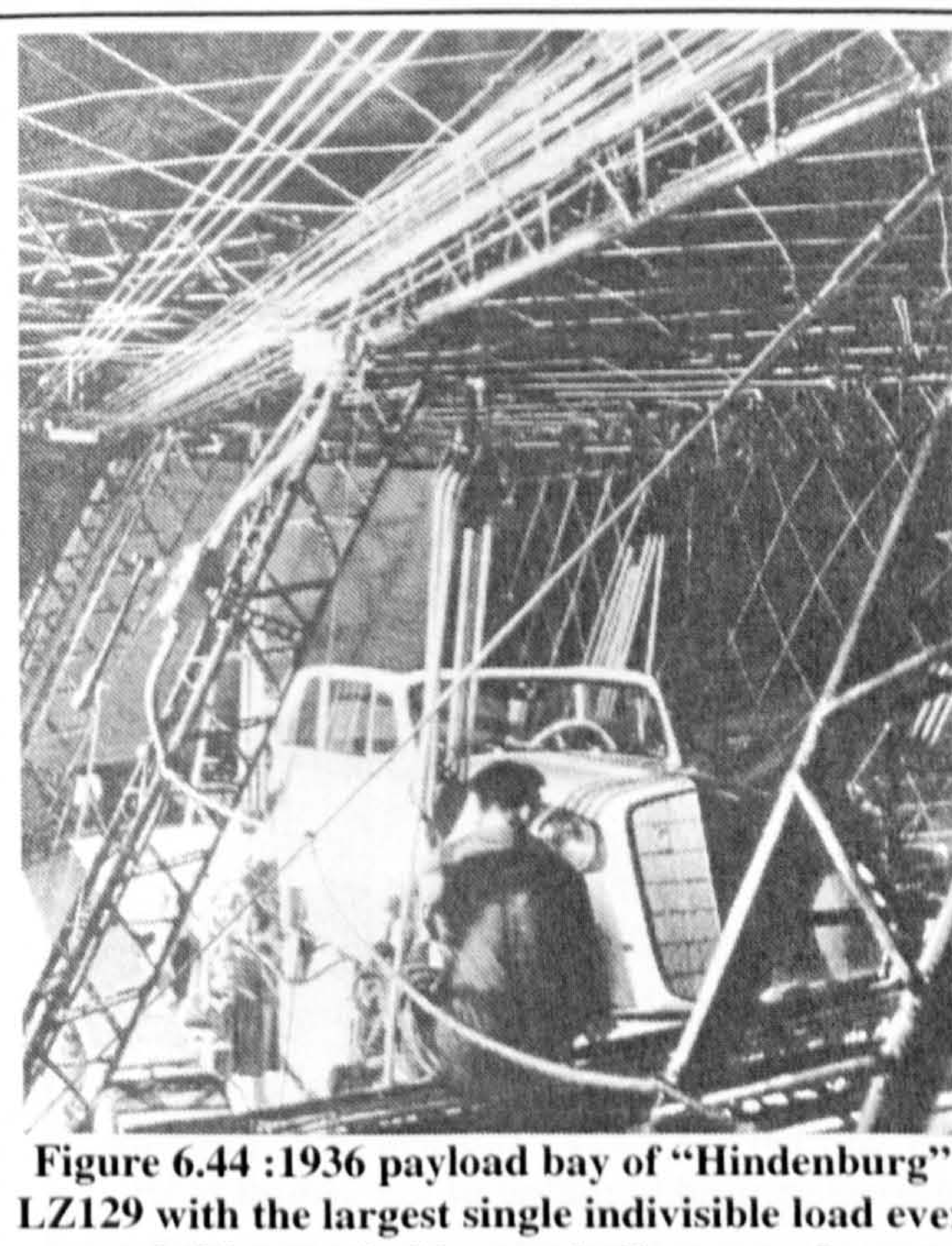

Figure 6.44 :1936 payload bay of "Hindenburg" LZ129 with the largest single indivisible load ever carried by an airship - excluding aeroplanes

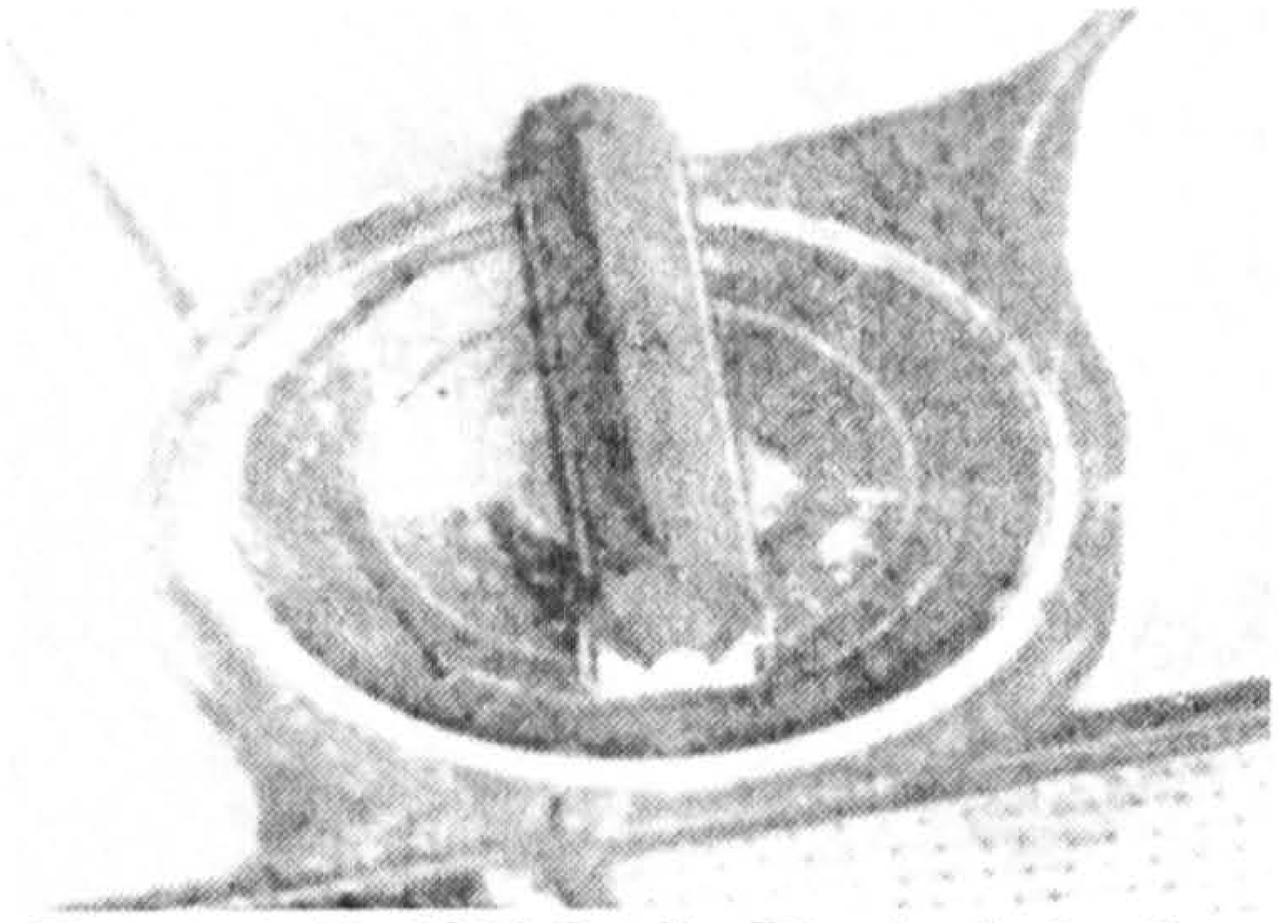

Figure 6.45 :1910 Berlin Biesdorf, the first land-based rotatable shed

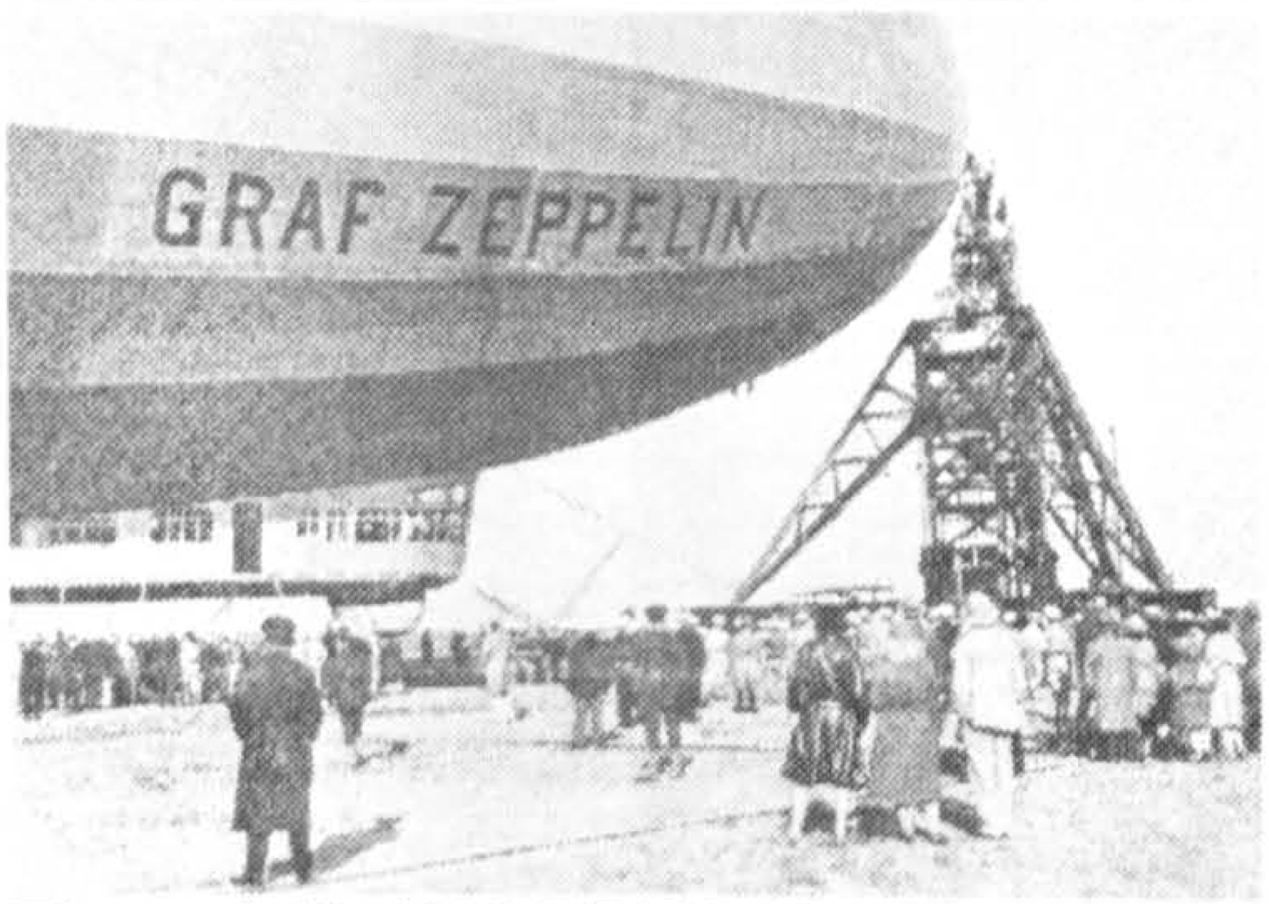

Figure 6.48 :1929 LZ129 "Graf Zeppelin" on the "Iron Horse" at Lakehurst NAS

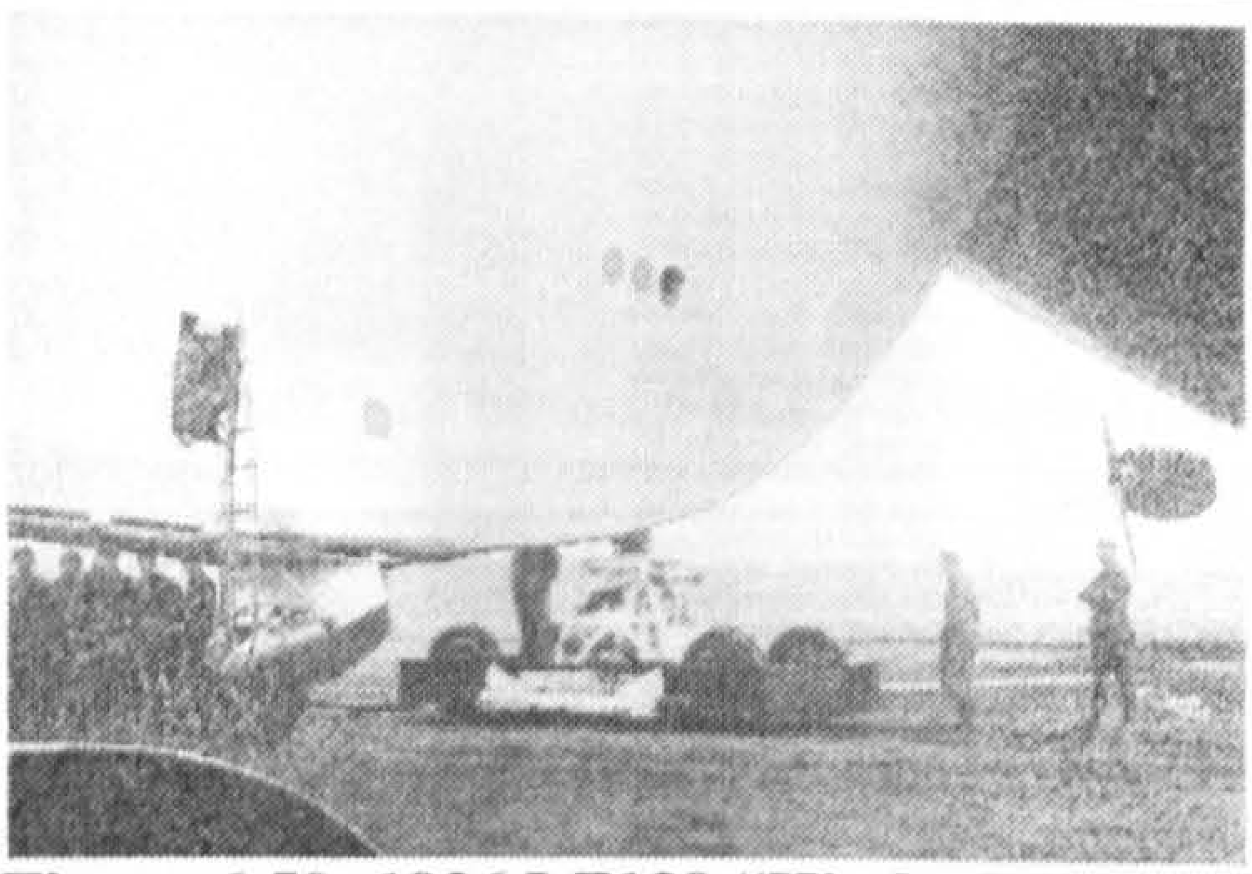

Figure 6.50 :1936 LZ129 "Hindenburg" tail on "riding-out" car at Lakehurst NAS

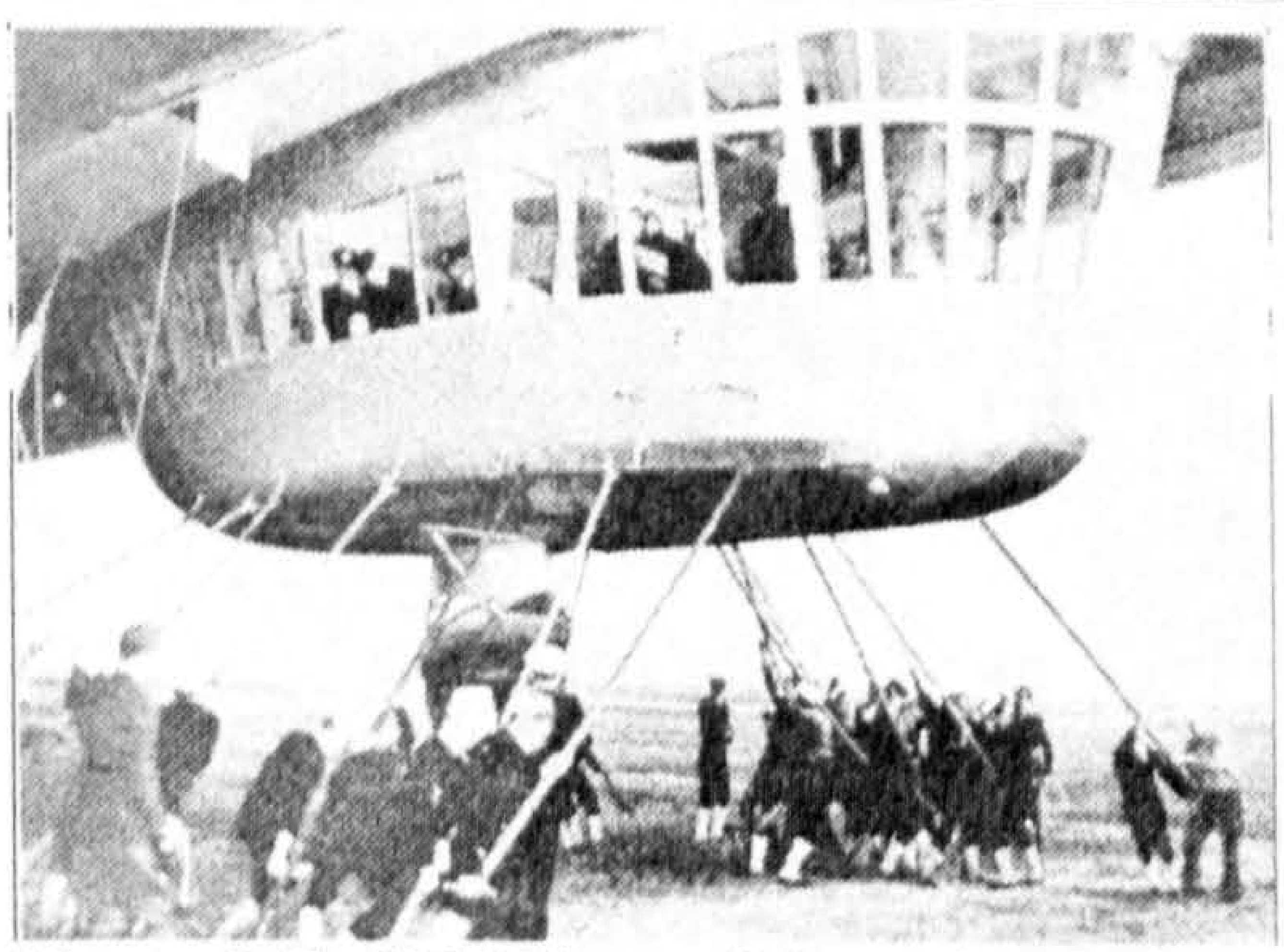

Figure 6.51 :1936 'State of the art' technique for control of LZ129 "Hindenburg" gondola during ground handling at Lakehurst NAS

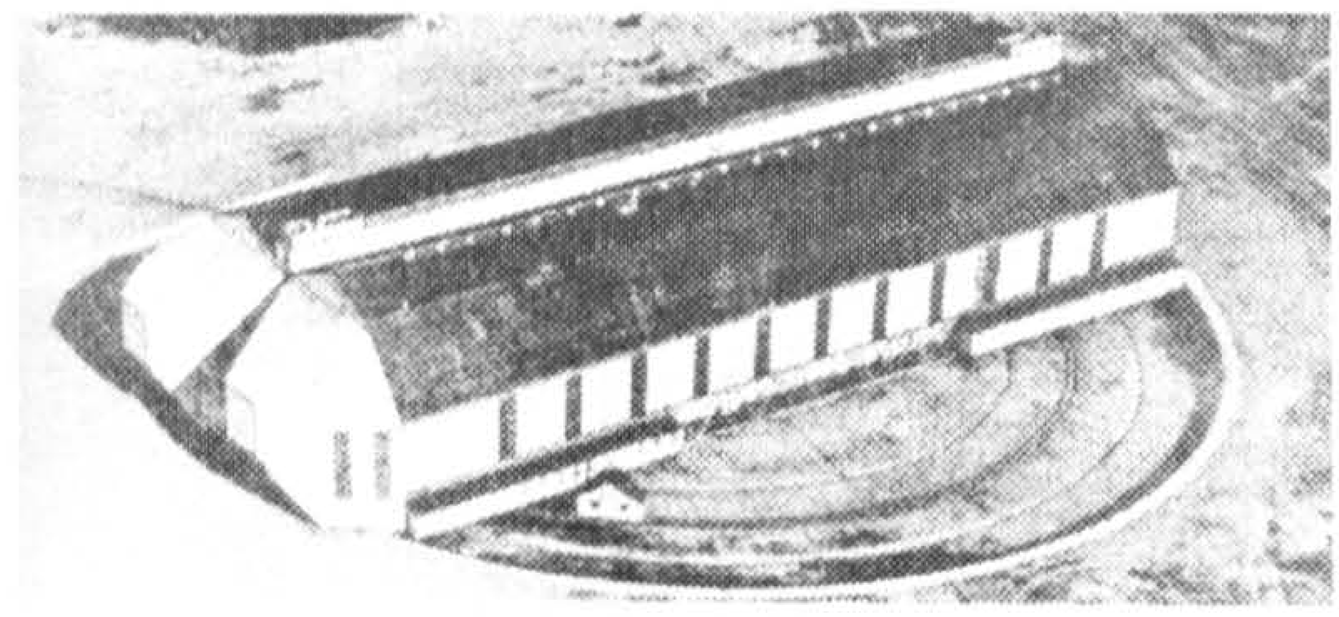

Figure 6.46 :1914 Nordholz twin rotatable

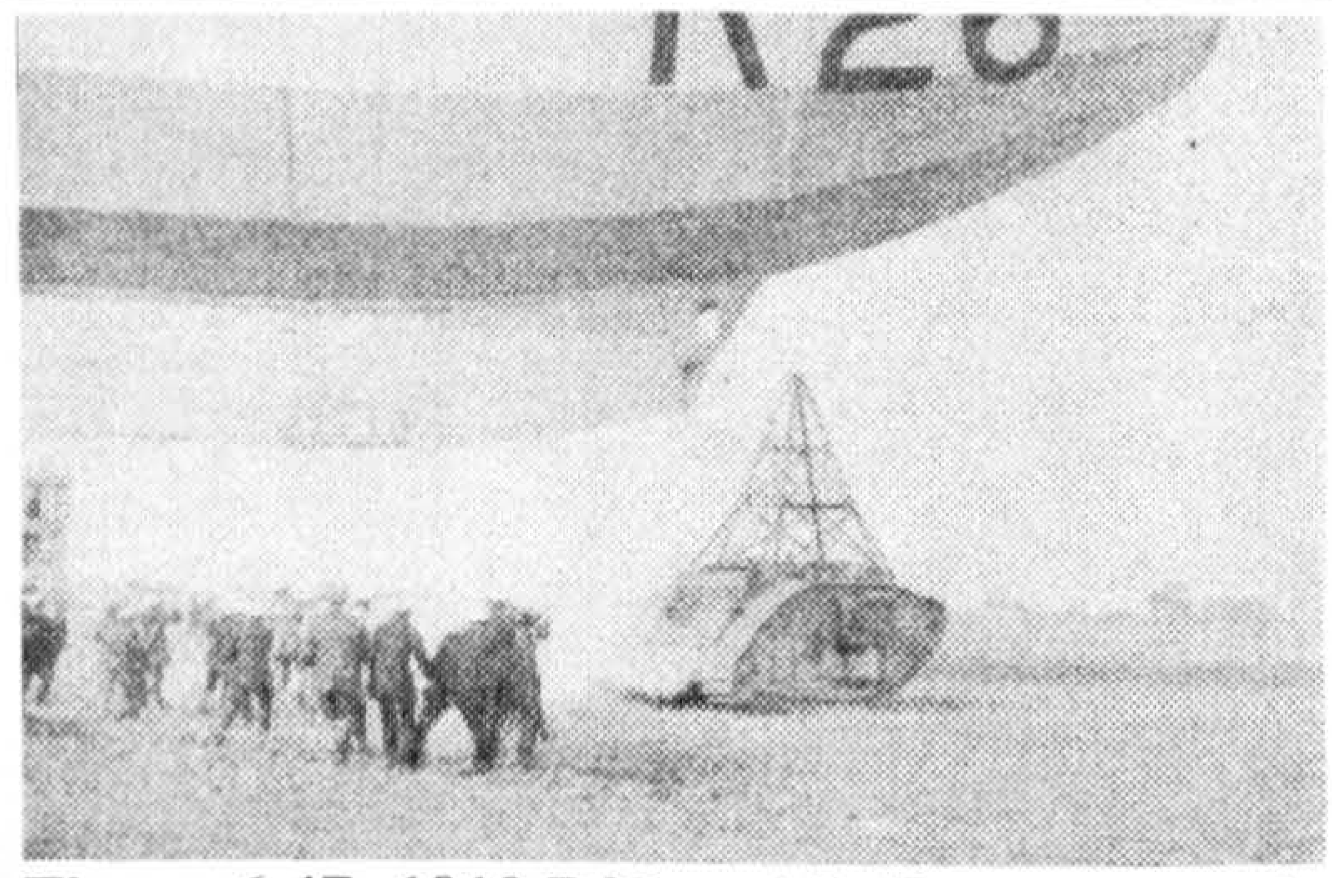

Figure 6.47 :1919 R26 and Pulham tow-tank

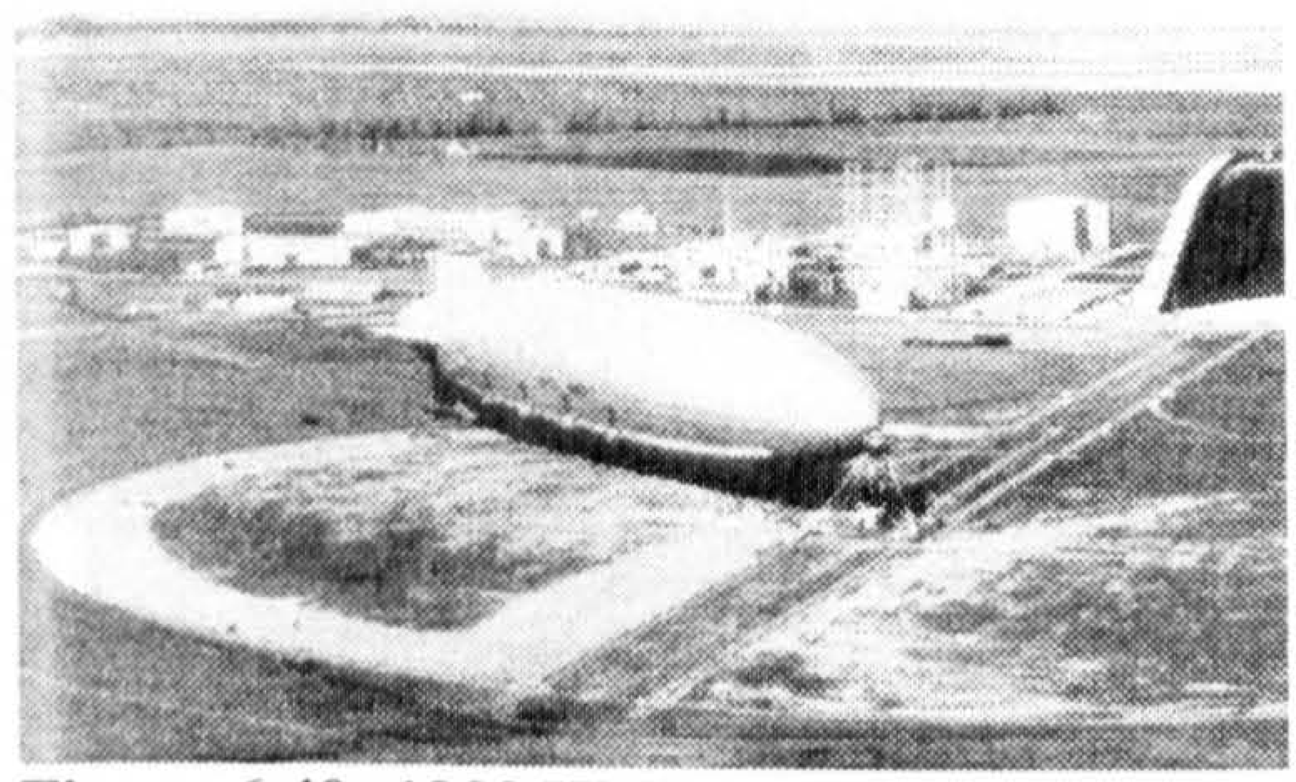

Figure 6.49 :1933 Wellman railroad mast

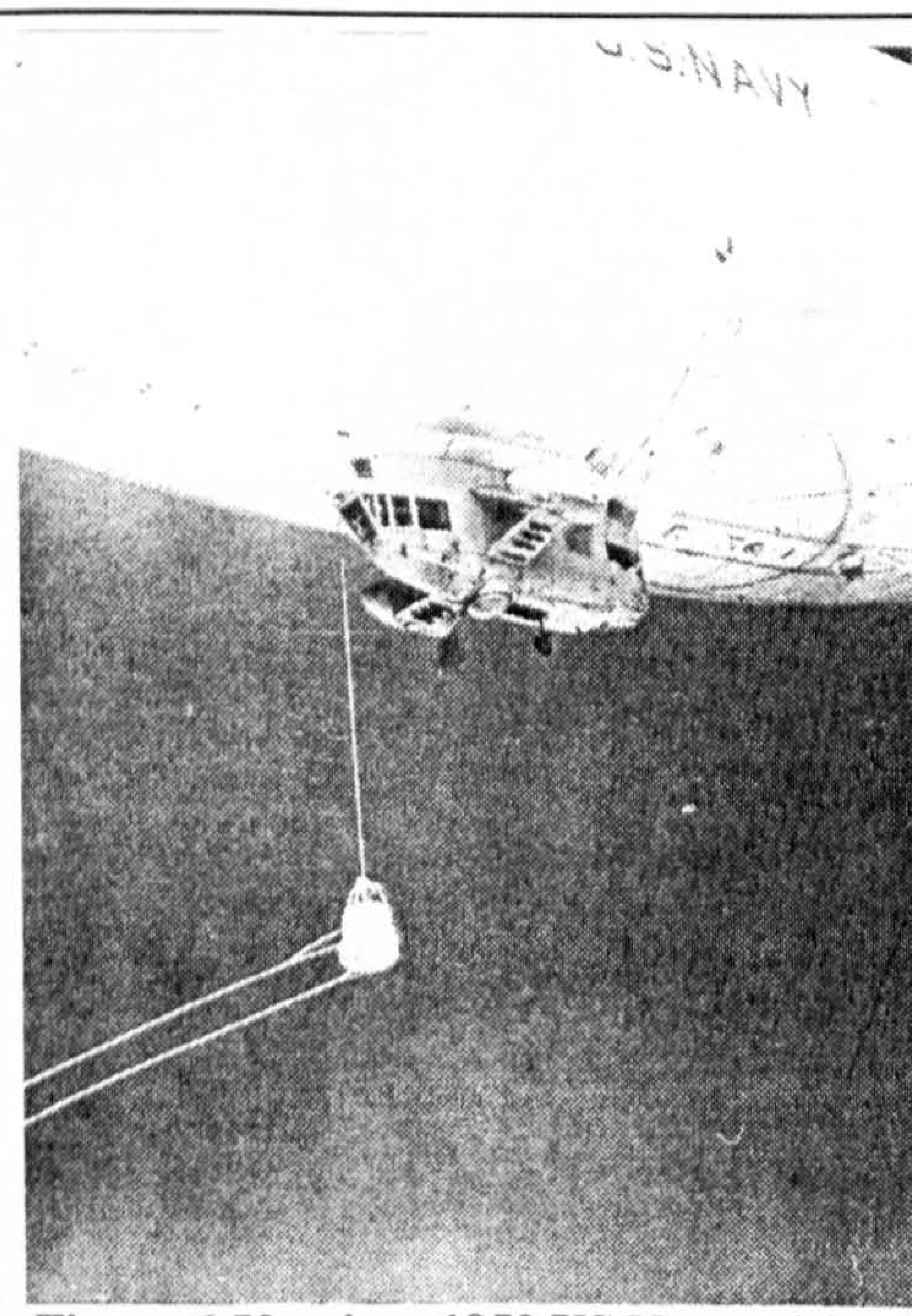

Figure 6.52 : circa 1950 US Navy trials of in-flight crew exchange via onboard winch with suspended basket