The ROLE of INTERVENTION in STRATEGIC CHANGE

by

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Two volumes:
Volume 1: This Volume.
Volume 2: Bibliographic References and Notes. (Annex 5)

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You can Never Plan the Future By the Past
(Edmund Burke)

In the LONG RUN, MOST DYNAMIC SYSTEMS show NO DISCERNIBLE REGULARITY or REPETITIVE PATTERN.
(Poincare)

" A UNIQUE CHARACTERISTIC of LIFE is that it is an ORGANISED SYSTEM capable of CREATING MORE ORDER from LESS ORDER."
(Litterer)

"CHAOS seems to be RESPONSIBLE for MAINTAINING ORDER in the NATURAL WORLD"
(Percival I)

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ACKNOWLEDGEMENT.

I wish to record my greatest appreciation to my research supervisor, Dr.F.Charlwood, who has encouraged, supported and guided me during the entire research and in particular during my data driven journeys whose destinations, to myself, were often obscure.

I would also like to record my appreciation to my family and the many friends and colleagues in ESA and industry whose frank and generous inputs provided much of the substance of this research.

DECLARATION.

The contents and conclusions of this thesis do not necessarily represent the views, opinions, practices nor intentions of the City University, London, England nor of the European Space Agency, Paris(HQ), France.

ABSTRACT.

In spite of decades of intensive study of practically all aspects of management, it still seems to be almost impossible to complete large development projects according to originally predicted timescales and cost. Examples are the Concorde supersonic airliner, the Channel Tunnel, the Humber Bridge.

This research started with the premise that the future is not predictable, and has concentrated on addressing the life-cycle dynamics of projects involved in the development of complex systems. It has also focused on the human characteristics of organisations with initial convergence to "open systems" concepts and the need to increase orderliness with increasing complexity i.e locally decreasing entropy.

The theme that runs through the thesis is that of assessing the current risk, and the likely tendency that such risk will increase or decrease in the future, that the project will be completed according to claims made by the contractor in his Bid to the customer.

An analysis of data from four actual projects together with various subjective appraisals by managers who were involved in them, and an assessment of the current state of related knowledge, has resulted in the formulation of a new type of management method.

The "new" aspects of the method relate to its ability to take into account the dynamics of the project circumstances as the project products pass through the design, manufacturing, testing, and operating phases. This is done by "taking soundings" deep within the projects working infra-structure.

During this development a number of conventional concepts have not been used. For example, the concept that a company exists within an environment that can be represented by hard-lined diagrams has been avoided.

The method involves the use of static and dynamic risk indicators, open and closed loop systems, and the utilisation of patterns constructed from real time data to identify whether the project dynamics are in a steady state, turbulent or chaotic condition.

The method also contains an "intervention" function as a necessary element to ensure that the project and corporation strategic aspects are adequately considered.

The method has been developed in a pragmatic manner such that it can be implemented by a practising manager.

EXECUTIVE SUMMARY

The prime objective of this research has been to identify why so many large development projects, world wide, significantly exceed their budgets and scheduled completion times; in spite of intensive analysis of the bids and comprehensive monitoring during the project lifespan. These discrepancies between prediction and achievement frequently result in impact at corporate levels and often cause strategic change to the companies concerned.

The secondary objective of this research, as important as the first objective but naturally penultimate to it, since it derives from it, has been the definition of a pragmatic Method, which could be applied with currently available management resources and expertise, to enable the above overruns to be significantly alleviated.

Both objectives have been achieved.

The main problems have related to:

- the presentation and processing of multi-dimensional data;

- the definition and monitoring of project dynamics; and

- the interaction of deterministic and behavioural aspects within a project.

The main findings of the research are summarised in outline in the next chapter, entitled "The Research Results", and relate to the prime objective.

The following chapter, entitled "The Dynamic Risk Management Method", relates to the second objective and is entirely based on the work done to resolve the problems related to the prime objective.

The final chapter in this "Executive Summary" addresses the application of the Method within an organisation.

The RESEARCH RESULTS.

The research was carried out in four main phases

Initially over 200 references were reviewed to establish the state of the art world wide of 15 subjects which relate closely to this research.(chapter 3 and annex 4).

The second phase involved a detailed examination of four multi-national projects involved in the design, manufacture, testing, launching and operation of European space vehicles.
This work covered the period 1973 to 1992 and resulted in

interviews and documentation review.(chapters 4 and 5, and annexes 6, 7 and 8).

The third phase concerned the analysis of the complete data set collected during phases 1 and 2. The results of the research were established during this phase.(chapter 5).

The final phase was devoted to the definition of the method and its application.(chapters 6 and 7).

The main results are summarised as follows.

1) **Currently used management methods for prediction, review and monitoring do not, in general, consider the complex, interactive dynamics present in medium and large development projects.**
The methods typically in use do not consider data in the integrated form in which it occurs in real life e.g. resource utilisation together with manpower and cost exspenditure with project time advancement.
In the planning domain, schedules are actually a series of static snapshots which are usually obsolescent at the time of print due to the long processing times.
In spite of an upsurge in recent years of the importance of inter-personal and psychological relationships, these aspects are rarely seriously integrated into the overall management and decision making structures.
They seem to be the root of many problems which are attributed to other causes.
A remarkable aspect of risk analysis is the variation in its definition, application and the quantitative/qualitative data on which it is based.

2) **Projects consist of flows or streams(see fig.ES-1);** they are defined as any activity which requires the expenditure of resources(money, manpower, time). These streams progressively bifurcate as problems arise and multiply, and workaround plans are implemented.
The increase and interaction of these bifurcations, which are not predictable and involve deterministic and behavioural aspects, **can cause the streams to move from relatively steady state conditions through turbulence to conditions of chaos(see fig.ES-2)** wherein the management do not know what to do to bring the situation under control i.e. to some form of predictability.

3) **The project streams relate to each person, individually and collectively, within the project.**
The problems that develop, assessments of their criticality and resource apportionment, are made by those persons. Each person and each committee to whom they report and each report that is generated by persons and committees form an information channel which EVENTUALLY reaches the executive decision makers e.g. the prime contractor.
Not only is the information very late in arriving at the executive decision makers but it is often corrupted due to

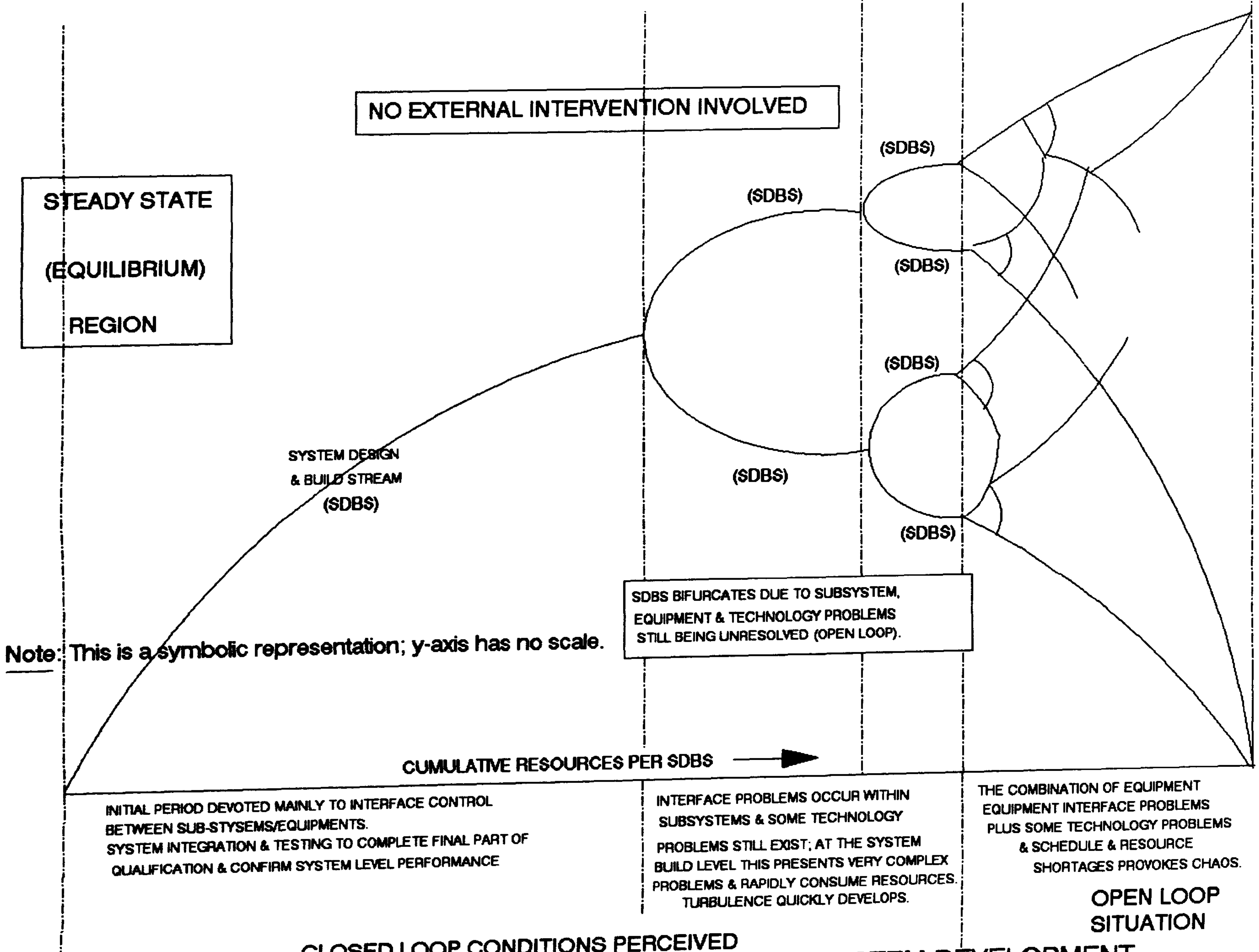


Fig.ES-1: PROBLEM PROPAGATION APPLIED to SYSTEM DEVELOPMENT

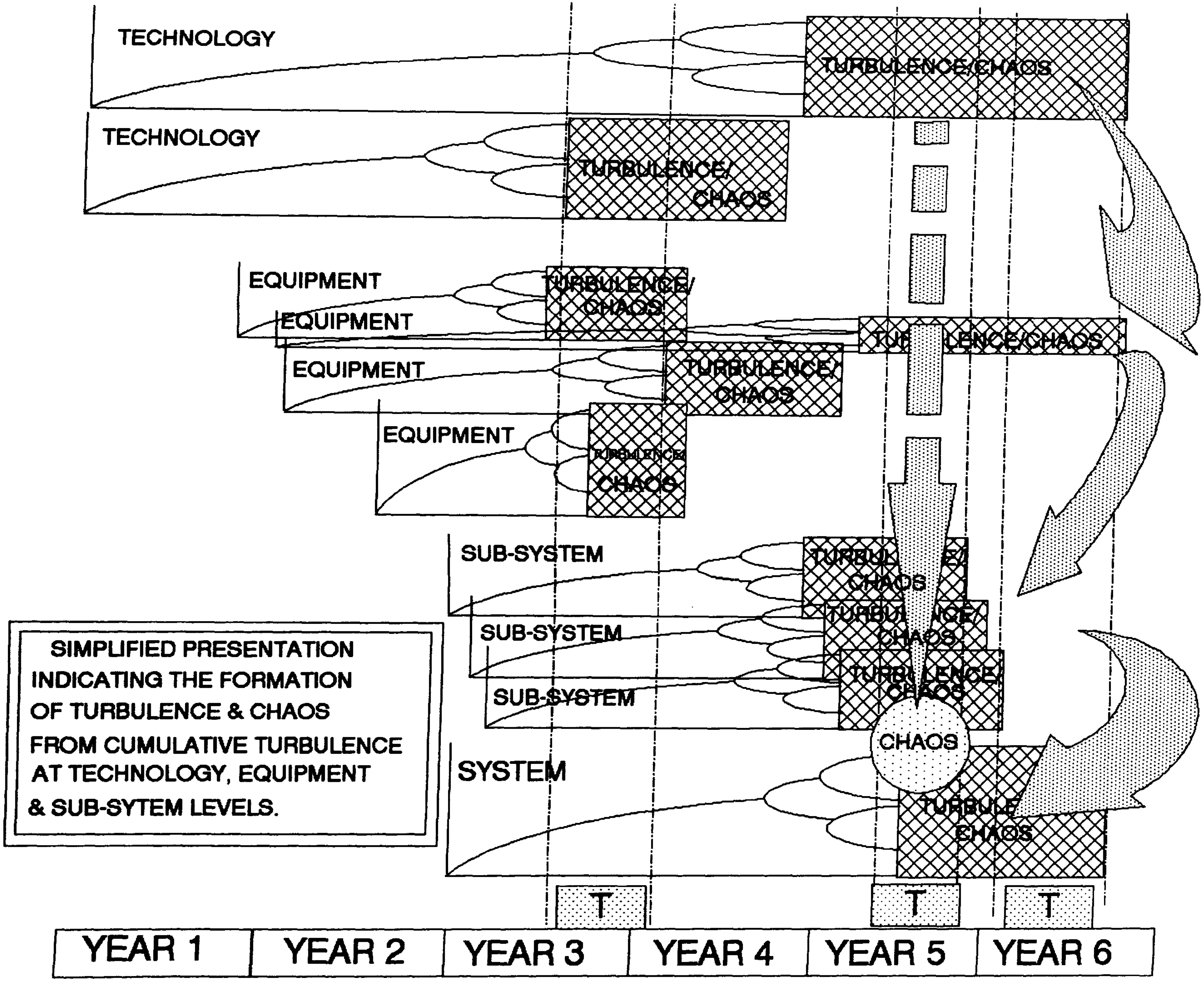


Fig.ES-2: PROBLEM PROPAGATION DIAGRAMS APPLIED to PROJECT LIFE CYCLE the large number of persons who "review and approve"(filter/censor) it before passing it to the next level(see fig ES-3). Personal as well as professional influences can exist in this process.

4) In order to obtain an "early warning" of possible change of project dynamics e.g. from steady state to turbulence, it is necessary to "take soundings" of the lower level streams. This can be done by requiring, contractually, that lower level data is immediately fed into a computer network such that it is available to executive management in almost real time. The data will have to be carefully processed and expert judgement will be necessary.
This data will form a pattern that will indicate the onset of a change in the dynamics.

5) Four main patterns have been discovered which can be used to manage project dynamics.

They are:

a) relating to 4) above, the **frequency** with which particular subjects* are discussed at various levels of meetings e.g. at sub, co, and prime contractors(see fig.ES-4);

b) the **evolution and impact of particular problems** as the project advances(see fig.ES-5);

c) the **characteristics of the reduction of project turbulence due to intervention** e.g. by the customer increasing resources or giving additional schedule time(see fig.ES-6);

d) the **structure of the initiation and growth of problems** producing a progressive splitting or bifurcation of the streams involved.

* The "particular subjects" are initially defined at the Bid review.

6) In order to realistically assess the adequacy of the resources they should be presented, and maintained, in 3-dimensional form to simultaneously include project timescale, manpower utilisation and financial expenditures(see fig.ES-7A).

7) Planning should primarily emphasize "open loops"(see fig.ES-8).
Open loops are defined as an activity or system in which the meaning or outcome of any of its elements either cannot be completely defined or cannot be directly linked with a previously experienced "similar" item which had a successful result.
The 3-dimensional resource presentations should clearly indicate how open loops have been accommodated(see fig.ES-

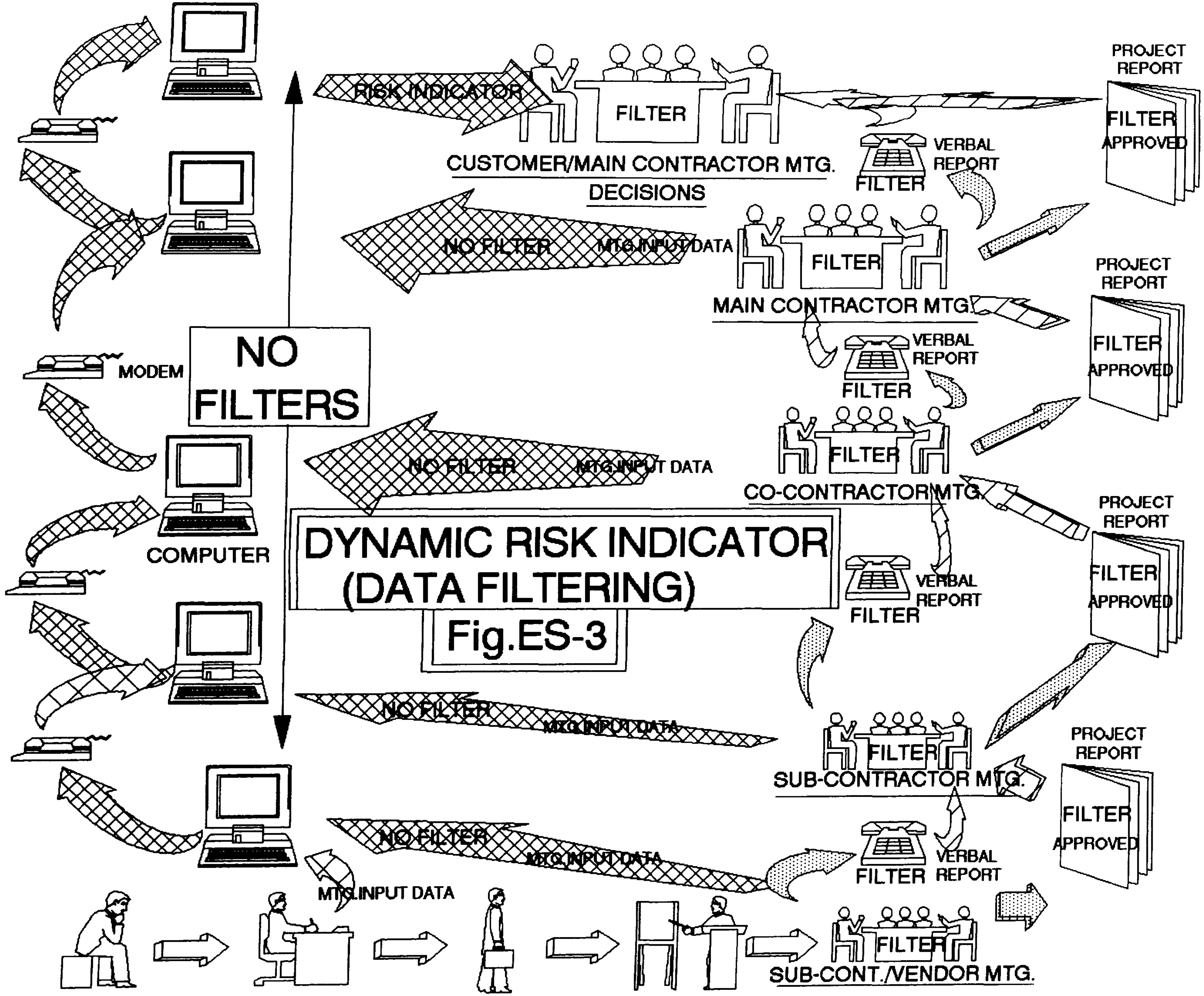
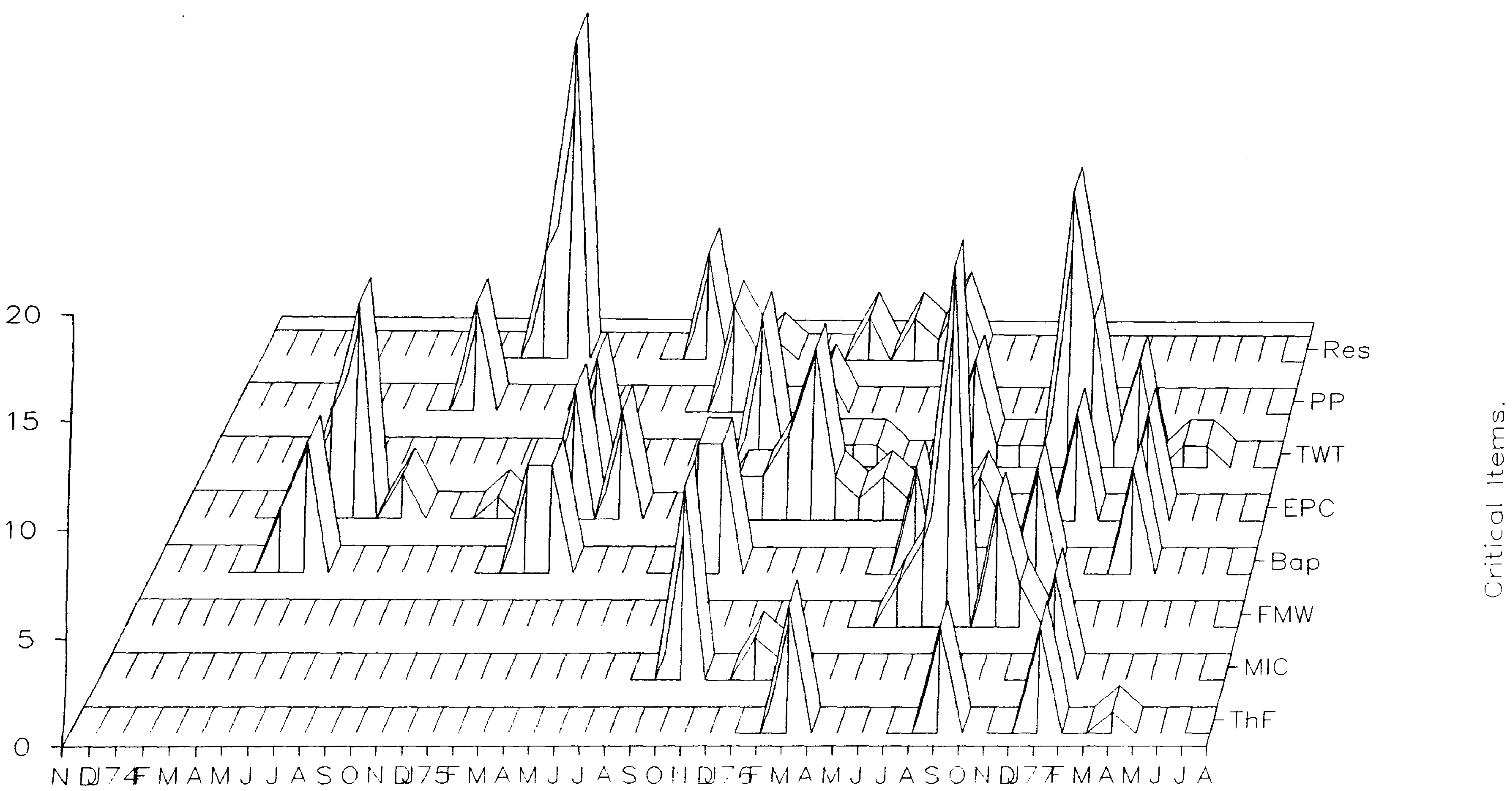
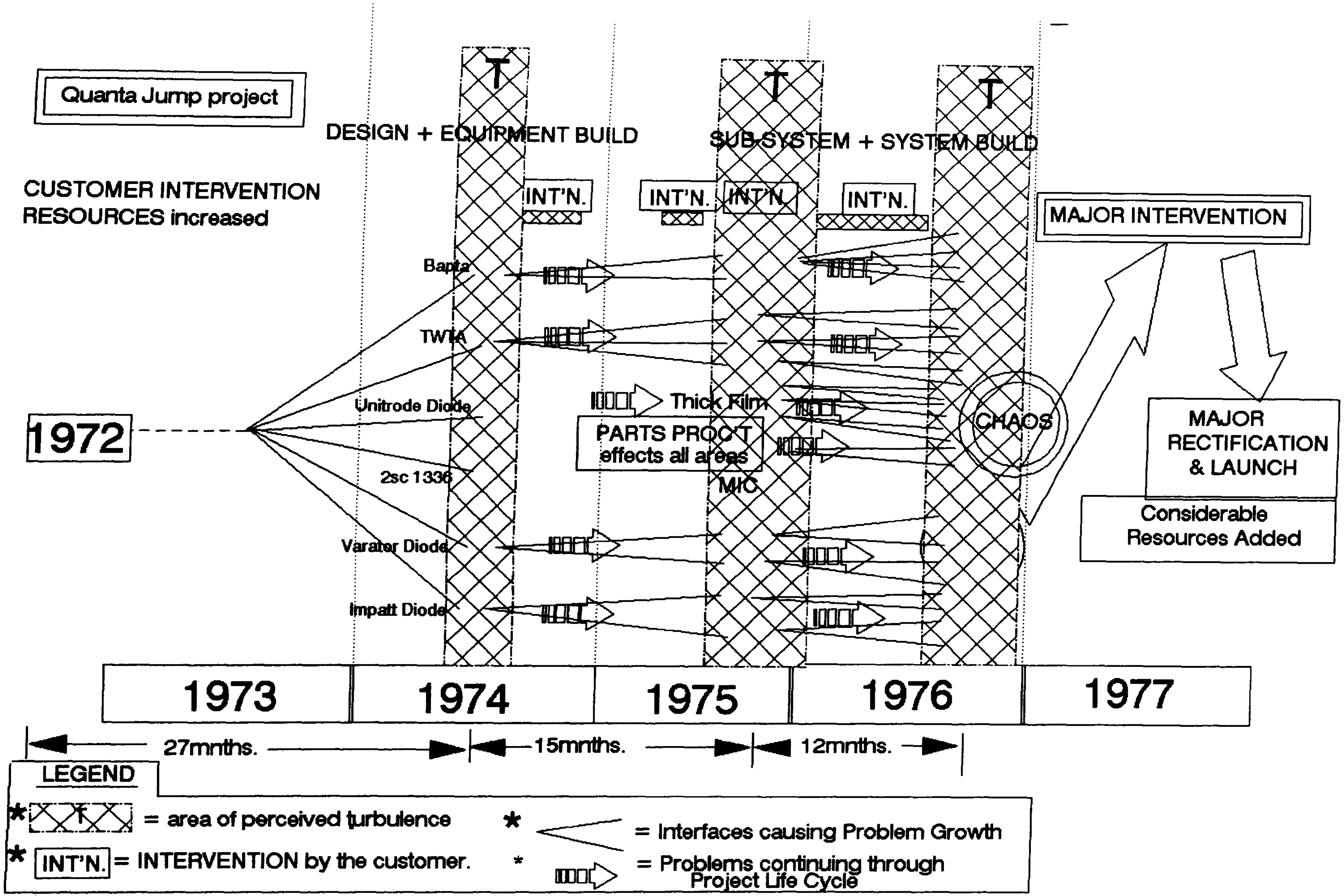

RISK INDICATOR
FILTER
CUSTOMER/MAIN CONTRACTOR MTG.
DECISIONS
PROJECT REPORT
FILTER
APPROVED
FILTER
VERBAL REPORT
NO FILTER
MTG.INPUT DATA
FILTER
MAIN CONTRACTOR MTG.
PROJECT REPORT
FILTER
APPROVED
VERBAL REPORT
FILTER
NO FILTERS
MODEM
NO FILTER
MTG.INPUT DATA
FILTER
CO-CONTRACTOR MTG.
PROJECT REPORT
FILTER
APPROVED
COMPUTER
DYNAMIC RISK INDICATOR
(DATA FILTERING)
VERBAL REPORT
FILTER
NO FILTER
MTG.INPUT DATA
FILTER
SUB-CONTRACTOR MTG.
PROJECT REPORT
FILTER
APPROVED
NO FILTER
MTG.INPUT DATA
MTG.INPUT DATA
FILTER
VERBAL REPORT
FILTER
SUB-CONT./VENDOR MTG.
Fig.ES-3

Fig.ES-4: Project A:Meetings Frequ's.

Dynamic Risk Indicator.(1974/77).





ACTUAL GROWTH of PROBLEM CONSEQUENCES due to INCREASE in NUMBER of INTERFACES as VEHICLE BUILD moves from TECHNOLOGY through EQUIPMENT & SUB-SYSTEM to SYSTEM LEVEL.

Fig.ES-5 PROJECT "A"

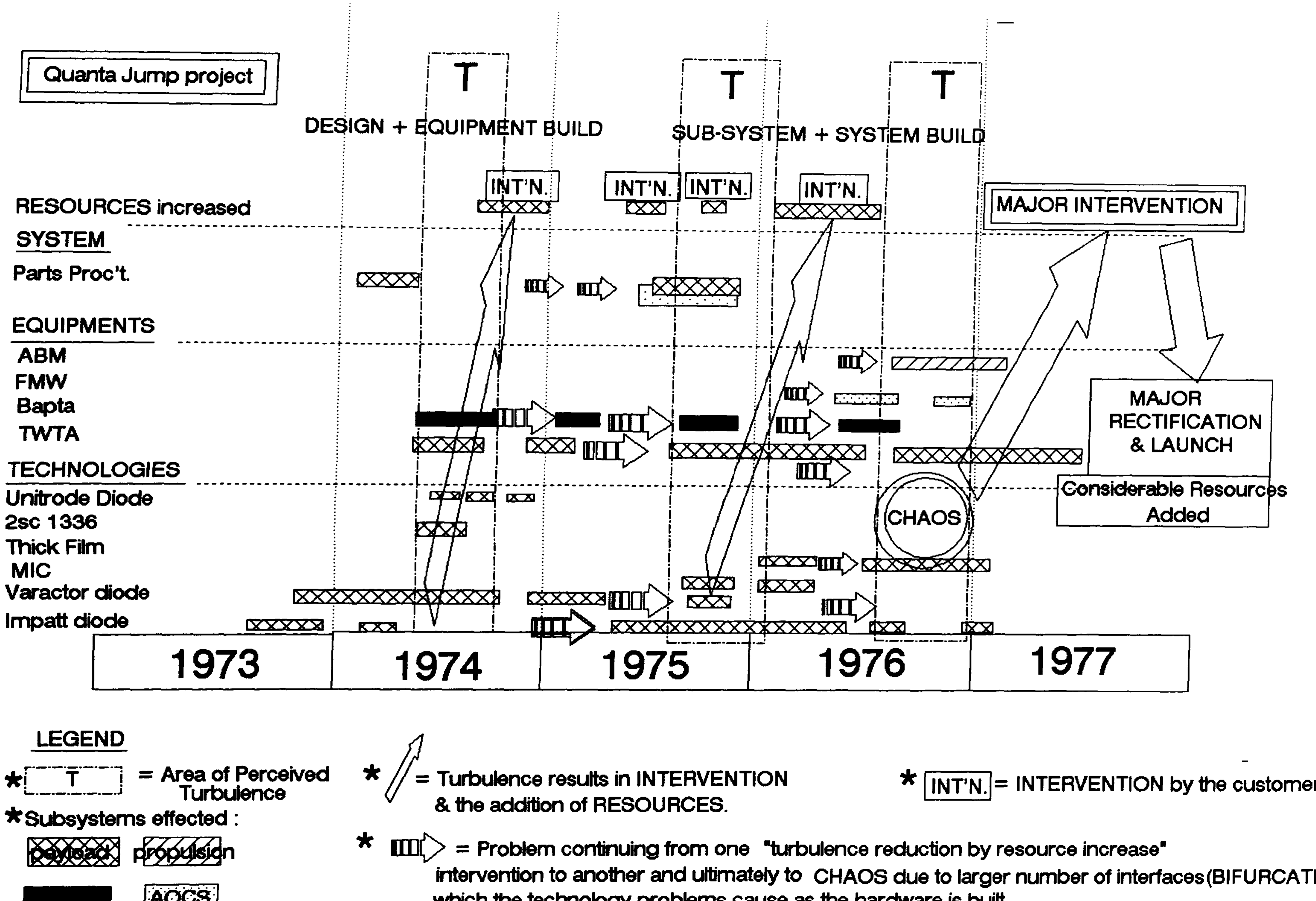


Fig.ES-6 PROJECT "A" AREAS/DURATIONS/INTERACTIONS and TURBULENCE/CHAOS of MAJOR PROBLEMS

Fig.ES-7A: Manpower/contractor/year
(1000s man-hours)

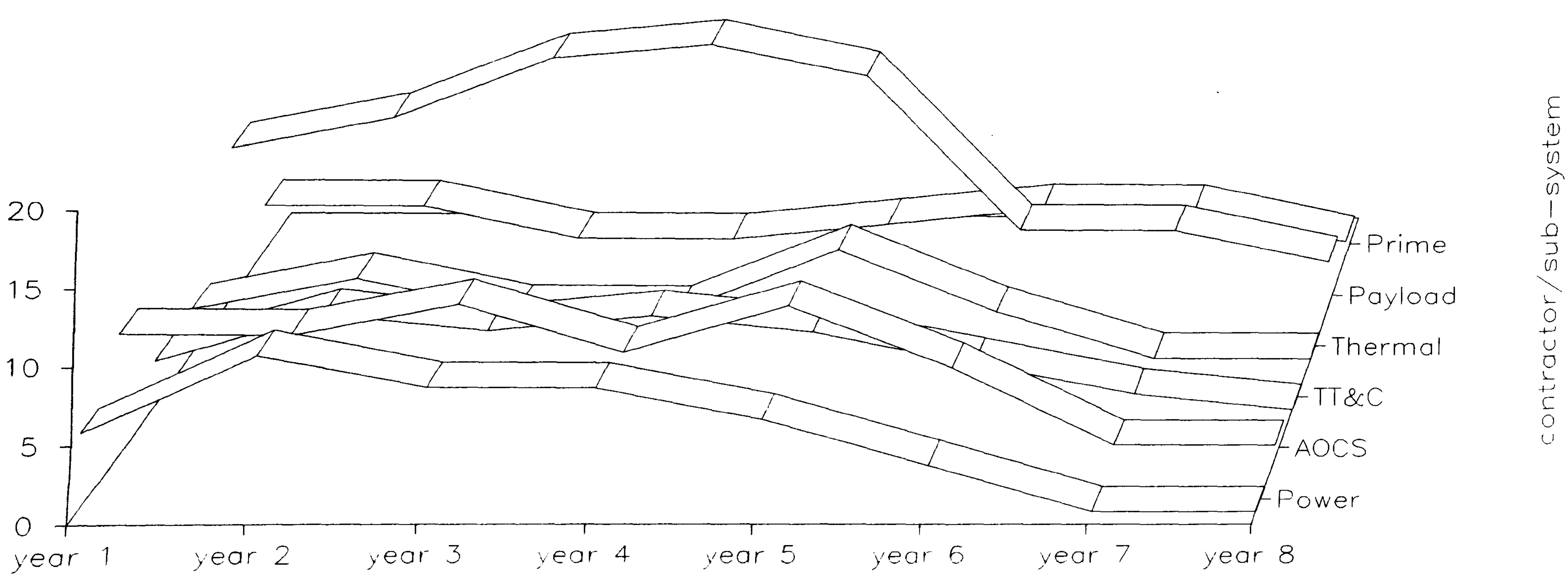
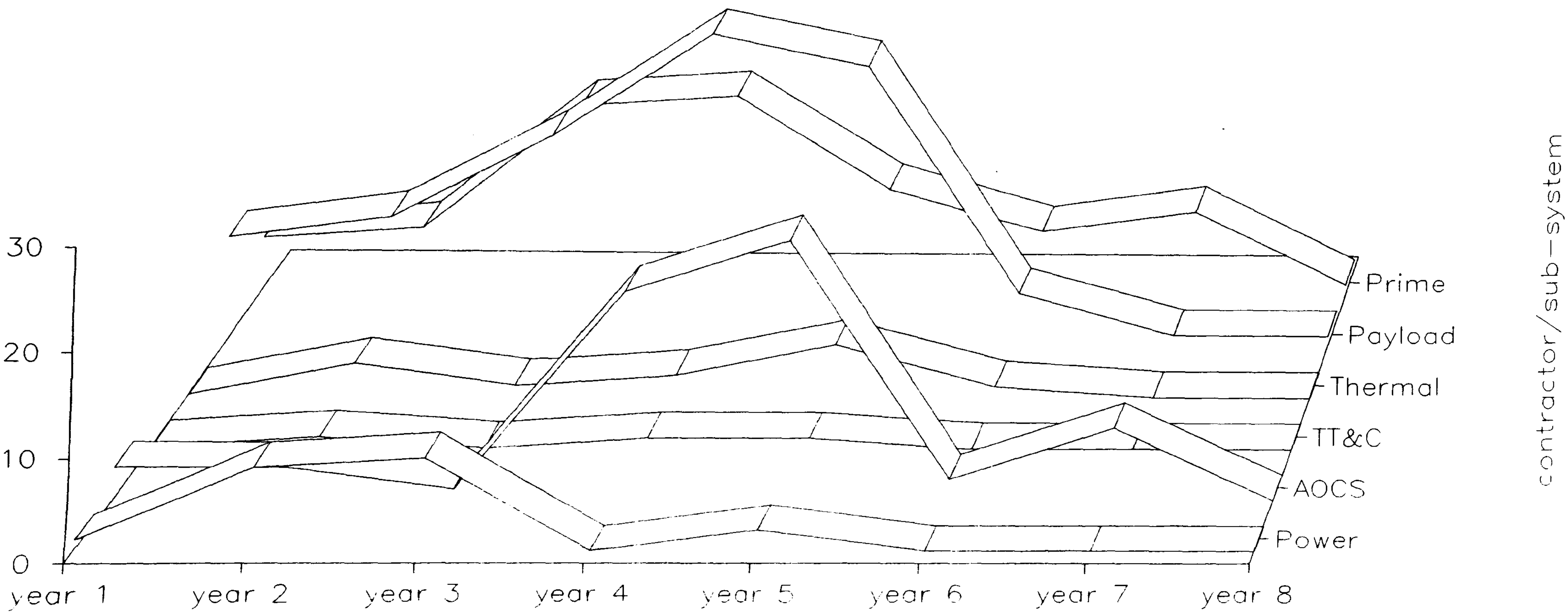


Fig.ES-7B: Main Open Loops Profiles

(manpower rqts. per open loop area)



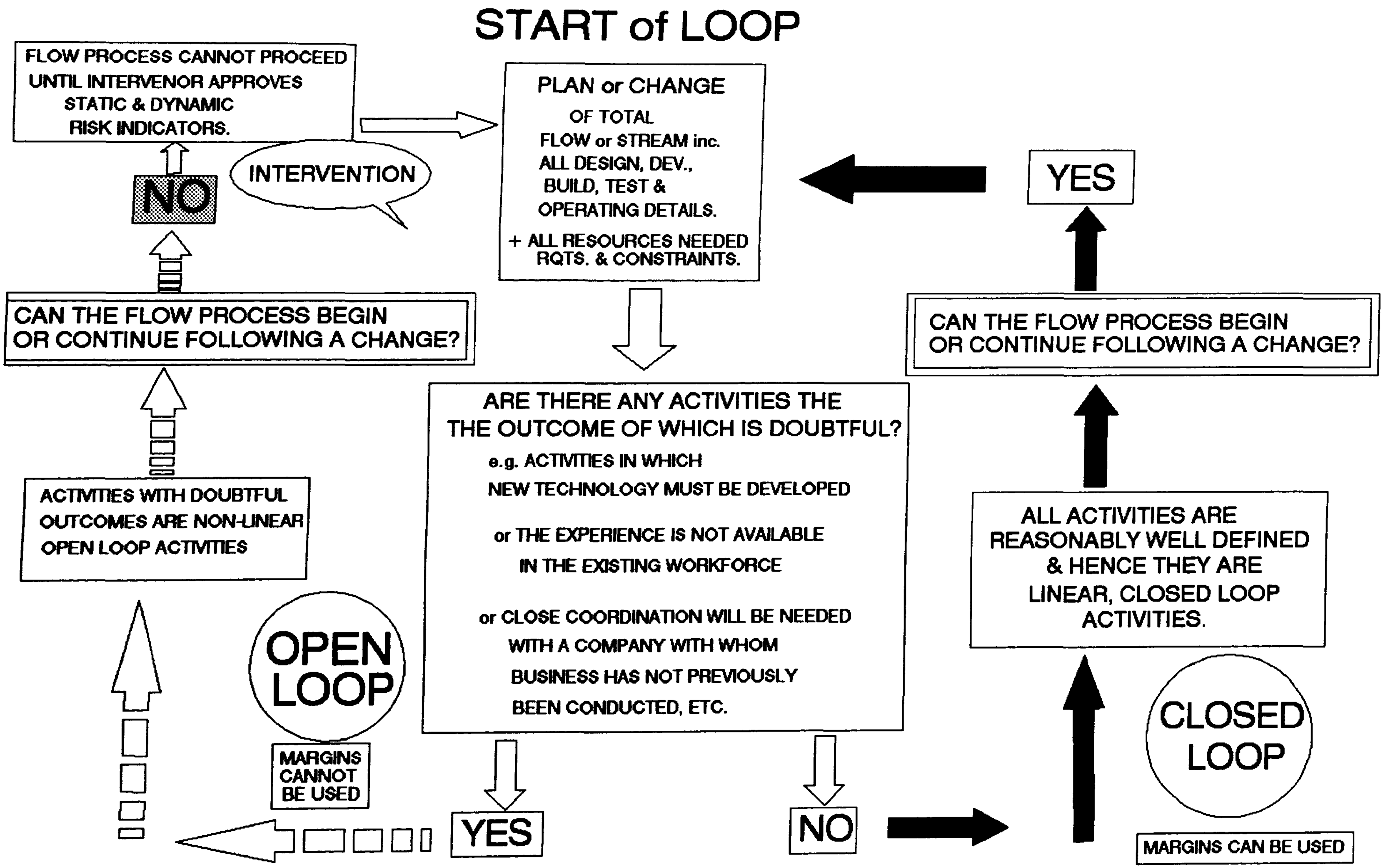


Fig.ES-8: MODEL of OPEN and CLOSED LOOPS.

7B).

8) Risk indicators, both static and dynamic and covering behavioural as well as deterministic aspects, should be used.
A static risk indicator is based purely on static or snapshot data whereas a dynamic risk indicator contains information concerning the increase or decrease of the flow rates(streams) within a project.
Examples of risk indicators, in addition to those mentioned above, are;

- lack of experience;

- the need to VISIT companies to make assessments;

- maintaining key people in post;

- rate of utilisation of schedule slack;

- the rate of reception of invoices and non-conformances;

- planners who do not understand the project subject matter.

- cultural and educational differences.

9) The role of "intervenor" should be established.
Intervention is defined as the temporary application of influence or control to a project by a third party e.g. a corporate level manager other than the project manager.
The intervenor primarily uses risk indicators, open loops, project phase close-out status and corporate strategy to perform his work function.

The DYNAMIC RISK MANAGEMENT METHOD(DRMM)

The DRMM overview is shown in fig.ES-9 and in detail in fig.ES-10, a) through e).

The fundamental objective of the DRMM is to identify and control those dynamic entities that could cause the project to move from steady state to turbulence.

The DRMM is based on the function of intervention; via the intervenor.
Two fundamental issues define the role of the intervenor; they are:

1) perception, covering behaviouralistic aspects, and

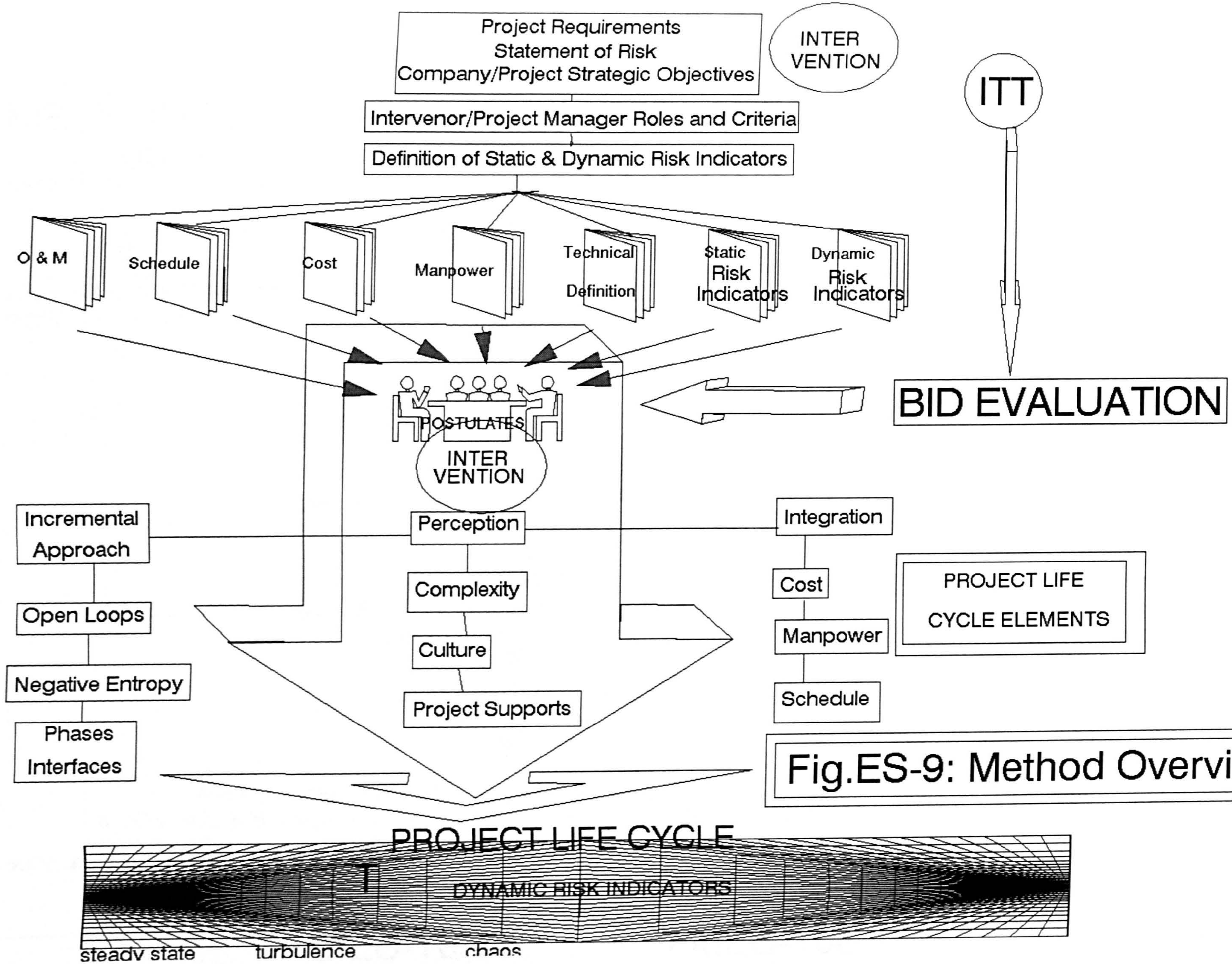


Fig.ES-9: Method Overview.

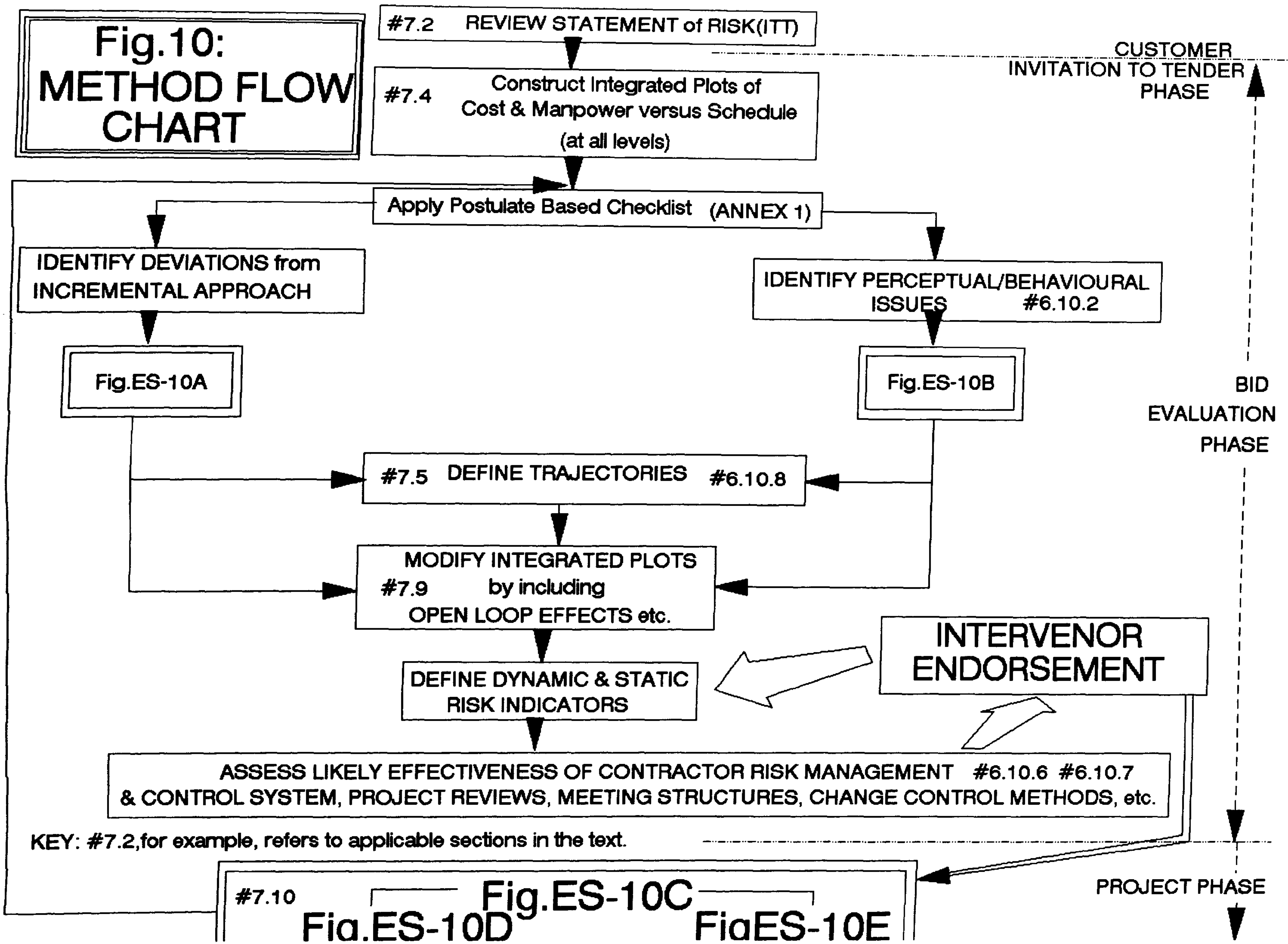


Fig.10: METHOD FLOW CHART

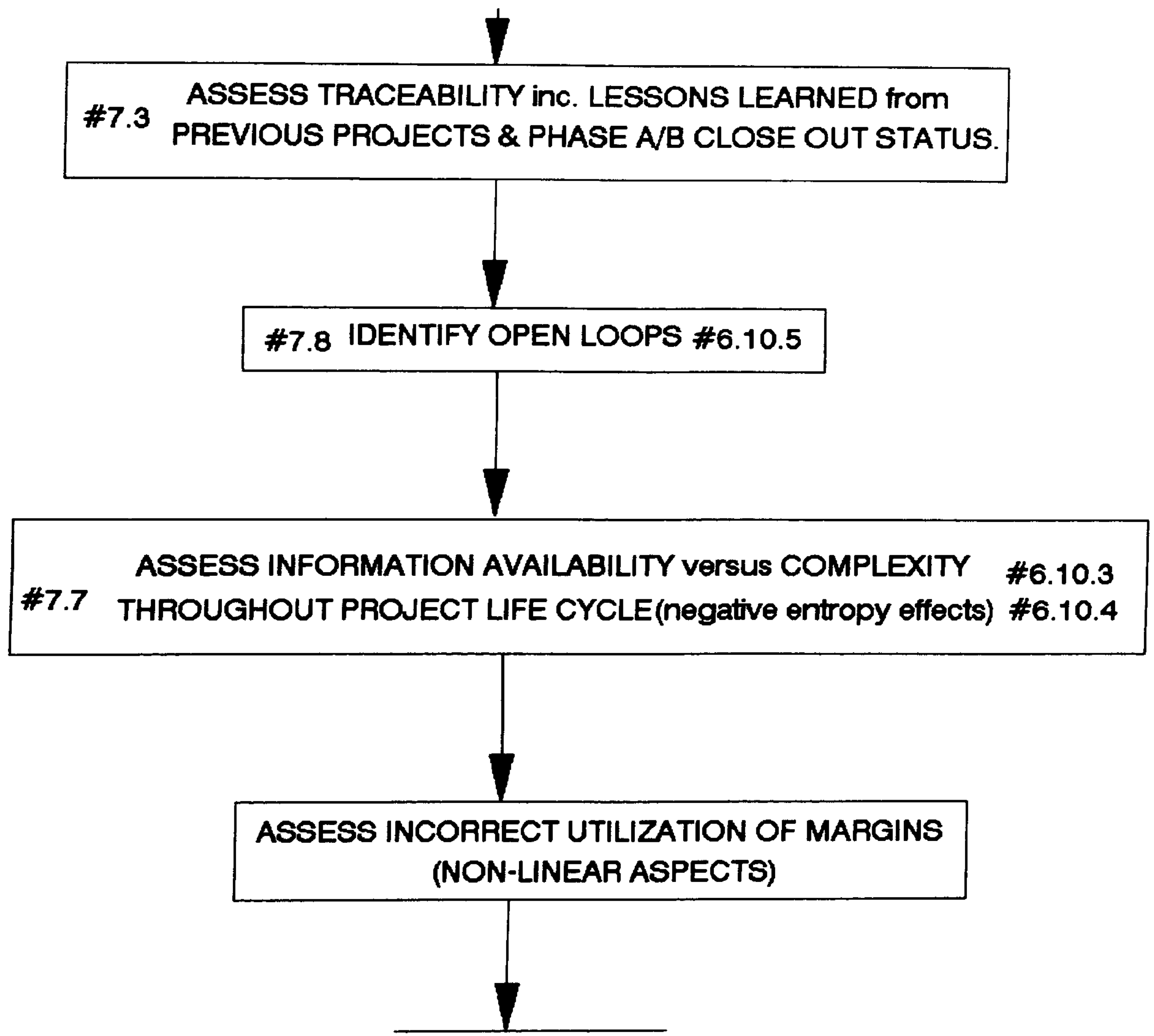


Fig.ES-10A: Method Flow Chart; BID EVALUATION PHASE.
(DEVIATIONS FROM INCREMENTAL APPROACH)

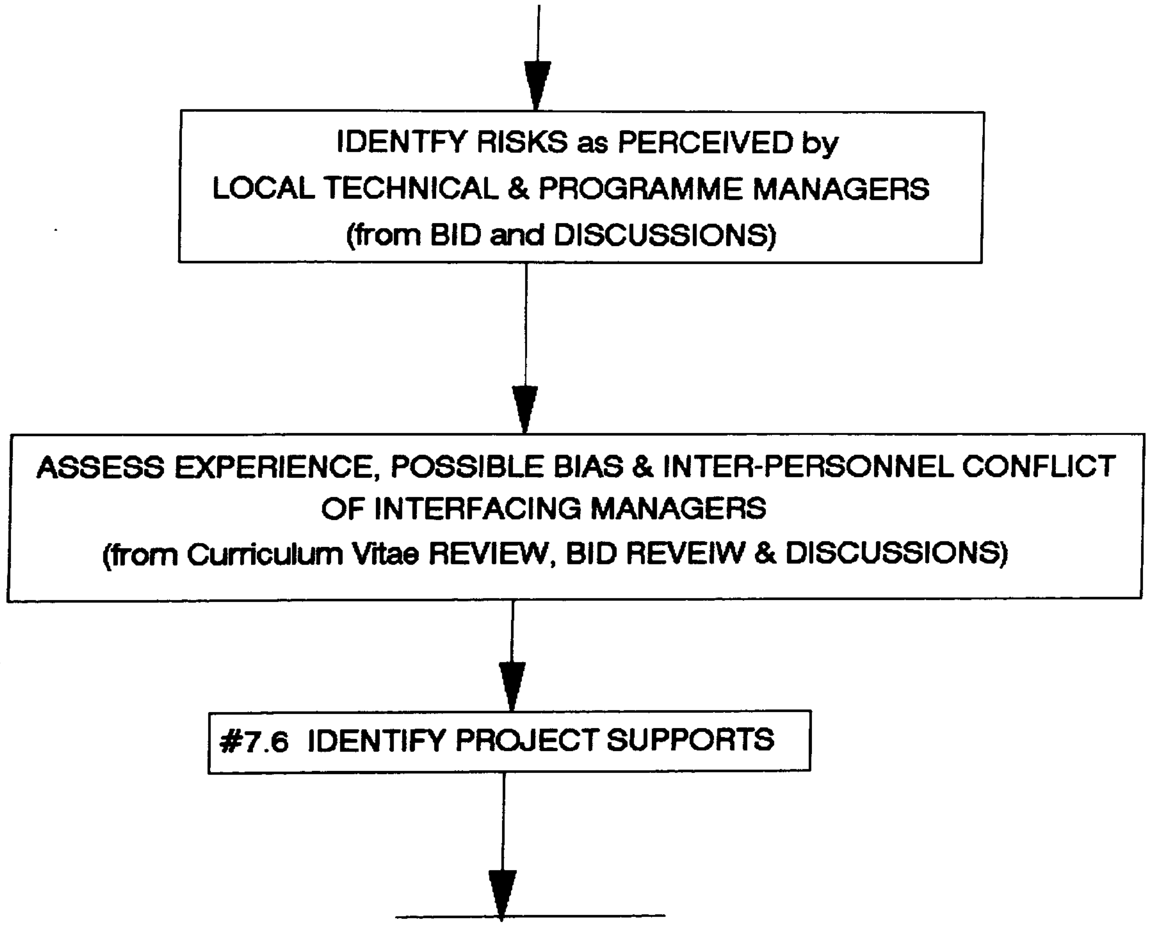


Fig.ES-10B: Method Flow Chart; BID EVALUATION PHASE.
(PERCEPTUAL/BEHAVIOURAL ISSUES)

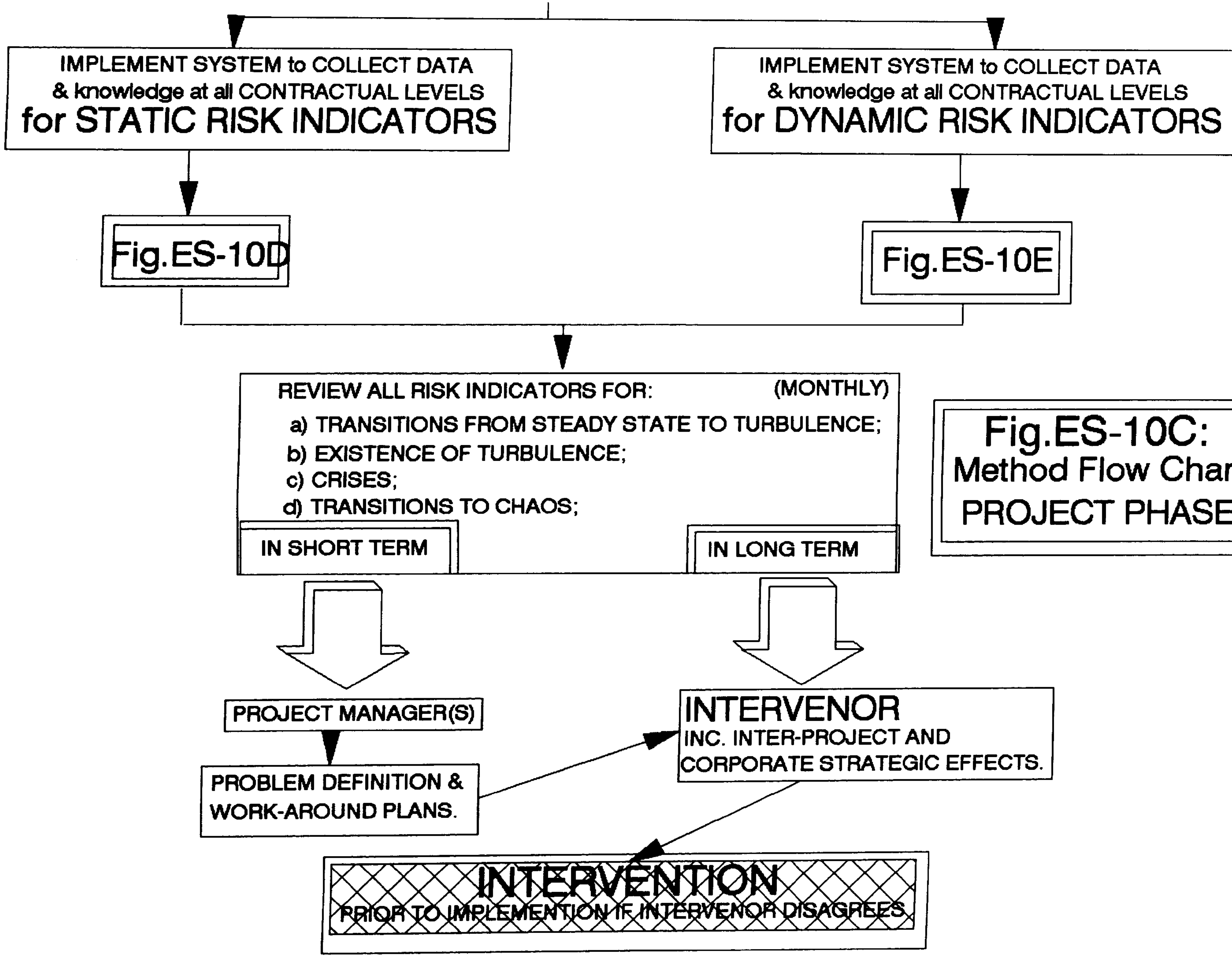


Fig.ES-10C: Method Flow Chart PROJECT PHASE

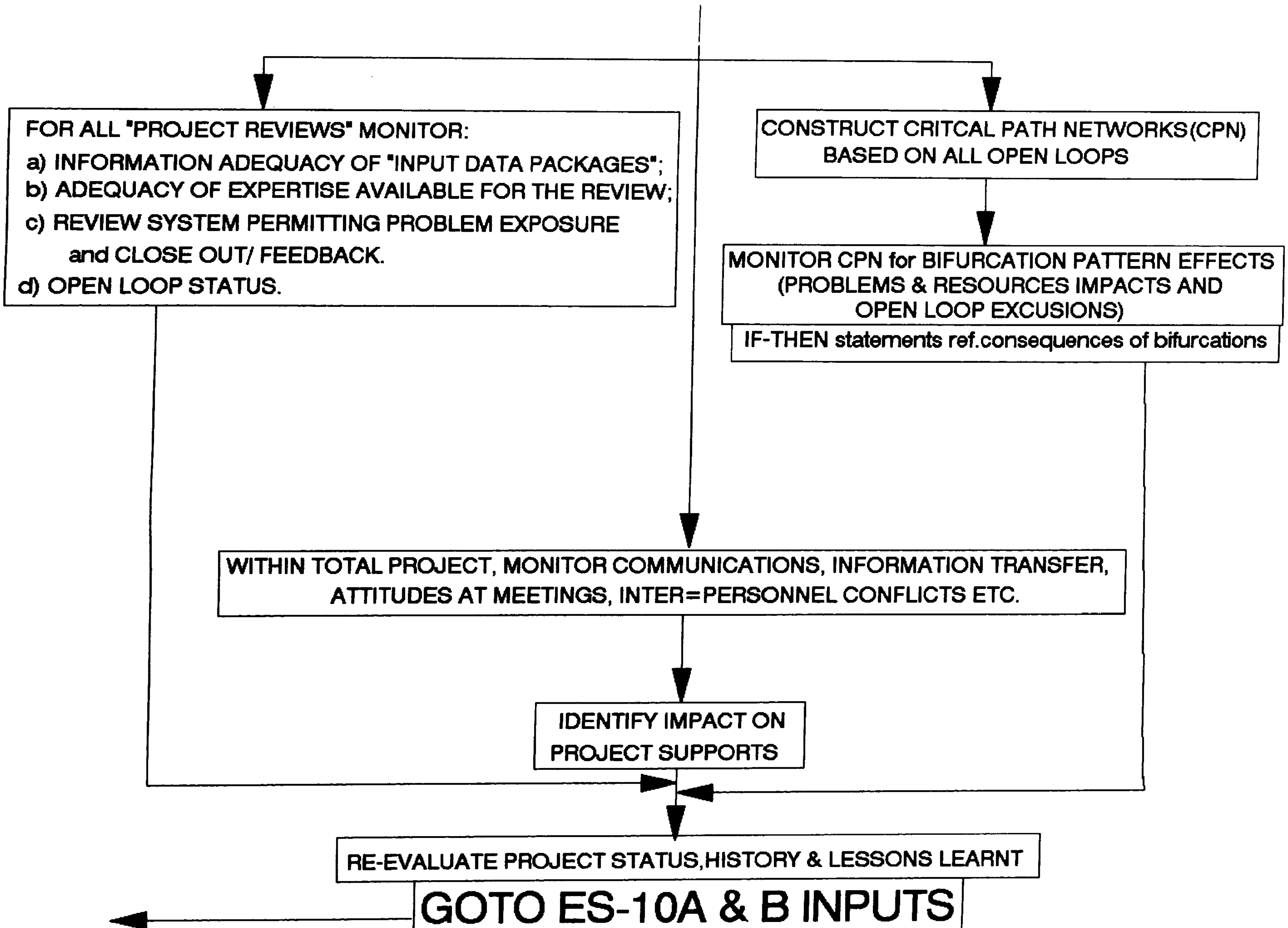


Fig.ES-10D: Method Flow Chart; Project Phase(STATIC RISK INDICATORS)

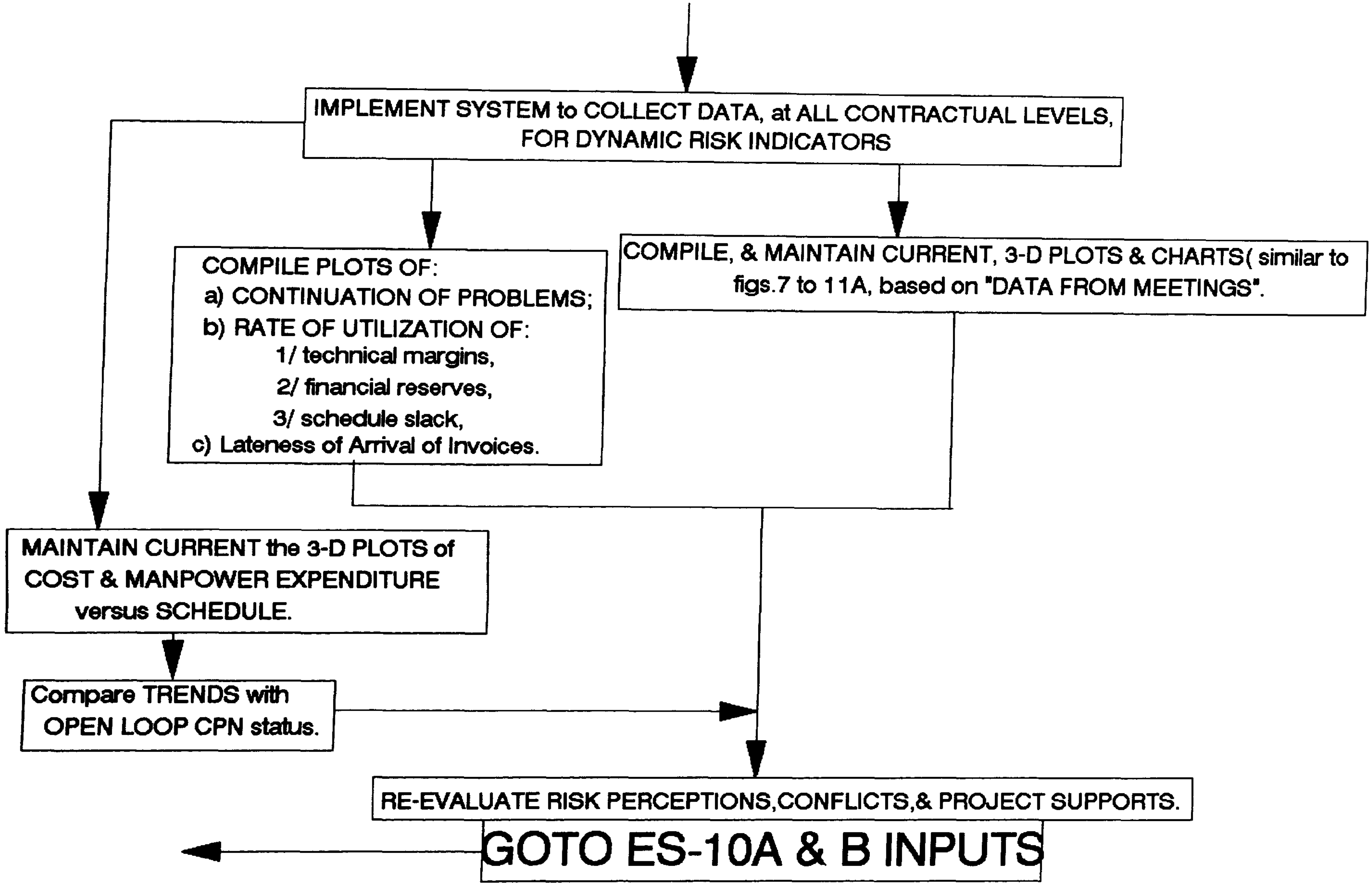


Fig.ES-10E: Method Flow Chart; Project Phases.
(DYNAMIC RISK INDICATORS)

2) the incremental approach, covering traceability and limitation of risk.

These two issues are addressed in the two branches contained in figs.ES-10 and ES-11.

The DRMM focuses primarily on the following aspects:

a) the agreement of a statement of the projects mission and acceptable project risk, by the customer and contractor;

b) cost, resources and performance data being presented and monitored in an integrated fashion;

c) evaluation of the project documentation and plans, at project commencement and during the project life cycle, in such a way that open loop and negative entropy situations and static and dynamic risk indicators can be identified;

d) characterisation of hard and soft aspects;

e) identification of the role of intervention utilising the four patterns that have been identified during this research.

APPLICATION of the DRMM.

The prime reason for incorporating the DRMM into organisations, now, is to increase management performance, to the point of credibility, for complex, development projects.
Not only would company strategies then become more achievable but society as a whole would benefit due to public utilities etc. becoming available on time and on cost; tax and social benefit schemes would thus be mutually more supportive and optimal.

The application of the DRMM would require organisational and cultural changes in the majority of industrial, contractor and customer, organisations.

The traditional polar role of project managers, or their immediate superiors, would be replaced by a team function at that level by the project manager and the intervenor.

The current segregation between the project manager level and the Executive Director level to which it reports would again be replaced by a team function by the Director and the intervenor.

The accountability of all parties would significantly increase with the utilisation of definitively defined risk indicators, open loops etc.

The blurring of Project Phase and Action close-outs would be outlawed and strict hierarchical project and corporate structures would be replaced by essential data sharing to enable the "interdependence-via-overlap" job functions to be achieved.

The intervenors influence would be felt at all levels since his bailiwick would have wide vertical and horizontal dimensions. A risk indicator Fault Tree could be used by the intervenor as an aid to his decision making activities(see fig.ES-11).

The central aspect of the DRMM is the access to low level data.
This characteristic would enable the achievement of the above organisational changes but would, itself, need a new type of "general contracting" in which such visability was made available.
Significant incentives, and penalties, would probably have to be written into the new style contracts.

Possibly the greatest change would be the DRMM requirement to consider, executively, the behavioural aspects of project personnel.
This would require attention to the inter-personal side of management, and industrial work in general, and would initially consume significant time and resources.
The intervenor would figure very significantly in this activity.

The result of implementing the DRMM would be the formation of an open type of organisation that functioned by knowing and working through its main strengths, per application, and minimising conflicts and risk situations. Such an organisation would be constantly reviewing its own competence due to the DRMM requirement for feedback and closed loops.

CHAPTER 1 : INTRODUCTION

1.1 Background and Direction of the Research

In spite of extensive research in the domain of organisational behaviour, decision making, strategic management etc. major organisations continue to experience catastrophes in their development projects. Originally forecast budgets and schedules are exceeded to the extent of causing local bankruptcy & threat to project completion; even though periodic updates are implemented. This phenomena is experienced in Space AND many other industries, both national & international e.g. the Humber Bridge, the Concorde airliner, British Railways High Speed Train, the Channel Tunnel, North Sea Oil Rigs, the Europa Launcher, and the ESA Hermes spaceplane. In government contracts the bankruptcies are often averted by additional funding.

It is clear therefore that methods do not currently exist, or are being utilised, which enable programme risk to be identified and controlled.

The focus of this research is the identification and control of total programme risk in a dynamic environment, relating to a development activity; the subject matter therefore relates to complex systems.

A starting point of the research has been the postulate that the future cannot be predicted with a significant degree of certainty. Predictions which are made, based on present and historical data for example, seem to be dependent on a number of assumptions which are often questionable and ambiguous. The sensitivity to initial conditions is the key to understanding why determinism does not necessarily imply predictability(153).

The above points have converged the research towards:

a) the development of a system which enables progress, or lack of it, to be measured incrementally in the case of "linear" activities; and,

b) the search for, and definition of, certain patterns to enable the anticipation of non-linear activities and their possible consequences.

A fundamental **HYPOTHESIS** relating to the research has been defined as follows:

" A development project, which is a complex, open system, commences from a **perceived steady state**, equilibrium condition. The planning representation of this condition consists typically of a number of interfacing **static** diagrams; strategic objectives are shown to be achievable within stated cost and schedule constraints; with **margins** in the technical domain and **reserves** in the cost area. An essentially **closed loop** situation is thus assumed as reflected by the majority of contracts being fixed price. Even the cost reimbursement and cost plus contracts have a maximum ceiling price so nothing is considered to be open loop.

As activity increases, the steady state is upset by problems which occur, **unpredictably**, here and there; their origins are within, or external to, the project authority and responsibility boundaries. An interplay of **hard** and **soft** aspects exists within these scenarios.

Due to the multiple, complex, and many common, interfaces, and the different **perceptions** by the involved parties, the problems generate other problems in a dynamic but still unpredictable fashion. The steady state condition thus becomes **non-linear** with many **open loop** situations.

Without **risk indicators** and **intervention** the project objectives will become increasingly vulnerable to the proliferation of problems; with resources being used in a fire-fighting mode but the basic causes of the problems remaining obscure. The achievement of the strategic objectives is not now definable nor predictable; the project is going out of control and constitutes a high risk element.

The above perceived increasingly unstable evolution is analogous to a flow condition moving from **steady state** to a state of **turbulence** and ultimately to a state of **chaos** as the flow rate is increased.

The inter-state movement takes place due to bifurcations which increasingly multiply if their reactions are allowed to proceed unchecked.

The **high risk consequences** can be avoided if the bifurcation patterns, involving both hard and soft aspects, can be identified thus permitting the restriction of excursions to the turbulent and chaotic states by utilising risk indicators and intervention. This constitutes the role of intervention in strategic change."

In summary, the study has focused on the definition of a mechanism of "intervention" and "risk indication" which, when applied incrementally and in conjunction with the pattern recognition aspect mentioned above should enable the changing risk, due to excursions from a strategic plan, to be limited.

In general the study has concentrated on the identification of the "risk related" systems and mechanisms that exist within companies, projects,and their "environments"; and how to use them in dynamic situations to contain the divergence of risk within certain limits.

The study has addressed, in particular, the European Space Agency development programmes. The space industry in general is characterised by the manufacture of a very small number of space vehicles of particular types. Single item or small batch production techniques apply; duration production scenarios do not apply.

Programme risk is considered with respect to the achievement, or not, of a-priori formally defined objectives. For a Space programme the objectives are usually stated in terms of the space vehicle(the product) obtaining a certain orbit operational performance, with specified reliability and safety requirements, and within declared cost and schedule limits. These objectives are in fact applicable, in a general sense, to most industries; not just Space.

Space activities have tended to have a "pioneering/adventurous" aspect in their image. This aspect has often conveyed the impression that Space development is different and not subject to normal business risks; the space shuttle "Challenger" accident, which resulted in the death of seven persons and practically reduced NASA(the U.S. Space Agency) to a standstill for two years, has largely dispelled that concept!

European Space Agency projects consist of a large number of technologically, culturally and linguistically differing companies brought together, usually as a result of political influence, to solve major technical and logistics problems with severe budget and schedule constraints. A lead contractor, usually referred to as the prime contractor, forms a consortium of the companies concerned and unilaterally represents those companies, contractually, with the customer; in this case the customer is the European Space Agency(ESA). The work is financed by the ESA member states, consisting of fourteen countries. In general they require contracts to be placed in their respective countries equivalent in value to their contributions; financially balanced on a programme by programme basis.

The organisations and methods used to manage European Space programmes are rather classical; mainly matrix type organisations utilizing typical project plans, reports, meetings and reviews. An unusual element is the generation of "critical items" from technical, hazard(safety) and reliability analyses. Unfortunately hundreds of critical items are generated and, with an inadequate system for prioritising or ranking them, they tend to be ineffective as a method of defining and controlling project risk.

A major element of the study is an analysis of the complete organisation including "hard"(technical, contractual) and "soft"(behavioural) problems.

1.2 Objectives of the Research.

The main aim of the research has been to determine a rationale defining why, when and how intervention should take place in a (European space) development programme in order to minimise the chances of failing to meet the objectives.

The objectives of the research can be summarised as:

1. extending currently available "fragmented" management methods, and data, to form an integrated Method which will also cover non-linear and "soft" aspects;

2. defining a system of intervention and risk indicators, with warning and control limits; including the aspects of perception, subjective judgement, qualitative data, etc.

3. determining the interrelationship of programmes, companies and their environments.

1.3 Scope and Limitations of Research.

The scope of the research subject matter is believed to be general however the Method and hypothesis have been derived and commented using data from the European Space Agency projects.

In the context of the above comment it is clear that the programme parameters being monitored in a different industry would be different and therefore the risk sensitivity of the programme objectives to them would have to be determined. This point does not address the method but only its application.

One of the basic reasons for the research i.e. the inability to predict the future, has resulted in scoping the study towards the identification and understanding of patterns; and their utilisation for risk identification and monitoring of the dynamic project life cycle.

The research has been directed at producing a general Method for applying intervention to a typical (Space) development programme; production manufacturing aspects have not been addressed.

The scope of the data collected during the study has been mainly related to the European Space industry.

The organisations, project methods and the authors own experience relate only to the European Space business.

A limitation of the research is due to the lack of recorded data on the subject matter. This observation has been made by many researchers e.g. N.Nelson et al.(70). This has resulted in the use of expert opinion and judgement; a subject matter which has generated some controversy e.g.at the 1981 Society for Risk Analysis Workshop. The various aspects of the above debates are not considered in this study however caution needs to be taken in extrapolating the findings of a group of experts to be "representative" of, for example, a group of general managers. Attempts have been made in this study to minimise this distortion by distinguishing between expert opinion based on "the experts actual experience" and "extrapolations" of his actual experience.

A major aspect of the study is that it has, to the extent possible, been based on the actual working environment in which projects "succeed or fail".
For example, assumptions concerning the availability and utilisation of sophisticated data collection, processing and presentation systems have not been made. Assumptions have also not been made concerning similarity of management styles nor the lack of effect of hierarchy on individuals; where there can be a strong cultural influences.

1.4. Outline of the Thesis.

1.4.1. General.

The following sections give a short summary of the research in terms of the content of the chapters of this thesis.

The numbers in parenthesis refer to "references" from the bibliographic review and this authors "notes" compiled from those references. The combined references and notes are contained in annex 5; a particular reference and its associated note carry the same reference number.

A number of terms used have a specific meaning for the subject matter of this thesis. The definition of such terms is given in annex 9. Examples of terms which have such specific meanings and for which the reader should become informed by consulting annex 9 are:

- open loops;

- negative entropy;

- open systems;

- non-linear.

The bibliographic listing is contained in annex 4.

1.4.2. The Aspect of Risk.(chapter 2).

This chapter presents an overview of risk, including quantitative versus qualitative issues and "hard" and "soft" aspects. It also discusses the impossibility of predicting the future and the attendant difficulty of assessing long term risk; and putting a cost on it! The overview addresses the three main areas of risk identification, analysis, and management.

1.4.3. An Assessment of the current "State of Knowledge" (chap.3).

In order to be aware of current thinking and practise in this area of research 240 references were reviewed; the detail results are contained in the "notes" in annex 5 and summarised in chapter 3.

The objective of this assessment was to identify definitive connections with the hypothesis and thus to provide correlation from the previous work of other researchers. Hence the following were established:

a) extensions to existing research, and

b) new initiatives where previous work does not exist.

The assessment was carried out using the following fifteen sub-headings:

- strategic definition;
- strategic planning;
- decision making;
- organisation;
- interventions - increments - feedback;
- risk and risk indicators;
- culture;
- perception;
- dynamic environment;
- systems approach;
- living systems;

- closed loop systems;
- open loop systems;
- open (self organising) systems;
- chaos;

1.4.4. The Environment the Method.(chapter 4)

The general circumstances in which the Intervention Method has to be used are outlined in this chapter. The manner in which the ESA space business is conducted is explained with identification of a number of shortcomings.
The European "Space" industrial infra- structure is also outlined together with infringements of contractor responsibilities often initiated by the customers. It is noted that ESA, with its dominating political pressures, has some dis-similarities compared with the purely commercial domain.

1.4.5. Knowledge and Data Collection and Utilisation (chapter 5)

1.4.5.1 Knowledge and Data Collection.

The knowledge and data which have been collected, and the location(in parenthesis) of that knowledge and data, in this thesis are as follows:

a) the current research status (annex 5 with a summary in chapter 3);

b) the current European methods of doing space business (chapter 4);

c) the evaluation of four projects; including orbit performance (annex 6);

d) the results of interviews of eight project and corporate managers (annex 7).

e) The authors experience, which covers interfacing with or working on all ESA projects, and a number of non-ESA projects, over the past twenty years.

Each of the above five locations contain "local" conclusions which constitute the starting point of the knowledge utilisation given below.

1.4.5.2 Knowledge and Data Utilisation.

The knowledge and data collected from the five sources outlined above has been utilised to establish support, or not, for the hypothesis. This work has included the following:

1) an analysis of the current status of relevant research and practices, under the 15 sub-headings listed in 1.4.3 above, to derive the following information.

a) Latest situation of each of the 15 sub-headings;

b) Supportive links with the thesis e.g.quantitative methods are inadequate.

c) Identification of problems, conflicts, and areas of lack of data.

d) Difficulties to define certain aspects in terms of "what they actually are" e.g. the dynamic environment, decision making(due to perception definition problems etc.).

e) Interconnections e.g. between patterns, risk, and resources.

f) Central concerns e.g. with perception.

g) Modelling concepts e.g. the physiology of perception.

h) New areas addressed by the thesis e.g. open and closed systems, open systems, non-linear aspects, risk indicators cf. points b), c), d), and f) above;

The above has produced 240 knowledge references.

2) an analysis of the results of the interviews with key project and corporate managers, see annex 7;.

3) an analysis of the "life cycle" documentation of four major development projects; see chapter 5. The following aspects were covered:

a) availability and authority of risk statements;

b) hard and soft risk indicators e.g. technology risk assessment, conflict situations, margins used in non-linear situations;

c) negative entropy aspects e.g. provision of appropriate data at the right time;

d) causes for orbit problems.

4) utilization of the 20 years personal experience of the author concerning such aspects as:

a) being involved in decision making at progressively higher levels;

b) witnessing project and corporate management in operation both at ESA and in industry, world wide;

c) noting the role of ambition, insecurity, ego, ignorance, etc.

d) noting planning assumptions such as static situations, linear future developments, blind acceptance of quantification.

e) recording the occurrence, propagation, monitoring and control of problems(1200 data points);

5) an analysis of the problems which have occurred on orbiting space vehicles(900 data points).

1.4.6. The Method.(chapter 6)

This chapter presents **the Intervention Method** which has been developed to enable analysis of actual project situations and thence to define the role of intervention in the presence of strategic change; the major characteristics of the model are summarised, very briefly, below.

The Method initially requires an assessment of the likely efficiency of the project, and its interfacing partners, to utilize data and resources such that increasing complexity, e.g. work load, problems, etc., will result in increasing orderliness i.e. an increasing ability to remain fully informed with clear definition and ranking of critical issues and appropriate use of resources.
This process establishes the "open system" characteristics of the project.

The Method then requires the classification of **all** the activities of the project(s) into **closed loop and open loop** systems; with margins being permitted only in the closed loop systems, and **expert systems and pattern recognition** being used in the open loop, non-linear, systems. The latter enables the "unknown risk" aspects of an open loop system to be enveloped and emphasises that knowledge transfer will probably dominate data availability.
It is further required that the "margins" and the "unknown risk" envelopes are defined in terms of the resources required to achieve the particular task and to solve the related problems.

The Method depends on a clear understanding of the project elements and critical support items.

The term element is used in the context of "a datum or value necessary to be taken into consideration in making a calculation or coming to a conclusion; as an example the elements of an orbit, in astronomy, are the quantities whose determination defines the path of a planet or celestial body, and enables us to compute the place of such a body at any past or future epoch."(206). In this thesis the astronomical example is rather appropriate since it addresses a dynamic situation and even has the commonality of "trajectory".

Nine "hard" and "soft" project elements have been identified; they are as follows.

Hard elements:
- margins
- closed loop systems
- engineering data

Soft elements:
- open systems
- decision making processes,
- complexity,
- trajectories,
- interventions,
- project supports

A project support is analogous to its namesake in a structure but in this case refers to those aspects of the project that are essential in order that the main objectives are achieved. They relate to the stability of the dynamic equilibrium of open systems.

The use of **risk indicators and pattern recognition combined with an incremental approach** constitutes a central aspect of the Method in order to enable its pragmatic application to minimize deviation from the strategic plan and risk statement.

This chapter contains criteria to enable a project to be assessed vis-a-vis the application of the Method.

1.4.7. Advantages gained by Using the Method.

This chapter outlines the advantages to be gained, and the currently experienced problems which can be avoided, by using the Method.

The utilisation described in this chapter makes no assumptions concerning the availability of very sophisticated tools or data and knowledge.

1.4.8. Summary & Conclusions.(chapter 8)

A summary of the main elements researched is covered including an explanation of how proper application of the Method would avoid many of the problems experienced in the past.

Conclusions are given and the main contributions of this work to research.

Chapter 2. The Aspect of Risk.

2.1 The Definition of Risk.

Risk is typically considered in terms of uncertainty, hazards, threats, unknowns, lack of success, failure, relative merit, etc.

These considerations are applied to the whole spectrum of challenges ranging from Mega-projects, involving billions of pounds, thousands of personnel and many years of work, to relatively small single product projects.

Risk fundamentally addresses man's concern with unknowns; the greatest of which is the future.

Definitions of risk vary from qualitative to purely quantitative; the latter relating to a numeric risk requirement. A number of researchers have evolved the following definition of risk:

"risk is a probability-weighted, non-decreasing function of payoff dispersion below a specified target".

This definition implies a **quantitative** approach.

An example of a **qualitative** risk requirement is that " no single failure at any point in the system shall cause the overall objectives not to be met."

The **definition of risk**, by the author, used in this thesis is as follows:

" risk is a function of the perceived probability of the occurrence of a known hazard(s), the perceived severity of the consequence(s) of that hazard, and the associated assumptions"

This definition states that risk is limited by perceptual capabilities; the latter are a function of the human analyst and the system and organisation in which the analyst is situated. Hence absolute risk is considered to be a fictional entity; pragmatically it is used on a comparative basis.

It is necessary to define the **"thing"** that is being considered when referring to risk, or increments etc.; the risk to "what" and the increment of "what", etc.?

The definition used in this thesis is that the "thing" is considered to be:

> **"the capability of certain resources to create a product or service with a certain reliability and safety".**

In the above definition it is important to understand that:

- reliability includes the probability that a certain performance will be achieved for a specified time, and that
- safety embraces the risk that:

  life,

  the system, and

  the mission(project objectives),

will not be destroyed nor degraded beyond a specified limit.

2.2 The Analysis of Risk.

As indicated above, "perception" and therefore "subjectivity" play a dominant role in the definition of risk. In fact man's perceptual limitations are considered to be a major driver in requiring intervention in the project affairs as the project "apparently" progresses on its strategic path. The word "apparent" has been used to emphasise that the project managers "perception" of the projects strategic congruence may not conform with the perception of his superiors.

An immediate problem facing the project manager and risk analyst is that knowledge and data are often available in a rather incomplete manner with respect to the total system. The total system is considered to consist of hardware and software elements and the interface with, and the involvement of, man. At this time, in the development of engineering and the natural and behavioural sciences, quantitative data is inadequate to model the "hardware/ software/ man" aspects of a typical development project. Recourse must therefore be made to qualitative assessments which must be able to combine judgemental(perceptual) knowledge with quantitative data.

A commensurate problem with the above is the impossibility to predict the future even though the project manager is required to "predict" that the project objectives will be achieved within certain resource and time constraints. This "prediction" is often required for a 5 to 10 year period after the Bid submission date.

There are a number of dimensions to the aspect of risk. For example, one can refer to the risk of the technology failing; reliability analysis attempts to cover this aspect but adequate data and methods exist only for electronics.

One can also refer to the risk to man; either in, or adjacent to, the vehicle or in overflown populated areas. Safety and hazard analyses attempt to cover this aspect. Once again this is data and method limited.

A major issue, in the opinion of the author, is that neither reliability nor safety analyses are used concurrently with the engineering design process. They are, partially, used after the initial design has been established. This practise often results in severe conflict situations between designers, product assurance personnel(responsible for reliability, safety and quality aspects), and managers. The overall result is increased risk due to lack of optimal resources for:

- territorial,
- subjective,
- non-integrated,
- inadequate problem orientation,

reasons.

Postulate 1: The degree by which the reliability and safety/hazard analyses are not concurrently used in the design process needs to be represented by a risk indicator.

In addition to the above one can also refer to cost and schedule risk; both being tied to the technical(reliability and safety) dimensions but involving other inputs such as management, and efficient use and availability of resources.

This introduces the concept of HARD and SOFT aspects; the former referring to engineering rules, dimensions, quantities and laws; etc. and the latter to behavioural aspects such as beliefs, culture, experience, personality and traits.

The definition, role, effects, extent and interactive influence of soft aspects is not significantly addressed in current project and corporate management from the risk identification viewpoint.

Postulate 2: Soft aspects can constitute major potential risk generators and must be assigned risk indicators. The interface between hard and soft aspects must be addressed in the definition of the risk indicator.

2.3 The Management of Risk.

The management of risk is generally based on the following steps:

1) the elimination of the hazard;

2) the minimisation of consequences of the hazard;

3) the control and containment of the consequences of the hazard.

Risk management thus requires a clear identification and understanding of the hazards themselves, the consequences of their propagation, and a detailed technical and behavioural understanding of how the system functions; the role of man is particularly important, and constitutes a special area of vulnerability for the system.

The modelling and analysis of the system is essential for risk management and criteria must be established by which hazardous conditions can be classified as acceptable or not. In the risk analysis environment great attention is given to the existence of common mode and common cause failures. For example, an aircraft with four engines being supplied from a single fuel tank would have a common cause failure for all engines if the fuel tank ruptured. If all turbines failed after 10,000 hours operation due to design-fatigue problems then a common mode failure would have occurred.

Comprehensive risk analysis and management are rarely implemented due to the complexity of the models and the large amount of data and computing power. There is also a high dependence on subjective aspects and knowledge bases; both of which are generally unavailable.

The situation at this time is that general analysis of risk is carried out at the system level and, as part of the risk management function, certain highly vulnerable areas are subjected to detailed analysis and management.

Chapter 3. An Assessment of the "Current State of Knowledge"

3.0 General

This chapter contains a selected summary of an extensive bibliographical review; the bibliographic reference(annex 4) is given in parenthesis. The various statements and conclusions summarised herein are:

a) used to help substantiate the work in this thesis, or

b) disputed, with justification, due to the current work not being supportive of them.

The results of a) and b) have been used to validate the hypothesis; see chapter 5, Knowledge and Data Collection and Utilization

A complete set of notes per reviewed item is attached to this thesis as annex 5.

Many of the headings used in this chapter correspond to those used for the model in chapter 6. This has been done to facilitate correlation.

The model has been developed from an analysis of the bibliographic review, the authors experience, the project studies, the interviews, and in-orbit experience.

3.1 Strategic Definition

The definition of strategy is variously described in the research as:

a) the set of basic characteristics of the match an organisation achieves with its environment(11);

b) the actions & resources necessary to achieve long term goals(4);

c) the definition of what business the company is really in(4);

d) having only corporate, business and functional levels(5);

e) referring to information flow and decision making hierarchy(6);

f) the results of "purposeful social units" (organisations) co-ordinated to contribute to goals(7);

g) the array of options and priorities with which one elects to compete and to survive(10).

h) operational data is more concerned with measuring internal performance and has predominantly a cost control function. Tactical and strategic data begin to look outwards towards markets and how the organisation is going to position itself in those markets.(76).

The differences of the above definitions are indicative of the difficulties that have been experienced by researchers and company management and strategists in defining the role or function of the company and its dynamic environment; the latter is specifically addressed in chapter 3.9. The differences are indicative that different people perceive strategy in a different way. Relating to the hypothesis this indicates that the perceived steady states, or whatever various people conclude a particular state to be, may be different because of the different perceptions of both the state and the applicability of the criteria they are using.

This is a major point. Since strategy is defined in different ways one cannot directly compare programmes and these different strategic perceptions could occur in the same project, company or consortium.

This thesis has essentially adopted the definition of Hofer & Schendel(11) whereby the strategy of an organisation is defined as:

"the means of coping with both the external and internal changes; the path charted for the organisation being linked to the organisational goals & objectives which are to be achieved."

3.2 Strategic Planning.

The concepts of what strategic planning is, and what it entails, do not vary widely but some significant differences do exist; the main points are summarised below.

a) Since we are still in an industrial revolution the Japanese will continue to lead because they have the characteristics that Europe and the USA had at the time of the commencement of their industrial revolutions(8).

b) Forecasting consists of the identification, translation and development of objectives and resources(9); strategies can form as well as being formed(18).

c) Strategic planning is a journey and probes the need for change(10); it often emerges rather than being separately formally defined(49). Its management relates to the implementation of modifications in the fundamentals of how one competes and survives(10); and to the crafting of thought and action, control and learning, and stability and change(18).

d) A strategic plan should include risk, audit and prioritisation functions(11); the three planning horizons of cyclical(< 5yrs), architype(< 15yrs), & exploratory (> 20yrs) apply(15).

e) Strategic goal setting provides a means of reducing environmental turbulence and controversy(12) and relates to the socio-political(involving scanning and solicitation) nature of the organisation, to perception(13,15,55) and to upper level management interpreting unanticipated environmental events(13); it is a step-by-step process involving trends and options(14).

It is not known how to measure success or failure and debate appears to have negative connotations for executives; most managers seem to understand the complexity of the strategic problem formulation process(13).

f) Technological strategy is institution building, political, and positioning(39).

g) Benchmarking of competition is used to define and modify strategic plans.(64)

h) Many strategies develop not through any formal strategy formulation process but through the emergence of a pattern, often unintended, in a stream of decisions made by an organisation.(55).

i) A power-strategy model containing external environment, departmental capability, organisational tradition, operational procedure, departmental power, managerial perception of the environment, personal preference, strategy formulation and implemmention, realized strategy, and emergent strategy elements has been defined(55).

j) the morality of planning & management is covered under three definitions relating to:

  1) exploitation(defines co-operative behaviour by comparing the effectiveness of my best action with and without the presence of your behaviour;

  2) the application of Kants moral law (the ultimate justification of a principle for assigning benefits costs is that it must be capable of becoming general law)(68);

  3) it is immoral to treat people like machines(75).

The statement by Denning(16) that "strategic change still appears to happen largely as a result of crisis or from the impact of a key individual" supports the raison d'etre of this research work.

Strategic planning seems to include goal setting, risk, resources, external and internal influences, capabilities, and morals. Although there appears to be a common thread because the subject matter relates to the definition of strategy since the latter has significant variations, the strategic planning process is also likely to be different. Maybe the result would be more a matter of different emphasis but these differences could prove major because resources and decision making would follow those different emphases.

The references, sometimes rather oblique, to living systems, incrementalism and perception are significant and constitute important links with three of the main thrusts of this thesis.

3.3 Decision Making

Many different techniques are discussed ranging from purely subjective to, almost, entirely quantitative. A number of important points are summarised below.

a) Managers:

- work at an unrelenting pace; their activities are characterised by brevity, variety and discontinuity; they are action orientated and favour oral media. They handle exceptions and regular work; and process soft information that links the organisation with its environment. The managers' programmes relating to decision making, information processing etc. remain locked inside their brains(18).

- spend as much time with peers outside their organisations as with subordinates and through such interpersonal contacts they emerge as the nerve centres of their organisations(18).

- at CEO level, decisions are made in small steps; particularly very complex ones to allow time to understand the problem(16,55).

b) The risk(R) relating to the decision making process in a technological programme is given by the following formulae.

$R = P * E$ where P = probability of failure/ partial success

E = expenditure.

P = B * C * F * T where B = technology barriers
C = competition
F = fit with resources
T = transition difficulty

Also, Impact(of technology programme under consideration) is given by:

I = M * G * K * S where M = market size($)
G = market growth
K = market share
S = sensitivity to technology.

Note: 1) the sign "*" means multiplication;
2) the factors B, C, F, T, and S are all subjectively defined and could have values from 0 to 1.0;
3) the results were plotted using semilog scales.

Risk is the "moving away" from an existing situation in technology, product and market directions(19).

c) Decision making in high velocity environments e.g. where the rate of change of product life cycles is high, is characterised by:

- analytical, rational, comprehensive, short term & fast processes;

- assessment of innovative, risky strategic alternatives with "decision execution-" and "implementation-" triggers;

- centralised power in the CEO but with high delegation to trigger points/ executives(21).

d) Strategy and the related decision making include the collection of objective and perceptual organisational data at multiple points in time as the strategy unfolds. The board of directors(an external coalition) may be dominated, divided or passive; in the two latter cases the lower management levels will get the opportunity to intervene and influence to their own ends. CEOs must respond to departmental power which can be direct; external environmental impact is seldom direct and the cause-effect relationship often unclear. Although CEOs often interpret their environment as it is perceived to exist, they may also create or enact an environment that is different from the one they have been experiencing(22).

e) Multiple goal behaviour of men & organisations has traditionally been approximated by single, unchanging, and technically manageable criteria; the results of psychologists and social scientists concerning multi(non-mutually destructive) goals has been ignored. These goals are not independent of the means used to pursue them. Dealing with such "incommensurable" as quality of life, education, etc.. can no longer be avoided. Many researchers are sceptical about mans ability to choose among multi-attributed alternatives- suggesting an interaction(23).

f) A multi attribute utility measurement rating scale exists to identify the values of each participant in the management through "decision by consensus" approach. Druckers decision making process requires definition of the question, discussion of dissenting opinions, focus on alternatives, and determination of who should take the final decision.
The Japanese differ from this process by not including the discussion as a result of dissent. The Delphi method requires four phases in the decision making process viz. exploration, understanding, reconciliation, evaluation. Lateral thinking(DeBono): simple, non-verbal images for management situations; is used in the horizontal organisation together with the horizontal network and shared decision premises,and an incremental strategic approach(25,26).

g) In a field study of a single organisation the main components of the decision making process were found to be goals, expectations, and choice; four relational concepts were declared to be: organisational learning, conflict resolution, problemistic research, & uncertainty avoidance. Points emphasised relate to the relative ignorance of superior to subordinate, and different perceptions...of uncertainty for example.(28,29).

h) The public definition becomes an integral part of the situation(30) and cognitive dissonance, relating to the reordering of goals, is defined as being a direct function of the number of items the person knows are inconsistent with the decision(31).

i) If-Then rules can serve as a structure of a decision making process.(91).

Some limitations of current decision making processes are noted e.g. the representation of multiple goal behaviour of man and organisations being approximated by a single unchanging and technically manageable criteria. Some quantitative methods are extremely complex and rely on well defined input data and in general do not take account of the soft aspects nor the dynamics of the situation. "Rules of thumb" abound but are often coined for different situations as they arise and are, in any case, very general and dangerous due to undefined assumptions. The utilization of these methods for "real life" prediction could not be recommended with any confidence and are in fact rejected by a number of researchers due to their ambiguity(160,159).

A major problem, in this and other areas, is the lack of definition of all assumptions and the likely consequences of those assumptions being incorrect. In other words what is the sensitivity of the conclusions, from using the various techniques, to the assumptions? No positive answer has been found to this question. The conclusions of many different researchers are different. It is concluded that there is no single universal method that has been selected to define the decision making process. Quantitative methods are rejected by a large number of the researchers. Consideration of soft aspects is very small.

The research addressed above refers to the problems currently in existence due to the multi-facetted nature of decisions, perception differences, the avoidance, or tacit acceptance(e.g. due to the "possible" weight of public opinion) of "soft" aspects, and the numerous and different decision making rationales; the latter encompassing organisational, checklist, and formulative approaches. The research has also recorded that decisions are often made in small steps and intervention is frequently present.

The current status is fragmented and often contradictory.

The need to find a more realistic and useable approach is self evident.

3.4 Organisation

A number of models of organisations and their growth characteristics are contained in the research; the main elements are outlined below.

a) The organisation is defined as a domain which exists in an environment in terms of two dimensions, stability & homogeneity. It is assumed to act rationally,upon which its growth depends, and to have the reduction of uncertainty as its goal. High efficiency functions are placed within a technological core to protect them from uncertainty. Boundary spanning units are used to interact with the environment. Later work specified four types of organisation, defender, reactor, analyzer, and prospector. It is noted that it is difficult to separate organisations from their environments and that the organisation generates its environment more than is generally appreciated; the only reality is the environment which is perceived by the organisation. Earlier work indicated two polar types of organisation: mechanistic,governed by rules, and organic, adaptable to a fluid environment(32).

b) Metamorphosis models: growth is not smooth but involves discontinuities when the degree of change is too large for the existing structure. Age, size, complexity are regarded as driving forces for the metamorphological changes(33,182).

c) Research & development can be classified as academic, governmental, independent, or industrial; also as offensive or defensive, and basic, applied or experimental(34). Innovation can be demand- or supply-induced; the latter is more risky. The most critical factors are: market orientation, relevance to corporate objectives, an effective selection and evaluation system, project management, a source of creative ideas, an organisation receptive to innovation, and commitment by one or two individuals. Ideas can be interventions. Opportunity criterion depend on the relationship between the "value-in-use" and the projected project price. Another approach uses project profile reports to measure R & D effectiveness looking at such aspects as the type and nature of the project, the probability of success and the cost and estimated income; the ratio of offensive to defensive research is also considered(34,35).

d) Technological research faces two conflicting attitudes from management due to a) declining profit and b) growing social conscience. A major reason for failure is the isolation of R & D from other corporate functions. Decision making depends on the organisational structure; resource allocation has three levels, viz. definition, impetus, and approval. Diversity and uncertainty will push decision making down the organisation. In multi-national corporations five different management styles are identified: centralised, participative centralised, co-operative, supervised freedom, & total freedom(36,). From a 1991 survey involving 12,000 managers,business boundaries have not been detected but are believed to be on their way(115).

A number of organisational types are defined but it is also stated that organisations can move through phases of being related to one type or another. For example, the metamorphosis models, in which growth is not smooth but involves discontinuities when the degree of change is too large for the existing structure, probably applies at the macro and microlevel of every organisation at some time or another. The real point is whether the organisation adjusts itself to adequately handle the new situation in time to avert failure to meet strategic objectives or not. This seems to connect with the bifurcation principle since failure to amend the organisation to meet changed environments or even changed objectives could result in bifurcations and thus possibly lead to crisis; or chaos! There are many different definitions and descriptions of the so-called environment; it seems not to be definable in a specific manner.

This review indicates the difficulty of defining the environment and the conflicts that can be generated within a company working in the development field; the latter evidenced by the number of different systems which have been devised to measure performance and risk. The need to limit progress to "small" finite steps and the concept of intervention is concluded. These aspects are addressed in some detail in the current work which constitutes a continuation of the research summarised above.

3.5 Intervention - increment- feedback

The classical concept of intervention is essentially related to some form of programme reviews, usually scheduled at the commencement of, and during, the programme. Additionally, special reviews may be held "following" a problem or crisis. These aspects are addressed by such authors as Drucker, Crosby, Juran etc. In general, however, the principles and actual application of intervention seems not to be well documented as such. Feedback is mentioned in the research but mostly in the manner of "it must be present"(48).

The works of E.DeBono(38), concerning lateral and creative thinking, are innovative but fit well with the authors experience and have formed important stepping stones in the development of this thesis.

A number of relevant abstracts from the bibliographical review are listed below.

a) The cutting edge of any particular technology represents the accumulation of incremental improvements(39).

b) Product changes are stabilised as dominant designs emerge & become the basis for both incremental changes in the product and for process improvements(39).

c) The nature of strategy must fit the environment(39).

d) The firm must position itself to participate in & benefit from the process of technological change supported by the infrastructure. Viewing technological change as a series of discrete choices or decisions obscures its strategic nature(39).

e) Feedback inhibition, which occurs in all living things, consists of an enzyme being blocked by a product many steps removed from it(40).

f) Successful organisations tend to have a traceability "back" to previous work which had some similarity with the current work; monitoring & feedback must be built in(44).

g) From a survey of 12,000 managers, world wide, oriented to define "business boundaries" the following main points were noted: cultural perceptions shape managers; the borderless company is on its way; each company is but one point in an extended network of equals; hierarchy still rules industrial organisations because companies are reluctant to embrace the logic of the technology and dismantle the walls that separate levels of management(115).

h) The General Electric task force, for the CEO, generated the following key performance measures: profitability; market share; productivity; employee attitudes; public responsibility; balance between short and long term goals. The writer prefers to link incentives strongly to performance but leave managers free to determine their subordinates rewards(46).

There are clear statements in the research which indicate that where an incremental approach has been used success has resulted; also that the strategy must fit the latter statement is very ambiguous since definitions of "strategy" and "environment" are not well agreed.
The issue of incrementalism, traceability and feedback is mentioned increasingly and related to successful projects. Correlation is not made with linear, non-linear, closed or open loops. There is also the point that the borderless company is on its way; this conclusion is made from a survey, world wide, of 12000 managers. This is interpreted to support the contention in this thesis that the border between a company and its "environment" is not representable by hard lines; in this thesis it is defined as the locus of the perceptions of the managers within that company.

As can be seen, previous research has identified a connection between "incrementalism and traceability" and "success". This is an important support for the incremental approach which is one of the main thrusts of this thesis.

3.6 Risk & Risk Indicators.

The subject of "risk indicators" as such has not been found in any of the research reviewed to date; it has been alluded to by implication.

Risk is mentioned in various references, as indicated below, but the definitions are not clear and certainly not standardised.

The following summary covers a wide spectrum of research and observation. Once again the listing has been selected to provide direct correlation with the work of this thesis.

a) Organisations tend to be blind to the importance of events that could signal disaster(36).

b) The level of safety in a complex technological system is usually not directly observable except when accidents occur(36).

c) Ideally, feedback mechanisms should be based on indicators which are tightly coupled to safety but which do not themselves reflect an immediate hazard; this ensures that a-priori lessons, from risk analysis, will be learnt(36).

d) Management must appreciate the subjective assessment of probability(49).

e) Risk measures are:

- probability of missing the target;
- probability of not breaking even;
- expected loss;
- loss potential(49).

Management must understand the relationship between the measurements and their concerns.

f) Subjects appear to reconstruct the meaning of inconsistent labels so that they fit the "learned" relations(50).

g) When two functions were learned under different conditions, subjects erred in the direction of allocating more resources to the subject learned under less uncertain conditions(50).

h) Risk is associated with the possibility of loss or failure to reach a certain target(51).

i) We have to live with uncertainty because the future is unknown; societies are either "weak uncertainty avoidance" .ie. they tend to accept uncertainty or they are "strong uncertainty avoidance". The former produces managers more involved in strategy.(53).

j) In the Viable System Model(VSM; by Beer et al) the whole structure is seen as an organised set of interlocking controllers. Viability requires each controllers criterion to be satisfied. Each level was so preoccupied with the operations below it, particularly so as to detect deviations from the budgetary plan, that the proper tasks at each level(formulating adaptive strategies and identifying synergistic opportunities for the level below) were being neglected(84).

k) Behaviour in organisations was seen, by Checkland et al, as following from human intentions and only to be understood in terms of the perceptions and meanings that correspond to them. The interest of the intervenors was in the phenomenology of the situation; less in the cybernetics of control.
What is important in the VSM is that the model is distinct from the modelled(the map is not the territory). The model can and should be completely defined; the reality it is intended to represent, cannot(103).

l) Techniques of analysis for organisations have to be compatible with the level at which they are applied(56).

m) The likelihood of a socio-technical system failure is a function of the number of "resident pathogens"; the problem is defining a pathogen(56).

n) Risk is the probability multiplied by the severity, or known unknowns; uncertainty is about unknown unknowns(57).

o) Nothing should be frozen until a decision on that particular element is required in order to proceed with the work(57).

p) The voice of the customer flows through all activities & quality control becomes a design led rather than a production led process. This approach is more a process of evolution & continual improvement than a series of irregular quantum jumps(58).

q) Taguchi concepts involve inner noise(controlled by standard process control methods) and outer noise(relates to variation imposed by circumstances which occur after the product leaves the producer)(58).

r) Major contractor issues are:

- 1) lack of responsiveness of the customer to the changing environment, and,

- 2) failure of the customer to give the contractor more autonomy as maturity is gained(59).

s) The following thirteen factors, referred to as the Project Implementation Profile(PIP), are stated to account for the variance of project success:

1) clearly defined project mission;

2) top management support;

3) project schedule/ plan;

4) client consultation;

5) personnel; recruitment/ training;

6) availability of required technology & expertise;(top performers have technology on tap but are not obsessed with it e.g. less Information Technology means simpler production lines(64)).

7) client acceptance;

8) monitoring & feedback;

9) communication;

10) trouble shooting;

11) implementation process;

12) perceived quality;

13) client satisfaction.

The perceived value of the project, by the project manager, to the user has a significant effect on early failure.(88).

t) Continuing with factors that cause projects to fail; mathematical models are rejected due to: data relevance, basis, currency, financial health of organisation, & timewise prediction inabilities.(81).

Three reasons submitted for failure of organisations to appreciate and alter pervasive and prevailing assumptions are:

1) structures & processes designed to monitor selectively;

2) potentially disruptive changes must be delayed to an optimal point ref. the "cost of not restructuring";

3) organisations are not hierarchically ordered machines but are political systems composed of constituencies of interests.(75).

Three approaches to analyze corporate collapse:

1) management or trajectory models; three types of trajectories relating to:

- small, single, owner companies(high gearing plus early launch of a large project);

- companies which survived a) but have charismatic (salesman) type proprietor;

- mature organisations with "one-man" ruler syndrone.(81).

2) financial prediction models;

3) case studies.

u) From 157 German firms 70% stated it was not possible to reliably predict the political future of the country. Enterprises prefer unstructured/ unsystematic evaluation methods. Trade avoidance, diversification, establishment of global markets stated as active strategy to overcome political risk(124).

v) risk conversion factors, relating to factors that effect peoples willingness to accept risk that has the consequence of death(cost and benefit data NOT included), show for example that:

1) voluntary risk is 100 times more acceptable than involuntary risk;

2) natural risk is 10 to 20 times more acceptable than man-made risk;

3) ordinary risk is 30 to 50 times more acceptable than catastrophic risk.(129).

w) Concerning the use of expert judgement in risk assessment three models are discussed viz. classical, Bayesian(recommended), and paired comparison.(66)). Engineering is stated to be an art because it depends so heavily on judgement. A heuristic device is defined as "anything which provides a plausible aid or direction in the solution of a problem but is in the final analysis unjustified".(130).

x) The information revolution is effecting competition in three vital ways:

1) changes industry structure and alters

competition rules;

2) creates new ways to achieve competitive advantage;

3) spawns whole new businesses.(140,142).

Only one reference has been found that actually mentions feedback mechanisms being based on indicators; this is stated to be an ideal case(49).
There are many references concerning the subjective appraisal or perception of risk and the fact that allowance must be made for such differences. This is rated as a positive support of the hypothesis.

There is also the strong support that when two functions were learned under different conditions the subject erred in the direction of allocating more resources to the subject learned under less uncertain conditions. This supports the brain - chaos theory where we always try to relate something to a familiar aspect i.e. something we have experienced before. A point is made here that the interest of the intervenors was more in the phenomenolgy of the situation than in the cybernetics of control. In saying this, Checkland et al reject many types of modelling including VSM.

In the Project Implementation Profile method thirteen factors were written down which account for the variation of project success. At the top is a "clearly defined project mission" or, in the terms of this thesis, the "statement of risk". Lower down in the list are "monitoring and feedback", "communication", and "perceived quality". These points all support the hypothesis and the thesis in general.

There are a number of references to perception; emphasising that one must take account of perception and that it is a major element in early failure.

There are also a number of comments relating to the unpredictability of the future.

The above notes indicate the concern of a number of researchers with the lack of understanding, and consideration, of what organisations, and their environments, are and hence what risk actually means e.g. organisational safety is only apparent after an accident. Some researchers have clearly referred to the need to advance incrementally with a brief mention of indicators and feedback. Uncertainty is defined as the "unknown unknowns" which is congruent with the thinking in this thesis. There are a number of references relating to "perception" and behavioural aspects, and in particular the main contributors to project failures are stated to be:

1) perception ambiguities;

2) communication & feedback problems;

3) planning & phenomenological(158) issues.

It is also interesting to note the occasional analogy to some aspect of "living systems" e.g resident pathogens. In general this synopsis indicates that this thesis represents a "natural advance" of a number of research directions that have already been identified and to some extent initiated and substantiated.

3.7 Culture

The word "culture" is used extensively in management textbooks and articles; it refers mainly to such aspects as the Japanese culture, the U.S culture, the European culture, etc. Each of these "cultural designations" are typified by management styles, company and worker relationships, company and worker objectives, constraints, strengths and weaknesses and so on.

In this thesis culture is considered as a system which includes concepts and objects; hence it is directly related to perception.

The author refers to the customer and contractor cultures as being different. The former being based on, in the case of ESA, rather altruistic objectives whilst the latter is almost entirely profit motivated. It is emphasised that in many commercial cases the customer and contractor objectives are very similar i.e. profit.

An interesting "definition" change has been formulated by Kristian Kreiner(note 71,annex 4) in which he expands the sphere of culture from:

- the underlying, often subconscious, foundation for people's thinking and acting(the traditional approach);

to

- the surface and manifestations of such thinking and acting in organisations.

This latter definition is utilised in this thesis.

As with environment it is not clearly defined; there are a number of descriptors including the one finally selected and reproduced above.

3.8 Perception

The reliance, and vulnerability, of many aspects of decision making and risk assessment on the subjective

perception of the individuals directly, and indirectly, involved is becoming a central concern in the related research.
(28,31,38,45,47,50,54,56,59,60,61,65,66,67,88,91,240)

It has been well documented that **the process of defining the nature of a problem is dependent upon the histories and backgrounds of those responsible for defining the problem.**(41,240; plus, Bruner and Kresch 1950; Hayes and Simon 1977; Herden and Lyles 1981).
In a similar fashion perception and culture "colour" the way a child, and therefore an adult, develops; there is a continuous interaction between the developing trajectory of the brain, perception and the dimensioning effects of culture.

Perception is affected by the presence of a distorting medium and is processed by something which has certain limited capabilities. A general uniformity of nature is both necessary and sufficient to justify inductive reasoning.(74,240).

Perception is considered to involve the following "set": context, instructions, expectations, motivation, emotion, past experience, individual differences, cultural factors, reward and punishment(240).

The association of perception with the brain is considered to be axiomatic.

From the work of W.J.Freeman et al(91) it is apparent that chaos exists in the brain, and in fact is an essential factor in enabling the brain to cope with the enormous amounts of information presented to, or perceived by, it. Perception is defined as a step in a trajectory by which brains grow, reorganise themselves, and reach into their own environment to change it to their own advantage. (authors comment: This "own advantage" point is important; it implies that the brain will "convince itself" in order to satisfy e.g. hunger, thirst, sex acts.....which is clearly correct. The relationship between executives decision making and their "needs" (from psychological, material, moral aspects/ conflicts) thus becomes clear(er)). Perception is not the copying of an incoming stimulus.

The similarity, at a different level, with de Bonos' work(50) is clear.

Hence, in terms of modelling there now appears to be a "physiology" that can be used to depict perception.

It seems that the Freeman model is applicable to this thesis. If one substitutes the word "intervention" for the words "odour molecules" that strike the receptor neurons in the nose (and by similarity and the comment of Freeman, the eyes & ears..) then a link is established with the thesis.

Hence there is now an established scientifically accepted model of brain perception; which involves experience and familiarity and a constant conflict between out of balances primarily due to the existence of experiencal knowledge resident in the brain. Therefore the brain will always relate every new or different perception to a previous experience; even if the relationship is not correct. In other words the reinforcement given by experience to a stimulus enables a selection and identification, of that particular stimulus to be made. In the absence of experience no selection is possible.

Society, the public etc., is generally classified under technocentricism or ecocentricism; the former further divides to cornucopias(who believe in the infinite ingenuity of mankind to solve problems) and accommodators (who believe the structure of the bureaucracies will not fundamentally change but mankind will always adjust to change). (88).

From the above, and returning to the pragmatic management and decision making scene where decisions and selections must be made, it is clear that the executive must find a piece of his experience that his brain can manipulate, in the stepwise growth process mentioned above, to relate to the "new" input so that he can "handle it"!

This thus explains the finance man interpreting high technology in terms of cash, and the engineer construing the balance sheet as a mathematical equation, etc.

Hence in terms of risk and decision making bias it is necessary to review the experience of the decision makers (selectors).

As mentioned earlier, the concept of entropy is considered indigenous to the Intervention and Strategic change problem.

The complete world of commerce, business, technology, science, engineering, economics, micro - macro politics is seemingly chaotic. However, in every "local" area there is a perceptible order and purpose.....by the perceiver!(91)

The basis of the Strategic Contingencies Theory(3) is that power is a function of a departments capacity to cope with uncertainty, its non-substitutability, and its centrality in the organisations flow of work. A power perspective resolves much of the conflict between the three competing environment-strategy approaches:

1) the predominant rational-economic view;

2) strategic decisions based not on the environment

itself but on perceptions of environmental realities;

3) interpretive or enacted view: organisations create or enact their environment by the decisions they make; they thus create their own opportunities and threats.

Hence, if one assumes the "complete world" to be the environment and the company; and its "immediate interfaces" to be "the programme" then the programme will appear non - chaotic to the executives involved until there is a mismatch in somebodies brain concerning an input they receive(perceive) and trajectory position of the growth function of their brain at that point in time (see 2) above).
Similarly the chaos of the environment will be rationalised vis-a-vis the brain experience at that time(the trajectory position once again) and certain conclusions(selections) drawn. This latter activity would relate to "intervenors".

In attempting to understand the chaos of the environment the intervenor would consider such aspects as "influences", traceability, and increments.

An interesting aspect is that the original definition of risk would be subjected to the same "brain - perception process"; with consequent bias & limitations.

This whole discussion is of course simply another way of defining "subjectivity"!

The above also means that a risk indicator must be tailored according to the experience of the user of that indicator. It must not contain data that would be translatable in a certain biased direction due to the attempt of " a brain" to relate it to its "limited" knowledge, or particular "greed"; unless the "greed" coincides with the strategic aim.

Many references refer to perception. It is becoming a central theme in the research. A model of "brain perception" has been devised and is adopted in this thesis. It fundamentally states that the brain will always relate every new or different perception to a previous experience even if the resulting relationship is not correct. It seems clear therefore that a bifurcation may, or may not, be recognised by someone or it may even be invented where it does not exist simply because experience in the brain does not exist to indicate otherwise. Risk indicators are not mentioned significantly in the research this is therefore essentially a new concept.

3.9 Dynamic Environment

The dynamics of the "environment" relates generally to the changes of data, situations, interactions etc. with time. However, chaotic behaviour has been defined as a dynamic aspect(71). The following points have been extracted from the research.

a) In most cases change was found to consist of the adjustment of structures and systems to secure consistency & coherence within an architype(75).

b) For many middle managers personal aspirations have more powerful influence over decisions concerning technological change than organisational objectives(56).

c) Two dimensions define the environment:

   1) simple/ complex;

   2) static/ dynamic.(14).

d) Major challenge facing firms with intermediate rates of technological change is the problem of changing from a product to a process focus in the engineering and R & D activities.(29)

e) Company technological profile has five factors:

   1) R & D balance;

   2) product life cycle;

   3) R & D coupling;

   4) proximity to state of the art;

   5) R & D investment ratio.(29)

f) Business occurs along three co-ordinate axes labelled:

   1) customer groups;

   2) customer functions;

   3) alternative technologies.(29)

g) In high velocity environments, firms have higher performance if they:

   1) use rational decision making;

   2) implement more analysis in decision making;

   3) try new things;

   4) use strategic alternatives that are

more innovative and risky;

5) make quick strategic decisions;

6) vest power to implement strategy in the top management team;

7) delegate the "execution triggers" to the top team;

8) have greater power centralisation in the CEO;

9) do not have great political behaviour among top management teams.(21).

The outstanding aspect of the research to date is its inability to consistently define what the dynamic environment is, how it is characterised, and how it interacts with the company; the latter definition is similarly difficult. The VSM(viable system model) of Beer, which attempts to embrace both the company and its environment, is severely criticised(84) on the grounds of the unrealism of expecting that the "multiple control elements" have almost unlimited powers of perception, computation and action.

The above status demonstrates the problems and, in the writers view, indicates that an alternative approach is necessary.

This thesis has adopted the approach that the company and environment boundary, if there is such a thing, is generated by the limit of individual perception.

The dynamics of the environment are defined in many different ways involving different numbers of factors and different types of factors. The inability to agree or define the dynamic environment, the static environment and the strategy constitute imponderables that support the contention that what is being done today is inadequate; that we cannot make hard line models and that we cannot usefully predict.

Many of the points referenced in the research seem not to be realistic because they appear to be based on premises which are not firm e.g. "high velocity environments" without explaining what is moving at high velocity, and "rational decision making" should be used in high velocity environments...what is a rational decision?

3.10 Systems Approach

The word "system" occurs repeatable in the research and in this thesis; it is important to understand precisely what it means and its scope. The following related points have been extracted from the literature.

a) A system is an assembly of components, connected together in an organised way.(54). An assemblage of things forming a regular and connected whole is a system.(66).

b) The first steps in the systems approach entail:

- awareness
- commitment
- detection
- separation
- selection
- description.(54)

c) Failure is the production of undesirable events.(84)

d) Four key tests of a system are:

- organised connectedness
- essentiality
- interest
- behaviour.(54)

e) The typical relationship between the parts of a system is defined as follows:

"when organ A shifts from state m1 to state m2, & organ B shifts from state n1 to state n2 after k days(weeks etc.), organ C will change its state from q1 to q2 with probability p."(66).

f) A firm which stays in the same business has a finite life span; an organisation must do four things to survive viz. produce, administer, be entrepreneurial, and integrate.(29).

g) R & D must lie at the edge of the organisations domain & is in a powerful position if it can demonstrate that it can reduce uncertainty.(29).

h) An organisation has three main systems: marketing; econo-technical; scientific.(29).

i) Technical profile is a function of rate of change of environment and distance of technology from the state of the art.(29).

j) A firms life cycle should be portrayed in terms of the "product class" life cycle with emphasis on "significant increments of innovation".(29).

k) Three R & D strategic policy dimensions(from 11 Swedish companies) are:

- concentrated versus diversified;
- technology or market oriented;
- offensive versus defensive.(29).

As indicated above, the literature has explored and established some definition and relationship of various functions of organisations which have then been delineated as a "systems approach". The systems approach has some consistency in the research and discussion also takes place concerning the life cycle, or the finite life span, of an organisation.

In general this status has been utilised as an input and no significant conflict has been detected.

There are differences concerning where R & D must be positioned in an organisation and in the systems approach.

3.11 Living Systems

Life has been described as "a phenomena almost impossible to define or to explain in all its varying aspects"(150).

A unique characteristic of life is that it is an organised system capable of creating more order from less order.(63).

In this thesis, companies and organisations are considered to incorporate some of the characteristics of human living systems i.e. man. The company is not considered to be a separate entity to the people in it although such a separation is often used in a legal sense e.g. the liability of a company is limited to the shareholders stake in the company. The rational of this approach is contained in chapter 6.5.1.

In the literature, comparisons between organisations and aspects of living systems are frequent e.g. life cycle(86), resident pathogens(56), neural networks(92), metamorphosis-age(33), conflict (28,29), multiple goal behaviour(23), the participation of the firm(39),the company is a cumbersome dinosaur whose first goal is survival(111), and each organisation, like a human individual, has three dimensions to its activity; namely intelligence, sentiment, and volition(185).

Living systems are considered to be open systems; the latter are discussed in detail in section 3.14.

Phenomenology is significant to this subject(151).

This thesis considers all organisations as living systems simply because they fundamently are controlled by, and consist of, human beings; and therefore human brains. The usefulness of this aspect to the thesis is that a unique characteristic of life is that it is an organised system, a living system, capable of creating more order from less order. The rational therefore is that companies and organisations can create more order from less order.

3.12 Closed Loop Systems

Closed loop systems have been extensively explained in, for example, automated systems.

Closed loop systems depend on feedback; a closed loop feedback system contains the following five elements(97):

1) Programme elements: they determine what the automated system shall do and how the parts of the system must function in order to accomplish the desired result.

2) Action elements; they are generally of two kinds:

   - energy application,

   - transfer & positioning.

3) Sensing elements: to detect and measure a specific property of the processed item and present that measurement in a form upon which the automated system can act.

4) Decision elements; use information from sensors that measure how the system is operating and compare these data with information from the process program that describes how the operation should proceed.

5) Control elements; the mechanisms by which decisions are carried out.

The whole feedback loop, input-system-output-controller, has a very special behaviour; it manifests "purpose".(97).

Since feedback is an essential element in a closed loop system, margins can be used to monitor a decreasing or increasing risk profile.

Closed loop systems are mentioned in the organisation and management research; particularly in the cybernetics domain.

3.13 Open Loop Systems

Open loop systems are generally defined as systems in which feedback is not present, nor possible, because the output of the system is unknown.

In detail, the definition of an open loop system which is used in this thesis is:

- a system in which the meaning or outcome of any of its elements either,

    1) cannot be completely defined, or,

    2) cannot be directly linked with a previously experienced "similar" item which had a successful result.

This definition naturally excludes closed loop systems since both the conditions 1) and 2) are not applicable.

Using the same rational, "margins" cannot be used in open loop systems.

It seems that critical elements of open loop systems are knowledge as well as data based.

It is considered to be axiomatic that a "total and complete dynamic system" can be defined solely in terms of open loop and closed loop systems.

Open loop systems, as defined above, have not been directly addressed in the literature reviewed by the author. Hence the research review has centred on the concepts and techniques that seem to be necessary to be able to "manage" open loop systems. The following points have been extracted from this review.

a) Pieces of knowledge in the form of rules can be chained in an inference process i.e from some premises one can obtain a conclusion. If the internalised premises(rules) match the external premises(facts from users), the inference process is started and the machine exhibits intelligence.(116). The above is called forward chaining; backward chaining(or goal driven inference) is based on matching an initial goal(assertion) with rule conclusions. The conditions of the rules with matching conclusions then become input to the backward chaining process.(122).

b) Theorem of Representation: a fuzzy set can be represented by a family of crisp sets, which we call level sets; and any subjective evaluation defined on any support is equivalent to a family of intervals.(116).

c) Aristotelian logic needs to be replaced by dialectic (critical analysis of mental processes) logic which assumes that A and non-A do not exclude each other as predicates of X.

d) The system is observable whenever two distinct states yield observably different responses; observability is a vague predicate. Vague can be given a precise meaning; vague input(0,1), vague output(0,1). (116).

e) Complexity is a property of a system arising from interactions of the system with its observer-regulator rather than being an intrinsic property of the system itself. Linguistic models can be used to avoid complexity.(116).

f) Most managers have decided to use heuristic rather than mathematical models i.e. problem solving by inductive reasoning. Four basic approaches to scientific truth: Liebnitzian; Lockean; Kantian; Hegelian.(116).

g) Quantitative model representation of complex systems is questionable. Language expresses ideas and beliefs. Formalism errs on the side of sameness and seeks to exorcise vagueness; functionalism errs on the side of difference and encourages us to look at the uses of vagueness. Silence may communicate what is beneath or beyond words.(116).

h) Probability theory studies statistical inexactness, due to the occurrence of random events, and fuzzy set theory studies inexactness due to human judgement.(116).

i) An important element of sensory & motor systems is the existence of topological maps in the brain which tend to dedicate greater area to activity that is utilised more.(116).

j) The LS-1 learning paradigm is composed of three interacting components:

    1) the problem solving component;

    2) the critic;

    3) the learning component.(118).

k) Basic elements of an expert system are: user terminal, experts terminal, inference engine, knowledge base results.(96).

l) expert systems and A.I techniques are characterised by the combination numerical and symbolic computation.

m) Knowledge Specification Formalism: to facilitate the communication between knowledge engineers and domain experts. The current "deterministic" management approach, using predefined procedures, is less and less able to verify with respect to growing complexity of new satellite requirements with respect to autonomy, reliability and performance. Modellistic knowledge representations allow combination of mathematics, forward and backward rules, and high level programmes.(122).

The above elements give a general impression of current thinking with respect to possible methods of "dealing with" actual real life open loop situations; the latter containing, by definition, behavioural(soft) and engineering(hard) aspects. The clear conclusions from the research that quantitative methods are not adequate is a solid foundation block for the "direction" of this thesis i.e. the only valid approach that can be made to encompass programmatic dynamics, non-linearities, and hard and soft aspects is qualitative.

As with closed loop systems relating to complex systems, open loop systems have also not been directly mentioned. References in this research assessment again refer to the inadequateness of mathematical models. Most of the research on open loop systems deals with fuzzy mathematics, probability theory applications, and expert systems. There is a clear conclusion, made a number of times, that quantitative methods are inadequate. In fact, most of the open loop statements deal with definitions and the possibility of this or that method being applicable to different situations. In this area a significant amount of philosophical discussion is taking place and informatics modelling techniques using fuzzy algebra, subjective judgement etc. are under consideration.

3.14 Open Systems(self-organising)

The notes on Chaos in chapter 3.15, with their frequent references to the brain and other living systems, should be consulted in conjunction with these notes on Open Systems.

Fundamental to the research of this thesis is the concept that organisations can be self organising i.e. they can become more orderly. This apparent violation of the second law of thermodynamics is only possible with the injection of negative entropy.

This thesis submits the achievement of a reducing entropy* situation in the following manner. If data, hard and soft, received by a programme is valid and current i.e. relevant and timely, and the programme has, and uses, the capability to apply the data, then the programme problem solving ability will increase, the problems will decrease, the risk will decrease, the orderliness will increase, the complexity will decrease; therefore the entropy will decrease. It is thus an essential feature of defining intervention that the entropy reduction capability, qualitatively and relatively, is known; an increasing or decreasing entropy can thus be deduced. The criticality of 'the right data at the right time" is thus paramount.

* The entropy reduction is a local phenomena; globally it

is increasing and hence the second law of thermodynamics is not violated with reference to the total system.

The following points have been selected from the bibliographical reviews as key elements in support of the hypothesis.

a) An open system is where the stability is in dynamic equilibrium; in which continuous change occurs yet relatively uniform conditions prevail, like the conditions in a pool beneath a waterfall.(65)

b) Both negative and positive feedback, in the form of individual and species behavioural patterns, are involved in maintaining the overall dynamic equilibrium of the community.(65).

c) The objective of everything is survival; feedback is involved everywhere.(93).

d) Cognitive functions have to be learned:

"Seeing" has to learned during a critical period of post natal development.(93).

e) The developing brain ought to be considered as a highly active and primarily self containing system which, when born, already possesses substantial knowledge about the structure of the world into which it is going to adapt itself. Thus when the brain is born and confronted with a dramatic expansion of accessible environment, it poses a number of precise questions to this environment with the purpose of optimising and adapting its internal structure to reality.(109,110).

f) The brain and its environment appear as components of a closed, highly interactive system.(109,110)

g) The cause of developmental errors is suggested by the particularities of the self - organisation process. The possibility must be considered that the brain does not formulate the right questions or does not ask with sufficient insistency to obtain answers.(93).

h) The character of a sociobiophysical system may be strongly affected by sudden changes in its subsystems or the systems environment e.g. the advent of new technology.(104).

i) Self organising systems are concerned with circularity, recursiveness, and self-reference.(92).

j) Memory and consciousness can be readily separated.(138).

k) Learning is not how people feel, but how they think.(139).

l) Information is not only produced by dissipating the degrees of freedom in a system, but also by increasing resolution in systems with few degrees of freedom.(140).

m) The large scale behaviour of complex systems, often hidden by fluctuations, can be interpretated in terms of an organisational scheme for all underlying events.(152).

n) The presence of periodic solutions implies the presence of steady states.(152).

o) A chaotic system can be locally unpredictable, globally stable.(153).

p) A complex system can give rise to turbulence and coherence at the same time.(153).

The above statements clearly identify the predominating role of feedback, the learning process, the dynamics of the situation, and environmental interaction with the brain. These characteristics are key elements in the thesis.

All of the points that have been extracted from the research are considered to be supportive of the hypothesis and the thesis in general.

3.15 Chaos

The aspect of chaos is central to this thesis.

Chaos could be described as an artistic science since it encompasses mathematical concepts and beautiful, complex pictorial presentations; possibly like life itself.

The functioning of living systems according to the principles of chaos is documented, although not extensively proven, by numerous authors.(152, 153, 180). The involvement of chaos in the functioning of the brain has been substantially commented in this thesis e.g. chapters 3.11, 3.14 and 6.5.4.

The concept of bifurcation whereby "changing one parameter can cause the system to move from steady state(equilibrium) to a point where the equilibrium splits in two, these bifurcations then come faster and faster, and then the system becomes chaotic(152, 153)" seems to fit the actuality of business, and projects, very well.

The observation has been made(152) that "chaotic dynamics discovered that the disorderly behaviour of simple systems acted as a creative process. It generated complexity; richly organised patterns, sometimes stable and sometimes unstable, sometimes finite, but always with the fascination of living things."

The above, from the experience of this author and as shown in chapter 5, describes project situations. Life can be tranquil, steady state and apparently linearly extrapolatable for a certain period and then suddenly, often from an "apparently insignificant" source, everything becomes turmoil with "tiger teams" being formed to deal with potentially catastrophic problems. **The situation has become non-linear**. Panic situations frequently develop and managers "throw money at the problem" on the basis of solve quickly now and thus avoid more serious impacts later in the programme.
This approach can be very damaging since the turmoil may actually spread due to the predatorial effect of the "throw money at the problem" approach depriving other areas of necessary resources.
The documented statement(152) that "dynamical instability is the average of a measure of the rate of growth of small deviations" seems to be very appropriate.

For this author the science of chaos has provided the only realistic conceptualisation of project and business life as they really are.

The notes 124 through 130(annex 5) provide a telegraphic summary of the status of the science of chaos at the time of writing this thesis.

These notes provide a strong foundation to the developments made in this thesis.

3.16 Negative Entropy.

Historically negative entropy, in relation to Information Theory(222), seems to have been formalised by Leon Brillouin; he coined the term "negentropy".(209,214).

The work of Brillouin et al(180,209,214) stands as a reference(104) in this subject matter and is used as such in this thesis.

The following notes, designated a), b) etc., have been extracted from the above references to provide a basis for the negative entropy aspects of this research.

It is important to realise that the following notes only address the quantity of information and DO NOT address the "value" nor the "meaning" of the information being transmitted; nor the aspect of the significance of its timing.

In this thesis the meaning and value of the information, and the timeliness of its arrival at the receiver, are considered to be of prime importance in the increase or decrease of risk and hence on the role of the intervenor.

a) A definition of information, derived statistically, considers a situation in which there are P' different possible cases or events of equal a priori probability. This is considered to be the initial situation when there is no special information about the system undergoing review. If more information is obtained about the problem then it may be possible to specify that only one out of the P' outcomes is actually realised. The greater the uncertainty in the initial problem, the greater P' will be and the larger will be the amount of information required to make the selection. If the final information state is represented by I", then it is stated that:

$$I'' = K \ln P'$$

where K is a constant.(209)

b) The relation between Information and entropy is given by the expression:

$$Ib'' = k(\ln P' - \ln P'') = S' - S''$$

$$S'' = S' - Ib''$$

where S' and S" represent the entropy at the initial and final states, and

Ib" represents the "bound*" information at the initial state.

* Two classes of information are distinguished:

1) Free information, If, which occurs when the possible cases are regarded as abstract and have no special physical significance;

2) Bound information, Ib, which occurs when the possible cases can be interpreted as complexions of a physical system. Bound information is thus a special case of free information.

In the above expression, Ib" appears as a negative term in the total entropy of the physical system and hence it is concluded that:

bound information = decrease in entropy S

= increase in negentropy N.

Evidently, in this scheme, the system is not isolated: the entropy is decreased when information is obtained, reducing the number of complexions(from the Planck usage of the term to define the discrete configurations formed when an atomic system jumps from one structure to another one while absorbing or emitting energy, and here considered to be the same as the equally probable causes P'), and this information must be furnished by some **external** agent whose entropy will increase. Hence the second law of thermodynamics is not violated.

In the case of free information, it is considered that there is no connection between information and entropy, since the relation between entropy and the number of cases is defined only if the cases are complexions of a physical system.(209).

c) Entropy is usually described as measuring the amount of disorder in a physical system. A more precise statement is that:

> "entropy measures the lack of information about the actual structure of the system".

This lack of information introduces the possibility of a great variety of microscopically distinct structures, which we are, in practice, unable to distinguish from one another. Since any one of these different microstructure can actually be realised at any given time, the lack of information corresponds to actual disorder in the hidden degrees of freedom.(209).

d) Entropy suggests that organisms, societies, machines and so on, will rapidly deteriorate into disorder and "death". The reason they do not is because animate things can self-organise and inanimate things may be serviced by man. These are negentropic activities which require energy. Energy however can only be made available by further degradation. Ultimately, therefore, entropy wins the day and the attempts to create order can seem rather a daunting task in the entropic scheme of things.(124)

The above notes indicate the origin and concept of negative entropy and its relation to Information. They also emphasize the purely statistical derivation of the theory and its limitation in that it does not address the quality nor interpretation of information. This work is considered to be an adequate basis for the utilisation of negative entropy concepts, in connection with self organising systems and the indication of risk, in this thesis.

3.17. Conclusions.

In addition to the conclusions which are implicit in the preceding sections the overriding conclusions of this assessment of the status of current knowledge are:

1) the methodologies and modelling techniques do not, in many areas, represent the "real world"; they are only stated to be "useable" providing certain, very significant assumptions are made. In many cases, the author submits, those assumptions cannot be made whilst still retaining the hard pragmatism of day-to-day business life.

2) the application of the above models would be almost impossible, in the real world, due to the unavailability of the required data, at the required times and with the required detail, and computational expertise;

3) the "soft' or behavioural aspects are spasmodically addressed and very rarely in conjunction with the "hard" aspects. This lack of a total system approach when addressing, by definition and without choice, the overall system is considered to be a serious flaw. This point has been made by a number of researchers.

4) the qualitative versus quantitative aspects do not seem to be converging and seem to be rather irrelevant considering the increasingly recognised prime function of behavioural aspects.

The result is a rather fragmented situation with no clear concept concerning the direction that "applied" research should take in order to be credible and provide, therefore, outputs that can actually be used by the average manager in the average working environment.

It is submitted that this thesis may provide a trigger for a new approach or direction i.e. based on a detailed development, expansion and utilisation of the Intervention Method, see chapters 6 and 7, together with the collection of more real field data converging at the system level.

Chapter 4) The ENVIRONMENT of the Method.

4.1) INTRODUCTION.

Before defining the Intervention Method it is necessary to describe its purpose and function and, prior to those descriptions, to explain the environment in which the Method must function and "why" this work is necessary.

The latter points are addressed by outlining the current state of application, fundamentally in the European Space industry, of the various aspects involved and formulating a number of statements to envelope the shortcomings; thus covering the "why" aspect.

A term which is used extensively in this thesis is risk indicator. This is used to fundamentally refer to a signal that is received by:

1) the project manager, and

2) the intervener,

indicating that a significant risk contributing element is present which "could" prevent the "programmatic and, or, strategic objectives" being achieved. (Refer to annex 3).

4.2 CURRENT PRACTICE in the European Space business.

4.2.1 GENERAL.

As mentioned above this section describes the project management methods currently being practised by some space industries in their development activities. From discussions and bibliographic reviews (1, 2, 6, 17, 18, 39, 58, 101) the Aerospace business appears to be more structured reference project planning, data flow and decision making, and more sensitive to ensuring some form of independent element in the Review process, than many other industries e.g. chemical,civil engineering.

Prime amongst the Aerospace industries, Space seems to predominate in these aspects; particularly the desire to "appear" to be open to external accountability. During an interview with an ex-director of an advanced civil aircraft development programme the remark was made, "an aircraft chief designer would not tolerate his work being questioned to the extent that designs, and designers, are interrogated in the European Space Agency business". It would thus appear that the Space industry may represent the "best case".

4.2.2 The DEVELOPMENT PROJECT.

The development project is characterised by the necessity to produce a small number of products requiring the solution of "engineering"* problems, which are often technologically severe, with limited funds and within a stipulated timescale.

> * Although "engineering" problems are stated it is often the case, for space projects, that new concepts are also implemented for the first time in a development vehicle; albeit with some a-priori ground testing. Hence the general use of the term "engineering" also tends to obscure(..limit the perception of...) the inclusion of research type activities. As technologies and systems develop the terminology must be re-assessed for possible ambiguities and change of scope. This would avoid the mis-application of classical practise.

Postulate 3: The terminology generalisations progressively being used are considered to be significant contributors to the difficulties concerning the definition and control of risk. A risk indicator needs to be assigned to this area.

The development problems are usually categorised as not fundamental in nature; this being the realm of "pure" research. However, the transition from "pure" to "applied" research and thence to "development" is rather fuzzy and becoming even more so with the increasing automation and compression of the so-called "development and production" environments; for example: CADCAM, software domination, miniaturised custom built technology, shorter "technology" generations(life cycles), etc.

The development problems actually encountered are often different and more difficult than those that had been identified in the planning and financial definition and commitment stages. Soft aspects are not ignificantly addressed.

The result is that the development projects often contain **"embedded research"** elements but the majority of managers refuse to categorise them as such. A possible explanation for this attitude is that "research" is construed to be driven by the data that emerges as the research continues. Such a situation, whose direction & end point(...& risk...) are relatively unpredictable, would be difficult, if not impossible, to define contractually such that it formally interfaced with, and properly contributed to, the total "system" contract. According to current methods the situation would be "unmanageable"!!

The use of "quantum jump" technology and compressed schedules often results in the acceptability of the technology being established during final assembly of the space vehicle. This often results in significant problems occurring at this time and interventions which have not been planned but have been FORCED by the circumstances due, significantly, to the lack of risk indicators.

Postulate 4: The use of technology which has been developed in well defined, and traceable, incrementally advancing steps would avoid the inherent risk of the "quantum jump" approach.

Postulate 5: The failure to identify, and the lack of proper definition of, embedded research, in development programmes is a major risk contributor.

4.2.3 The QUALIFICATION MANDATE.

In the Space business hardware, software and man-machine aspects must be "qualified", and "flight approved", prior to use. This essentially means that they must demonstrate their ability to do the job required, with "margins". Until this "verification" is achieved the product will not be accepted by the customer.

The development project manager and his team must therefore not only solve all problems within a tight cost and budget but they must also demonstrate their technical solutions, with confidence(margins).

The existence of this latter mandate seems to satisfy many of the risk management requirements; however its implementation is not so simple. It requires, for example, statistically significant data samples. Such data is very often not available and hence "qualification by similarity", with "other hardware", techniques are used; these are often very questionable, distorted and truncated for cost and schedule reasons. Also, the simulation of the operating environment concerning all stress levels and complete durations(acceleration testing is often not representative), with comprehensive instrumentation to provide static and dynamic status, is essential; this is usually not possible so more assumptions have to made.

The end result is that the qualification process does ensure that margins do exist for possibly 80% of space vehicle parameters but in the more critical areas e.g. high density technology, software, advanced R.F. equipment, deployable mechanisms, solid fuel engines, man-machine interfaces, etc., margins are often not demonstrated. Also, in this system, the demonstration of margins occurs towards the end of the project; hence negative results are almost impossible to rectify without substantial hardware impact.

It is also unfortunately still true that designers are almost totally success orientated i.e. the consideration of all design failure modes, and their consequences, is not an intrinsic part of the design process. Failure aspects relate directly to risk and hence constitute, when presented and used appropriately, a form of risk indicator.

Postulate 6: The outputs of "failure mode and hazard analyses" constitute risk indicators.

4.2.4. The PROJECT PHASES.

A space project is divided into phases; with particular objectives and functions per phase, viz.

- phase A: system definition from baseline design supplied by the customer.
- phase B: sub-system trade-offs plus optimisation of system design; preparation of bid for phase C-D.
- phase C: audits, detailed design, final system optimisation, design freeze and manufacture; component & equipment qualification.
- phase D: assembly, integration, testing, system qualification and delivery; milestone and delivery incentives(large) and penalties(small)*.
- phase E: commissioning & operation; orbit incentive/ penalties(both small)*.

In spite of the existence of phases A & B, and prior definition work by the customers "future projects" teams, it is typical for major problems to occur during phases C,D & E which require significant additional funding, and time; and sometimes can even result in the loss of the vehicle.

* The parentheses refer to ESA projects.

4.2.5 CRITICAL ITEMS

Critical items are defined as those aspects of design, hardware, software etc. that could cause loss of:

- life,

- the system i.e. the investment(e.g.the vehicle itself) or,

- the mission i.e. what the space vehicle or crew have to do.

The latter refers to the orbit function of the space vehicle e.g. to carry out earth resource measurements.

Although a "CRITICAL ITEMS LIST" does exist there is no established method of prioritising or ranking the critical items such that the most critical, say, top ten can be given top management attention. Hundreds of critical items can be identified during the course of a project.

Postulate 7: the definition and implementation of a "RANKING" system for critical items would enable them to be used effectively as RISK INDICATORS.

In the context of the definition of critical items it should be noted that currently there is NO METHOD of DEFINING the RELATIVE IMPORTANCE of such aspects as:

- commercial utility;

- resilience(capability of an organisation to survive a major accident);

- politics;

- geographic distribution(individual country financial returns must be proportional to their contribution to ESA);

- technical performance degradation.

4.2.6. INVESTMENT MAGNITUDE

As an indication of size of the investments involved in the projects referred to in this thesis the following general statements are presented.

For a communications satellite phases A and B would cost of the order of 50 - 100 million dollars each whilst phases C and D, awarded as a single contract, would cost between 300 and 600 million dollars. For a manned vehicle the costs would be approximately one order of magnitude higher.

The phase C-D contract is thus the sought after "prize".

4.2.7 The CONTRACTOR SELECTION PROCESS.

The phase C-D contract is awarded after assessment of the competitive bids by customer technical, managerial(inc. resources), financial and contractual review panels using standardised criteria.

Final reports are submitted by the review panel chairmen to top management(customer) Boards who finally decide the contract winner. This latter process significantly addresses political issues e.g. in the case of the ESA the contract value awarded to the member countries must be proportional to the contributions made by those countries to the ESA budgets.

There are often, during this phase C-D evaluation, cost cutting activities but rarely a significant reduction in the scope of work; the Board members concerned tend not to be commercially experienced nor orientated.

The dimensioning of the project technological, schedule and cost problems, by ESA at the contractor selection point, is carried out with very little involvement of expert engineers; a new method is needed.

During the selection process the interface between the contractor and the customer is maintained. The predominant contractor thrust is clearly to win the contract and important decisions concerning the definition and resources have to be made at this time, in a competitive mode.

The author has never seen a risk analysis presented during these negotiations. Risk indicators, as such, do not exist.

Risk is fundamentally defined by the Review panels in terms of:

- technical non-compliancies with the customers requirements,

- non-credible aspects based on panel members experience, and

- knowledge,

- and omissions.

The technical and financial parts of the bids are carefully segregated to avoid "corrupting the technical assessment with cost aspects"!
The technical and financial aspects come together only at the Board level. A Board meeting may last a few hours or a couple of days. Actions can be placed by the Board for later close-out; usually under the responsibility of the project teams!

The correlation of the various technical deficiencies and the impact on the financial inputs is a matter for the Board. In other words the customers(mission) objectives and the contractors(financial and profit) objectives come together at this point for the first time; and then in a very shallow fashion.

The complete review process is based on a numeric marking system related to the acceptance and rejection criteria used to assess the bids.
No attempt has been made to relate the marking results with risk, nor to carry out a "lessons learned" activity to determine the actual versus predicted(from the Review results) performance of the companies involved; and thence to estimate the predicted versus actually experienced risk. In other words the veracity of the bid review system is not known. The same comment applies to the project system reviews mentioned later in this section.

4.2.8 The CONTRACTOR MONITORING PROCESS.

Once the contracts have been awarded, the selected contractor proceeds to implement the negotiated "statement of work". The customer then enters into a monitoring role which is effected via progress meetings, e.g. quarterly, based on progress reports which have been submitted by the contractor. The progress reports are written to an agreed format and the meetings usually follow a similar pattern; identified problems, essentially by the contractor, will predominate the meetings attention.

The author has attended many(hundreds!) progress meetings and reviewed even more progress reports, during the past 15 years, and has rarely seen RISK mentioned.

The problems that are identified are, as mentioned above, defined by the contractor or, by "happen-chance ", by the customer. The contractor will endeavour only to expose those problems which he considers not to be his liability.

The system is thus not rigorous and may even be self-effacing to the extent of prolonging the identification of a problem such that the risk becomes programme threatening.

Postulate 8: A properly structured problem definition system requiring intervention when problem consequences a certain, a-priori defined, magnitude would enable risk profiles to be defined; and, with additional measures, to be controlled. RISK INDICATORS need to assigned as necessary.

4.2.9 The REVIEW PROCESS.

At certain points in the overall project timescale, the customer convenes System level reviews. These reviews are based on data packages produced by the contractor(s) and the customer assessment of that data. The contractor is also required to make a verbal, with viewgraphs etc., presentation to the customer. The cost and time dedicated to these reviews is considerable. For a medium sized space vehicle a data package could run to 25 volumes, each volume containing approximately 400 pages. The reviews could last for one to five weeks and involve approximately 200 persons. It is actually on record that for the Inmarsat-3 satellite, the five competitive proposals generated 11 tons of paper and necessitated a team of 80 persons working three months to assess them!
The review structure is similar to the bid review outlined above; with panels per major discipline and a review board to finally declare the conclusion of the customer. The project manager would be a secretary to the Board, but not a voting member. All panel chairmen would be either non-ESA staff or, at least, not a member of the project. Hence a certain independence is achieved. The main shortcoming of this latter system is that, in the time available, it is almost impossible for the "external" members to become sufficiently familiar with the project status. The major problems(risk) lie at the detail level; not in the system level descriptive(voluminous) prose as presented by the contractor!

Postulate 9: The ability of the panel members and panels chairmen to become familiar with the review material is critical to defining programme risk. A RISK INDICATOR must be assigned to this area.

The system reviews are supported by contractor(prime) and sub-contractor reviews at the lower levels. Such reviews may be attended by the customer as observers; customers may only comment in writing, after the event, or at the next progress meeting.
The opportunity for filibuster tactics is present; time intervals between the event/problem and a customer response to the related report, with clarifications, verifications etc., can render the whole process ineffective.

In general, the system reviews are as follows:

- phase C:
  - Requirements Review(continuing appropriateness, coherency of the total requirements set).
  - Conceptual Design Review
  - Critical Design Review(design freeze/ manufacturing go-ahead)

- phase D: - Qualification Review
  - Flight Acceptance Review
  - Launch Readiness Review
- phase E: - Commissioning Review

It should be noted that NO PRIORITISATION of the major DESIGN OBJECTIVES is provided by the customer and no permitted degradation of those objectives. Thus when failures occur in the vehicle, methods of utilising this degraded state are not available. In other words the risk profile related to the gradual transition of system state from perfect functioning to complete failure is not addressed.

Postulate 10: An assessment of the risk involved in the progressive loss of the vehicle performance would enable a better cost/ schedule optimisation during the design and operational phases and more realistic RISK MANAGEMENT to be implemented.

4.2.10 MARGINS

At the commencement of a project certain parameters are given margins. For a space vehicle such parameters typically are:

- mass(kg)
- power(watts)
- memory capacity(bits)
- etc.

Margins are also applied to the schedule(days).

As the project proceeds it is the intention to permit these margins to be gradually eroded in such a way that the actual values needed will be achieved. The principle is that since unpredictable problems will occur, the margins will enable their solution whilst maintaining the parametric and schedule performance according to specification and delivery dates, respectively.

The problem is that since the relationship between the parameters, including their margins, and the project resources is unknown it is practically impossible to monitor the effect of parameter degradation on RISK i.e. of achieving the project objectives on time within cost.

Similarly, the criteria for fixing the size of the parametric margins are unrelated to any form of risk definition and, in fact, seem to be established by some(unspecified) rule of thumb....apparently based, by someone(???) on experience(undefined)!!! Justification for using these, relatively unchanged , margins on succeeding projects and technologies is missing.

Postulate 11: If the total resources are calculated on the basis of producing parametric performance(inc. the associated margins) and similar relationships are established relating to performance and profit (including incentive/ penalty effects) then the parametric margins could be used as RISK INDICATORS. It should be noted that the "resources/ parameter calculation" would involve ALL contributing ACTIVITIES to the achievement of the performance e.g. design, qualification, testing, etc.; hard and soft aspects and the interactive effects of different margins would also have to be included.

The above signifies that the programmatic and risk relationship of parameters to objectives and profit is unknown.

4.3 STRATEGIC VULNERABILITY

4.3.1 General

Due to the relatively long duration of the space vehicle projects, which can last from 3 to 12 years, the strategic planning and associated decision making is vulnerable to utilization, political and international aspects that may significantly change during the above timescales.
The annual accountability could be considered as an "increment" bounded by financial interventions.

4.3.2 Utilization Aspects.

The objectives and applications of the projects when initially defined are often at a fairly general level. This has the political advantage that funding can be made available in order to commence the programme, which results in jobs for constituency members etc., but has the technical and programmatic disadvantage that the design requirements have to be defined in detail as the programme develops. This can result in the final product being significantly different than the current needs; such divergences have actually occurred.
Another aspect of the vulnerability of the projects is the

increasingly shortening technology generation life cycles. An obvious example of this aspect is the 8, 16, 32 bit computer technologies associated with the 8086,80286 & 80386 microprocessor developments; these technologies lasted approx. 10, 5 and 3 years respectively.

With the increased performance from the newer technology, and its attendant mass and power advantages, the risk of obsolescence of the precursor technology is high.

One must not forget that not all technology increases produce improvements. Sometimes the newer technology is unreliable or exhibits unknown reactions in certain circumstances; it is then stated that the validation, or qualification, of the technology was not properly carried out.

There is also the aspect that with the inception of a newer technology, the older technology may not continue to be supported by the manufacturers; serious maintenance problems may thus arise.

Whatever the impact the newer technologies may have it is clear that either a relatively undefined risk must be taken, in selecting an advanced but relatively unproven technology thus relying on a successful qualification programme, or relatively little risk is taken by adopting an existing well tried technology with its performance limitations and obsolescence problems.

Postulate 12: If the strategic plans of the product user community and the technology developers are monitored by the related corporate management

and,

the project is defined for technology insertion, and a wide range of possible applications of the product are kept open as long as possible

and,

the "critical supports"(see section 5.1) are established and maintained for the project life cycle,

then,

risk in this area would be minimised.

4.3.3. Political & International Aspects

The justification for many, possibly all, budget allocations is, ultimately, political. The political drivers change, often dramatically, and occasionally quickly.

In the Space business, the main drivers ten years ago were:

- to establish telecommunications & broadcast links via satellite;
- to establish space laboratories for material & life science research;
- to utilize the US space shuttle as much as possible;
- to establish an European autonomy in space, even at very high cost.

Today those drivers have been significantly changed and may be presented as follows:

- to improve cost effectiveness of space projects;
- to limit the use of manned space vehicles to only those missions that really need man on board;
- to concentrate on science & earth resource missions;
- to support commercial exploitation of the space segment e.g. telecommunications;
- to support major space developments such as a space station and space transportation vehicle providing they can be funded by a conservatively increasing budget.

Postulate 13: If political and economic trends, at the macro level, are monitored and utilised in the compilation and update of Space strategic plans then overall risk will be reduced.

Postulate 14: The absence of direct executive authority, on the project, by a design review board is considered to seriously diminish the effectiveness of the design review.

A listing of postulates is given in Annex 1.

4.4 Summary Conclusions on Current Situation

Concerning the "role of intervention in strategic change" as currently practised the following summary, based on the authors experience and discussions with colleagues, is presented:

a) strategic planning is implemented at the macro level in the European Space business but with the undermentioned limitations:

- at the ESA level the strategic planning is programme rather than (Space) industry related; at the programme level it is variable in structure, content, objectives definition, resource identification and duration. Some programmes plan 15 years ahead, others 3 to 5 years. In some cases the operational phase is not addressed. The ESA directorates are vertically organised which tends to significantly limit lateral communication and co-operation; programmes and R & D are sometimes integrated into programme directorates and sometimes contained in a separate R & D directorate.

- in the area of ESA research and development(R & D) strategic planning is based on programme(projects) needs, but this requires the agreement of the programme management and that agreement may tacitly admit the existence of embedded research (see section 3.2.2), and the independently perceived needs from the R & D organisation (brains) viewpoint. The latter point presents a conflict situation since all budgets are programme orientated and the independent perceptions may not converge to be (seen to be..) useful to programmes for a number of annual budget reviews. In many cases this planning is short term (1 to 3 years) and is driven to a large extent by annual budgeting. In general the programme planning, on which the R & D planning is based, is not queried by the R & D planners, due to lack of opportunity as a consequence of vertical ("water-tight") directorates; they are also not involved in each others strategic efforts.

- European space industry strategic planning seems to be significantly based on the ESA planning.

- it is thus clear that any deficiencies in the ESA programme planning will tend to be promulgated at the R & D levels and industry.

- the ESA planning is based on establishing certain "milestone achievements for Europe", such as a space plane, a space station, a Saturn probe etc. In many cases these objectives are driven by national prestige, or territorial survival or expansion reasons within ESA; both aspects result in the related strategic planning data being questionable with the risk of causing severe under-estimation of budget and schedule needs.

- the industrial planning is based on return on investment and profit i.e. return to shareholders, dividend payment and hence increasing opportunity for recapitalisation.

- the failure to meet strategic objectives thus has very different implications for ESA & industry; for the latter it may even involve survivability!

- many directors seem to associate themselves more with day to day events than strategic and macro issues.

- the "soft" aspects are not significantly considered.

- there is almost no 'lessons learned" activity i.e. other than purely local.

b) Intervention is implemented in a rather rigid fashion through a "review" system that is not driven by risk divergence but according to loosely defined milestones related to programme status. The review procedure depends on the review honestly and completely presenting all problems in an easily understandable form. In many cases it is not in the contractors financial interest nor his human exposure, ego, credibility,etc. inclination to do so. It is also often not possible for the reviewer to do a thorough job due to inadequate time to become familiar with the complete review documentation.

c) risk indicators, as such, have never been identified and the concept has not been addressed.

In conclusion, the "role of intervention in strategic change" in the European space business is perceived to be vague and rather ineffective. The latter is evidenced by project cost and schedule increases and space vehicle failures and degradations; insurance premiums have oscillated around 20% for the past decade.

Annex 7 contains the results from an analysis of space-, and space related-, problems that occurred during the past 10 years. This shows that, although a number of the orbit problems were identified in design reviews, they still remained to cause major problems in orbit. This situation is analyzed in chapter 5.

Chapter 5. Knowledge and Data Collection, Analysis and Utilisation.

5.1 Knowledge and Data Collection.

The knowledge and data collected to enable and support the research has been derived from seven main sources. These are listed below together with the chapter and, where relevant, the number in which the knowledge and data resides.

1) An Overview of Risk; see chapter 2.

2) A Description of the ESA-European industry working environment; see chapter 4.

3) A Review of the knowledge status of research and practices to date:

   - approximately 180 references have been reviewed; see chapter 3 and annex 4.

4) Interviews with key project personnel:

   - eight key personnel, at the project and corporate management levels, have been interviewed; details of these interviews are contained in annex 6.

5) Documentation of two projects, involving the key personnel mentioned in 3) above, have been examined; see section 5.2.2.

6) Personal experience of the author over a 20 year period:

   - this experience knowledge, which triggered the need for such research from the authors viewpoint, has been used to converge the research to explore the actuality of the risk situation in the ESA space development business.

   This exercise provided over 1200 data points.

7) Problems which have occurred on orbiting space vehicles have been analyzed to determine if they could have been caused by management, interface control, technology etc. issues or prevented by intervention; the basic histogram data is contained in annex 7. Approximately 900 data points were used.

The availability of knowledge and data was different for each of the four projects, as shown in table 1, but was adequate for comparative and absolute assessments in a number of significant areas e.g. occurrence, propagation and management of problems at most levels by the, extensive, ESA project teams. The project documentation variously included the Invitation To Tender from ESA to the bidder, The Bid, the Project Progress Reports, the Planning and Resource assessments, and the authors fifty eight daily record books covering the period January 1973 until the present time.

TABLE 1.

The Availability of Knowledge and Data

Interviews					Project	Project	Ground
	Customer		Contractor		Documen-	Daily	and
PROJ.	proj. mngr.	proj. contr.	corp. mngr.	proj. mngr.	tation	Records	orbit analysis
A	n	y	y	n	n	y	n
B	y	y	y	y	y	y	y
C	y	y	y	y	y	y	y
D	n	n	n	n	n	y	n

n = not available;
y = available.

In total over 140 specific knowledge points and over 1200 specific data points have been collected and utilised in this research; the latter are considered to be real "field data". These numbers exclude the knowledge and data derived from the interviews and project examinations.

5.2 Knowledge and Data Analysis.

5.2.1 Introduction.

The analysis of the knowledge and data collected during this research is analyzed in this section. The "knowledge" chapters 2(Risk), 3(Current State of Knowledge), and 4(Situation of the Model) are not included here since the respective subject matter has already been analyzed in those chapters. The outputs from these chapters are incorporated into section 5.3. entitled Knowledge and Data

5.2.2 Project Documentation Analysis.

5.2.2.1 General

This section contains some general comments plus a limited project management documentation analysis for project B, and a detailed analysis of the ITT, Bid, and Project Management documentation for project C. The project documentation for projects A and D was not available.

5.2.2.2 Space Project B.

5.2.2.2.1 General

This space project followed the general structure contained in chapter 4 of this thesis.

The project was not competitive.

Four of the interviews which are contained in annex 7 relate to this project; they involved the managing director and project manager from the prime contractor, and the deputy project manager/ systems engineering manager and project controller from ESA.

The project was heavily dominated by ESA; both in terms of the detailed design constraints imposed on the contractor in the ITT, and concerning the decision-making role of ESA as the project progressed. This occurred in spite of the ESA systems manager being very aware of this problem, from the previous project, and really attempting to avoid it.

In fact the intervention by ESA, as on most ESA projects, was almost continuous and, due to this mode of management, much of the decision making and risk devolved from the contractor to ESA. This aspect is quite apparent from the interviews.
The contract required the delivery of five satellites over a seven year period. The first satellite was originally scheduled, in the Prime contractors Bid of July 1976, to be ready for launch in mid-1980; it was actually accepted for launch in December 1982 and could have been launched, if the Ariane launcher had been ready, in February 1983.

For this work ESA was the customer. The industrial consortium had established its qualification for this contract by competitively winning the previous, and first, European communications satellite contract; project A in this thesis. The industrial consortium contained companies from Italy, Sweden, UK, Belgium, France, Germany, Spain, Holland and the USA. Most of the contracts between the prime contractor and the co-contractors were firm fixed price. The contract between ESA and the prime contractor had fixed price and cost plus elements. Under the contractual rules of ESA, and most commercial

organisations, cost data cannot be required from a contractor on a fixed price contract.
Even where ESA required cost data it was not included in the quarterly reports since it was considered to be proprietary to the prime contractor and not for public view; except to the ESA project office. The writer has had limited access to this data. In order to explore the effectiveness of the ESA cost control the writer reviewed the ESA cost control system(ECOS). The most important aspect of this review was that a form on which bidders were required to state the risk basis of their financial inputs was never submitted; and ESA never insisted on it being completed! This comment applies to all ESA projects!

A not un-typical method, used by contractors, of avoiding payment for changes was to establish that they were out of scope of the contract, or that ESA had made, or had majority involvement in, a decision which then resulted in the change. ESA would then be obliged to pay if it was considered that the item was essential for project success. The interview with the ESA Systems manager shows his clear, moral, acceptance of this abrogation of responsibility(see section 5.2.4). The almost "autonomic" overlapping of ESA requirements and activities with those properly reserved for the contractor was suicidal in this respect.

On the contractor side the project manager and his immediate superior, the executive director, have been interviewed as part of this research. On the customer, ESA, side the systems manager has been interviewed. It is not considered to be a problem that the ESA project manager was not interviewed since he was largely a public relations figurehead; the project was essentially run by the systems manager.
The writer held an ECS customer managerial position for a short time at the commencement of the project.

5.2.2.2.2 The Quarterly Report

The report was divided into four main sections, with sub-sections as indicated:

1. Management
   - overall project management
   - programme problems
   - technical problems
   - ECS export programme

2. Technical Status
   - system
   - repeater*
   - all subsystems individually addressed

   * the repeater is the satellite "payload" and is named

thus to indicate that the uplink signal(telephone or television) is "repeated" as a downlink signal after appropriate amplification and frequency adjustment.

3. Schedule Status

4. Product Assurance Report.
   - reliability
   - quality assurance
   - materials & processes/ future activities
   - parts
   - parts procurement.

This content was used throughout the project; changes were sometimes made to include specific comment on particular problems.

The report was used as the input to, and the agenda of, a quarterly top level ESA/ prime contractor meeting; co-contractors were present as required by the prime contractor. These meetings often included detailed technical and schedule discussions.

5.2.2.2.3 Conclusions

No programme risk analysis nor contingency planning was supplied to support the bid. The resource allocation and planning seems to have been based on total success oriented tasks with no identified resources for working problems that might have occurred due to, for example, "known" specification inadequacies and difficult qualification activities.

For the Bid the cost, manpower and schedule data were supplied in different documentation packages and as such were not capable of evaluation in an integrated fashion i.e. as they relate in practise. In fact, as verified from the interviews, it was not possible to make complete evaluations of any of the three areas at all. It was, also, thus not possible to assess the resource and planning impacts of the various technical issues.

During the project, the status reporting documentation did not refer systematically to the utilisation of resources or possible increasing risk situations at the various contractual levels. The layout of the reports provides a detailed chronology, from one report to the next, of practically every equipment and service area involved in the project. There is no prioritised list of problems, with their overall resource and schedule impacts, nor a rational concerning intervention by the prime or co-contractors.

In many parts of the reports the situations are reported as straight accounts of events as they have occurred with no judgement or "value added" interpretation. For example, an audit is reported with no mention of its success or failure or problems exposed. Also, analyses were carried out with no comment concerning the conclusions. This lack of reported judgement by the prime contractor, the author of the reports, seems to reflect a passive prime contractor role due to the abrogation of his responsibility and authority by the customer, ESA. This point has been confirmed in the interviews. In fact it appears that the attitude has been to give the "facts" to ESA, wait for a response and the commitment of effort from the (large) ESA project teams, and then react in the most economic manner.

The data provided in the project progress reports (PPRs) "could" be labelled as "risk indicators" and "open loops"; this has never been done during this, or any other ESA project. The result has been that the perceptions of the key players in the project have probably never been given the opportunity, in a timely manner, to converge. From the interviews it is clear, for example, that the perception of the accountability of the work-package managers was quite different by the project manager and the corporate manager, his "boss"! The entire project, from inception to launch, was dominated, and continuously intervened by ESA; even major decision making devolved to ESA.

The general management style, from the documentation submitted to ESA, seems to be one of generally "expecting" the co-contractors to progress as planned and "waiting for something to happen".

In general it is interesting to note that the QPRs did not contain any specific reporting on resources. Schedule slips were frequently mentioned and it is clear that additional resources must then automatically be involved but their criticality was never mentioned. It is also interesting that "risk" was never specifically mentioned although it was alluded to in a rather conversational manner e.g. "great concern over the ability to make the Eurobeam antenna meet the specification".

5.2.2.3 Space Project C.

5.2.2.3.1 General.

This project was much bigger, in terms of the space vehicle size, its technical complexity, and the number of companies and monies involved, than project B.

The general scenario described in chapter 4 also applied to this project.

The eight interviewees, see annex 7 for the related reports, worked on this project but not continuously.

The entire undertaking was based on a market analysis report issued by ESA; supported by a rather shallow re-assessment of the market survey by the future contractor. As with project B, this project was not competitive.

5.2.2.3.2 The Invitation To Tender(ITT).

The project risk was defined in the ITT in terms of:

a) the reliability to be achieved by the satellite i.e. the probability of meeting the specified performance for the design lifetime of the spacecraft.

b) the outages, or downtime, permitted during the spacecraft operation.

The above had to be achieved within the following constraints:

1) a certain amount of time and money being available under certain contractual conditions e.g. fixed price etc.

2) the contractor successfully completing, according to ESA subjective judgements, certain design reviews which were defined in the initial contract.

3) the successful achievement of "qualification" for the entire spacecraft, down to and including each electrical component, prior to launch.

The letter to the Bidder from ESA did not mention risk; it commented only on dates to be met, project phase definitions, open actions from the contractor pre-view of the draft ITT, and documents not yet ready from the contractors pre-view. On the latter aspect ESA stated that since the documents were late the ITT could be changed if ESA deemed it necessary after reading the late documents.

5.2.2.3.3 The System Performance Specification(ITT).

In the System Performance Specification, which was part of the ITT, ESA stated that the objectives of the programme were to develop the spacecraft platform and demonstrate the payload capability in orbit.

A very interesting point was that the "outage" requirement did not apply to the payload but only to the platform. Thus this very important risk indicator, in the view of this author, did not exist for the payload. The payload performance is of paramount importance to the customer who procures the spacecraft services.

The reliability requirements were stipulated for every mode of operation of the spacecraft.

Certain design requirements were specified in great detail for the payload but very briefly for the platform by the customer even though the contractor was declared to be the design authority.

The above points indicate a large involvement of ESA in the contractors business.

5.2.2.3.4 The Project Management Plan(ITT).

This ITT document outlined the main project management requirements and provided the content of the **Project Progress Reports(PPR)** and the **Quarterly Executive Reports(QER)**.

The **PPR** required the status to be provided to ESA under the headings:

- management;
- technical;
- Actions;
- parts procurement, sub-contractors & suppliers.

Risk was only alluded to in:

a) the "management", and

b) the "schedule" areas,

in the following manner.

Under management: "a concise description of the important programme problem areas, their critically and anticipated impact e.g. delays in schedule or non-conformance with contract requirements shall be provided."

Under schedule: "it is required that the latest prediction of completion dates of identified milestones shall be made taking trends and problem areas into account".

The purpose of the **QER** is stated to be to enable ESA to inform interested third parties, particularly potential users of the spacecraft system, of the status and progress of work with the following constraint:

> "The information contained in this report shall comprise that which is suitable for unlimited distribution."

The above is unlikely to be useful to an intervenor or a third party attempting to assess the programme risk.

A section on "critical items" embraces almost everything and does not provide, or require, a ranking system. The amount of detail is very great in some instances.

5.2.2.3.5 The Executive Summary(the BID).

The above document, supplied by the bidder in his response to the ITT, discussed only positive aspects of the project. Risk is not mentioned and the only occasion when some doubt, or concern, is addressed is at the end of the report, under "management policy", where it states that " the bidder recognises the LARGE DEVELOPMENT NATURE (this authors capitals) of the programme". This comment is made in the context of the bidder considering that he has not been given adequate independent, of ESA, authority and responsibility. Nothing is said about the consequences of the above statement!! The planning presented in this document shows no margins, nor slack, and the presentation of the main design drivers per platform subsystem is not applied to the payloads. Hence it is also not possible to gauge a coherent risk, or design problems, picture.

The usefulness of the above documents to assess project risk, or likelihood of success, is marginal.

5.2.2.3.6 The Bid Evaluation

5.2.2.3.6.1 General

This exercise, carried out by the customer, involved approximately 100 persons and a period of about three months; between October and September 1981.

The evaluation commenced with a detailed assessment of the various subsystems and management and administration aspects by Panels of technical experts; and culminated with summaries of the detailed assessments being presented to an Evaluation Board. The Board then made recommendations to the Project who implemented "to the best of their ability within the prevailing constraints and top management instructions".

This section addresses the Panel Evaluation reports and then the Board report.

Wherever a **"Note"** occurs it indicates a comment by the author.

5.2.2.3.6.2 Sub-Systems Evaluation

a) Management and Contractual Panel

The average marks per criteria were as follows*;

1. Organisation and management 30

2. Contractual..........not marked

3. Policy and Adequacy of Plans for Marketing..40(actual marks varied from 30 to 45).

* In the general marking criteria 40 is ranked as barely acceptable, 50 as fair, 60 as good, less than 40 as unacceptable:

The main points from the report were as follows.

The low marks were attributed to missing information in the Bid; two of the five panel members refused to mark because of missing information. The other members did mark because their previous involvement had given them a-priori knowledge and they considered they had sufficient "total information" to make a valid judgement. This is actually in contravention of the rules of Bid evaluation whereby it is required that only the data presented in the Bid is reviewed.

There still remained a serious lack of credibility to the payload aspects of the management proposals. The main problem with the overall management approach was that the procedure to be adopted for resolving conflicts between the prime contractor and its sub-contractors, which could not be settled at project level, was not described.
Note: This effectively relates to intervention.

It is stated that interface management problems with the Prime and sub-contractors(subs) had been resolved. It was also noted that the management team would have to be supplemented by additional resources and people.

Under "industrial structure and marketing" it was noted that a number of equipment level sub-contractors had not been identified or the commitments had not been made. The statement on the fairness and correctness of the competition was not provided. No visibility was given of the commercial agreements between the Prime and its subcontractor although it was stated that considerable progress had been made.

Under "company experience and resources, and work load projections" the information required regarding the work load projections had not been provided and in general it had not been demonstrated that the necessary experience and manpower was available in all areas to undertake this complex project. With reference to the payload contractor in particular the panel considered that there would be considerable difficulty in manning up in time to the proposed levels and even if a fixed price contract was applied, as was currently foreseen, the customer should seek to impose an obligation on the contractor to submit regular manning levels reports which should be monitored closely by the project.

Under "organisation and key personnel" sub-contractor monitoring and supervision, project control and parts procurement were designated as unsatisfactory.

Under "contract conditions" an explicit statement of acceptance of the contract was not provided. The payment profiles also were not received but it was foreseen that significant negotiations would be necessary due to the customers limited availability of monies in the early years. There was some feeling in the panel that a fixed price contract was not the most appropriate price basis for the payload contractors in-house activities and a cost reimbursement type with a cost sharing arrangement as foreseen for the Prime, system level activities, was preferred.

Note: This latter statement seems to reflect a doubt that the payload contractor could do the work, for the stated price; in later panels the technical capability of this contractor was also doubted and the interview with A) and B) clearly stated the primes opposition to this contractor. A number of serious open loops are apparent which at this stage of the contract seems unlikely to be a recipe for success!

b) Planning and Cost Panel.

The overall marks awarded averaged at about 50. Although this rather good mark was awarded the report noted that there were still many omissions and inconsistencies some which would have to be resolved as a matter of urgency in order to make possible the preparation of a formal contract.

Note: This seems to be a major inconsistency!

The major areas requiring immediate attention were stated to be the overall prices, the payment profile, and commitment to launch date. It was noted that the chairmen of the Technical panels gave a verbal briefing of their findings in particular highlighting where possible areas of weakness in design could lead to cost and/or schedule impact.

Under the "credibility and acceptability of schedule and planning and the adequacy of supporting details" it was stated that the comparison of the required delivery dates and the current prediction was difficult to verify and the overall payload schedule was rather imprecise. A glib statement was given that the Prime recognised the inconsistencies and problem areas but expected confidently to launch in March 1986 following contract start in December(1981).

On the subject of task definitions it was apparently

satisfactory but there were a number of serious omissions and inconsistencies with lack of clarity in the equipment level hardware matrix e.g. whether there will only be provision of parts or completely integrated equipments. There was a wide discrepancy between the Prime and the payload contractor concerning the quality of the planning documentation; but the marking method obscured these problems! The chairman of the Mechanical panel drew attention to the criticality of the Structure model and the necessity to determine current status.
Note: It seems extraordinary that this status was not known.

The payment profile was incomplete and was incompatible with resources available from member states.

Geographic distribution was not taken into account in the evaluation.

In the cost breakdown the Prime stated they were not satisfied with the Payload contractors input; some of the major omissions being the subcontractors cost plans, parts costs analysis sheets, and facility costs. An attempt to correlate the detailed and summary cost sheets failed! The final comment in the report stated that in the time available the surface had only been scratched nevertheless providing the omissions and inconsistencies could be rectified in an appropriate timescale the panel judged the submission acceptable.

Note: The above statements represent major platitudes that brands the report as rather meaningless; a major risk indicator.

C) Product Assurance Panel

The differences in the Bid submissions by the prime and the payload contractor were considered so great that two marks were given; one for the complete satellite and one for the payload. For a number of the criteria the payload received zero marks!

The report indicates an inadequate management organisation, expertise and resources. It also indicates that a dynamic, well integrated and technically competent prime and sub. teams are necessary but the bid indicates that the converse is likely to occur.
A number of previous show stoppers have been removed e.g. lack of fusing and derating policy, software controls etc. Technical requirements at the prime level were considered to be compliant but a software manual was considered mandatory to complete the definition and control compliance for software and firmware.
A list of many areas requiring rectification was given which included FMECA of interfaces, failure propagation, configuration control of analyses and interfaces, etc. The

sub-contractor P.A. plans were substantially non-compliant with the prime having made very little progress in negotiations during the past four months.
The report states that the bid could not be accepted or the phase C/D contract committed until the sub-contractor status was significantly improved.

Under the "quality of analyses" criteria the bid was ranked as barely acceptable and totally unacceptable if the payload contractor was considered. It was noted that the payload contained a large number of unqualified, advanced technology parts; this constituted a high risk area of design definition, schedule and cost. It was also emphasised that no defined qualification existed at that point in time.

Under "optimization of design" the bid was rated to be non-compliant. No system level trade-off was performed and many fundamental optimization tasks probably would not be done since they would now be overtaken by events.

Under "suitability and adequacy of the development test plan" it was considered satisfactory but with unrealistic equipment operating temperatures in many areas; a major cause of concern with respect to technical risk.

The bid was unacceptable in the area of "work task descriptions" with major omissions and inconsistencies. The definition of organigrams, personnel functions,task and responsibilities and methods of monitoring and control emphasized the general weakness of the prime in this area.

d) Mechanical Subsystem Panel

The panel considered the time available was inadequate and the report lists a number of significant issues that should be resolved before the start of phase C/D; including significant design changes required before the performance specification could be met.
The structural analysis demonstrated that the mass and alignment budgets could not be met. Many analyses were obsolete and many interfaces incompatible.
The structural and thermal sub-systems were considered non-compliant with the technical requirements of the RFQ. In spite of this major problem the bid was considered compliant concerning the understanding of the customers requirements and the analyses were also considered satisfactory; except in the thermal area. This latter non-compliance was very serious since thermal control is a particularly critical, and difficult, arae for space vehicles. Overall optimisation was satisfactory except in the thermal area.

Note: Significant negative entropy problems exist.

e) Attitude and Orbit Control System(AOCS) Panel.

The report begins with the statement that the AOCS was non-compliant concerning mass, power, outage, and reliability. Note: the latter were eventually major problems in orbit.

It was also stated that "fine pointing" did not appear to be solvable with the current design baseline of solar arrays and thrusters but that mass and power requirements may be achievable when the detailed design phase was reached.
Note: This is a very interesting comment since these two requirements usually become harder to achieve as the detail design proceeds.

Testing of the failure detection and reconfiguration system was missing. Note: This was a major problem later on.

There was also no adequate trade-off and recommendation of options of the AOCS closed loop performance and functional test and verification; including computer analysis and simulation with real hardware.
Note: These issues became major problems during the programme and finally the system became so complex that only one or two people fully understood how it worked.

In spite of the above problems the compliance with technical requirements, the correctness of interpretation of the requirements, the lower level sub-system and equipment level requirements, and the quality, depth and consistency of the analyses were all considered to be generally acceptable. There were however important deficiencies in the analytical area.
Note: Subjective elements are at work here. The "essentially compliant" reports were written due to higher level management attitudes developing a culture wherein career advancement became a function of the smoothness by which the ESA side of activities could proceed.

f) Propulsion Panel.

The propulsion sub-system(PSS), in general, received quite a good mark but there were many TBDs in the PSS specification and a number of serious problems were identified including plume impingement and no detailed qualification plan for equipments.

g) Electrical Sub-System(ESS) Panel.

In summary the ESS report contained a number of unsatisfactory features e.g. the absence of satisfactory power sub-system protection, payload distribution design, the absence of a complete proposal for the Telemetry and TeleCommand(TTC) sub-system, and the selection of an unacceptable contractor for the S-band transponder. Also

the resources at the prime for the power, TT&C and harness sub-systems were declared inadequate. Severe doubt is raised in the report about the capability of the prime in the TT&C area.
New technologies were identified including the On Board Data Handling Unit(OBDH) design. It was mentioned that a detailed evaluation of the resulting schedule risk from the above problems must be made. Also the refusal of the prime contract, which was also the TT&C sub-contractor, to fail to appoint a technical assistance contractor.
Note: Surprisingly the marks were about 40 except that the "definition of tasks" was significantly down. The depth of analysis in TT & C was considered low and a cost reimbursement contract for the TT & C sub-system was rejected. Most of the work packages and task descriptions were missing!

h) Payload Panel

The payload was stated to be "not yet acceptable". It was stated that only after the planned Baseline Design Review(BDR) and the negotiations of major items leading to further descoping of the payload performance could an acceptable status be reached. This would thus enable the gap between requirements and the proposal to be closed; and allow clear commitments. For the overall payload low marks were given against each criteria.
The following major points were identified. The very large reliability non-compliancies were ignored. Many technical aspects were not discussed. A short overall specification, only, existed. the overall layout and design were not optimised; particularly for thermal and OBDH interfaces and utilization.
Practically no analysis was provided.

From the task descriptions and planning aspects there was low confidence and a disproportion existed between the manpower available and the cost proposals. Major non-conformances existed for practically all technical outputs.

i) Assembly, Integration and Test Panel

No significant problems were identified in any area except for the aspect of software task descriptions.

j) System Level Panel

Surprisingly this panel considered that the proposal reflected a sound basis for the start of phase C/D even though the sub-system inputs did not fully reflect the system definition. New mass budgets were presented but no attempt was made to justify the changes and the data presented in the system budgets was not supported by data in the sub-system level documentation. Similar comments applied to the system pointing budgets and the thermal budgets.

The report was written in rather a politically acceptable manner. The general statements seem to indicate compliance but detailed review revealed major problems that did not support the top level statement.

5.2.2.3.6.3 Technical Evaluation Board(TEB.

The TEB report was compiled after panel report summaries had been presented to the TEB.

The conclusion of the TEB was that the proposal was not yet acceptable but it was capable of being rendered acceptable and would require about three months for that process. Also that the BDR should be delayed although a preliminary session should be maintained.
The TEB stated that the normal outcome of the present situation would be an extension of the bridging phase but if for programmatic or other reasons a decision was taken by the project management to start phase C/D activities then the TEB recommended three steps.
Note: This statement of course opened the door to project management to start phase C/D; once it was started it would be practically impossible to stop. A mass of open loops clearly exist and yet the top evaluation authority essentially gives the go-ahead!

The three steps were:

1) to hold a review meeting at the end of the bridging phase to review the list of problems;

2) continue negotiations on the contract during the following month i.e. in parallel with the above meeting, in order to finalise as many areas as possible prior to the start of phase C/D.

3) give an initial limited release for phase C/D sufficient only to maintain the validity of the offer in terms of price and schedule and to furnish the means for further work to resolve the above problems.

The TEB further considered that special measures were necessary to deal with the payload contractor manpower and organisation and recommended that top level customer, prime and payload contractor meetings take place to ensure implementation of those extra measures.
The payload contractor also to be informed that its role at the overall payload level could be descoped. Also there should be introduced a strong customer, and prime, presence at the payload contractors site to ensure close supervision.
Note: This is very interesting since it shows the customer positioning itself above the prime contractor over the main co-contractor; the main contract was between the prime and the customer only. This payload contractor was selected by the customer under the geographic distribution rules. Following this selection the prime forced additional cost

plus contractual coverage on the customer i.e. some fixed price areas were eliminated.
Finally, the payload contractor was obliged to accept a cost reimbursement with ceiling price arrangement,thus forcing cost and manpower reporting, with a view to subsequent conversion to a cost sharing or fixed price agreement.

5.2.2.3.7 The Project Progress Reports.

This section relates to the PPRs supplied to ESA during the project.

As with project B the reports are mainly a collection of problems which currently beset the project. There is no classification nor grading of the problems and the only indication of impact is the effect on schedule. However the reasoning behind schedule impact is not given. In the Product Assurance(PA) area, which is where risk would normally be considered, the report is very complacent. The PA report is limited to statements of status with practically no interpretation of the impact. For example, "an audit was carried out" and "a reliability analysis has been completed" etc. The result of the audit and reliability analysis are not given; hence possible risk or problem areas are not exposed.

As mentioned by the ESA manager in the interview, the most useful information to ESA was gleaned at sub contractor meetings; where ESA had observer status only but nevertheless often intervened, usually indirectly, see annex 2.

A number of examples exist demonstrating the unpredictability of project life. For example, "In spite of uncertainties in other areas it is clear that the Special Services payload needs improving. The related antenna farm testing is constrained by the APME delivery which is held by industrial action at company X."

The reports are notorious concerning the lack of interpretation of the consequences of the presented status; in the short and long term.A recommendation, of this thesis, is that Risk Identification, Assessment and Management are introduced as continuous functions in the project management role. This is covered by dynamic risk indicators in the model; see section 6.8.

Technical problems are discussed extensively in many areas with finally a conclusion of the effect on schedule. The methods used to arrive at these results are usually very subjective and for their effectiveness depend on the alertness, experience, knowledge, memory and communication abilities of a few involved persons i.e. project supports, see section 7.6. A methodical approach using established principles is not used and "apparently small" issues can

escape attention simply due to lack of understanding. An example of this latter point concerns "software". Many engineers and managers do not understand the potential for error in software, nor the difficulties involved in its validation. In this project, software problems were being briefly listed, but were ignored due to other more important problems, even in the early years. Some years later software problems "suddenly erupted" and caused very large cost and schedule overruns. The early risk indicators could have reduced the seriousness of the eventual consequences.
This is an example of turbulence developing unnoticed even though many sub-systems relied on software functioning correctly. Hence the bifurcation possibilities were documented.

5.2.2.3.7.1 Comments.

Unless the reader was very well informed it was impossible to judge the importance of the "statements of doubt" in the PPRs. Even for the informed reader, the relative risk of this or that problem was not indicated. In fact the PPR almost seems to be an invitation to the customer to ask certain questions, in certain pre-selected areas, where the contractor probably has an answer "on hold". This is of course a rather cynical statement. It is probable that the contractor does not use this as a deliberate tactical ploy but rather adopts this style of behaviour because it has typically "always been done like that." Having made this "disclaimer" the author has known project managers who have always done their best to delude or confuse the customer to cover up their own intentions or errors....or insecurities. Such project managers have also had the tendency to restrict, or share, information with their own project management! This indicates the need for an intervention mechanism based on independently supplied information. The QER contains practically no information concerning risk; it having been specially prepared for "unlimited distribution" and particularly to possible future customers. Hence corporate reliance on such a report as an input to another strategic plan would probably be a waste of time.

It is clear from the above and the interview inputs that a more rigorous method of reporting is required. The orbit problems of project C were extensive and can, in hindsight it is true, be traced to brief references in the reports, which were not prioritised concerning their possible consequences.

It is recommended that the risk indicators, which have been defined as part of this research, are constructed in the form of trees(see Fig.0) for the ITT, the Bid, and for the duration of the project. The trees, which could be analyzed using a Fault Tree Approach(see Fig.00), should be based on:

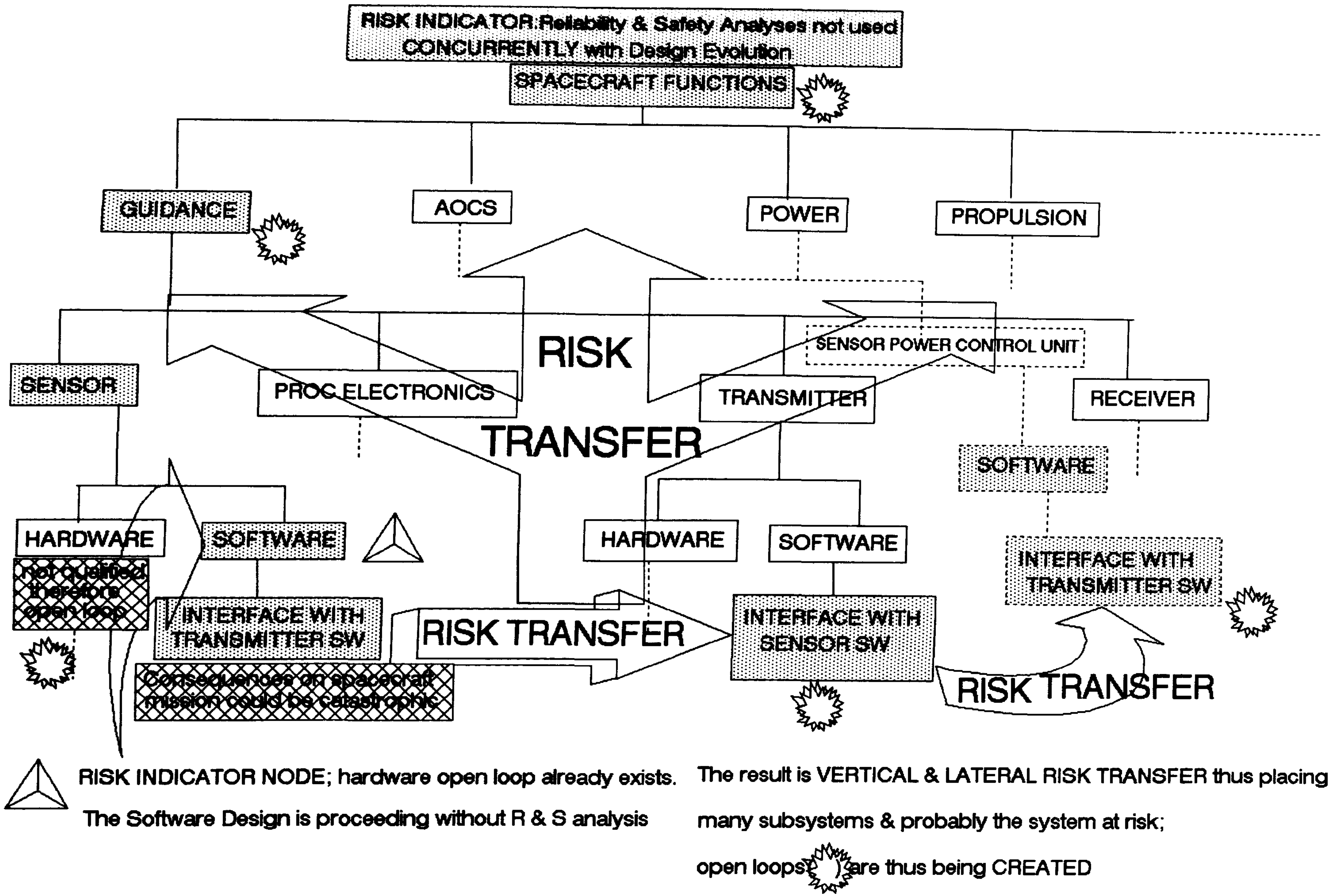
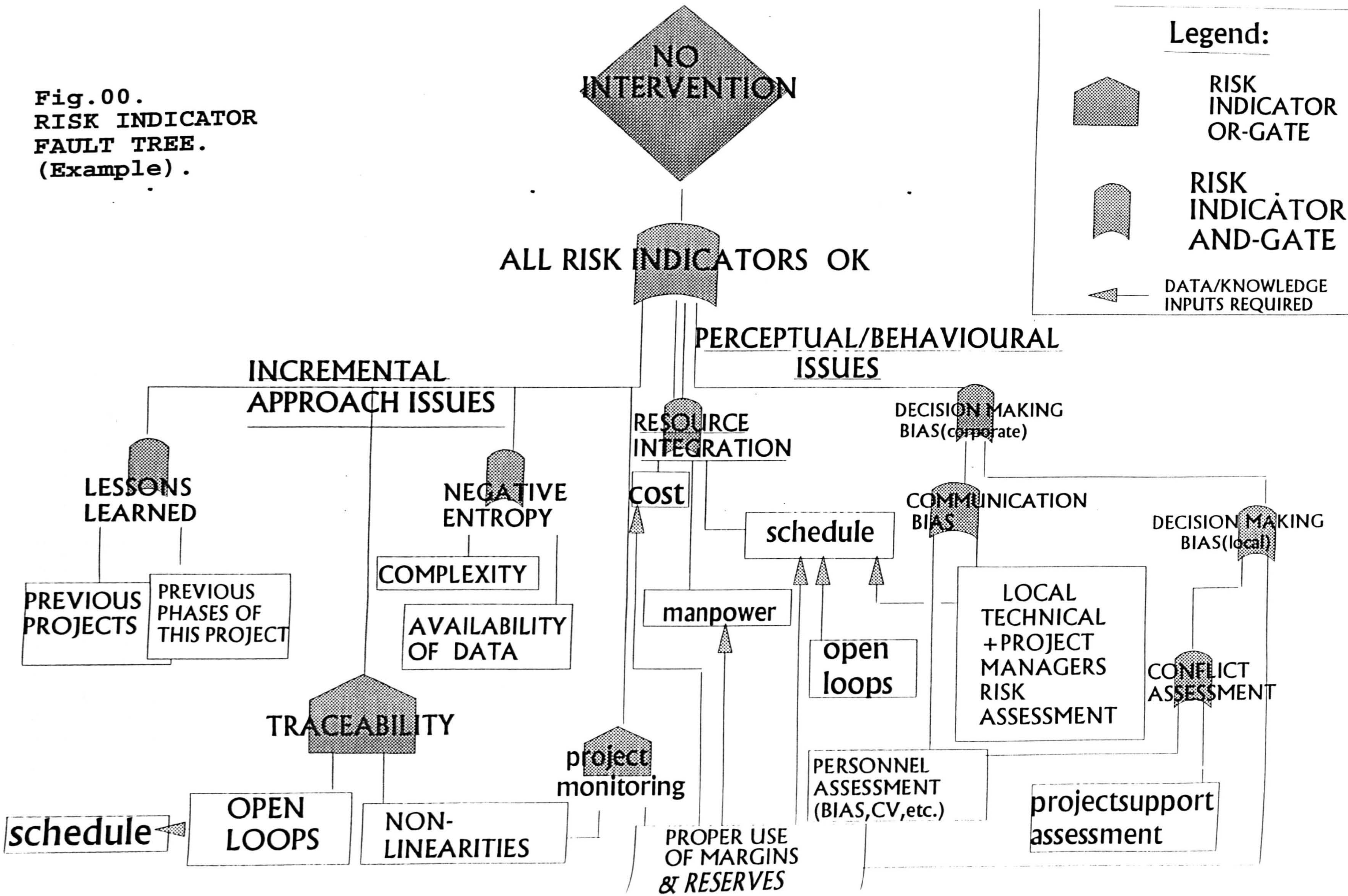


Fig.0 EXAMPLE OF RISK INDICATOR in SPACECRAFT FUNCTIONS TREE

Fig.00.
RISK INDICATOR
FAULT TREE.
(Example).



- spacecraft functions such as guidance, navigation;
- interfacing hardware and software;
- contractually linked companies, with their products;
- financial aspects; essentially penalties & incentives.

Each risk indicator node should also be identified according to:

- its location in an open loop system;
- whether it has multiple interfaces, with other equipments for example;
- its consequences on the spacecraft mission, finances, schedule;
- the resources required to reduce or contain it.

As a final note in this conclusion the following statement is reproduced from the Bid volume entitled the "System Design and Development Plan":

"The elements of the trade-off involve Risk/Cost/Schedule implications. The schedule element is in itself complex; involving design/development feedback, the availability of parts, manufactured and developed items, the phasing of the study/design portion of the programme. In the more qualitative/ quantitative areas of risk/cost, the considerations of risk may be analyzed by converting the implications of "failure" or "what ifs" into schedule extension costs which can then be compared with the cost differences between the models, model standards, apparent schedule savings and the advantages which could be gained on follow-on commercial satellites."

It can thus be seen that there was, at least by the writer of this particular statement, an awareness of the need to assess risk. The problem is that the risk analysis was never done!

5.2.2.3.8 Conclusions

The analysis of the project documentation for projects B and C indicates a continuum of open loop situations, a serious lack of adequate information commencing from the bid submission, and perceptual issues that effectively resulted in the first two issues being camouflaged and then ignored. It could thus be predicted that the organisational orderliness would decrease i.e. inadequate negative entropy injected, and turbulent conditions would develop.

The reporting system addressed the project conditions as if they were static; no method existed to report or probe the multi-dimensioned dynamic situations. In this seriously undefined, non-linear and complex condition, margins were still applied as if linear, incremental conditions existed!

This research has emphasized the prime importance, in the identification and management of risk, of the project supports; the latter being managers and engineers who were perceived to be "very competent, trustworthy and supportive" to their immediate superiors. The documentation review reveals that the contract was commenced with a significant absence of project supports in several critical project areas e.g. the payload contractor.

It is clear that the intervention(review) system did not function in a strategically protective manner; if at all! Many of the problems identified during the Bid evaluation later caused cost and delivery problems during the procurement phases and then problems in orbit. These problems became strategic since they effected the availability of resources for, and the planning of, other space vehicle systems and the implementation of space vehicle dependent services i.e. telecommunications. Effective intervention would have avoided those strategic changes.

5.2.3 Analysis of Interviews.

5.2.3.1 General.

Eight interviews were carried out to support this research. They covered Corporate and Project managers from the prime contractors of projects A, B, and C, and Project, System and Project Control managers from the customer i.e. ESA. The detailed interview notes are contained in annex 6. Analyses of the interviews, based on the main elements developed from this research, are given below. The following analyses contain the authors comments from experience on all the projects concerned; such comments are provided as "Notes.

5.2.3.2 Prime Contractor Corporate Manager for Projects A,B,& C.

a) Experience - Perception Profile.

This manager has a background of a degree in physics and moved into corporate management from head of a "Systems Dynamics" department. A generally analytical attitude prevailed with a good knowledge of how engineers ordered their priorities. This resulted in a bias towards the view that technical problems, for the engineers and their immediate managers, were very predominantly more important than cost and schedule. A fundamental problem was thus construed as that of ensuring the accountability of the engineering responsible.

A clear perception was that if the customer directs a company then it assumes financial responsibility.

b) Strategy.

Macro strategy was established by following the strategy adopted by ESA and then bidding for the relevant programmes. Short term strategy, for example at the project level, was dominated by the conviction that ESA would assist industry if major problems occurred; to the extent of preventing the escalation threat to the programme or to the industrials concerned. By complying with the ESA formal and informal modus operand an ambience of security was established. As stated very clearly by a number of interviewees this was not enhancing the competitive abilities of European industry in the international marketplace.
Note: The result seems to have been that this industry did not establish its own strategic plans but did decide the strategic objective of working compliantly, and passively, with ESA in order to establish a relatively risk free profit; and build up of a large, experienced workforce.

The European consortia followed the ESA lead and met the available budgets, and budget profiles, often by implementing company and consortia investments; contractual clauses covered the recoverability of these investments.

At the project manager level there was no awareness of a company strategic plan; this statement was made in the interview covered in a para.5.2.3.3

C) Intervention.

Within the project it was noted that the fact that the corporate manager involved himself in project meetings, rather than just behaving as an observer, was perceived by the project management staff as intervention and the assumption of responsibility; thus relieving them of their responsibility.

Note: The overall responsibility thus devolved to the corporate manager and, due to the continuous intervention by ESA, to ESA.

d) Environment.

The environment was considered to be international and dynamic; with the main inputs coming from discussions with people in key positions.

e) Risk.

Risk analysis, with options and contingencies, was not carried out.
The main risk was considered to be technical. This aspect of the work completely eclipsed cost and schedule elements; optimisation rarely included the latter. The technique of negotiating a "bogey" price, with no clear definition of the risk thus being incurred, would not be feasible in the open market.
It is very interesting that risk with the co-contractors was, attempted to be, avoided by placing fixed price contracts; particularly where the contractor was involved in advanced technology. Of course, the same ESA "soft" contract conditions also applied, eventually, to the contractor so the risk was also probably perceived to be small. This latter point is very clear in the interview covered in para.5.2.3.5 where ESA actually employed high level experts to work for a contractor in order to "save the programme".

This manager believed in applying hard pressure to lower level managers to "put them on the spot" reference being responsible for the risk in their areas.(An interesting perceptual difference is that from the view of the lower level managers this aspect was not "hard"; see para.5.2.3.3).

f) Risk Indicators.

These were clearly stated as the ESA requirements and milestones. Cost, and cash flow, were also considered as elements to be given careful attention.

g) Open loops.

The defined concept of open loops had not been used but, after it had been explained by this author, it was stated that attempts were made to have as few as possible between the customer and the contractor; where they existed time and material contracts were sought.

When significant, unpredicted problems occurred massive resources were poured into the project to maintain milestones.
Note: It will be recalled that these milestones were defined by ESA and constituted payment points. As far as the industrial project was concerned the strategic value of the milestones was not established. The effect on the overall risk of the project of applying massive resources to problems as they occurred was not known and usually not significantly discussed. The organisation was not particularly designed for these concentrated efforts; lateral negative effects were often considerable.

h) Incremental Approach.

The financial analysis was incremental such that previous project costs were considered and independent assessors were used to gauge the realism of the extrapolations being made.
Note: It has never been clear how the differences between succeeding projects were defined from the risk-cost aspect.

i) Critical Supports.

For all the interviews these were stated to be a few trusted colleagues in key positions.

j) Margins.

Nothing was stated of substance regarding the criteria used to originally define margins nor their monitoring during the project. The concept, from this research, of relating margins with resources was received with enthusiasm.

k) Soft and Hard Aspects.

Major problems between project and line department staff: on the same issues disagreements could occur due only to territorial and organisational problems with no technical basis.
Note: Another example of significant behavioural impact.

l) Living Systems.

Organisations are like families.

5.2.3.3 Prime Contractor Project Manager for Project B and Project C.

a) Experience - Perception Profile.

The background of this manager is a degree in mechanical engineering, the attendance of a two year management course, part time, and movement to project management via technical engineering positions. As with the interviewee in para.5.3.3.4 the management course had a major effect. A belief is held that management must be an analytical process involving team work, sharing of information, and involving intuition.

The interviewee is now a Managing Director of a medium sized microwave electronics company; involved in the Space business in the open international market. This interview primarily addressed the project B and C experience.

b) Strategy.

There was no awareness of a company nor ESA strategic plan.

Now, in the international business domain, a strategic plan, for five years with annual updates, is maintained. Contingency planning, in the event of problems, are prepared. Research and development investment is driven from the strategic plan.

For research activities the feedback loop reference financial return from investments is probably of the order of 5 to 10 years.

c) Intervention.

In general defined as necessary when an area is detected as diverging from an expected situation; the problem was often because something was not happening. Organisational inertia can cause the right questions not to be asked.
Note: A similar comment appears in the state of knowledge review concerning the brain not asking the right questions.

Continuous assessment of managerial performance is necessary.

ESA decided the direction of ESA programmes was practically immoveable once that decision had been made.
Note: This constituted a passive or psychological intervention since it effectively blocked the contractors ability to "do something else".

The industrial company often gives up trying to achieve the best technical solution or contractor selection due to ESA politics.
Technical risk can be assessed more accurately and in more detail at the lower levels.
Note: Bifurcation aspect!.

d) Environment.

The environment is perceived to be something that has to built and maintained current concerning its information content; the local and world wide situation needs to be taken into account.
e) Risk.

Financial and schedule matters were very secondary to technical aspects in the Bid preparation work. Putting lower level managers "on the spot" to make them accountable for the risk in their areas was very soft. For the "correct information" on a situation it is necessary to have "eye-to-eye" meetings; this can be culturally sensitive e.g. it is difficult between Swedish and Italians.

Risk must be addressed at the start of a programme and consists in general of:

- things which are undefined;

- things which have not been done by the company before;

- things for which the output is not sure.

The above three points constitute open loops.

The expert that is known to have previously produced good results is trusted.

The initial assessment of resources required must be from a bottom up detailed analysis.

f) Risk Indicators.

Schedule lateness is more serious than slight technical deficiencies; waivers are usually possible for the latter.

g) Open Loops.

See e) above.

h) Incremental Approach.

This approach is growth limiting; an entrepreneurial jump is necessary for significant growth but the jump must have a solid basis; information for the latter may come from another company.

The most efficient research is done under pressure; for example of meeting a commercial deadline.

i) Critical Supports.

The following critical supports were identified:

- people; the quality of the people are the main resource of the company;

- attention to detail;

- balance between managerial control and freedom for innovation.

j) Margins.

Usually defined from experience and rules of thumb.

k) Soft and Hard Aspects.

No specific comment but the cultural perceptions in a) above relate.

l) Living Systems.

No comments.

m) Culture.

Germany and Sweden are perceived to be tough negotiators but then to work well. With Italy the negotiations are fairly easy but then there are constant questions.

It is considered that individual grow into the company culture; in fact they have to if they wish to make progress. A large company may have many cultures and a local culture can be formed by an individual. The culture can be a strong driving force within the company. There is more fear in large organisations.

5.2.3.4 Customer Project Manager for Project B, and Systems Manager for Project C.

a) Experience - Perception profile.

This manager had a degree in physics and moved into project management via hands-on design activities and lower level management tasks. A major element was the attendance of a management course, of two years duration, part time. This experience introduced management techniques and behavioural aspects which were then applied in the industrial situation. ESAs role was perceived to be that of accepting, or not, the contractors status as presented at reviews. ESA personnel perceive that they are better than their industrial counterparts; in many cases this is not the case. Also many ESA personnel do not appreciate that industries fundamental aim is to make a profit. These perceptions must be changed.
Note: They constitute a risk indicators.

The ESA -industry relationship deteriorated during the project possibly due to increasing scarcity of resources due to massive resources being expended on early problems and associated management problems.

b) Strategy.

The interviewee had experienced the over-specification of requirements and involvement by ESA, both as a member of industry and of ESA. As a strategic measure he attempted to correct this aspect for this project and introduced a "System Performance Specification" which contained all the spacecraft parameters that were applicable to the contractor and which would be monitored by ESA. This specification is now used on many ESA projects but the over-involvement of ESA continued.
The number of ESA reviews was reduced.

c) Intervention.

No direct interventions by ESA corporate management on the

ESA project team recalled.

Italian corporate intervention seemed to be significant.

The ESA intervention was often of the form of saying to the contractor "if you do so-and so then ESA will oppose you at the next major review and it will then cost YOU a great deal of money to change back". This usually had the effect of establishing the ESA position.

d) Environment.

The environment was not competitive. The prime contractor bid for a price but they previously knew how much money was available from ESA. The current situation with ESA supplying the launch vehicle (**note:** there is no reason why this could not be negotiated by industry) and the political domination of ESA means that it is not possible for ESA-industry contracts to emulate the open marketplace.

The main sources of information were the ESA engineers who attended contractor meetings and industrial visits; not the formal reports from the prime contractor.

e) Risk.

Only during the Bid evaluation were the resources considered; they were not monitored during the project. Great dependence was placed on the contractor BID statement that he would "put adequate resources on the project".

The judgement of risk was carried out using experts with this manager making the final decision. An expert with whom the manager had previous experience or knowledge was trusted more.

A significant contributor to the lateness of the project was that a number of ESA requirements, having a major impact on the design, were changed after the project started. The contractor then claimed that all schedule delays and cost overruns were due to these changes. ESA thus accommodated the contractors risk and inefficiencies.

The assessment of the validity of an industrial situation when presented is very difficult. There is a heavy reliance on experts.

f) Risk Indicators.

The imposition of several contractors on the prime by ESA, due to delayed budgetary release, by ESA, resulted in the prime coming to ESA for financial assistance very often for those particular contractors. For the contractors selected by the prime this rarely occurred.

Changing of personnel was considered to be risk increasing.

Weak penalty clauses in ESA contracts were considered to be a major source of risk; more severe contracts poaching good people from ESA contracts, and so on.

Note: Risk indicators was a new concept to this interviewee who preferred the terminology "unforeseen problem area"; even so the principles were not applied.

g) Open Loops.

They were not addressed as such on this project.

h) Incremental Approach.

This manager believed in this concept.

i) Critical Supports.

Key people were considered to be critical supports.

j) Margins.

They were defined based on experience and were often larger than necessary to provide additional protection for the prime.
Note: Margins-on-margins was a problem and on project A required a dedicated effort to a) determine exactly what margins were being used and where, and b) to establish and implement an overall margin policy. The margins-on-margins approach was actually increasing risk because design envelopes became too tight.

Resources per margin was never considered.

k) Soft and Hard Aspects.

Both hard and soft aspects were considered to be based on experience. Examples given related to the solution of project technical problems, where there is a dependency on expert judgement, and to the selection of staff.

l) Living Systems.

No comment was forthcoming on this aspect.

m) Culture

He perceived clear cultural characteristics.Italians would need extra support and their industrial stability was low. The French were politically difficult but technically sound. The Swedish and Germans were difficult negotiators but hen good workers and straight forward.

5.2.3.5 Customer Project Manager for Project C.

a) Experience - Perception Profile.

The background of the interviewee was a degree in physics, industrial experience in the European space industry at the design and management levels and corporate management experience with an American company in the Service industry.

The interviewee initially stated that the ESA(customer) project manager must have at least the experience and qualification of his industrial counterpart; otherwise serious errors of judgement could be made by ESA and respect, as well as money and schedule, will be lost. Mutual respect is one of the most important aspects of management. It is vital that an engineer or manager has actually had hardware experience.

b) Strategy.

At the Bid phase the resources must be very carefully checked; this will require visits and discussions with contractors. The strategic situation seems to be that industry expects ESA to help them if they get into trouble and ESA accepts that role by establishing large monitoring teams per project; and maintaining them current on all aspects of the project.

c) Intervention.

ESA frequently does the job of the contractor, often due to its political responsibilities. This intervention, which can be regarded as training, has improved the efficiency of some companies.

The corporate management should be ready and available to intervene at the request, and only at the request, of the project manager. When the ESA project manager wishes to intervene in the industrial business it must be via the industrial project manager.

ESA imposed external managers on the payload contractor into the key positions; this probably saved the project.

d) Environment.

This interviewee considered his environment to be very general but primarily management; the latter aspect dominated his reading selection and assessment of general situations. This appreciation was the result of his experience.

e) Risk

PERT can be useful for overseeing the project but it is difficult to maintain it current due to the vast amount of

input data update required. The only really reliable way to assess the realism of resource allocation is to visit the companies concerned and spend time understanding the problems and their situation.
The future is unpredictable.

A team of very competent engineers that can be moved to the problem area very quickly is required if risk containment is to succeed.

Some areas are predictable from the point of view of being "almost certain to give problems". Advanced technology is such an area and on this project most of the eventual technical problems were identified at the start of the project. The reason there was so much delay and overspend on this project is that after the payload problems were solved, by ESA inserting some high level managers from the U.S.A. into critical management positions at the payload contractor, serious problems at the prime contractor suddenly became apparent. The payload situation initially obscured the prime contractor problems.

In some of the high technology areas ESA placed back-up contracts because,at a certain time, failure seemed certain.
Note: This degenerating situation is clear from the daily records analysis; see para.5.2.5.

f) Risk Indicators.

Lack of experience is a major risk indicator; such persons would have to be monitored very thoroughly. This aspect could be detected initially by interview and Curriculum Vitae perusal. All key people must be known.

Most technical problems are identifiable at the commencement of a project. Its very difficult to estimate if the resources are adequate; company visits are the only way.

Company maturity and maintaining the key persons in post, not permitting the company to move them to another project, is fundamental to the control of risk.

g) Open Loops.

There were only very short periods when the project environment was in a steady state. Most of the time there were problems here and there; when one was solved another would arise. Major crises did develop and there was one particularly major crises(chaos!) when the prime contractor declared things were too complex to understand and control and ESA was asked to assist.
Note: This was a requested intervention due to a crisis(chaos?)!.

The cycle time from the project being reasonably tranquil to approaching, and reaching crisis conditions, was very short. This tended to be the case for most areas; even those that were originally thought to be benign.

The theory that problems start at a low level and emanate, or branch away, from that point is supported by the experience on this project.

Using PERT charts it would not be possible to identify open loops; there is also the problem that they are permanently obsolete due to the data, manpower and time needed to update them.

h) Incremental Approach.

Not specifically commented.

i) Critical Supports.

Very definitely stated to be experienced persons.

j) Margins.

Margins were not used in a linear fashion; they were based on experience. The margins can only really be assessed for their true value when hardware is being built. The margins are actually only monitorable in steps; for example, after initial build, qualification, engineering model.

k) Soft and Hard Aspects.

The aspect of mutual respect is very important; experience is the main attribute by which respect is judged.

l) Living Systems.

No comment on this point.

5.2.3.6. Customer Project Control Managers for Projects B and C.

This analysis considers the inputs from four project control managers. The classification of the information is different since these managers are not involved in decision making but provide a service to the project managers and engineers. They are intimately involved in the analysis of schedules and resources.

a) Strategy.

Large companies can be run by a few, very detached executive e.g. Brown Boveri from a small Swiss town.

Planning provides a static envelope of time and resources.

b) Risk.

The planning documents do not indicate risk, they do not adequately cover resources, and open loops are not apparent and are not addressed.

Many phase C - D contracts are started based on underpriced bids; this is generally realised but insufficient detail prevents substantial comment. There is often the intention to look at the details later but this is rarely done.

The Bid documentation does not permit correlation of schedule and cost; nor consideration of technical impacts. Many Bid evaluations are restricted to Master Bar charts and sub-system reviews; this is insufficient.

Many phase C - D problems are caused by lack of completion of phase B.

Many problems are due to top level specifications being incomplete; particularly from the customer.

c) Intervention.

To much intervention can cause crises to continue; detailed intervention is counterproductive.

The responsibility of the prime is reduced by constant ESA involvement

d) Critical Supports.

The tendency is to introduce many young people into projects. This results in freer thinking but loss of experience; this is proving expensive and very demanding on the time of the experienced staff.

e) Turbulence.

There does seem to be a pattern relating to the evolution of problems resembling some sort of transition from a relatively steady states to a crises.

f) Margins.

They are popular because they are simple and therefore everyone thinks they understands them; they are rarely communicated with respect to risk.

g) Perception.

Different cultural aspects are very important e.g. Germans manage differently than Italians.
Fixed price contracts impose large pressures on the company

internally.

A lessons-learned culture is essential.

h) Risk Indicators.

Planners must be technically qualified; they are usually detached from the engineers which generates risk.
Very few project management tools are capable of integrating cost and schedule.

A major risk indicator is that the project personnel are too far from the hardware and testing action.

Payloads, historically, tend to be more risky.

The rate of disappearance of project slack could be a good risk indicator.

The monitoring of invoices sent to the customer, at all levels, is a good risk indicator.

The superimposition of manpower and cost on PERT charts would be very useful.

5.2.3.6 Conclusions.

The interview comments represent various perceptions of the project conditions. These have very good agreement with relevant conclusions from the documentation analysis.

It is interesting to note that in general the comments of the managers did not seem to be customer or contractor dependent.

Financial, including schedule, risk was willingly shared or passed, and often unknowingly or unwittingly taken, from one level to the next even if loss of authority and responsibility resulted. Examples are corporate management involvement, rather than observation, in middle management meetings and customer involvement in contractor meetings. This usually resulted in more delays and expense since the information base and key persons influences often disadvantageously changed.

Strategic planning was almost totally absent but one manager did consider the limitation of customer involvement in the contractors business as a strategic issue.

Perception was a major issue. For example good data was considered to be only possible by "eye-to-eye" discussions with the involved parties. Also, the "hardness" of a particular managers approach from his perception, and that of his staff, were often very different. Another example was the decision not to monitor resource spending but to "rely on the contractors statement in the bid that he would make adequate resources available".

The environment was considered to be dynamic, defined by the information known at a particular time which had to built and maintained, and to contain clear cultural characteristics.

Risk indicators were considered to be:

- lack of experience;

- the need to visit companies to make assessments;

- maintaining key people in post;

- planners who did not understand engineering

- successful projects dependency on phase B;

- planners being too far from the hardware;

- the rate of disappearance of schedule slack;

- the rate of reception of invoices and non-conformances;

- weak customer penalty clauses.

Open loop situations were only contracted on a "time and material" basis but planning generally only indicated static envelopes and not risk. Advanced technology was considered in this area. It was also stated that major problems could obscure other developing problems which then became visible when the "smoke cleared" from the big problem.

There was usually a lack of detail when needed and lack of time to properly evaluate when the data became available; this is supported from the documentation review.

It was considered that relatively steady state, turbulent, and crisis, conditions did exist but that the steady state conditions were usually very short.

The definition of margins was generally considered to be by "rule of thumb" and they were thought to be popular because they were simple even though not fully understood; applicability only during the hardware phase was mentioned once, to try to limit the non-linear problems.

The future was considered to be unpredictable.

5.2.4 Project Ground and Orbit Failures Analysis.

5.2.4.1 General.

The objective of this analysis was to identify if, and to what extent, actual failures related to such aspects as inadequate risk definition, risk indicators, the propagation of problems etc. This would then give an indication of the criticality potential of the those aspects when they were detected during a programme; for example, during a review of Bid documentation.

This analysis was carried using a database conceived and designed by the author but not implemented by him. The database utilises RBASE and a front end software package that enables 2- and 3-dimensional histograms to constructed, according to the choice of the analyst, of the main parametric classifications.

The data covers the period 1981 to 1991 and includes a high percentage of all the published information concerning Failures, Non-Conformances and Accidents(FANCS) that occurred on space vehicles during ground testing and launch to, and operation in, orbit during that time frame; FANCs are referred as "problems" for the remainder of this chapter. Hence the data covers space vehicles world wide, not just European.It is considered that there are significant common aspects to data appertaining to space vehicles designed and built by different procurement organisations. One reason for this is that many qualification and management methods originated in the USA(NASA); another is that much of the technology is similar with annual seminars world wide to disseminate results and discuss problems. Yet another reason is that many customers use similar ITTs and methods of evaluating bids; see chapter 4.

A total of approximately 900 data points, or problems, were collected and classified in the database. Histograms of the parameter combinations used in this thesis are contained in annex 7.

5.2.4.2 Analysis.

Certain groupings of "causes of problems", and "interpretations of events" in terms of the concepts introduced in this thesis form the basis of this analysis. These grouping and interpretations are now presented; the numbers in parenthesis refer to the number of problems.

a) Risk.

- Programme risk not properly understood or adequately quantified(22).
- 30 propulsion sub-system(s/s) problems caused direct loss;
- 35 propulsion s/s problems caused mission loss;

- 10 system engineering level problems caused mission loss;
- 5 mechanical and structure s/s problems caused mission loss.

b) Open loop aspects.

- undetected/ ignored quality trends e.g. parts(10);
- qualification invalidated(32);
- inadequate failure mode consideration(47);
- design margin violations(13);
- inability to test or simulate(3);
- failure scenarios poorly understood(5).

c) Propagation of failure effects(bifurcations).

- problem effects spread to the next level(130); (component to equipment level)
- problem effects spread two levels(260); (component to sub-system level)
- problem effects spread three levels(190); (component to system level).

d) Propagation of failure effects by sub-system(risk indicators and bifurcations).

- propulsion s/s;
  - one level (38);
  - two levels (46);
  - three levels(50).
- on board data processing s/s;
  - one level (10);
  - two levels (15);
  - three levels(10).
- mechanical and structure s/s;
  - one level (13);
  - two levels (16);
  - three levels(18).
- attitude and orbit control s/s;
  - two levels (10);
  - three levels(17);

- power s/s;
  - two levels (13);
  - three levels(14).

e) Problems which could have been prevented with improved practices(perception; open loops; soft issues).

- propulsion s/s(110);
- mechanical and structure s/s(35);
- on board data handling s/s(30);
- attitude and orbit control s/s(20);
- power s/s(10).

f) Problems per technology or equipment type. (risk indicators).

- propulsion s/s(220);
- mechanical and structure s/s(70);
- valves/ leaks(62);
- on board data handling s/s(60);
- attitude and orbit control s/s(52);
- power s/s(45);
- software(27);
- deployment(25);
- turbopumps(23);
- gyros(9).

g) Interface failures. (trajectories; risk indicators).

- between project phases(7);
- between equipment and sub-systems(11);
- between sub-systems and system(7).

5.2.4.3. Conclusions.

The risk has been defined in the very pragmatic terms of loss of space vehicle, the mission, and money. The mission is what the space vehicle and the crew have to do in the operational domain.

Also, specific open loop causes have been identified with respect to space vehicles. A similar exercise concerning the products from any other organisation i.e. not concerned with Space, should reveal particular causes of open loops.

The progressive interactive effects of failures which originated at the lowest detectable level i.e. the space vehicle equipment, are clearly shown as impacting the two "higher" levels of sub-system and system. These are submitted as examples of "bifurcation". These effects are taking place within a designed hardware and software system with minimal human interface; the problems being addressed therefore relate primarily to "hard" aspects.
The value of this exercise is that the results indicate that particular sub-systems, and particular interfaces, are more prone than others to cause higher level failure effects; they should therefore be considered in the a priori definition of risk indicators.

5.2.5 Analysis of Daily Records.

5.2.5.1 General.

The daily records of the author covering the period 1973 to the present and containing details of all meetings, problems, investigations etc. in which the author was involved have been analyzed. This analysis required the consideration of the interview, documentation and in-orbit results and hence this section contains a final, collective analysis of all data.

It is emphasised that these analyses are based only on **actual, "real project", data.**

The above period was spent at ESA and during that period the authors work moved from engineering design to management of a technical division; project management activities took place en route. The author has been directly and heavily involved in projects A, B, C, and D. The objectives of the analyses were to;

1) search for dynamic risk indicators, and,

2) try to identify a pattern(s) or structure(s) which would enable an intervenor to function in a preventative manner concerning the degradation of strategic objectives.

It is submitted that significant contributions have been made towards the achievement of both objectives.

5.2.5.1.1 Dynamic Risk Indicators

As mentioned earlier a project is considered to consist of a number of linear and non-linear activities which respectively form closed and open loop systems; interactions can be numerous and complex. These activities constitute the flows which course through the project and which establish its dynamic nature. The function of a dynamic risk indicator is to provide, in as real time as possible, information of what is happening within the flows themselves.
An analogy with a climatic weather system has a certain relevance. In order to assess the developing non-linear dynamics of a storm front the meteorologist probes the atmospheric air flows with instruments that indicate to him the actual status at a particular time. When all the indicated information is placed on a chart certain patterns are identified that enable experts to predict the onset of turbulent and chaotic conditions which could lead to high risk consequences for involved persons.

In a project the sensors providing flow information are the people involved. When their perceptions are placed on a chart certain areas are revealed where a number of grave concerns exist; some occurring simultaneously. It is submitted that the **perceptions of the people involved constitute dynamic risk indicators** since they are essentially registering a particular situation at a particular time with respect to the acceptability of the consequential risk. Charts of these dynamic risk indicators are given for the four projects in Figs.7, 12, 17 and 22. Scaling factors have been used in these 3-dimensional computer plots to indicate the relative significance of the meetings which took place at three managerial levels viz. top, middle and lower.
The factors are related to the lowest level meeting and are based on a subjective assessment by the author. The scaling chosen is such that the top level management meeting is considered to have three times the impact, on the contractor if such an output is produced, as the middle management meeting; the latter is considered to have five times the impact of the lower level management meeting. This scaling is considered to be proportional to the criticality of the problem in terms of its possible effect on project success. The scaling factors thus present, in the computerised plots, one top level management meeting as equivalent to three middle level and fifteen lower level management meetings. Thus if a detailed technology item is discussed at the top level meeting then it is assumed that the managers at levels two and three have been unable to satisfactorily deal with it and it has been referred up.

The scaling indicates that:

1) the level three and two managers consider the criticality of an issue to be so significant at system level that it must be referred directly to the level one meeting; or,

2) the level three managers would typically make five unsuccessful attempts to resolve an issue before referring it to level two; the latter would make three unsuccessful attempts before referring it to level one.

The size of the scaling factors is not significant with respect to the conclusions of this research but they do emphasize the peaks on the charts.

5.2.5.1.2 Patterns.

The search for **patterns** has utilised top-down and bottom-up approaches; commencing with the former.

Current theories of pattern recognition centralise on three main approaches namely:

1) template matching:
in which comparison of information which has just stimulated the sense organs (retained in sensory memory) is made with the relatively permanent information acquired during a lifetime;

2) prototyping;
in which abstract forms, instead of templates, represent the basic elements of a set of stimuli;

3) feature selection;
the most influential theory in which each stimulus pattern can be thought of as a configuration of elementary features. Letters of the alphabet for example are composed of combinations of about twelve basic features.
The main problems with the above theories are;
- difficult to recognise the unfamiliar;
- they do not take account of context and expectation;
- prototypes have not yet been successfully defined(240).

The starting point in this thesis has been the 3-dimensional charts of the dynamic risk indicators mentioned above. It is important to recall that these charts have been constructed from the 1200 data points relating to the four projects analyzed, over a period of twenty years; see Annex 8.

5.2.5.1.2.1 Pattern 1.

The first pattern that emerged was on the 3-dimensional charts and consisted of increases in the density, and heights, of the "meeting frequency" peaks at various times. These clusters correlated well with statements of problems from the interviewees, as shown on the raw data charts in annex 8. These patterns of clusters have been further analyzed resulting in the identification of areas of turbulence and chaos in the following manner.

For each 3-dimensional chart of dynamic risk indicators two related charts have been constructed identifying areas of turbulence, chaos and intervention; see, for example, Figs.8 and 9. These identifications also used data from the interviews, the documentation analysis and the in-orbit analysis.

The two charts identify the following aspects.

1st chart:	The interactions of technology, equipment and system problems which caused turbulent and chaotic conditions to develop. Intervention by the customer is also shown and its occurrence seems to correlate well with the turbulent and chaos conditions. This description relates to Figs.8,13,18 and 23.
2nd chart:	The time between turbulent states is shown together with the growth of the consequences of lower level problems due to their being "built" deeper and deeper into the system as the project develops. Hence a technology problem may have limited impact at the technology level but can have enormous consequences if it occurs when built into a system due to the equipment and sub-system interfaces that might have to changed to accommodate the rectification of the problem This description relates to Figs.9, 14, 19 and 24.

An area has been identified as turbulent if six or more problems and/or problems of a certain significance e.g. middle management involved, occurred simultaneously at two project levels or more. An example of the latter are problems occurring at the technology and equipment build levels. In addition the perceptions of the managers involved at that time were considered and also whether adequate data was available to the managers concerned. Turbulence is denoted in the dynamic risk indicator charts by clustering of the "peaks".

The state of chaos has been defined by areas of turbulence increasing, and by higher peak densities, on the dynamic risk indicator charts. Chaotic conditions were identified by a number of interviewees, e.g. in project C at one point the prime contractor was faced with so many problems he did not know what to do next, and correlated well with the development of clusters.

It is submitted that the clusters represent turbulent and chaotic conditions and that the build up of the clusters can be used to indicate and predict, in a dynamic environment, the onset of turbulence and chaos.

5.2.5.1.2.2 Pattern 2.

The second pattern related to the continuation of certain problems throughout the project life cycle. In each project there were approximately twelve problems that remained active for a significant part of the project and dominated the development of turbulence and chaos. The domination process appears to be analogous to a positive feedback system whereby small effects grow into bigger and bigger effects as the system is transported along the project development cycle. The objective would be to replace the positive feedback with a negative feedback type system such that the small effects die away.

5.2.5.1.2.3 Pattern 3.

The third pattern shows that although intervention by the customer occurred after the turbulence had been established it did reduce the turbulence in most cases. This "intervention after the act" mode was clearly not cost nor schedule effective since cost and schedule overruns still occurred. The complementary pattern to this failure circumstance,i.e. intervening "after" the turbulence, is the association of the turbulence with open loop systems; it is the latter pattern which is significant for the intervenor working in a preventative mode. All critical items which have been analyzed in this section were basically open loop systems and were identifiable as such prior to the commencement of phase C-D. This static risk indicator approach, with its consequent patterns, was not applied by the management of this project.

5.2.5.1.2.4 Pattern 4.

The fourth pattern relates to the actual structure of the growth of problems which finally produces the turbulence and chaos. Specifically it relates to problem solving and consists of a low-level or bottom-up assessment of the project situation. The value of this pattern is that it can give advance warning of possible combinatorial effects which, emanating from small changes at the problem source level, could cause major problems at the system level. The initiating event at the lower level need not be the occurrence of a problem; it could equally be a slight change in a rule e.g. the truncation of a life test programme.

In fact the rules of the project should drive the various and non-linear tendencies, at all levels, to converge to achieve the project objectives. A change in the rules could cause a different objective to be sought, often unwittingly, by project management. Awareness of the significance of the project rules and their mutual criticality falls also within the domain of the intervenor.

The pattern that has emerged has been based on the authors experience and a wide spectrum of bibliographic review (5,10,13,23,36,42,58,62,104,177,185,186,188,191,193). The pattern is that when a problem is encountered by an engineer, or a group of persons, within the schedule and cost constraints of a typical project environment, then a number of alternative solutions are identified. Generally the alternative solutions are ranked according to their perceived probability of success, which is usually mainly subjective, and the "best" solution selected and translated into a work-around plan to be implemented in parallel with the on-going work. It has also been noted that as the life cycle progresses the number of pragmatic options to resolve a problem decrease i.e. there is increasingly less opportunity for work around plans that are significantly different, or require significantly more resources, to the baseline plan. This tends to make the persistence of problems more critical and their, potential and actual, propagation effects are perceived to be faster. Current research on the subject of problem-solving is supportive of the above and is broadly represented by the findings of Newell and Simon(196) and Klien et al(197,198). The former state that a problem space approach reproduces human style reasoning and that it involves a step-by-step mental search through a vast "problem space" of possibilities, with each step guided by a heuristic rule of thumb; "if this is the situation, then that step is worth taking". This is complimented by Klein et al who have concluded that experienced decision makers can usually recognise ways that situations are typical, including typical responses, and that relatively few decisions are made using analytical processes such as generation of a variety of options. They also stated however that as the situations increased in complexity then verification and eventually conscious deliberation including consideration of alternative hypotheses took place. It is also interesting to note that Flood and Carson in their work on Complexity(62, p.21) actually show a bifurcation type diagram indicating the "disassembly of complexity" over a three level process.

In view of the positive feedback potential to produce a growth of the initial small effects of problems, such that they could become dominating influences on the entire project, it is submitted that if the intervenor is be effective in the achievement of the strategic objectives these open loop and feedback mechanism patterns must be identified at the commencement of the project and monitored continuously.

If the combination of all the project flows are termed the "stream" which they take to achieve the project objectives then it can be interpreted that the stream, or part of it, will divide into two stream when a problem occurs, see Figs. 1 through 6.
It is also submitted that if another problem occurs, on

either the on-going or the back-up stream, then another division or branching will occur. It is emphasized that the above characterisation is based on the final result of the multitude of complex forces at work in problem definition, analysis, resolution and rectification process. From the bibliographical review mentioned above, and personnel experience, the author shares the rejection, by Klein(186), of the Deweyian, Gestalt(perceptual restructuring of problems) and Information Processing(step wise method) based problem solving models(240) and finds more acceptable the concept, also by Klein et al, that:

> " problem solving consists of two interacting processes; the on-going identification of needs, and the search for procedures to satisfy these needs. The needs(rules) constitute criteria for the adequacy of the solution i.e. a solution should bring about the satisfaction of the needs...needs must enter into an account of the problem. The needs, of an objective situation, stay constant(or else the entire problem changes); it is their psychological representation that changes. A limited number of alternatives can be generated and evaluated before the confusion produced offsets the information gained. For ill-defined problems, there are often several adequate ways to identify a problem. Any identification is valid that produces a procedure that alleviates the need. Misidentification is marked by a persistence of needs after procedures are implemented. An adequate identification of a problem includes auxiliary solution properties, such as environmental characteristics and personal needs. Evaluation consists of matching the solution criteria to the properties and inferred consequences of each alternative procedure."(186).

The parenthesis "(rules)" has been added by this author.

This conceptualisation of the problem solving process by Klein contains a number of points already derived in this research e.g. the allusion to confusion, and the significance of the psychological(perceptual) aspects as the main variables in the problem solving process, A number of additional observations are pertinent to the definition of the fourth pattern.

All organisations are trying to grow; quantitatively and/or qualitatively(63,187). This includes both the contractor and the customer and since they are working together they will either grow on a co-operative or predatorial basis. The co-operative basis can be exemplified by heavy customer involvement accompanied by light penalties and restrictions against going bankrupt together with good incentives. In this scenario there is almost a tit-for-tat liaison whereby the contractor "exposes all" and permits massive penetration into his work areas in return for the customers

"forbearance" and money when schedule slippage occur or extra resources are needed. This is the ESA approach.
The predatorial basis is where both the customer and contractor are continually trying to "win points" off each other, by ingenious tactical and strategic interpretation of the contract rules if necessary, in order to establish a dominating position and increase their corporate strength.
The general environment is very competitive with the self organising and adaptive capabilities of the contractor being critical aspects in his growth or survival.
In both cases there are losers. In the former it is a particular part of a large organisation, or the tax-payer, and in the latter it could be the contractor or the customer; usually the former. In assessing the problem solving patterns it is important that the intervenor interprets which of the above scenarios, completely or partially, apply.

Also, it has been submitted that a project is a self organising system. This means it is adaptive and therefore tends to turn events to its own advantage. The project, like most human organisms, will thus try to avoid problems because their existence will disadvantage the system due to the loss of positive feedback to provide self reinforcement. This avoidance process is a direct function of the perception of the project executives; in many cases their careers depend on their ability to demonstrate that everything, including the problems, is under control. There is often, regrettably, only a tenuous connection between the "demonstrated satisfactory status" and the actual factual situation; see chapter 5.2.2 and 5.2.3. The tendency therefore is to report that the situation is "steady state" until it degenerates to such an extent that the turbulence it is creating is self evident.
The result of the above process is that according to the project reports problems seem to suddenly erupt, almost from nowhere! However the picture according to the dynamic risk indicators, see Figs. 7 through 24, clearly shows a gradual build up of most problems i.e. an awareness which initiated discussions was present before the problem erupted to effect more than "its own local territory".
This gradual build up, which involves a similar increase in resources, is essentially a steady state process since the involved parties are convinced they can contain and solve the problem; it is probably not being communicated anyway.
At a certain point the problem seems to assume a different identity. This could be due to interface effects, too rapid depletion of resources, a failed test result, or slow progress due to industrial strife etc. This new identity is often perceived to be immediately threatening because it is considered that a rapid propagation of the problem consequences across the project may result with a runaway situation concerning resource utilisation. Intervention then takes place and resources may be "thrown at the problem"(see chapter 5.2.3) in order to avoid the above propagation.

At this point, with the submission that the research indicates that real life project situations require the application of the science of chaos in order to represent and understand them, it is interesting to hypothesise that the propagation of problems via a problem branching process as outlined above replicates the period doubling processes identified by Feigenbaum(152,153) as a prelude to chaos. The authors conclusion is that based on personal observation and experience it does appear that some kind of problem propagation process does take place. It seems, subjectively from the experience of being immersed in project business for many years, that the speed of problem propagation increases as the number of problems increase. It also seems to be the case that as the problems increase the resource utilisation becomes disproportionately high; both deliberately as a result of management instruction and involuntarily as a result of inadequate attention being given to control of resources in the increasingly turbulent conditions. These subjective conclusions of the author have been supported, subjectively, by many colleagues and by the interviewees; see chapter 5.2.3 and Annex 8.

The fourth pattern is summarised as follows.

It is submitted that the solution of project problems involves a branching process with respect to the stream of flows involved. The stream includes the technical and organisational direction, resources utilisation, and scheduling.

It is submitted that this branching occurs after an apparently steady state activity and can rapidly propagate if the initially identified problem solution is not successful. It is further submitted that the problem propagation is perceived to be rapid due mainly to its potential, in the presence of positive feedback mechanisms, to deleteriously effect other areas of the system; this latter perception is based on previous project experience and is subjectively interpreted as a real threat. It is submitted that a number of problems simultaneously propagating, particularly if they are at different project levels, will create intricate situations which will be perceived as very complicated, or turbulent, and, in the limit, chaotic by the project executives. It is also submitted that a single problem can cause a chaotic project situation to develop if:

a) it occurs in the technology; and

b) it is used in a number of system elements; and

c) its proper functioning is critical for system success;

and d) it persists as the project life cycle proceeds.

From the above it is submitted that the occurrence and propagation of particular problems in a project can neutralise the adaptive and self organising characteristics of the project such that it passes from an essentially predictable, linear mode into a non-linear and turbulent/chaotic mode in which prediction is not possible. A significant point being made here is that the projects ability to respond in a positive, resilient, confident and motivated manner when faced with problematic scenarios such that it adapts in a way which is most beneficial to itself may diminish or even be lost. It is submitted that this reduction in the projects ability to maintain its self-organising capabilities is itself part of a positive feedback loop which can cause local turbulence to grow to local and even general chaos. These characteristics are clearly shown in the analysis of project C; see Figs. 17, 18 and 19.

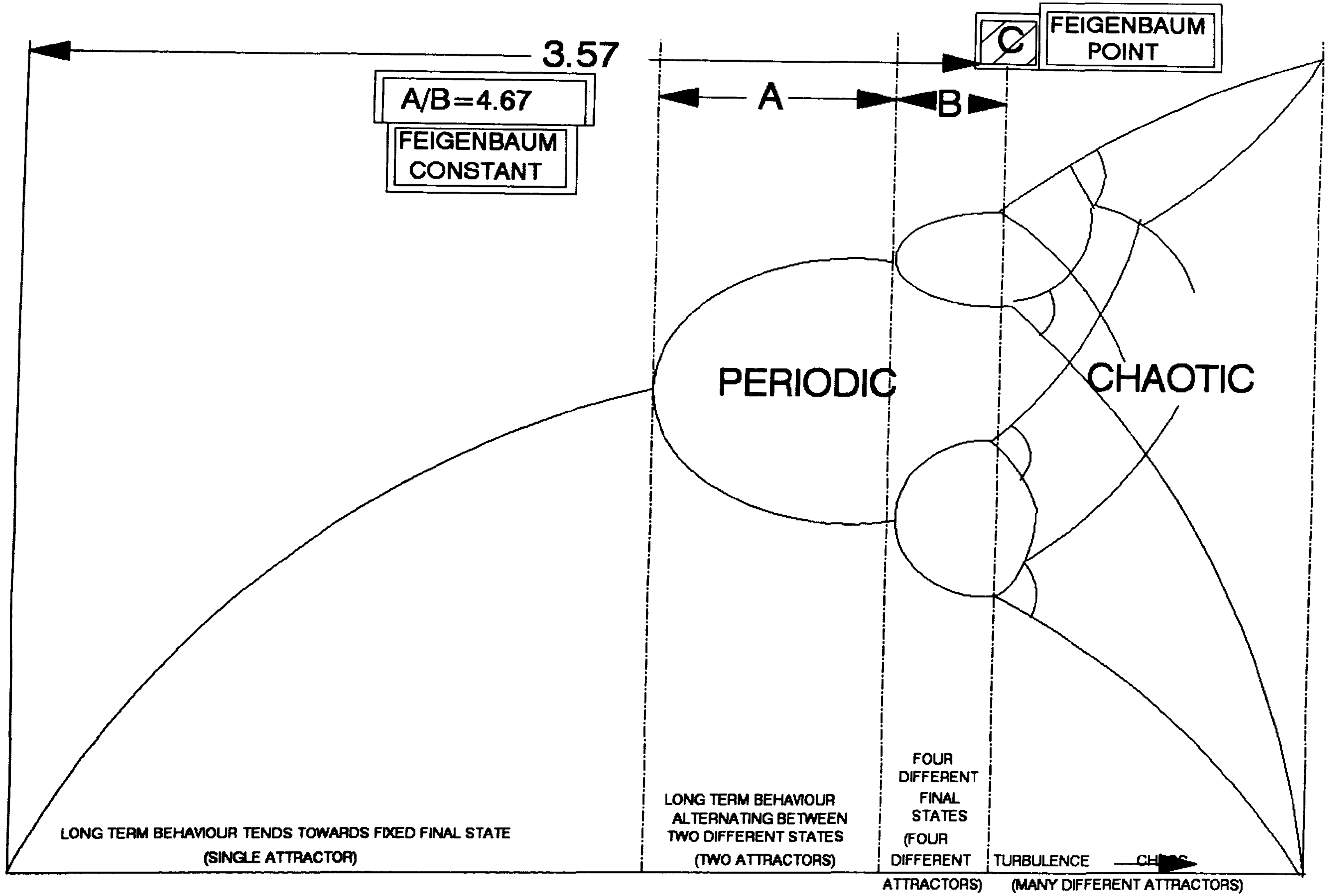
It is submitted that this situation **may** be appropriate for the use of Feigenbaum Diagrams but at this time insufficient data exists concerning the doubling, or halving, of resources, schedule time, or cost. It is clear that the resources, for example, increase very much faster, but not as a step function, when problems are present and they "seem" to be of power law magnitude; this however **has not been demonstrated**. A dedicated "problem propagation-resource, schedule and cost measurement" research programme needs to be implemented.

However by combining the problem propagation process, described above, with the pattern of problem evolution from the "frequency of meetings" charts, see annex 8, the pattern that emerges can be interpreted as being very similar to a Feigenbaum Diagram. It is submitted that the development of turbulence and chaos moves through phases of very similar configuration, or shape, to Feigenbaum Diagrams. It is not submitted that predictions can be made using the Feigenbaum Constant or the Feigenbaum Point; it is hypothesised that such predictions will be possible after more research.

In view of this conclusion an explanation of the Feigenbaum Diagram is given; see Fig.1. Figs. 2 through 6 have been produced to show the branching effects of problem propagation in the areas of technology, equipment build, sub-system build and system integration presented in the general manner of Feigenbaum Diagrams but omitting the predictability scaling factor, the Feigenbaum constant. It is emphasised that, in the authors experience, the actual development of problem scenarios is as indicated on these Figures.

In more detail Figs. 1 through 6 show:

a) the clear demarcation of the long term behaviour of a



NO INTERVENTION

Note: This is a symbolic presentation not a graphical plot.

FIG.1: CHARACTERISTICS of the FEIGENBAUM DIAGRAM

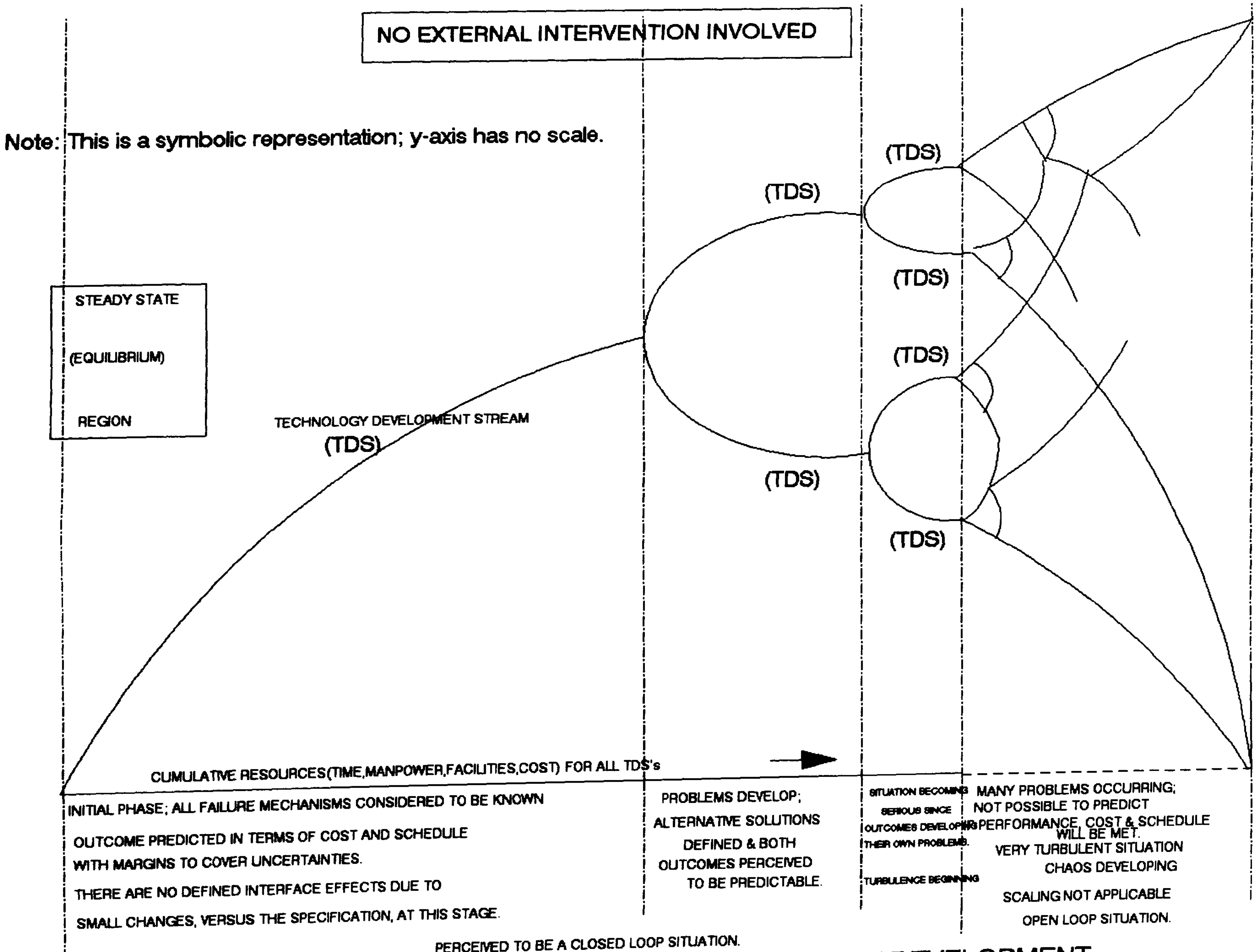


Fig.2: PROBLEM PROPAGATION APPLIED to TECHNOLOGY DEVELOPMENT

Note: This is a symbolic representation; y-axis has no scale.

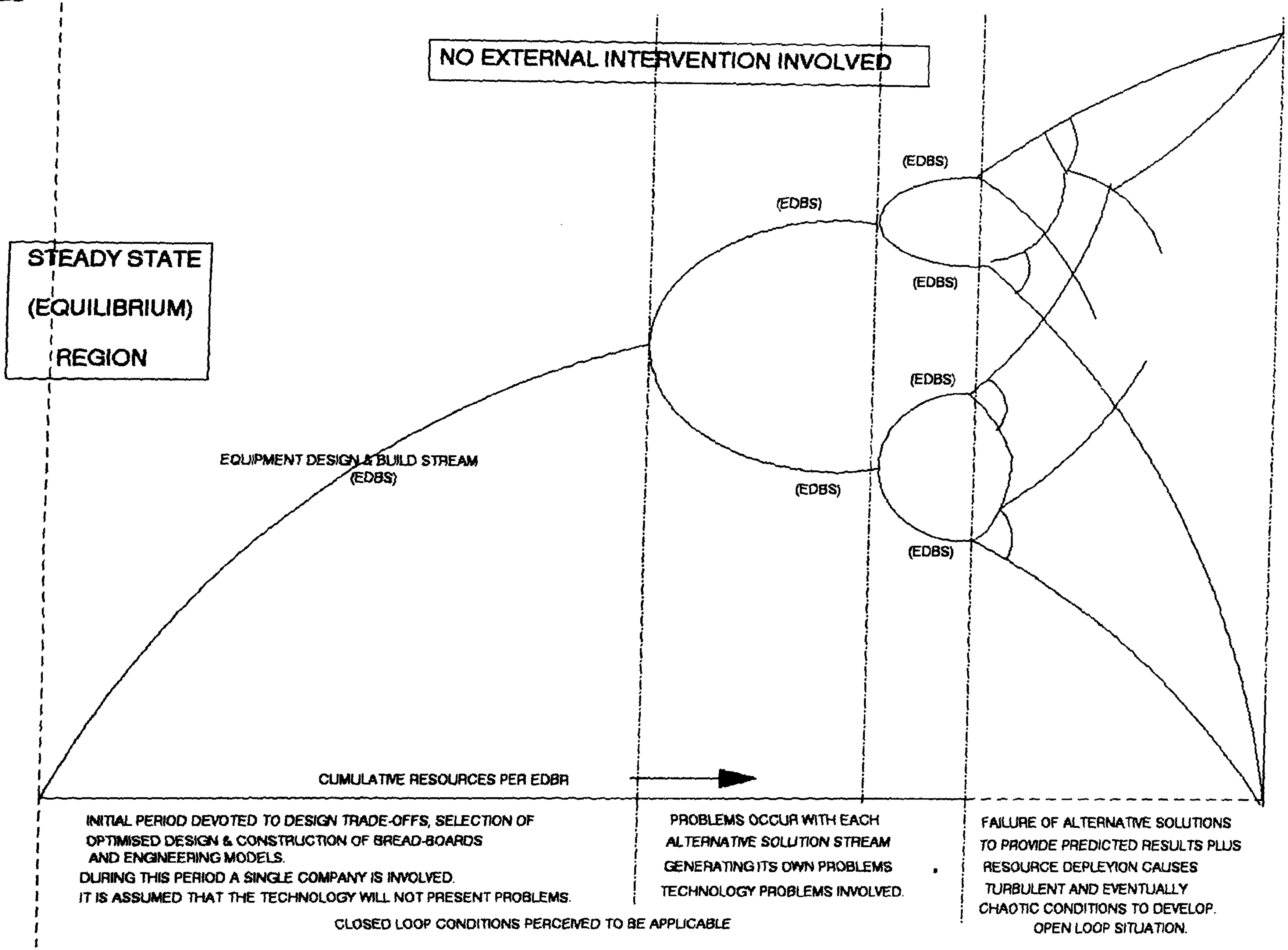


Fig.3: PROBLEM PROPAGATION APPLIED to EQUIPMENT DEVELOPMENT

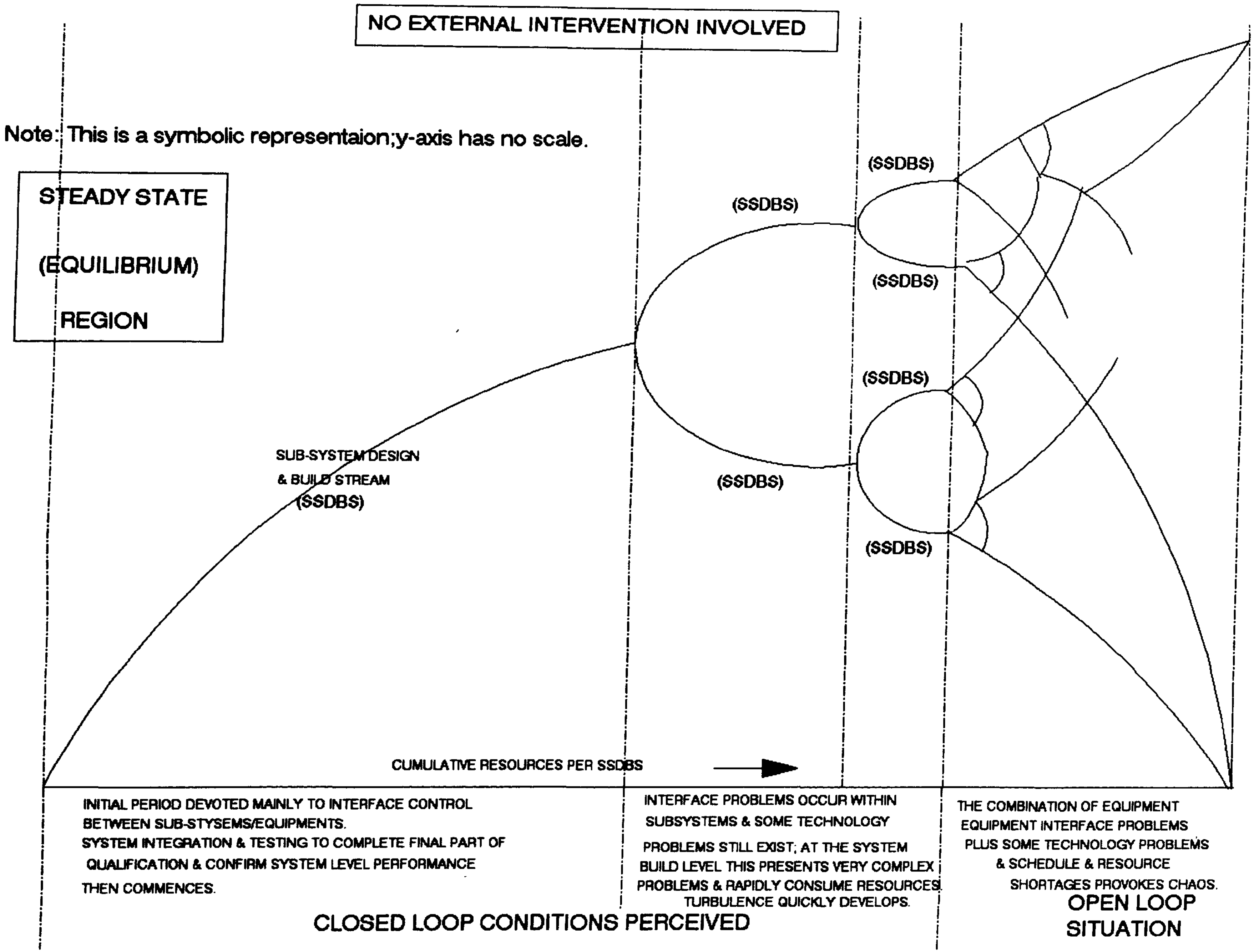


Fig.4: PROBLEM PROPAGATION APPLIED to SUB-SYSTEM DEVELOPMENT

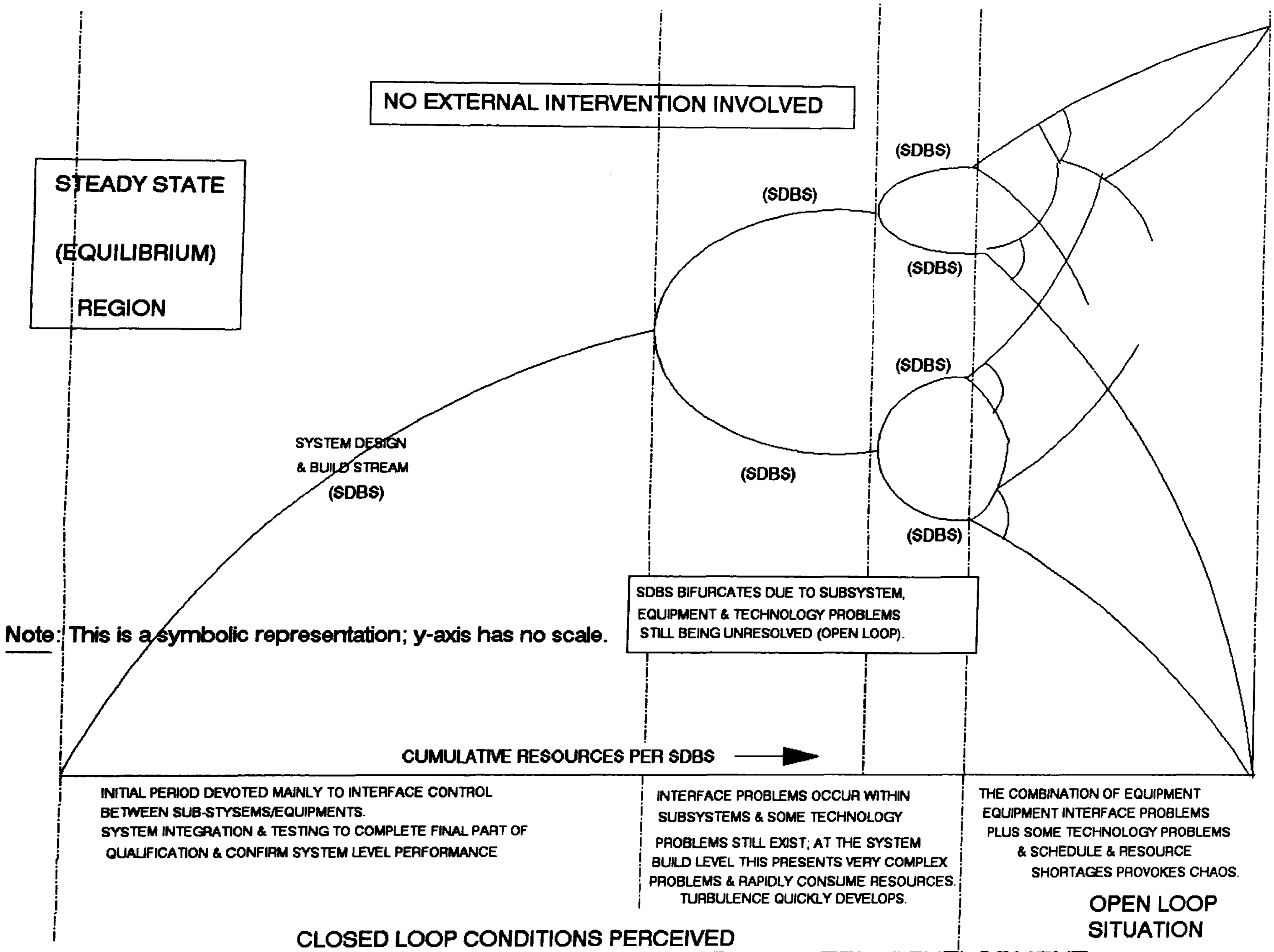


Fig.5: PROBLEM PROPAGATION APPLIED to SYSTEM DEVELOPMENT

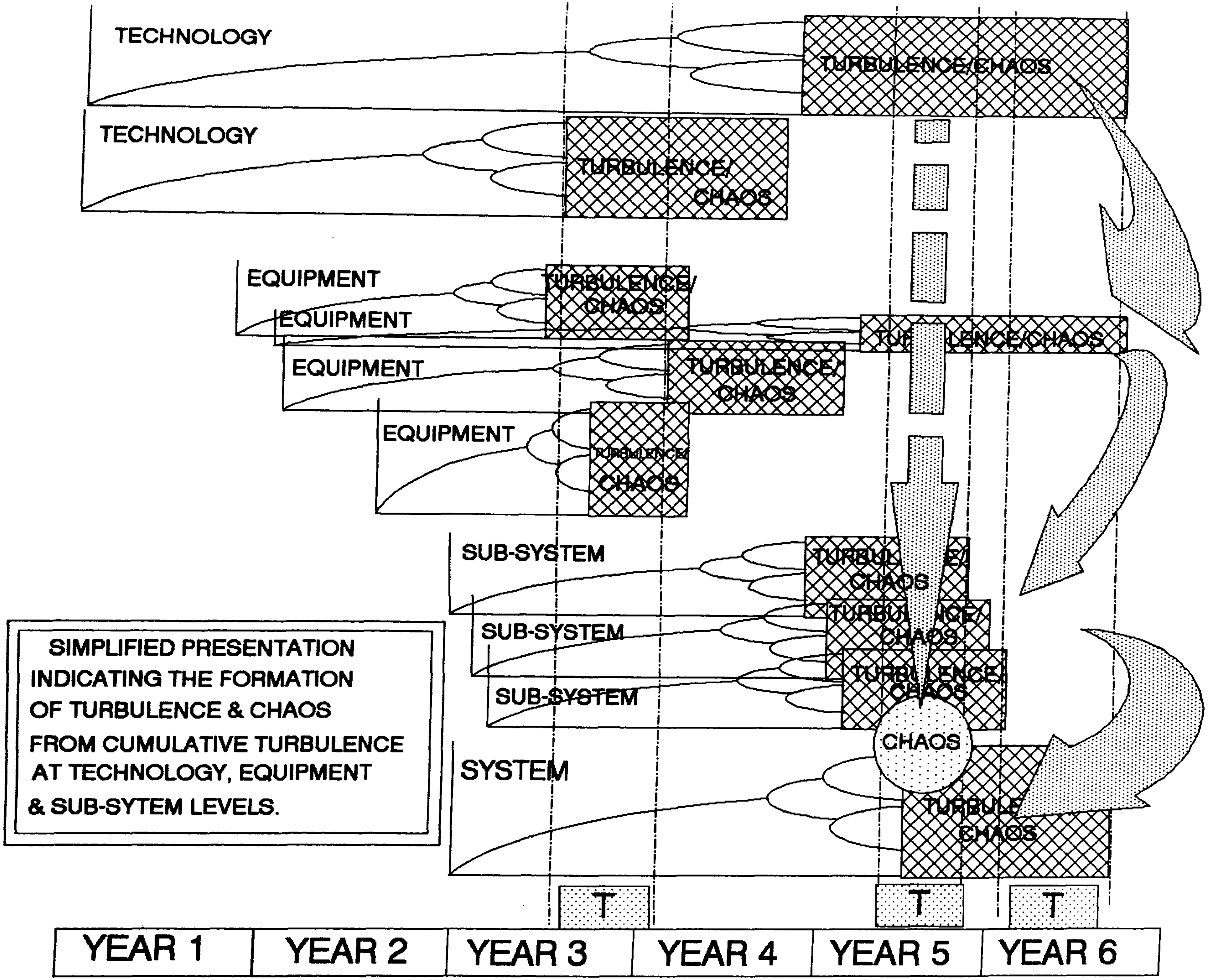


Fig.6: PROBLEM PROPAGATION DIAGRAMS APPLIED to PROJECT LIFE CYCLE

development activity into relatively steady state and chaotic regions,

b) that once problems begin then they accumulate relatively quickly; this has been the authors experience;

c) the development of an equipment(Fig.3) e.g. a transmitter, where the occurrence of technology problems and supply problems can quickly deplete the limited resources available and cause complex technical and logistic situations to occur;

d) sub-system development(Fig.4) where equipment interface problems and continuing technology problems can generate turbulent conditions;

e) system integration and development(Fig.5) where unresolved problems at the technology and equipment levels have a much stronger impact due to their being situated much "deeper" within the system, and can combine to cause turbulent and chaotic conditions.

f) the complete project cycle(Fig.6) showing the manner in which turbulence at the technology level for example can, in conjunction with problems and turbulence at the equipment and sub-system levels, produce a very complex, chaotic, situation at the system level.

The analysis of three of the four projects has included a problem propagation simulation, see Fig.10, and the actually experienced problem propagation, see Figs.11, 15, and 20. The latter figures represent simplifications of the raw data plots contained in annex 8. These figures demonstrate the dangers of technology and equipment developments overlapping; indicating the great complexity that can arise when multi-parallel problem propagation exists. Also demonstrated is the rapid growth of some problems whereas others seem to be dormant for months and even years before becoming manifest. It seems that the problems that erupt later in the project seem to persist longest and have the most significant effect i.e. cause more turbulence.

The four patterns cover top-down to bottom-up assessments of the project risk situations to identify the optimum intervention rationales such that dominating turbulent conditions can be avoided.

Due to the importance of Feigenbaums work and the authors view that it may contribute to the prediction of non-linear situations, an essential attribute for project management and corporate intervention strategies, a short overview of Feigenbaums, and others, work in this domain is now given to explain its evolution and context.

5.2.5.1.3 The Feigenbaum Diagram.

Mitchell Feigenbaums work, initially at Los Alamos in the 1970's, concerned attempts to construct methods for solving non-linear equations; using classical mathematics he concluded it was impossible.

Prior to this work Edward Lorenz, in the 1960's whilst working on dynamical systems, had addressed the question:

> "does any measurable behaviour, however it fluctuates, have an average"?.

He asked not only whether continual feedback would produce periodic behaviour, but also what the average output would be. He recognised that the answer was that the average, too, fluctuated unstably. This led him to conclude that hiding within a particular dynamic system could be more than one stable solution. An observer might see one kind of behaviour over a very long time, yet a completely different kind of behaviour could be just as natural for the system. Such a system he called "intransitive". An intransitive system can stay in one state of equilibrium or another, but not both. Only a **"kick"** from outside can force it to change states.(153).

Unconnected with the work of Lorenz but still addressing non-linear equations Feigenbaum decided to further explore, or map, the mathematical qualities of quadratic difference equations; particularly the boundary region at which the mapping changed from periodic and chaotic. He also became aware of the population work of biologist Robert May concerning the cascading of period doubling, the splitting of two cycles into four cycles and so on, en route to chaotic population growth conditions.

Feigenbaum noticed that the period doubling process exhibited a geometric convergence. In other words the period doubling was occurring faster and faster at a constant rate; see Fig.1. The ratio of one period to the next period in the doubling process is termed the Feigenbaum constant and is approximately equal to 4.67.

Feigenbaums theory expressed a natural law about systems at the point of transition between orderly and turbulent. Hence it was discovered that there were structures in non-linear systems that are always the same if looked at in the right way(153).

The Feigenbaum constant is a universal constant; that is, it is applicable to many different types of non-linear systems. A wide variety of extremely sophisticated experiments in hydrodynamics, electronics, laser physics and acoustics has produced a remarkable degree of agreement with Feigenbaums constant(181).

In this thesis it is submitted that the dominating systems in projects are non-linear. It is also submitted that the Lorenzian "Kick", referred to above, can be provided by an external intervention to a project thus reducing for example the state of turbulence present within the project. It is further assumed that chaos will be present after the second propagation or bifurcation state due to the limited problem solving capability of man(195); that is, problems will be increasing from four to eight.

In Figs. 7 through 24 the above definitions have been used to label certain areas as turbulent and chaotic.

The results of the analyses in this chapter are submitted as evidence of the existence of patterns indicating relatively steady, turbulent and chaotic states in projects. It is felt that the resemblance is no mere accident but clearly more detailed work needs to be done to fully benefit its application.

5.2.5.2 Project A Results.

Figs.7 through 11 have been produced from the authors recorded data contained, in its original "rough notes" form in appendix 8.

Fig.7 shows a plot of the frequency of meetings, scaled as explained above, for the most critical items which occurred during the project. All abbreviations are explained in annex 10.

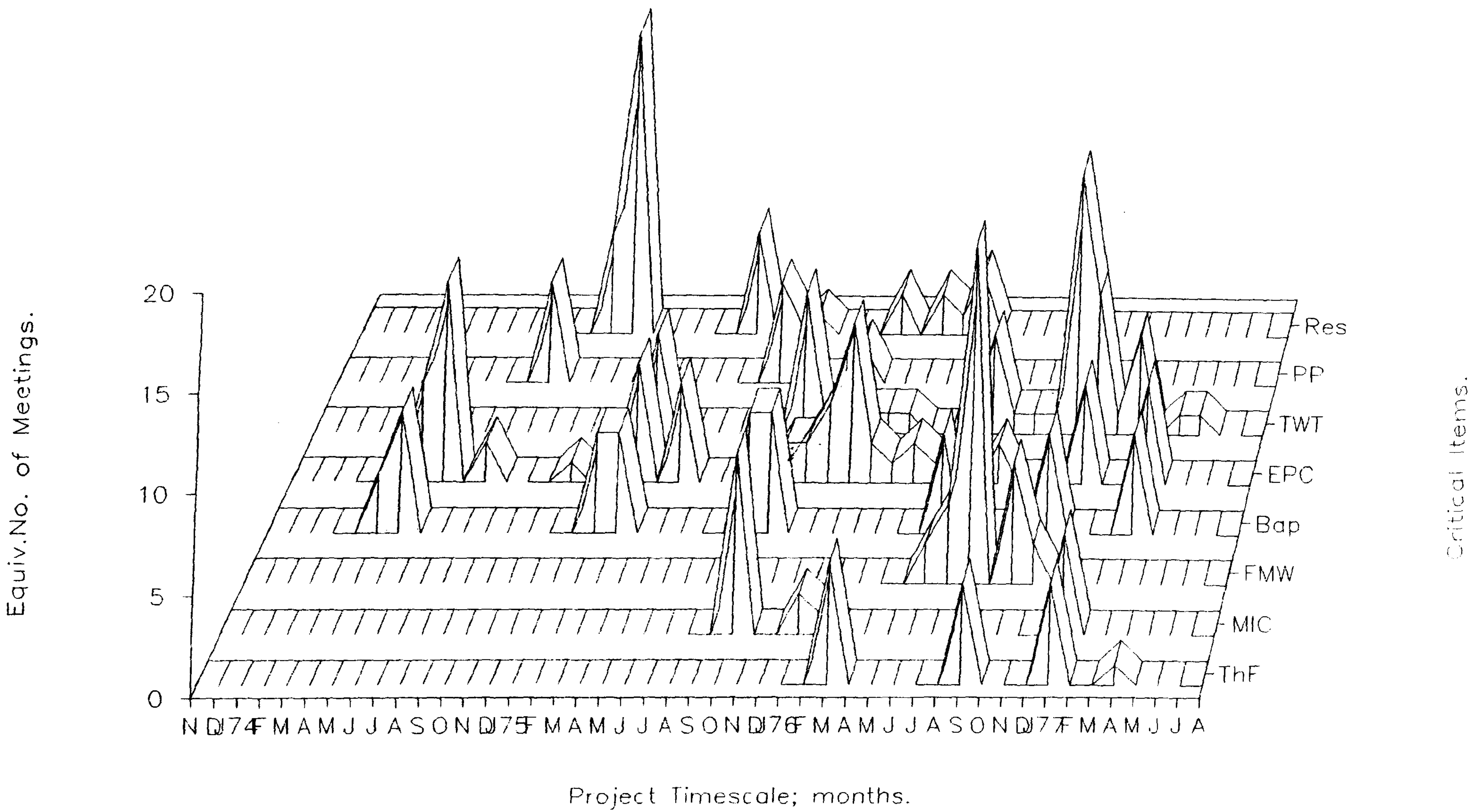
As an example the Bapta, the Bearing And Power Transfer Assembly enabling electrical power from the rotating solar arrays to be conducted to the spacecraft main power sub-system, was a subject of relatively great concern every year throughout the project life cycle.

Fig.8 indicates those regions during the project when a relatively large number of issues were under intensive discussion at the various management levels. These regions have been annotated "T" indicating turbulence. The relationship between the turbulence and the customers intervention is shown and where regions of extreme turbulence, annotated "chaos", developed. The sub-system applicable to the various technologies and equipments is also indicated on this chart.

The major problems encountered on this project related to the development of lower level technology; the pattern of which is clearly shown by the frequency of meetings for the varactor, impact and unitrode diodes, and the TWT, EPC, Bapta and FMW slip rings; see fig.7. The high, and prolonged, meeting density indicates embedded research issues with the consequences of open loops; under fixed price contracts! The varactor diode problems were so threatening to the success of the project that a very early

Fig. 7: Project A:Meetings Frequencies.

Dynamic Risk Indicator.(1974/77).



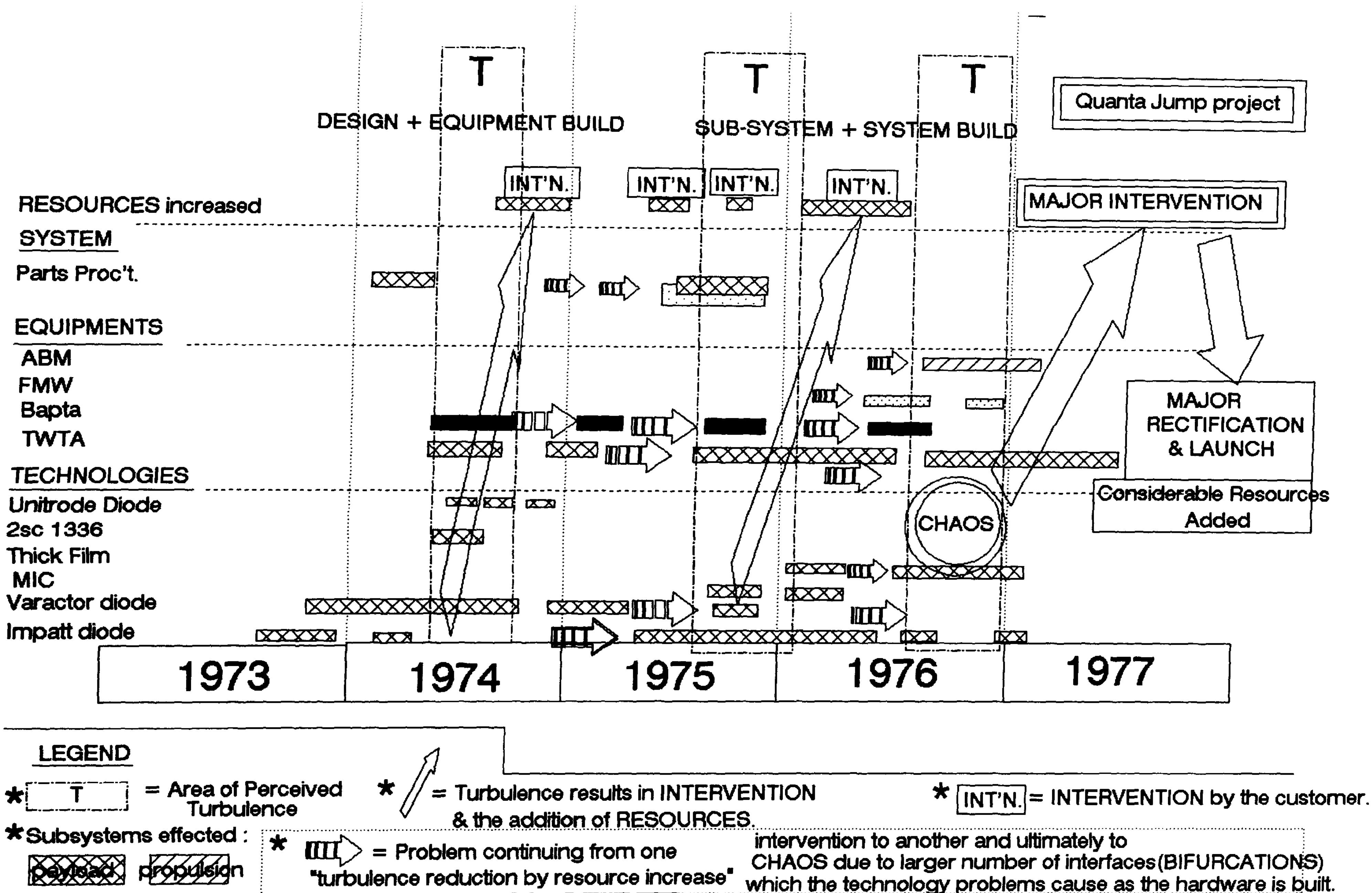


Fig.8 PROJECT "A"

AREAS/DURATIONS/INTERACTIONS and TURBULENCE/CHAOS of MAJOR PROBLEMS

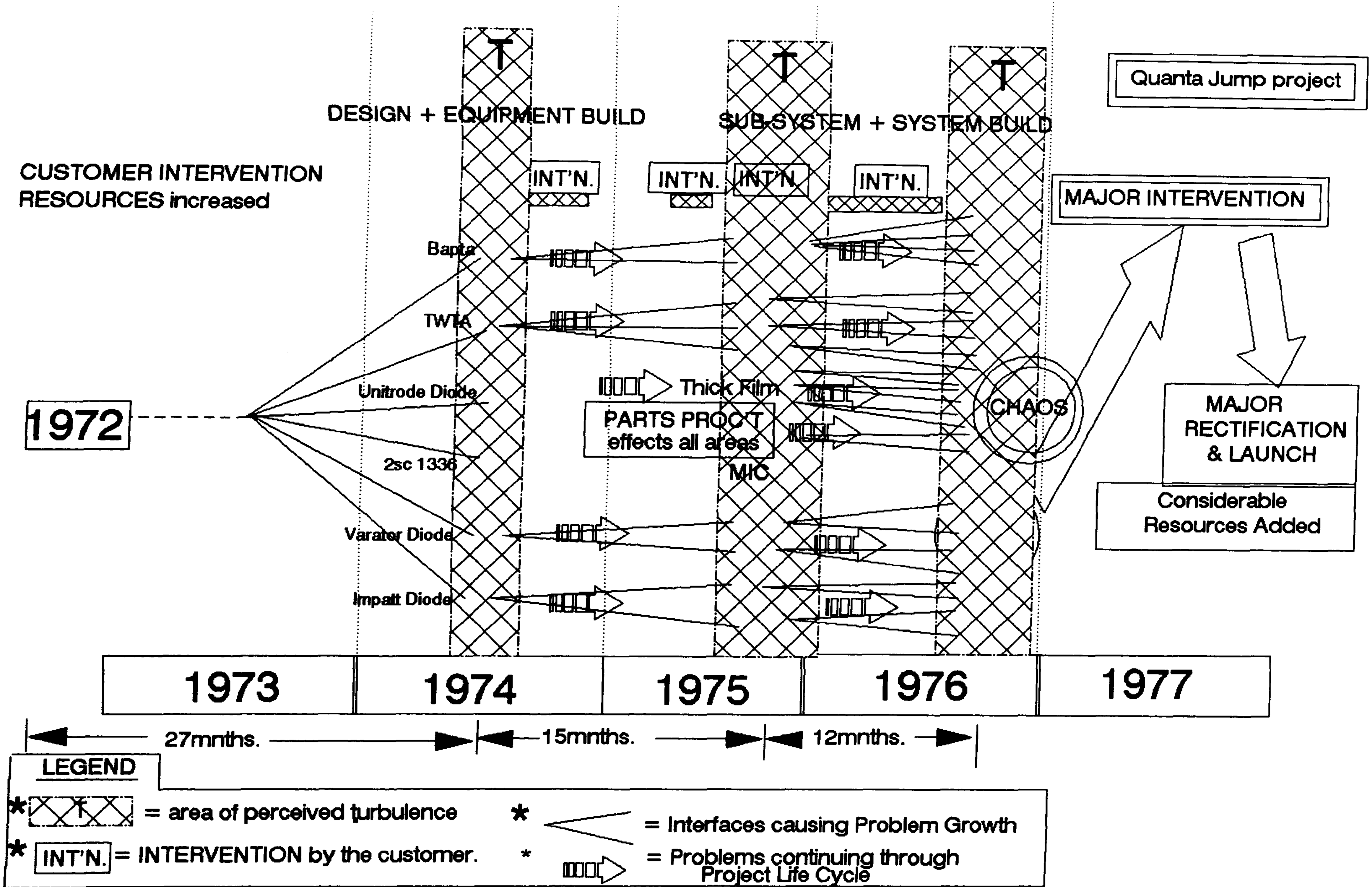
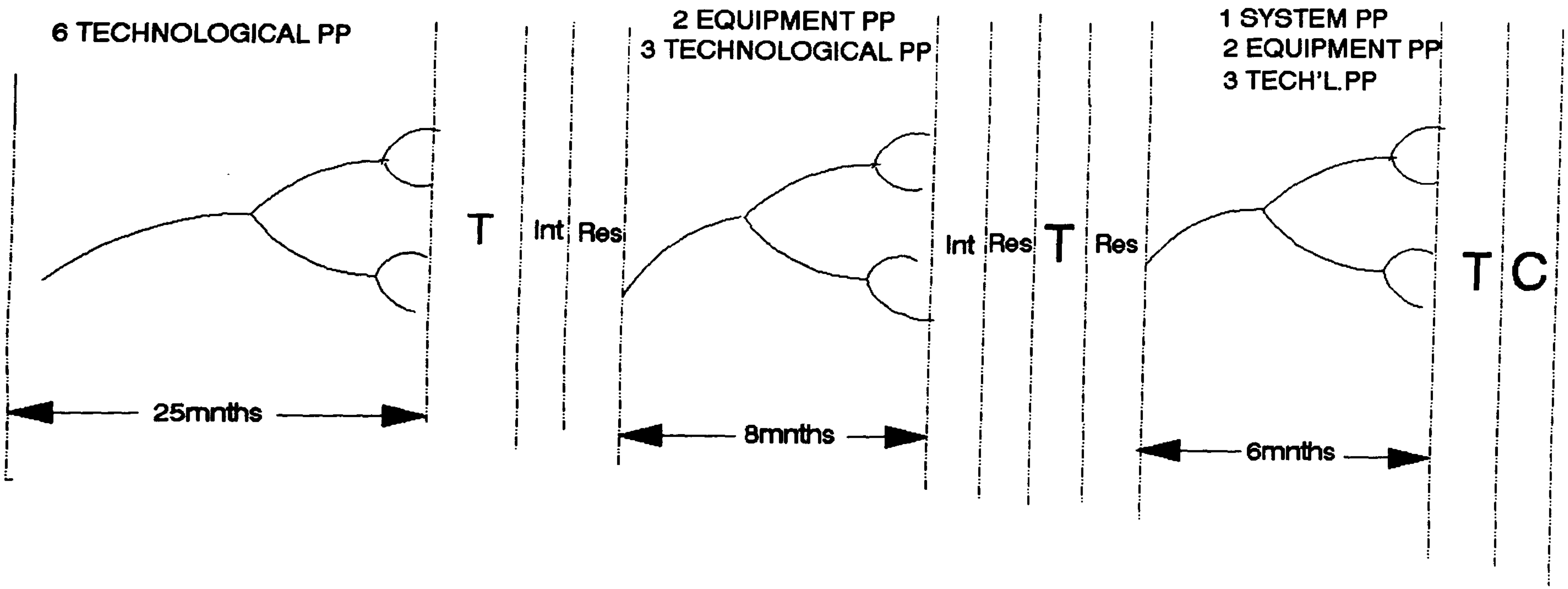


Fig.9 PROJECT "A"

ACTUAL GROWTH of PROBLEM CONSEQUENCES due to INCREASE in NUMBER of INTERFACES as VEHICLE BUILD moves from TECHNOLOGY through EQUIPMENT & SUB-SYSTEM to SYSTEM LEVEL.



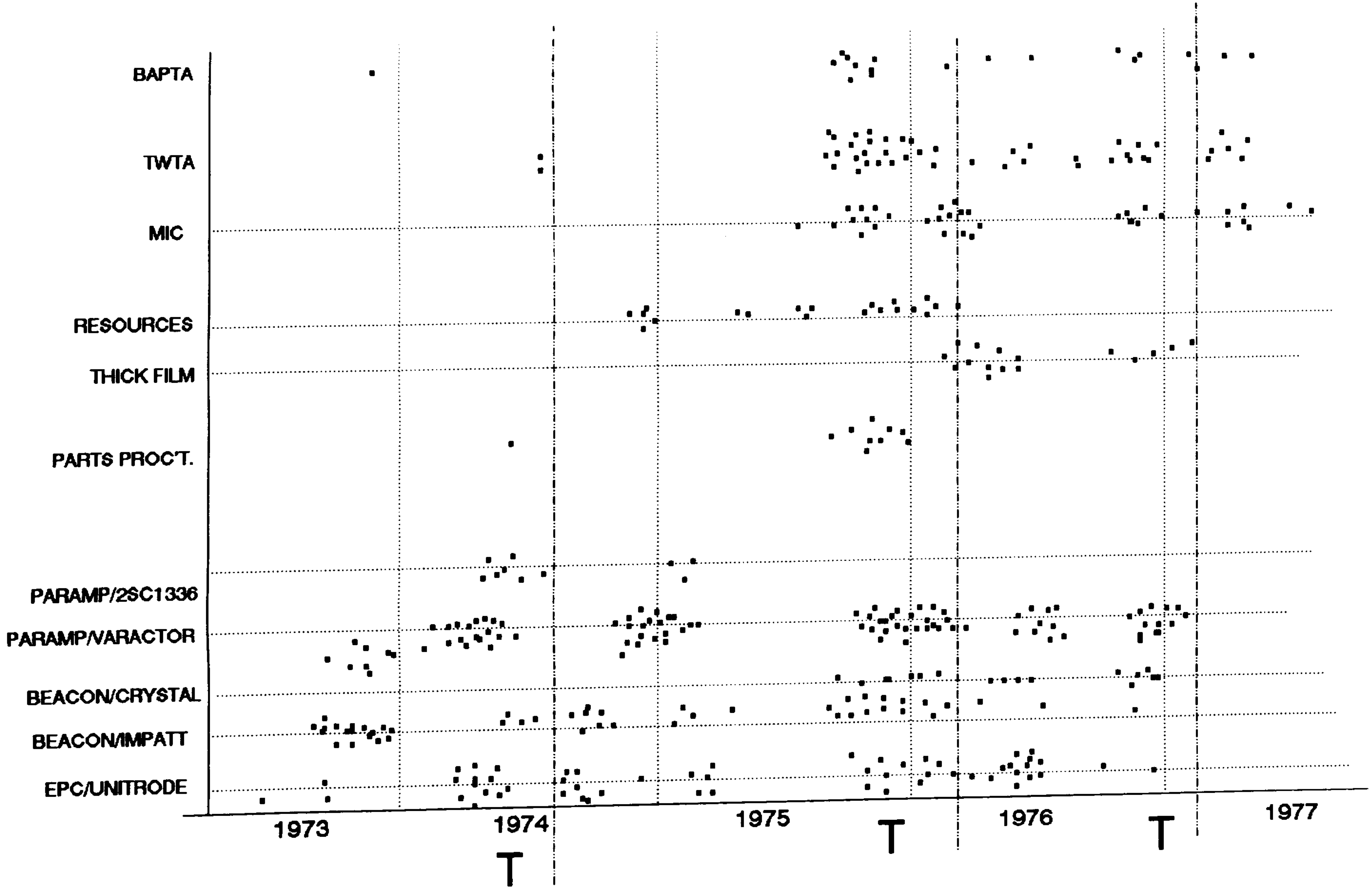
LEGEND:

T = TURBULENCE. Res = RESOURCES ADDED(BY CUSTOMER).

Int = INTERVENTION. C = CHAOS.

mnths = months of project life cycle. PP = Problem Propagation paths.

Fig.10: Project A; PROBLEM PROPAGATION SIMULATION.



LEGEND:

. = OCCURANCE OF A MEETING.

T = TURBULENCE

PROJECT A

Fig.11: ACTUAL PROBLEM PROPAGATION

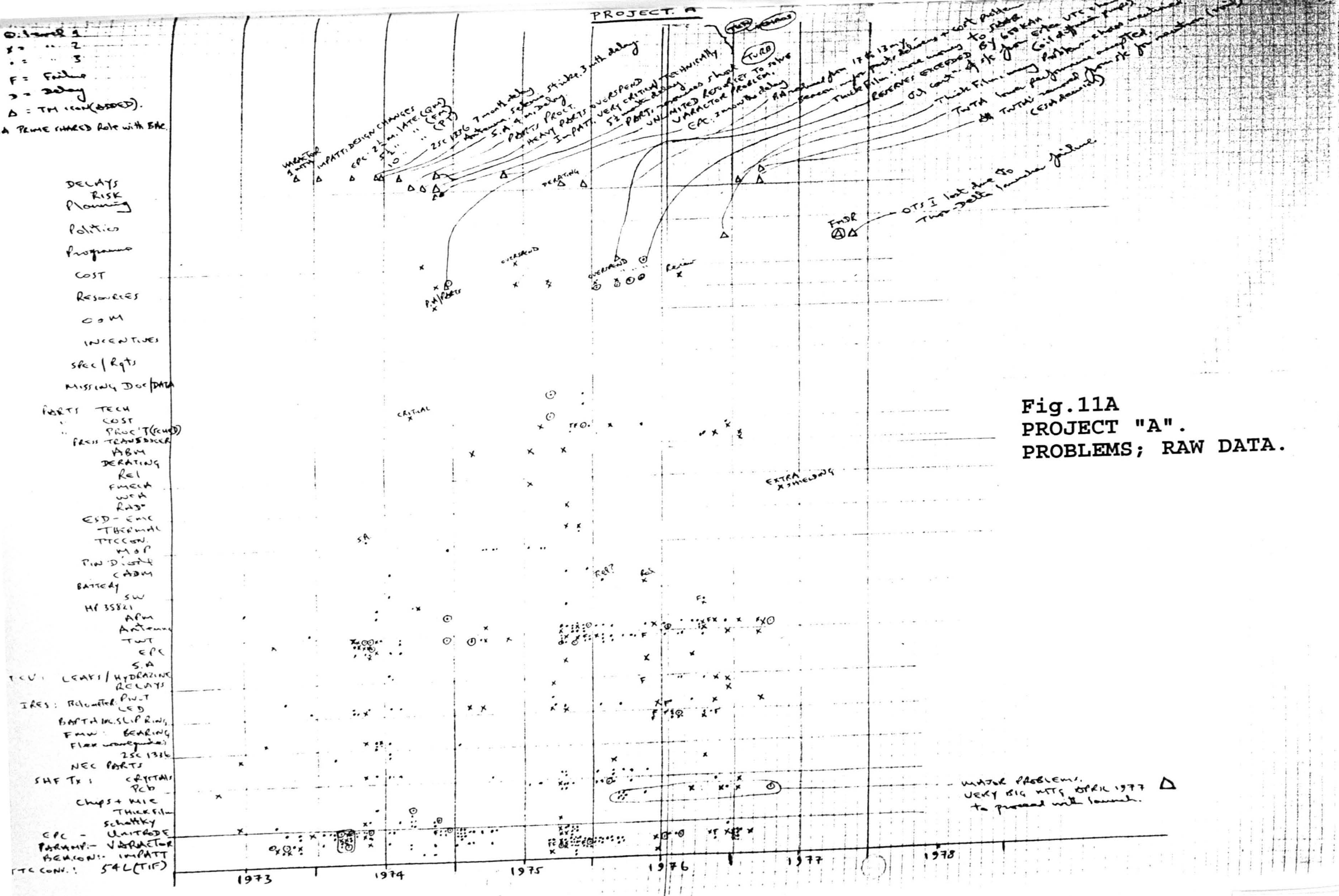


Fig.11A
PROJECT "A".
PROBLEMS; RAW DATA.

decision declared that unlimited resources were to be made available to solve the problems. From the "frequency of meetings" indicator that decision should have also involved the EPC and the impact diode; the latter eventually proved to be the main problem! Another major risk indicator is the heavy overspend on parts procurement and the MIC technology at a relatively early point in the project. It should be recalled that ESA effectively shared the prime management of this project since it was the first such programme in Europe.

The general appearance of fig.7 gives the impression of a reasonably balanced project but with some areas of high concern occurring near the launch campaign; in fact conditions were turbulent at that time.
There is also a large concern that the resources will be adequate at a point approximately 20% after the start of phase C-D!

This project was more of a joint ESA-industry business due to it being the first European telecommunication satellite; it was a test and demonstration satellite. Hence all problems were shared, the ESA team was very large, and when extra resources were needed they were supplied by ESA.
Note: for example, the ESA decision to allocate "unlimited resources" to the varactor diode problem.

Fig.7 does not indicate any rapid movements into crisis or chaotic conditions. The analysis is continued in Figs.8 and 9 where growth, or propagation, of the problems is indicated with respect to the increasing number of interfaces concerned as the technology is built into an equipment and thence via sub-system build to become part of the system itself. This chart also indicates the main turbulence, and chaos, drivers and the life cycle duration of some of the problems.

There was a significant amount of "embedded research" in this project and it finally created a chaotic situation during a turbulent period in 1976; the situation was resolved by the injection of considerable expertise and money by the customer. The figures also show the occurrence of major intervention, in spite of the day-to-day presence of the customer at the contractors premises, **after** the turbulence had established itself. However the interventions did result in periods of relatively steady state conditions of long durations. In the above charts the design phase, and the equipment, sub-system and system build phases are shown. Also provided is the classification of the project as:

a) involving either a "quanta" jump in the technologies involved, or,

b) being a relatively continuous, or incremental, development of previous work.

The above explanation applies also to Figs. 10 through 24 in total.

Due to the fact that Project A was a "quanta jump" project and it was the first of its kind in Europe, it was regarded as critically important, strategically, to the customer and the industry.
During phases A and B three consortia were in a highly competitive mode; the winner gained the lucrative phase C/D contract.
The perception of the customer was that his strategic future could only be safeguarded if he formed a large highly qualified project team to intimately monitor the contractor i.e. to enable, at his discretion, constant intervention. This was done. The result was that the customer effectively managed the project, took all the major decisions, and deployed his staff at all locations, world wide, to ensure that "he knew all things at all times". Hence whenever more resources, money, manpower or facilities, were needed they were supplied by the customer; often initiated by the latter.

There is no doubt that this project formed a significant "learning step" for European industry. It is also clear that the project was under-resourced for the large number of open loops involved. All of the critical items in Fig.7 were open loop since it was not clear whether they would finally successfully function.

The constant presence, and awareness, of the customer constituted a constant threat to the contractor; particularly since the customers expertise, which had been "bought in" from the U.S etc., was often superior to that of the contractor. The result was an adversial but tolerant relationship; the latter due to the customers "open cheque" approach. This modus operandi of the customer indicates little faith in the contractor selection process nor in the communication and management systems that had been established to keep him informed.
The issues involved in abrogating the contractors role were ignored; pride and independence of contractor authority were considered to be small sacrifices to pay for the customer accepting practically all the risk. As mentioned in the interviews, even if the contractor was convinced a customer decision was wrong it was almost impossible to reverse it due to the resistance of the established customer-contractor bureaucracy.

It is concluded that the customer plus contractor teaming approach did work in this instance but the subsidisation was very high and the contractors learning in the area of project-consortia management was low. This latter point is evidenced by the fundamental problems that occurred in project B. The launch date predictions were remarkably accurate. December 1776 was predicted in 1973; the satellite was launched in 1977. However, the resources to achieve this and the supporting technology programme was very considerable.

The main project "flows" were ruthlessly tracked by the customer and reaction was immediate when a divergence was perceived. It constituted almost the perfect management scenario with the top customer manager able to extend his perception outside the project whilst being informed of the actual real time status within the project without being formally directly involved. He could thus steer the project to adapt to changing strategic objectives as they occurred; this happened on a number of occasions.

The cost and schedule overruns were significant but the project was considered to be a success; particularly strategically. Project C was comparable to this project concerning the quanta jump involved; the results were very significantly worse! The respective charts show significantly different problem profiles and considerably more turbulence and chaos.

For both projects an intervenor using the meeting frequency, and other "flow", information would have performed quite differently.

The significance of the timewise occurrence of the regions of turbulence is that intervention delayed the "natural" branching of the problems, and hence the amount of turbulence, that might have occurred.

5.2.5.3 Project B Results.

This project followed on directly from project A; with the same team of industrialists and the same ESA persons. The analysis is presented in Figs. 12 through 16. The patterns that emerge as the project develops is of ESA top management involvement from the beginning and the late recognition of basic technology problems i.e. open loops. Problems at equipment level are indicated as receiving early and considerable attention; see the region 1977/1978 in Figs. 13 and 14. This was not a shared project, between ESA and industry, as in the case of project A; normal ESA contract conditions applied.

The industrial performance is indicated as being somewhat lacking, from the CDR low incentive payments, even after ESA intervened with "tiger teams" to rectify certain technical issues. The repeated launch predictions, starting with a 1980 predicted launch date in 1976, were repeatedly incorrect; the satellite was finally launched in 1983. The TWTs, EPCs, and ABM(apogee boost motor) seem to be embedded research from the frequency of meetings pattern i.e. starting early with many meetings at all management levels.

An aspect of the dynamics of the project is shown in

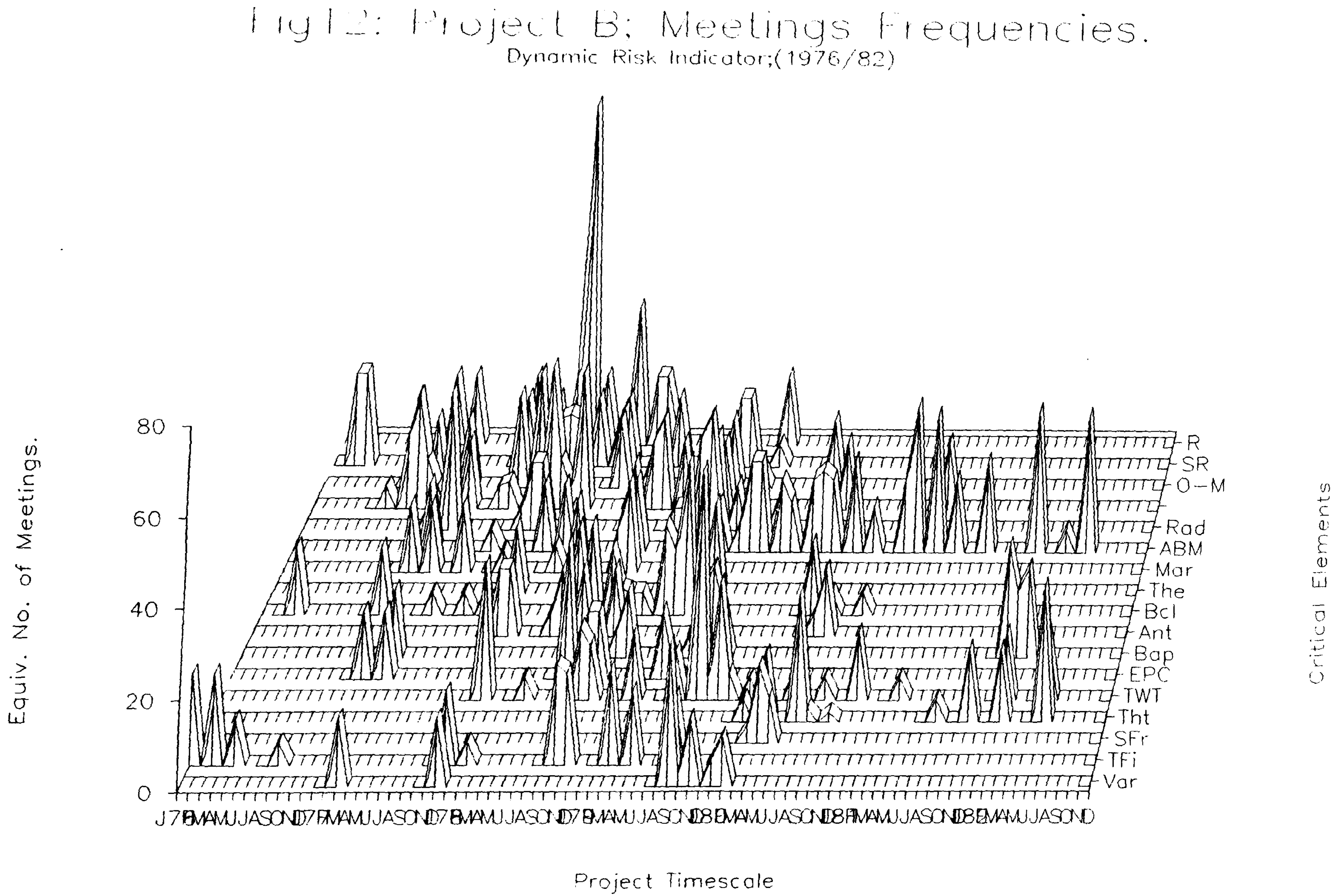


Fig12: Project B; Meetings Frequencies.
Dynamic Risk Indicator;(1976/82)
Equiv. No. of Meetings.
0
20
40
60
80
Critical Elements
R
SR
O-M
Rad
ABM
Mar
The
Bcl
Ant
Bap
EPC
TWT
Tht
SFr
TFi
Var
Project Timescale

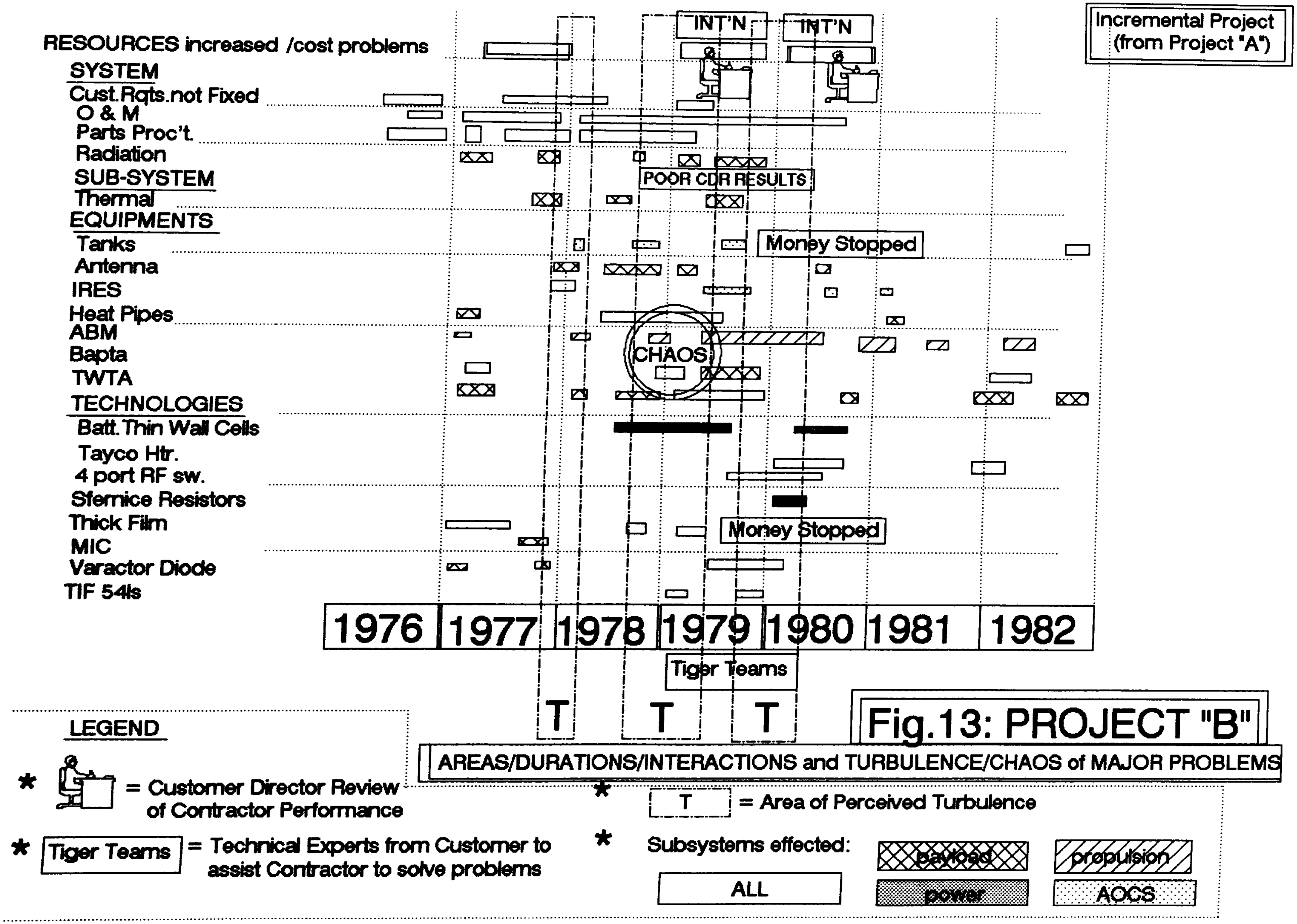


Fig.13: PROJECT "B"

AREAS/DURATIONS/INTERACTIONS and TURBULENCE/CHAOS of MAJOR PROBLEMS

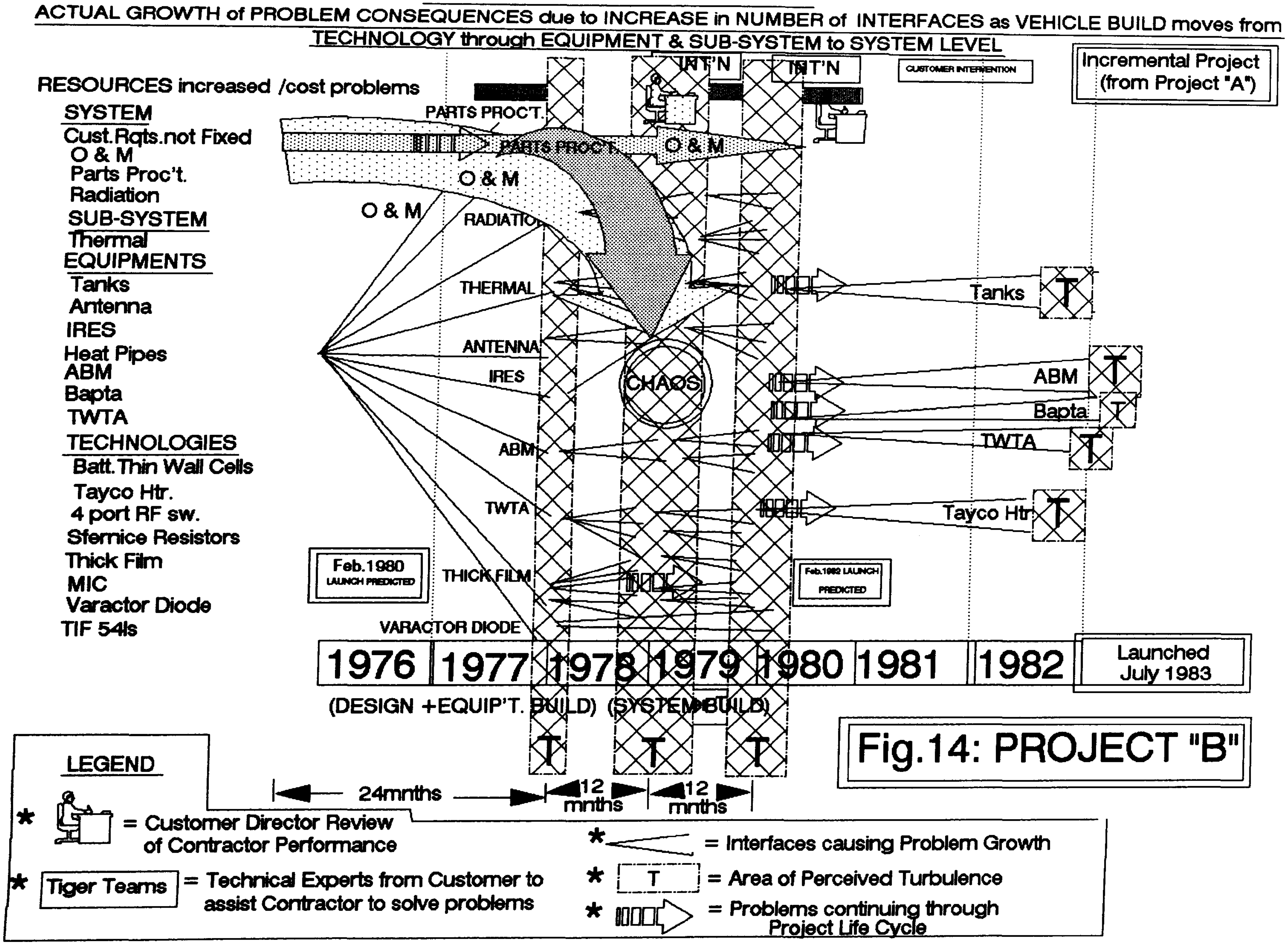
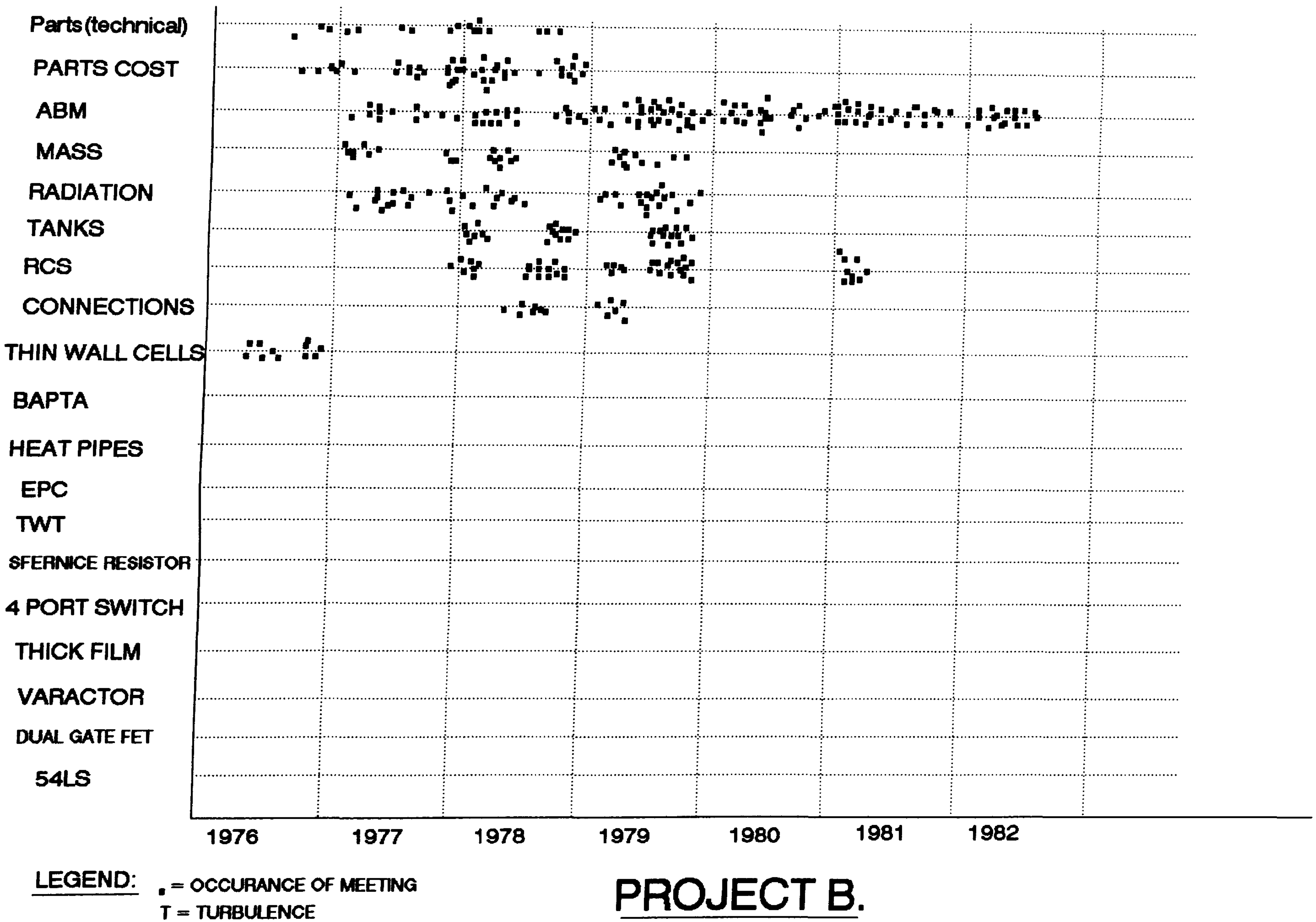


Fig.14: PROJECT "B"



PROJECT B.

Fig.15: ACTUAL PROBLEM PROPAGATION

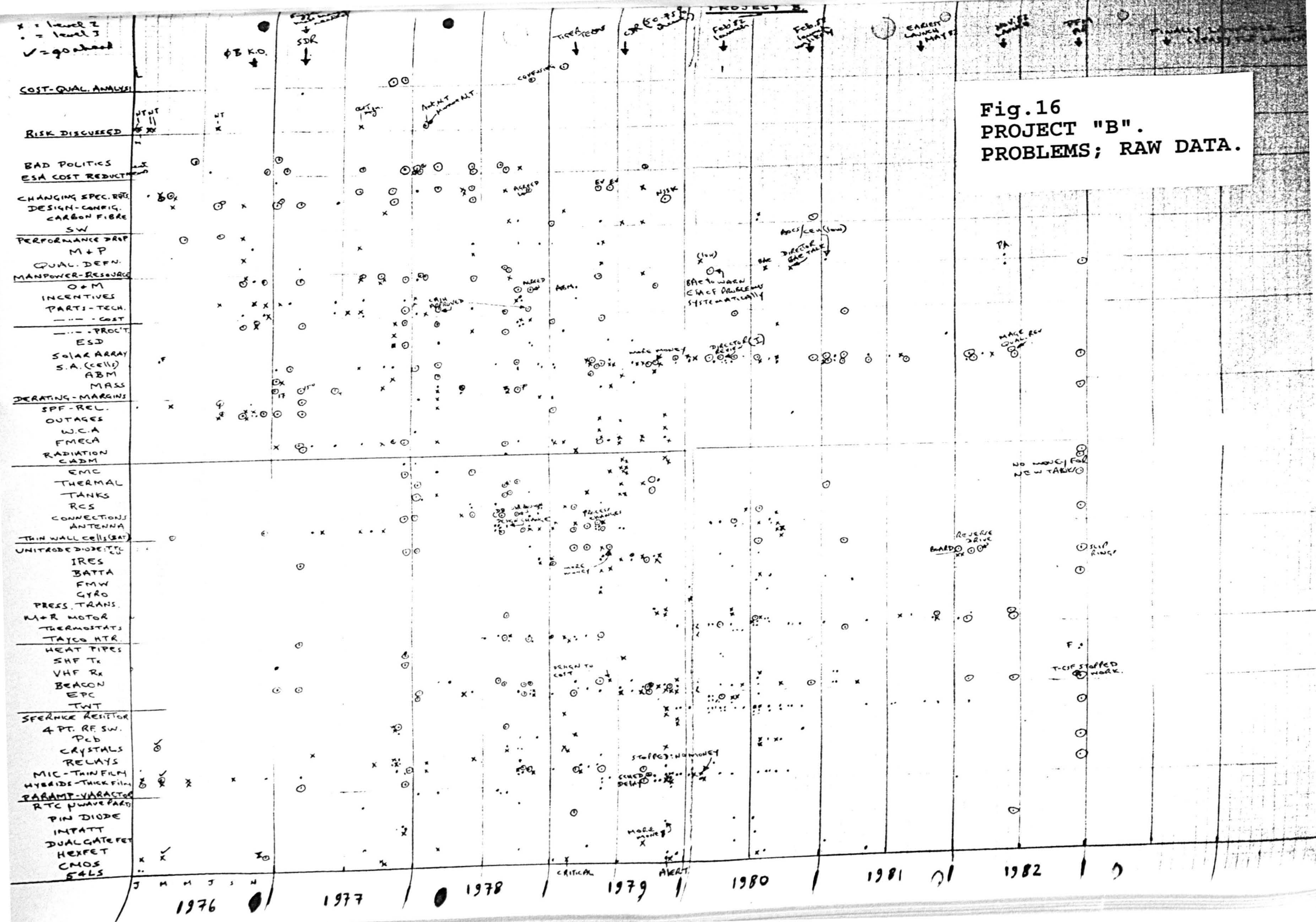


Fig.16
PROJECT "B".
PROBLEMS; RAW DATA.

Fig.12. The general appearance is very busy with domains of increasing activity indicating increasing concern. These areas have been labelled as increasing turbulence and eventually chaos. Just prior to the middle of the project conditions were so complex, and the way ahead so difficult to define, that specially convened ESA plus industry teams, called "tiger teams", were formed: conditions were chaotic. Fig.12 through 16 illustrates the growth of this condition from an initial rather steady, tranquil state. Once again the adequacy of the resources were of great concern very early in the project. The author links this circumstance with the unresolved problems remaining after phases A and B; see section 5.2.2.2.

The classification of this project as a follow-on project based on project A, and therefore assuming that the main problems were technological and had been resolved proved to be both optimistic and naive. As stated frequently in this thesis, the research indicates that the dominating problems tend to be organisational and managerial in nature.

5.2.5.4 Project C Results.

The general pattern of this project was quite different than project B; a comparison is not made with project A since that was essentially an ESA-industry collaborative programme. For this project the characteristics were of steady state- turbulence cycles working up to states of chaos; then relaxing back to the turbulent state only to evolve again to chaos. Clear patterns emerge from the plot of frequency of meetings and the occurrence of problems, crises, and chaos; the latter terms were actually used without prompting by interviewees, and were recorded many years ago in the authors daily record books. The analysis is presented in Figs.17 through 21.

The TWTs, EPCs, dual gate FETs, and CEU and software items gave so many problems and dominated the project to such an extent that they were clearly examples of "embedded risk" and "embedded research". As such they constituted open loop activities.

The situation was so serious that a director recommended a one year delay in the programme in 1977, see Fig.18. This was not implemented but such an intervention would probably have avoided the significant strategic failure due to the very late, and hence very expensive, launch.

The risk indicators, for high level intervention, are there and can be identified by:

a) the accelerating frequency of meetings in some areas;

b) comments referring to chaotic conditions;

c) prime management admitting major mistakes, see Fig.19;

Fig.17:Project C; Meetings Frequencies.

Dynamic Risk Indicator;(1976/85)

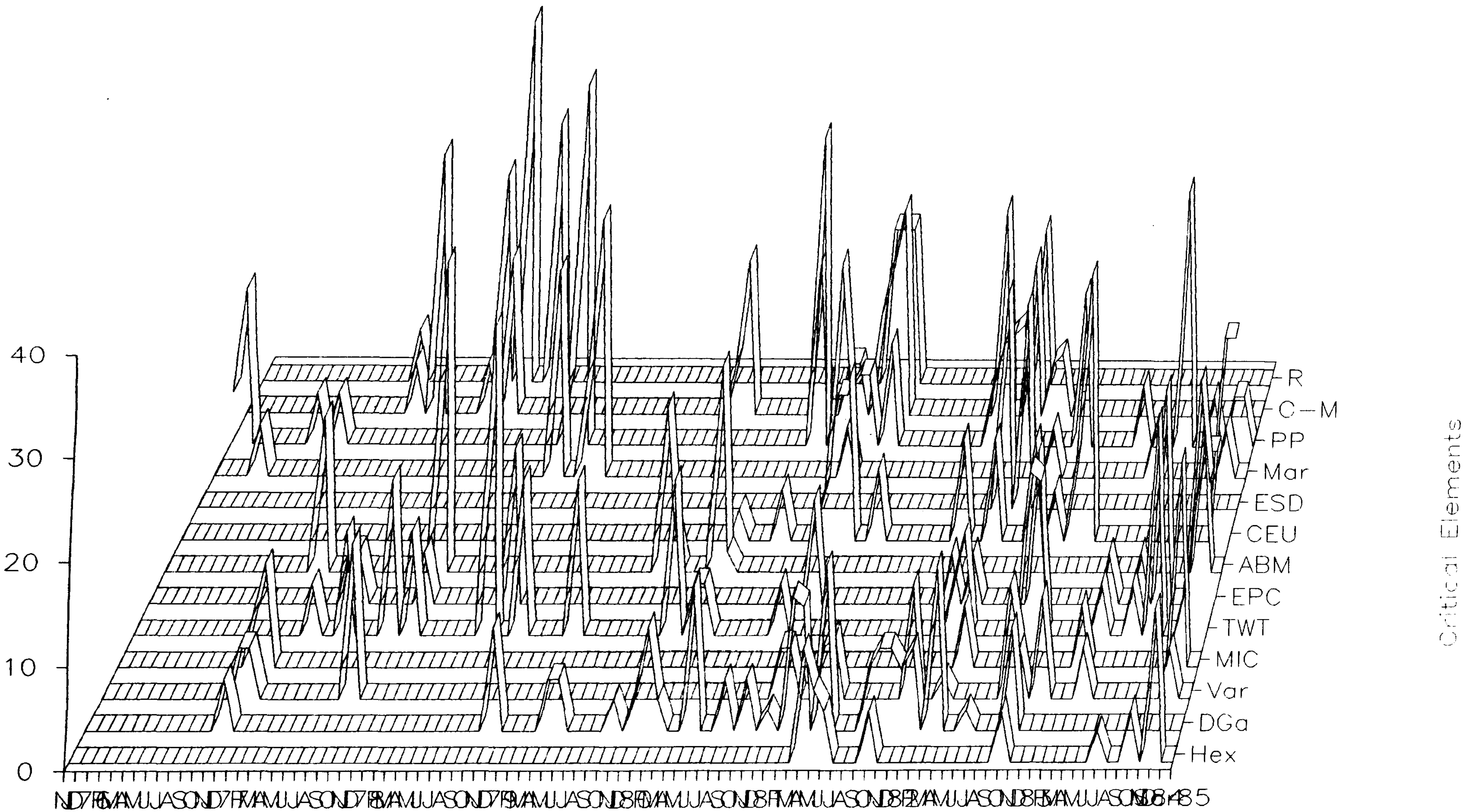
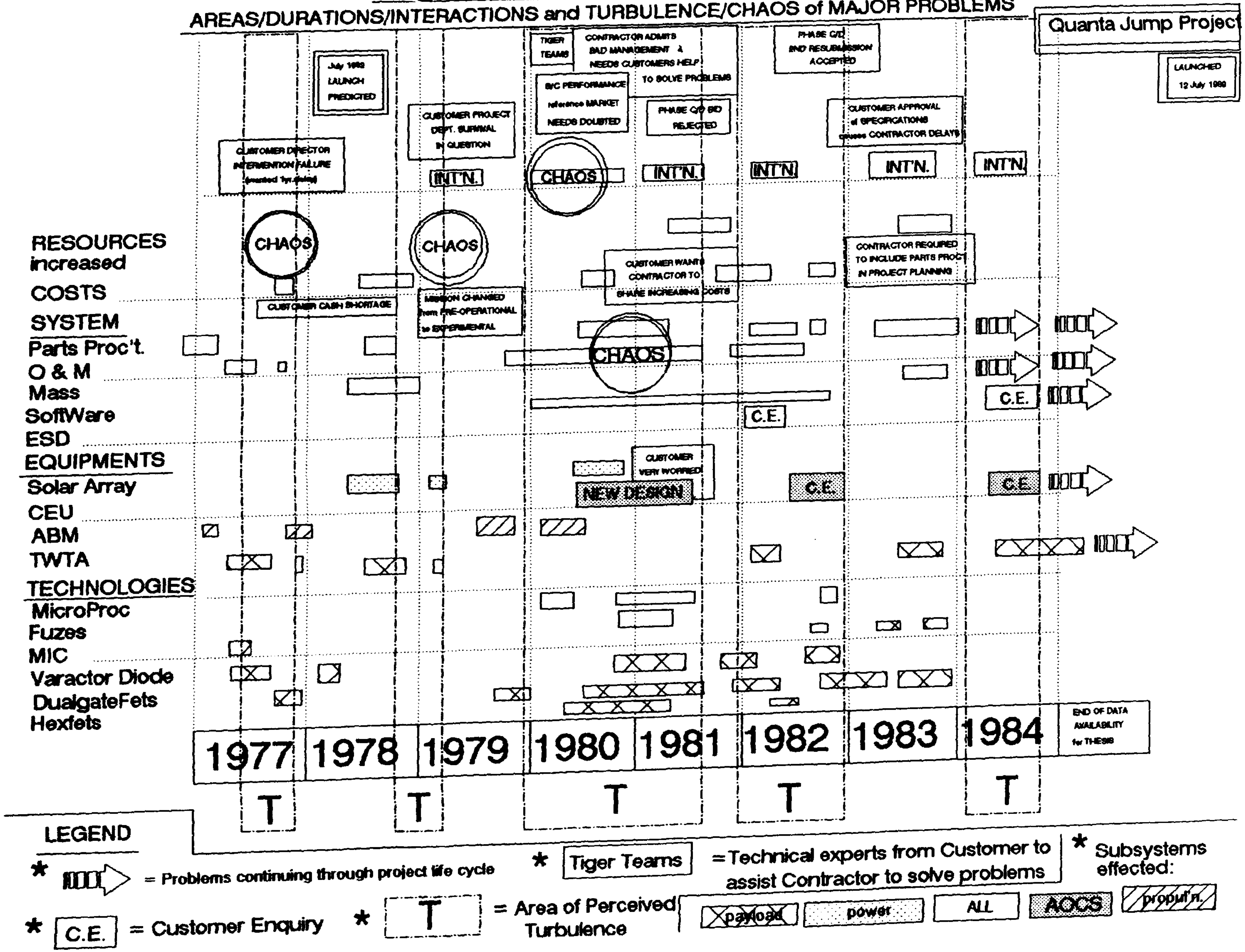


Fig.18 PROJECT "C"

AREAS/DURATIONS/INTERACTIONS and TURBULENCE/CHAOS of MAJOR PROBLEMS



ACTUAL GROWTH of PROBLEM CONSEQUENCES due to INCREASE in NUMBER of INTERFACES as VEHICLE BUILD INCREASES from TECHNOLOGY to SYSTEM LEVEL.

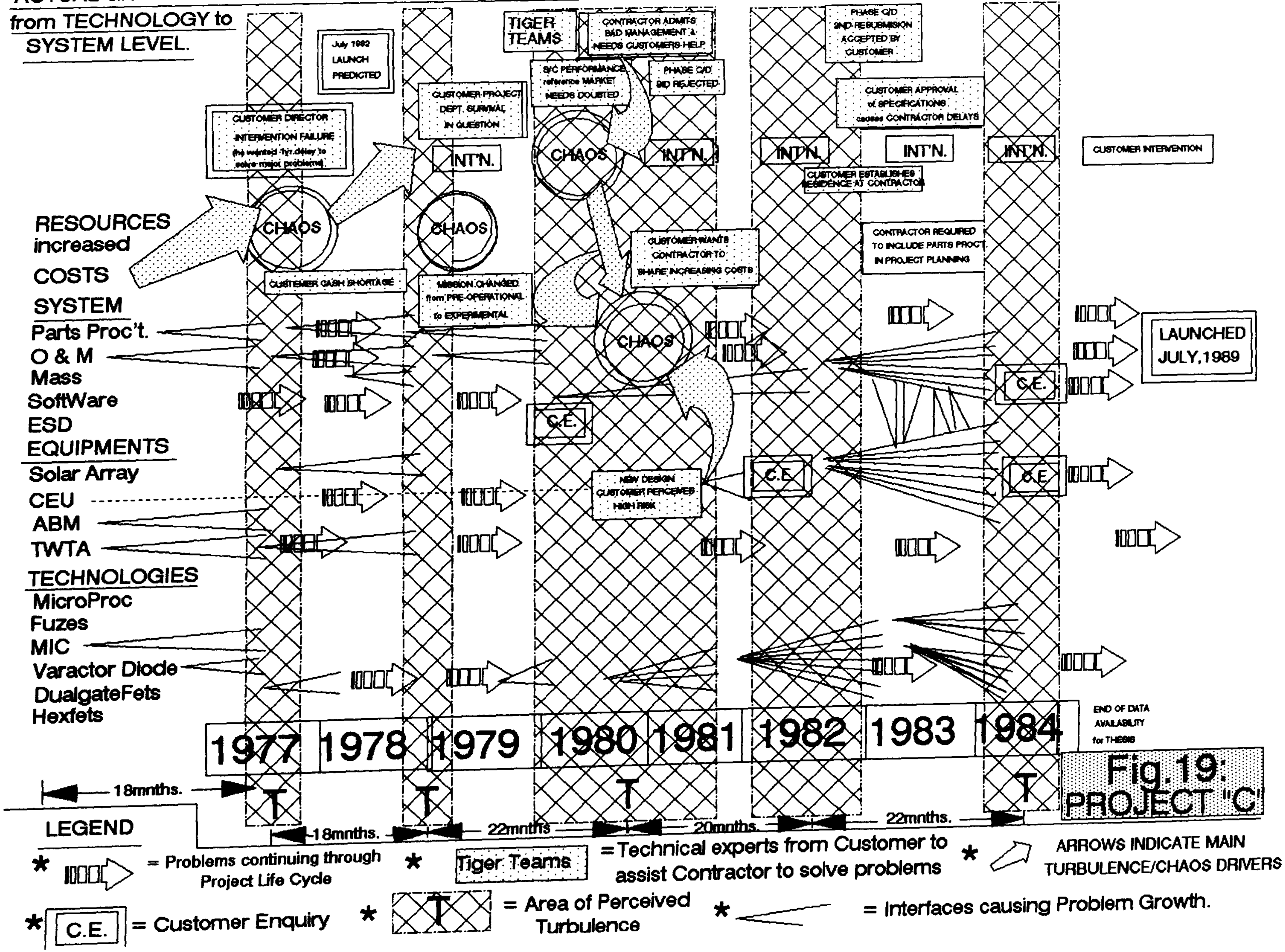
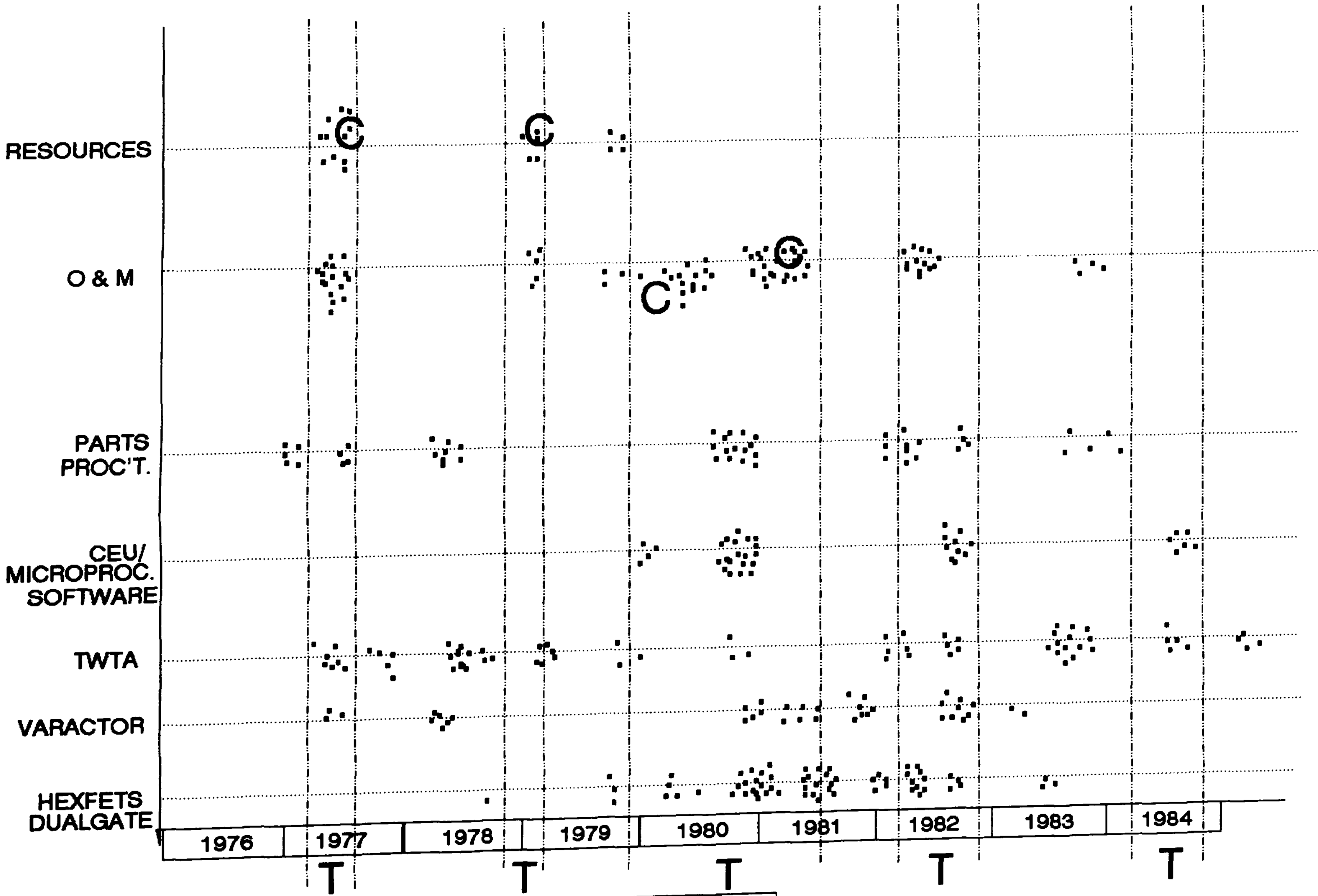


Fig.19: PROJECT "C"



PROJECT C

Fig.20: ACTUAL PROBLEM PROPAGATION

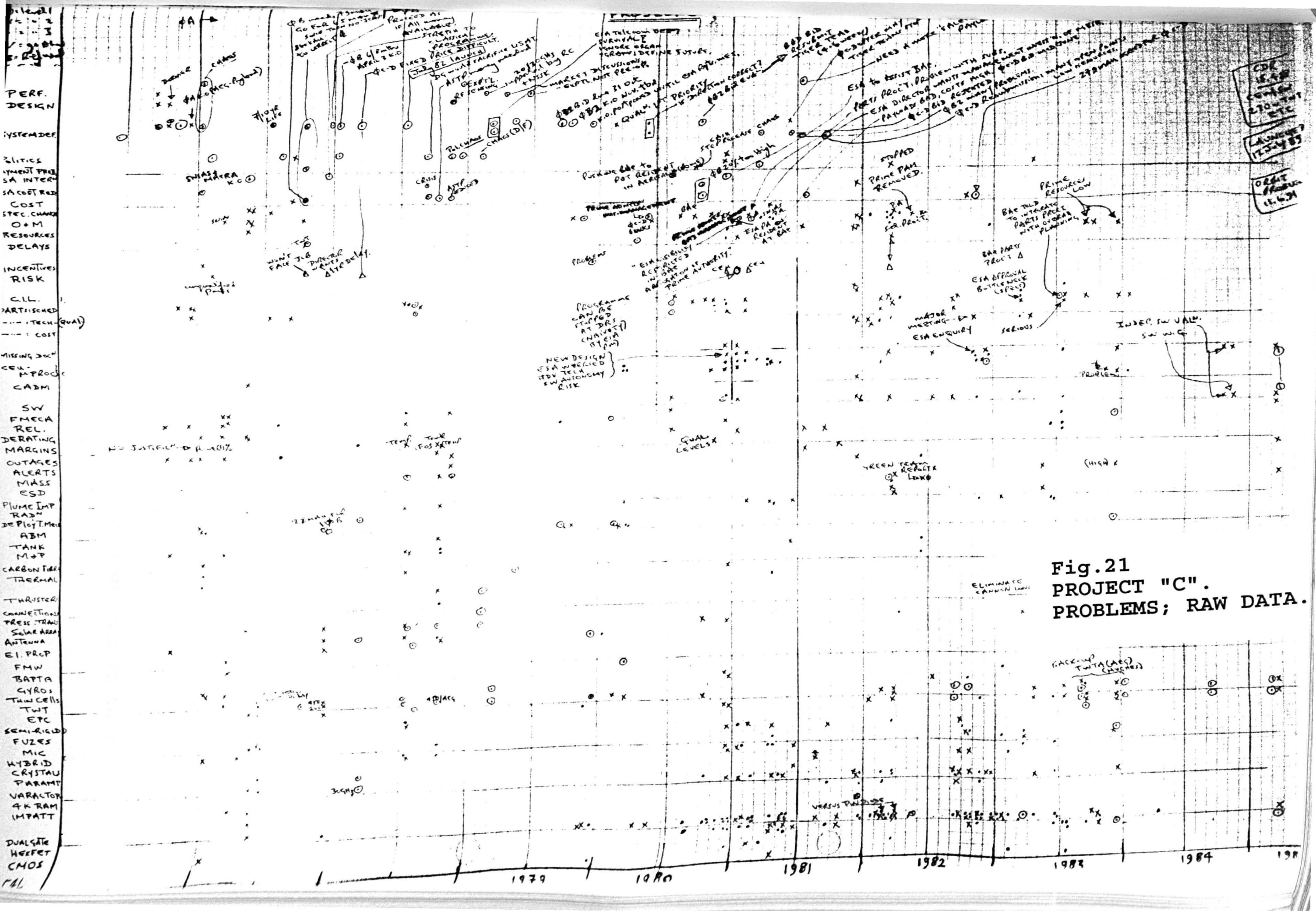


Fig.21
PROJECT "C".
PROBLEMS; RAW DATA.

d) prime management admitting to ESA that it didn't know how to proceed since it was besieged by problems from all sides;

e) the repeatedly inadequate bid evaluations;

f) the high rate of increase of meeting frequencies at about the same time; circa mid-1980.

g) the high divergence of the dualgate FET problems realising that these components are essential for the payload and must be built into the equipments at a very early point in the schedule.

The above illustrates that the basic issues were very serious and that was realised early in the life cycle of each issue; also that the interface effects were equally serious thus the delays were propagated across the project and the consortium.

In this project it is clear that chaotic situations did evolve and that the evolution was due to a simultaneous occurrence of major issues in the technical, managerial, resource expenditure and political areas. It also seems that the magnitude of these issues was due to:

- their interaction,

- starting the phase C-D with many open problems, and,

- very late intervention.

It is known that serious "soft" issues existed on this project from the start; not least of which was the prime contractors contention that ESA was too much involved in the day-to-day management of the project. This caused a very adversial relationship which permeated the entire industrial consortium. Proper intervention could have reduced if not eliminated this risk element.

Concerning an attempt to predict where the turbulence and chaos could be expected to occur, using the Feigenbaum constant and Figs.17, 18 and 19, the following aspects have to be considered:

1) the information available covers the definition phase, phase B and the commencement of phase C/D;

2) in 1978 a launch date of July 1982 was predicted; this was based on a 3 year development and procurement period commencing in late 1978;

3) the spacecraft was finally launched in July, 1989;

4) a significant amount of the technology used on this

space vehicle was close to the state of the art;

5) the survival of the customers telecommunication satellite department was strongly linked to the rapid commencement of this project;

6) the project commenced with a customer shortage of funding which was accommodated almost unconditionally by the contractor, no major risk areas were identified;

7) the phase C/D bid evaluations by the customer produced an impressive and daunting list of major problems, concerns, lack of visibility and lack of definition(see chapter 5.2.2.3) but, with many issues still open the phase C/D contract was initiated in late 1982;

8) the customer project manager declared in his interview that there were very few tranquil or steady state periods but most of the time conditions were very turbulent;

9) the project commenced with a very adverbial relationship between the customer and the prime contractor due to the latter contention that a customer commitment not to continuously interfere with the contractors role was not being honoured.

Many of the above aspects are addressed in the Model, see chapter 6, as items which must be eliminated or defined as risk indicators prior to the commencement of phase C/D.

This project took nearly thirteen years to complete. Both the ESA and industrial areas concerned with this project were in survival conditions at times during the project.

Figs. 18 and 19 show that an intervenor, using meeting frequency as a dynamic risk indicator, would probably have intervened very strenuously approximately 30% into the project.

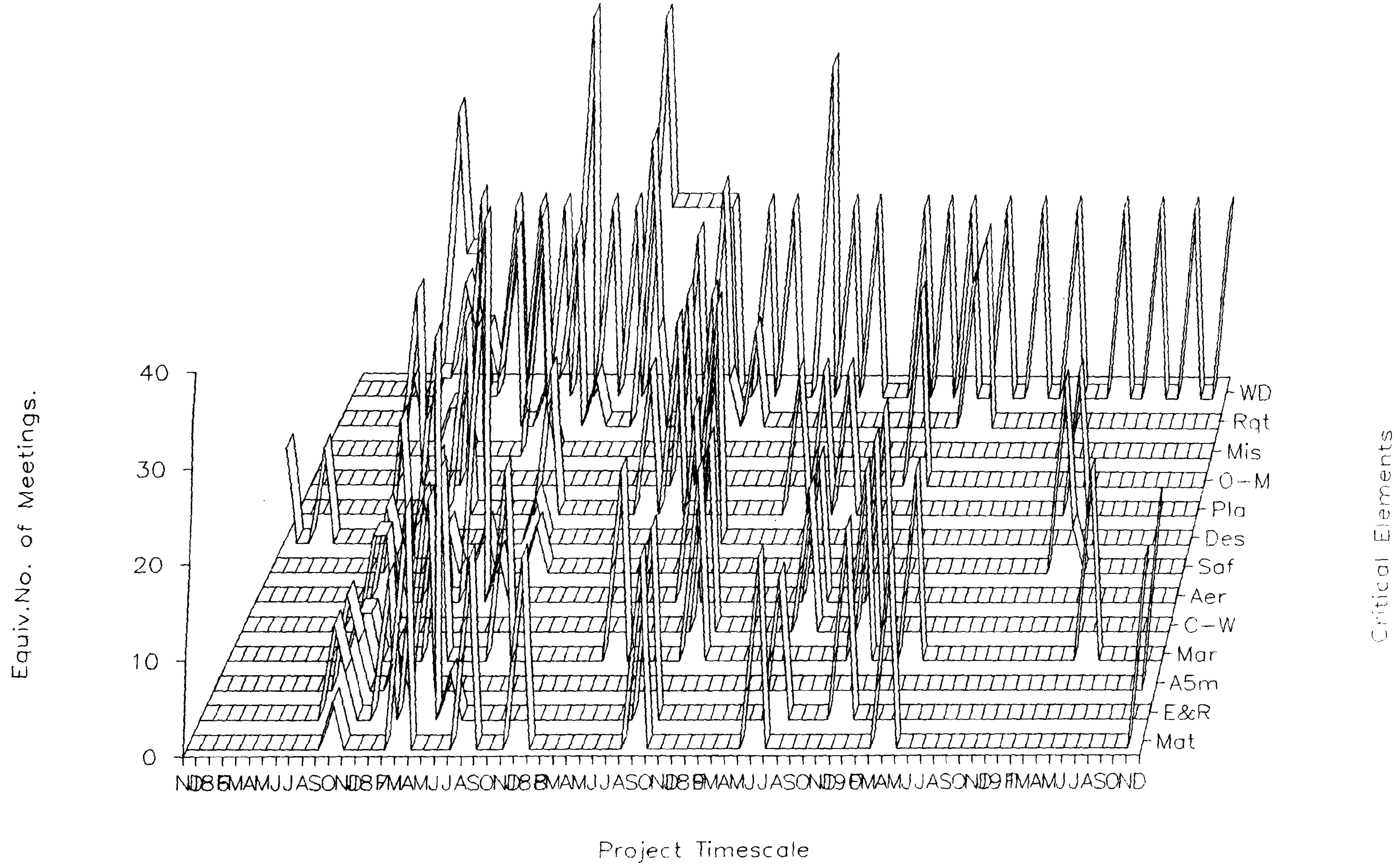
5.2.5.5 Project D Results.

Project D was a first time experience for the customer since it involved the design and procurement of a manned space plane. The analysis is presented in Figs. 22, 23 and 24. From the commencement of the project the decision making processes inadequately involved the manned safety constraints with the result that major conflicts developed and ultimately the programme was terminated. The general culture was of concealment; rather than open debate and exposure of problems as they occurred. The underlying cause of this condition was politic-budgetary.

The author was a member of a Director General safety committee (WD) and the chart, see Fig.22, for this project

Fig.22:Project D; Meetings Frequencies.

Dynamic Risk Indicator;(1985/91)



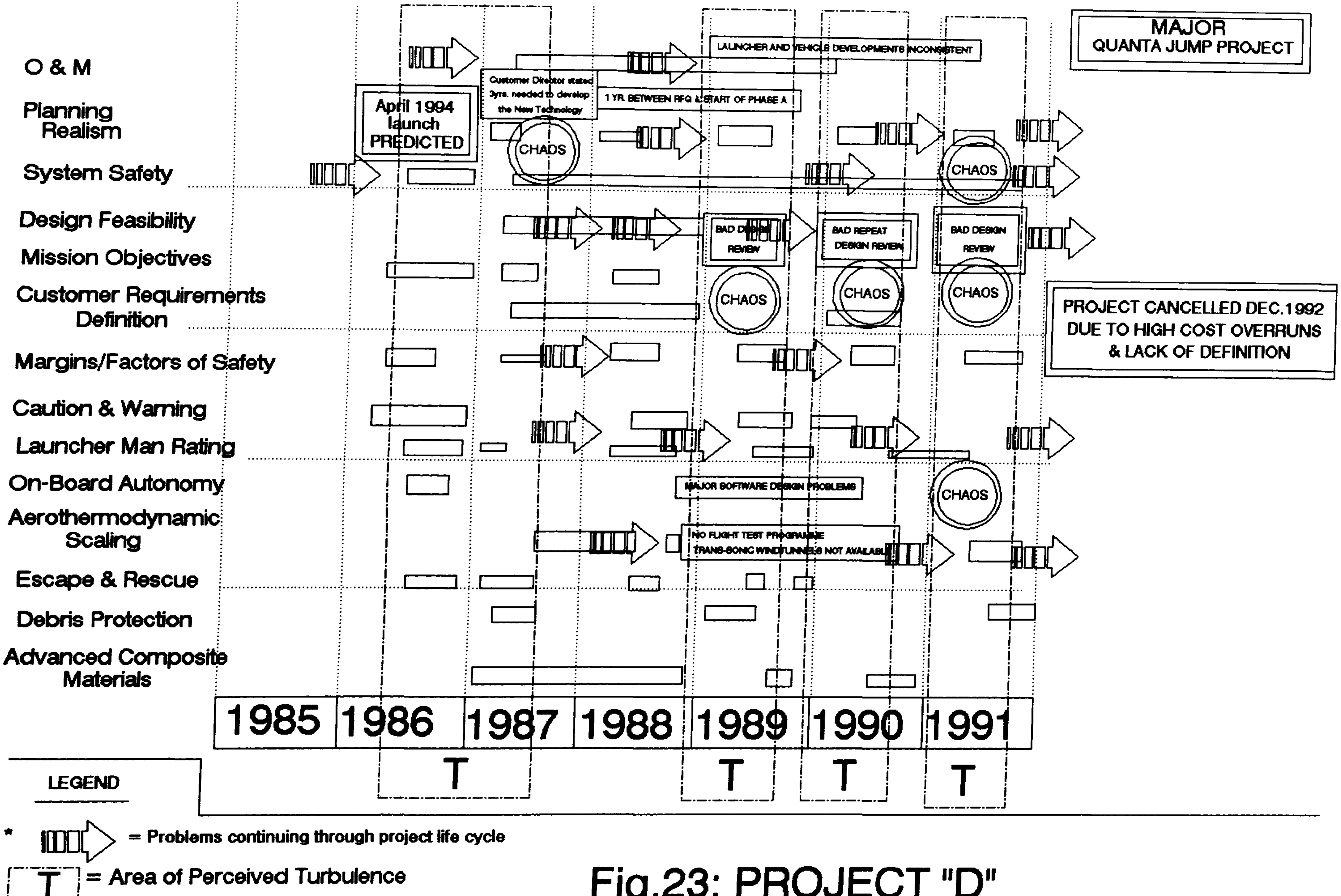


Fig.23: PROJECT "D"

AREAS/DURATIONS/INTERACTIONS and TURBULENCE/CHAOS of MAJOR PROBLEMS

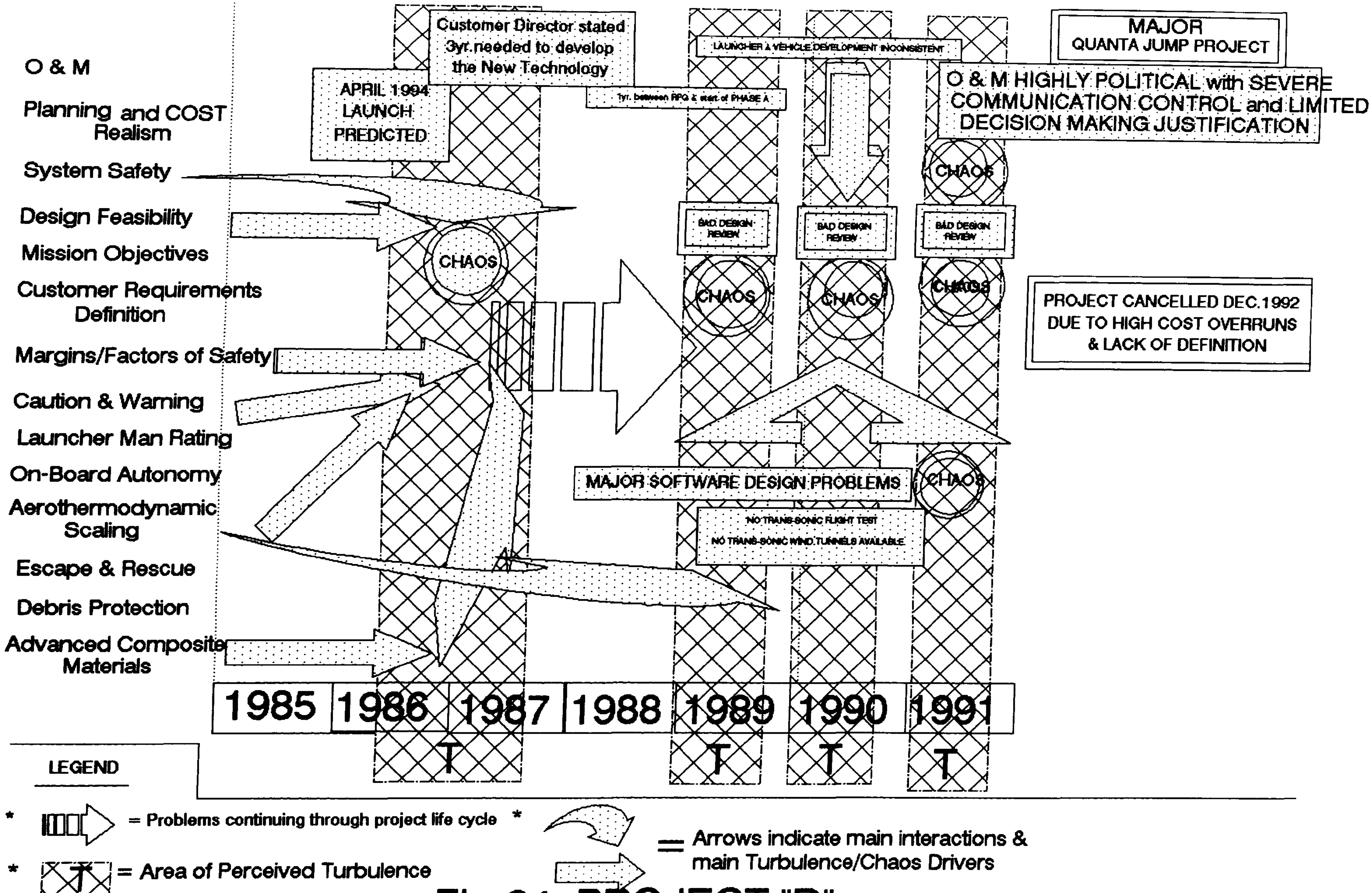


Fig.24: PROJECT "D"

ACTUAL GROWTH of PROBLEM CONSEQUENCES due to LACK OF DEFINITION in MOST MAJOR AREAS & THEIR INTERDEPENDANCIES

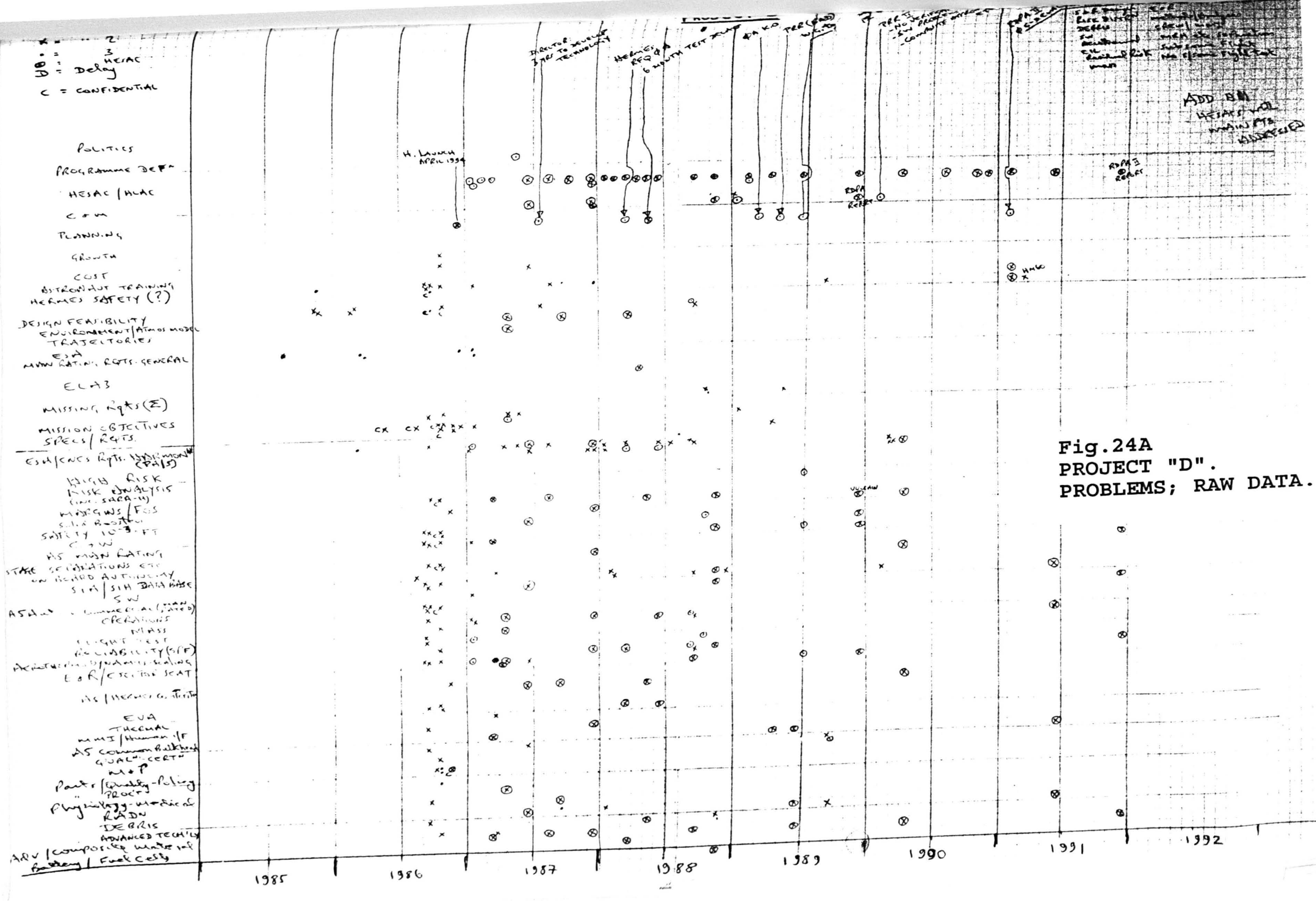


Fig.24A
PROJECT "D".
PROBLEMS; RAW DATA.

primarily reflects that activity. The main problems, as indicated by the frequency of meetings related to:

1) the definition and harmonisation of safety requirements,

2) the design and implementation of escape, and caution and warning, systems, and,

3) mans role on board.

This programme used confidentiality intensively, which had not been a previous customer practice, and thus restricted the flow of information, awareness and intervention. From this experience the author would now classify such a situation as a risk enhancing and negative entropy limiting.

The general appearance of fig.16 is of intensive and irregular activity; the frequency and concern of many major issues seems to be continuously high. This truly reflects the actual situation which finally forced cancellation of the project even though certain political elements were insistent that there were no significant problems! The financial loss was in terms of billions of dollars and the time to complete the project was being continuously extended.

This project required the customer to move into a completely new area of technology and operations with the result that expertise had to be bought-in. A similar situation also existed for the contractors so there was a significant element of "the blind leading the blind". The project thus required a major quanta jump in technological, and organisational and management areas.

A unique aspect of this project in comparison with all other projects conducted by the customer over a 25 year period was the inception of a special "watchdog" committee, reporting directly to the customer Director General(DG), to monitor on a non-executive basis all aspects relating to human safety; referred to as "WD" in Fig.22. The author of this research was the only customer employed person on this committee; the other members were not employed in the space industry but were directors of industrial establishments or university professors. This committee constituted an independent intervention presence and its influence resulted from its facility in being able to report directly to the customer DG.

For this project, as with project C, it is noted that the customer Directors proposal to delay the project, in this case for 3 years, was not implemented.

In hindsight it would appear that if this intervention had been successful then the project might not have been cancelled; this is a subjective judgement by the author but based on first hand experience.

The time frame represented by Figs. 22, 23 and 24 formally includes the start of the phase C/D but in reality the definition phase was never satisfactorily completed. This latter point is reflected in the repetitively bad design reviews during the years 1989 through 1991 and the large interactive effects of lack of definition occurring in other areas e.g. margins, factors of safety and aerothermodynamics scaling; see Figs.23 and 24.
It seems extraordinary that a 1994 launch could be predicted in 1986; followed by project cancellation occurring in 1992.

5.2.5.6 Conclusions.

From the analysis of the 20 years of data covering four major projects it is concluded that risk indicators can be identified which give information concerning the dynamics, as well as the statics, of a project life cycle.

A number of dynamic risk indicators have been identified, see section 5.2.3.6 for example, but the one used in this analysis related to the number of times a particular subject matter was discussed at low, middle and top management levels. The underlying assumptions are that people working intensively on complex systems will primarily discuss problematic issues and that the slow resolution of such issues, with increasing project damage potential as time elapses, will cause increasing higher management involvement.

Using the conclusions which have been made from:

- the documentation, interview, and orbit analyses,

- the assessment of the current state of knowledge,

- the research on problem identification and resolution, and

- work relating to steady state, turbulent and chaotic conditions,

in conjunction with static and dynamic risk indicators, four patterns have been identified.
From this work it is also concluded that apparently small and insignificant open loop situations can be influenced by positive feedback mechanisms such that they eventually dominate a project life cycle. An example could be a technology problem which increases as certain aspects of the problem remain unsolved and it thereby impacts an increasing number of equipments as they reach the need date to use it.

The four patterns enable a static and dynamic characterisation of a particular project to be made such that the existence and significance of strategic change drivers can be assessed.

The four patterns are summarised as follows:

1) a clustering, consisting of varying densities and heights of the plotted data, of the number of times problems on a particular technology or sub-system etc. are discussed;
2) a continuation of certain problems through various phases and periods of the project life cycle;

3) a reduction of turbulence after customer intervention in a contractors business;

4) a splitting of the main project "route" caused by the need to re-deploy and increase resources for the resolution of problems. The "route" is simply a symbolic way, i.e. a line on a sheet of paper, of portraying the general manner in which the project resources are being spent. One could say that the lines on a resource planning document also indicate routes.

It is concluded that if information is collected, in real time, such that static and dynamic risk indicators can be presented in the manner shown in this thesis then turbulence can probably be limited and significant strategic effects avoided.

Finally it is concluded that an intervention protocol is necessary in order to ensure timely and accountable utilisation of the risk indicators.

5.3 Knowledge and Data Utilisation

5.3.1 Introduction.

The objective of analysing the collected knowledge and data was to utilise it to validate, or not, the hypothesis.

This has been done by identifying knowledge and data which supported, or not, the various points contained in the hypothesis. During this work a number of points have been identified that seem to be obvious risk initiators if they were permitted to remain in a project; these have been recorded as postulates in annex 1. These postulates can be considered as being to complimentary to, and a consequence of, the hypothesis.

The following two sections contain

a) the hypothesis(5.3.2), and

b) a list of the "major points" (5.3.3) in the hypothec.

The remaining sections(5.3.4 and 5.3.5) contain the main discourse of the thesis concerning the validation, or not, of the hypothesis.

5.3.2 The Hypothesis.

The hypothesis on which this thesis is based is as follows.

HYPOTHESIS:

" A development project, which is a complex, open system, commences from a **perceived steady state**, equilibrium condition. The planning representation of this condition consists typically of a number of interfacing **static** diagrams. Strategic objectives are shown to be achievable within stated cost and schedule constraints; with **margins** in the technical domain and **reserves** in the cost area. An essentially **closed loop** situation is thus assumed as reflected by the majority of contracts being fixed price. Even the cost reimbursement and cost plus contracts have a maximum ceiling price so nothing is really considered to be open loop.

As activity increases, the steady state is upset by problems which occur, **unpredictably**, here and there; their origins are within, or external to, the project authority and responsibility boundaries. An interplay of **hard** and **soft** aspects exists within these scenarios.

Due to the multiple, complex, and many common, interfaces, and the different **perceptions** by the involved parties, the problems generate other problems in a dynamic but still unpredictable fashion. The steady state condition thus becomes **non-linear** with many **open loop** situations.

Without **risk indicators** and **intervention** the project objectives will become increasingly vulnerable to the proliferation of problems; with resources being used in a fire-fighting mode but the basic causes of the problems remaining obscure. The achievement of the strategic objectives is not now definable nor predictable; the project is going out of control and constitutes a high risk element.

The above "perceived" increasingly unstable evolution is analogous to a flow condition moving from **steady state** to a **state of turbulence** and ultimately to a **state of chaos** as the flow rate is increased.

The **inter-state** movement takes place due to **bifurcations** which increasingly multiply if their reactions are allowed to proceed unhindered.

The **high risk consequences** can be avoided if the bifurcation patterns, involving both hard and soft aspects, can be continuously identified; thus permitting restriction of excursions to the turbulent and chaotic states by utilising risk indicators and intervention. For example, very often a single problem at low contractual level can effect the entire project. This constitutes the role of intervention in strategic change"

5.3.3 The Main Points in the Hypothesis.

The main points are listed below.

a) A development project, which is a complex, open system, commences with a perceived steady state, equilibrium;

b) the planning presents situations in the form of static representations;

c) the planning presents situations as closed loops with linear margins and fixed reserves to cover all (including unanticipated) eventualities;

d) the project steady state is upset by unpredictable, hard and soft, problems;

e) the problems generate other, unpredictable, problems due to the complex, multiple, and many common interfaces, and the different perceptions of the involved parties;

f) the steady state becomes non-linear with many open loops;

g) without risk indicators and intervention the achievement of the project strategic objectives will not be definable nor predictable;

h) the perceived unstable project evolution is analogous to a flow condition moving from steady state to a state of turbulence and ultimately to a state of chaos as the flow rate is increased;

i) the movement from steady state through turbulence to chaos occurs due to bifurcations which increasingly multiply if their reactions are allowed to proceed unhindered;

j) the high risk consequences can be avoided if the bifurcation patterns, involving both hard and soft aspects, can be initially identified, and maintained current, thus permitting restriction of excursions to the turbulent and chaotic states by utilising risk indicators and intervention.

5.3.4 Knowledge and Data Supporting the Hypothesis.

The above ten points are now addressed individually with respect to the knowledge and data collected.

5.3.4.1 "A Development Project, which is a Complex, Open System, Commences with a Perceived Steady State".

This point contains the issues of:

- complex systems,
- open systems,
- strategy, by implication from a development project commencing with a perceived steady state,
- perception, and
- steady state.

A typical European Space Agency development project consists of approximately thirty contractors, one thousand personnel, eight different languages, seven different types of technology, eight different sub-systems, ten thousand documents, and three thousand changes during the five to fourteen years procurement cycle. Such a project is therefore considered to be complex.

The subject of "open systems" is addressed in sections 3.14, 6.5.4, 6.7, and 6.10.4. An open system is self organising and has the characteristic that its stability is in dynamic equilibrium; in which continuous change occurs yet relatively uniform conditions prevail.

The following statements from existing research support the statements in the hypothesis relating to open systems and existence of feedback loops, "soft" aspects and chaos.

a) An open system is where the stability is in dynamic equilibrium; in which continuous change occurs yet relatively uniform conditions prevail, like the conditions in a pool beneath a waterfall.(102)

b) Both negative and positive feedback, in the form of individual and species behavioural patterns, are involved in maintaining the overall dynamic equilibrium of the community.(102).

c) The developing brain ought to be considered as a highly active and primarily self containing system which, when born, already possesses substantial knowledge about the structure of the world into which it is going to adapt itself. Thus when the brain is born and confronted with a dramatic expansion of accessible environment, it poses a number of precise questions to this environment with the purpose of optimising and adapting its internal structure to reality.(93, 109, 110).

d) The brain and its environment appear as components of a closed, highly interactive system.(109, 110, 93)

e) The cause of developmental errors is suggested by the particularities of the self - organisation process. The possibility must be considered that the brain does not formulate the right questions or does not ask with sufficient insistency to obtain answers.(109, 110).

f) The large scale behaviour of complex systems, often hidden by fluctuations, can be interpretated in terms of an organisational scheme for all underlying events.(110).

g) The presence of periodic solutions implies the presence of steady states.(130).

h) A chaotic system can be locally unpredictable, globally stable.(153).

i) A complex system can give rise to turbulence and coherence at the same time.(153).

An open system will attain a steady state in which its composition remains constant, but in contrast to conventional equilibria, this constancy is maintained in a continuous exchange and flow of component material. The steady state of open systems is characterised by the principle of equifinality; that is, in contrast to equilibrium states in closed systems which are determined by initial conditions, the open system may attain a time-independent state independent of initial conditions and determined only by the system parameters. Also, in open systems, with transport of matter import of "negative entropy" is possible. Hence such systems can maintain themselves at a high level, and even evolve toward an increase of order and complexity; as is indeed one of the most important characteristics of life processes.(63). Basically, the development project is considered to be an open system simply because it is fundamentally composed of human beings; and human beings, life, are open systems(63). The project studies show that projects are capable of maintaining a degree of order as the data rate entering the project increases. However the extent of "creating more order from less order" varies and examples of projects going out of control, or out of order, abound. From the authors viewpoint a project CAN behave like an open system providing it is properly designed and structured to do so; the latter requires a defined intervention system.

The different interpretations given to the definition of "strategy" in the research, see chapter 3.1, are indicative of the difficulties that have been experienced by researchers and managers in defining the role or function of the company and its dynamic environment; the latter is specifically addressed in chapter 3.9. As an example, one definition states that "strategic definition refers to information flow"(6). This is fully supportive of the "flow" concept introduced in this research and finally linked to dynamic risk indicators. The differences demonstrate that different people perceive strategy in a different way. Relating to the hypothesis this indicates that the perceived steady states, or whatever various people conclude a particular state to be, may be different because of the different perceptions of both the state and the applicability of the criteria they are using.

This is a major point. Since strategy is defined in different ways one cannot directly compare programmes and these different strategic perceptions could occur in the same project, company and consortium. This could account, partially, for the adverbial relationships that often exist between co-contractors and even more between customers and contractors.

This thesis has adopted the definition given by Hofer & Schendel(11) whereby the strategy of an organisation is defined as:

"the means of coping with both the external and internal changes; the path charted for the organisation being linked to the organisational goals & objectives which are to be achieved."

In a similar manner strategic planning as defined in the research seems to, variously, include goal setting, risk, resources, external and internal influences, capabilities, and morals; see chapter 3.2. There are thus significant differences in the interpretation of both "strategy" and "strategic planning"; these differences could have major effects on resource allocation and decision making.

One area of research has concluded that "strategic goal setting provides a means of reducing environmental turbulence and controversy"(12); this constitutes a strong support to a main theme in the hypothesis.

In annex 6, the Bids of projects A and B are clearly identified as having significant problems with important data inputs missing and glaring inconsistencies. However in spite of these traumatic circumstances the ESA final report indicates that the perception of the ESA top managers is that within a period of about three months the majority of the shortcomings will be rectified and the project may proceed.

In the same annex similar situations have arisen, with similar rather open conditions attached, for the System Review Boards conclusions. Hence in most cases the programme continues with the problems, which should have been solved previously, being worked during the succeeding phase; often causing delays and resource depletions that increase the overall risk rather than diminishing it. In the authors view these are possible bifurcation initiation points.

Analysis of the data from the project studies indicates that moving from one phase to another with open problems provokes the onset of turbulent conditions.
This effect is particularly noticeable with projects C and D. It is clear that the objectives of phases A and B should be completely achieved before commencing phases C and D. This is rarely done in practise. In the case of project C phases c and D were started with many open problems. In July, 1978 the ESA top management announced that the satellite would be ready for launch in July, 1982; it was finally launched in July,1989! Nevertheless, since so much funding had been committed the budget was continued for seven years after the its planned completion!
The above statements were made by managers "doing their best". However the term "steady state" needs some discussion. It is the authors view that, in general, a manager considers a situation to be steady state if he can understand and control, cope with, the problems as they occur without too much doubt, stress, or conflict.
For a major development project such a situation rarely exists. There are so many dimensions to the project; from technical, planning, personnel, political, to inter-personal and cultural. Steady state, in the real business world, is thus a period when the turbulence is relatively low.
In all the projects being researched the top managers usually had to decide whether to proceed with a project with many open problems, or, not too proceed at all. The reason such dilemmas exist is due to annual budgeting; commit budget annually or lose it to some other predator. Since the very existence of the managers staff and department also often depend on the commitment of project budget it can be seen that the pressures to commit are very great; and constitute the relative steady state.

From the interviews the following points are noted:

a) even though a "bogey" price was used by the contractor, which represented less than the addition of all the sub-system minimum prices, he decided that all the incentives and profits would be realised!

b) the contractor often considered cost and financial aspects as secondary and concentrated on technical options to meet the customers technical requirements but even so he perceived that he would be successful;

c) many contractors perceived the situation as "steady state" due to a conviction that, because the customer frequently interfered in the contractors business and often changed the requirements, he could blame the customer for the major problems that were likely to occur; hence the customer would pay and the financial risk loops were closed!

d) in project C it was stated that although relatively steady states did exist they were very short and the cycle time from steady state to a mini or major crisis was fast. It was also stated that a number of such cycles seemed to be present simultaneously thus making the overall situation more complex.

It is the conclusion of this thesis that application of the Method, see chapter 6, would have resulted in early intervention in the above mentioned examples and the avoidance of such strategic disasters.

5.3.4.2 "The Planning presents Situations in the form of Static Representations".

This point addresses the issues of:

- project and environment dynamics,

- planning.

The summary of the research presented in chapter 3.9 indicates a wide divergence on the definition of the dynamics of a company and its environment. It is clear however that a dynamic situation is considered to exist.

This thesis has adopted the approach that the company and environment boundary, if there is such a thing, is formed by the limit of individual perception; this is a variable entity.

The dynamics of the environment are defined in many different ways involving different numbers of factors and different types of factors. The following conclusions have been extracted from the current state of knowledge to indicate the strong subjective(soft) content, and very wide definition, of the environment.

a) The dynamics of the "environment" relates generally to the changes of data, situations, interactions etc. with time. However, chaotic behaviour has been defined as a dynamic aspect(91).

b) In most cases change was found to consist of the adjustment of structures and systems to secure consistency and coherence within an architype(75).

c) For many middle managers personal aspirations have more powerful influence over decisions concerning technological change than organisational objectives(79).

d) Two dimensions define the environment:

1) simple or complex; and

2) static or dynamic.(14).

The inability to agree or closely define the dynamic environment, the static environment, whatever that is, and strategy, constitute areas of research that are still in their infancy. This situation seems not to support many of the assumptions that are made today e.g. hard line modelling and future prediction models.
By default it is contended by the author that the theory of steady state - turbulence - chaos, with an incremental approach being applicable to linear aspects, is supported because actual situations, or patterns, are addressed and the implementation does not rely on limited definitions and undimensioned assumptions.

Many of the points referenced in the research seem to be rather indefinite since they are based on premises which are not firm. Examples are references to high velocity environments without explaining what is moving at high velocity, and statements that rational decision making should be used in high velocity environments without explaining what constitutes a rational decision!

Most space companies use a simplified PERT planning system. This is essentially a longitudinal bar chart of task durations using Boolean logic to compute schedule criticalities and completion dates.
Each chart is a static representation based on data which often rapidly becomes obsolescent. The planning does not specifically identify aspects which can become very dynamic; the system does not have the capability to present the dynamic potential of particular events. An example of the latter is "embedded research"; see chapter 4.2.2. Another example of the static limitation of the current methods is that the planning is mostly success oriented; contingency planning is implemented but usually when the problem has occurred. Extensive consideration of failure consequences is rare; see chapter 4.2.3. The planning also does not attempt to incorporate the dynamics of strategic change. This is particularly significant for some space projects due to their long duration and international membership; see chapter 4.3.

During one of the interviews it was stated that in private business, as opposed to government business, contingency planning was prepared in parallel with the main project planning. This could accommodate some dynamic aspects. In other interviews it was stated that the PERT plans did not adequately represent the project and it was almost impossible to maintain them current due to the dynamics of the project and the large amount of time and manpower needed for updating. The conclusion here is that static situations do not exist. If a "static snapshot" must be used then priority consideration should be given to its sensitivity, in a limiting sense, to the dynamics of the situation.

5.3.4.3 "The planning presents situations as closed loops with linear margins and fixed reserves to cover all (including unanticipated) eventualities".

The following issues are addressed in this point:

- systems,
- closed loops,
- margins, reserves.

The literature has explored and established some definitions and relationships of various functions of organisations which have then been delineated as a "systems approach". The systems approach has some consistency in the research and discussion has also occurred concerning the life cycle, or the finite life span, of an organisation.

In general this status, concerning what a system is and what it does, has been utilised in this thesis and no significant conflict has been detected; see chapter 3.10.

There are differences concerning where R & D must be positioned in an organisation and in the systems approach.

In the research closed loop systems have been extensively explained in, for example, automated systems.

It is also stated that since feedback is an essential element in a closed loop system, margins can be used to monitor a decreasing or increasing risk profile; the closed loop implies a linear situation.

Closed loop systems are infrequently mentioned in the research in connection with management situations. No reference has been found addressing the manner in which closed loops are proposed in this thesis.

In many cases loops or feedback are not specifically shown on the planning but the feedback is assumed to exist via the management and monitoring activities of the project teams; of the contractor and the customer. The planning charts thus show a network of interconnecting, and in many cases interdependent, lines from commencement to termination of the project. This overall planning together with the "work breakdown documentation", giving details of every task, and the curriculum vitae of the key staff involved constitutes the entire planning submission.

Where, historically, difficulties have been encountered in meeting certain technical or performance requirements margins are allocated to absorb future, unanticipated problems; see chapter 4.2.10. From the interviews it has been stated that these margins are dimensioned arbitrarily! The margins are interpreted linearly i.e. it is assumed that the margin will decrease to zero by the completion of the project. The analysis of orbit results revealed that approximately 20% of all design related problems were due to design margin violations!

The perceived industrial risk, of not meeting the customers requirements on time and within cost, is covered by a fixed financial reserve which is agreed at the commencement of the project. Once again it is assumed that the reserve will, in the worst case, decrease to zero by the end of the project. By definition, therefore, the margins and reserve are assumed to cover all unanticipated events. The financial reserve has been insufficient on all ESA projects. This has not resulted in the contractor losing money due to the overlap of contractor and customer liabilities; promulgated by ESAs involvement in the contractors activities and responsibilities. The "openness" of the financial reserve loop is thus closed, as far as the contractor is concerned, by the availability of "alternative funding" from ESA. It should be noted that the ESA convention requires that ESA develop a successfully competitive, world wide, European Space industry. It is perceived to be counter productive to that objective to allow companies to suffer financially. That is not the view of this author.

There thus seems to be a confusion between the properties of open and closed systems resulting in their inappropriate application. Hence the representation of all eventualities by closed loop systems is not accepted.

In the interviews it was clearly stated that open loops are not addressed and the PERT planning would not facilitate such analysis or presentation.

A conclusion from the above, concerning the customer and contractor relationship, and from the interviews, concerning the corporate and project manager relationship, is that:

"continuous intervention will not support the accommodation of strategic change".

5.3.4.4 "The project steady state is upset by unpredictable, hard and soft, problems".

This statement involves decision making and project planning.

In the research some limitations of current decision making processes are noted e.g. the representation of multiple goal behaviour of man and organisations being approximated by a single unchanging and technically manageable criteria. Some quantitative methods are extremely complex and rely on finite well defined input data and in general do not take account of the soft aspects nor the dynamics of the situation. Decision making models have been constructed but they rely on significant assumptions and generally are only applicable to the particular situation for which they were formulated. The utilization of these models for "real life" situations could not be recommended with any confidence. A major problem, in this and other areas, is the lack of definition of all assumptions and the likely consequences of those assumptions being incorrect. In other words what is the sensitivity of the conclusions, from using the various techniques, to the assumptions? No answer has been found to this question. The conclusions of many different researchers are different. It is concluded that there is no single universal method that has been selected to define the decision making process. Quantitative methods are rejected by a large number of the researchers.

Consideration of soft aspects is very small.

The research addressed above refers to the problems currently in existence due to the multi-facetted nature of decisions, perception differences, the avoidance, or tacit acceptance(e.g. due to the "possible" weight of public opinion) of "soft" aspects, and the numerous and different decision making rationales; the latter encompassing organisational, checklist and formulative approaches. The research has also recorded that decisions are often made in small steps and intervention is frequently present.

The current status is fragmented and often contradictory; see section 3.3.

A typical answer when discussing decision making with managers is frequently that, after assimilating all the available data and knowledge, the final "go/no go" is made from gut-feeling or seat-of-the-pants directing.

The interviewees supported the above response but stated that they typically relied on a few "trustworthy colleagues"; which they also referred to as project supports.

The need to find a more realistic and useable approach seems to be self evident.

On the subject of planning it is considered that examination of any complex project would immediately reveal that the original plan had not been followed. Numerous cases exist and are reported monthly in the British Institute of Management journal, and in the Harvard Business Review, for example.

General instances of hard and soft problems which were not predicted are:

- icing problems on the Britannia Proteus engines(hard);
- fatigue problems on the Comet(hard);
- geological problems with the Humber Bridge supports(hard);
- embedded research problems in the Concorde project(hard);
- industrial action in the British Weaving and Ship Building industries(soft);
- secondary effects with the Thalidomide drug(hard and soft);
- many bankruptcies due to currency changes(soft);
- problems with the British coal industry due to the environmental impact of "dirty coal"(soft).

From the interviews it was stated by two project managers that it is essential that all interfacing managers know each other personally; this would enable behavioural idiosyncrasies to be ascertained.

On project C for example it was known that serious "soft" problems existed from the start; not least of which was the adversial relationship between ESA and industry due to the formers over-involvement.

The conclusion on this hypothesis point is that the status of the project will be upset by unanticipated problems since no realistic method, from the decision making and planning aspects, exists to accommodate them.

5.3.4.5 "The problems generate other, unpredictable, problems due to the complex, multiple, and many common interfaces, and the different perceptions of the involved parties".

This point embraces the following issues:

- organisation, culture,
- perception,
- problem generation.

The complexity of the interfaces is, at least partially, a function of the type of organisations involved. Also, the degree by which individuals "perceive" and operate is a function of the degree by which the organisation constrains or permits such attributes.

In the research, see chapter 3.4, a number of organisational types are defined but it is also stated that organisations can move through phases of being related to one type or another. For example, the metamorphosis models, in which growth is not smooth but involves discontinuities when the degree of change is too large for the existing structure, probably applies at the macro and micro level of every organisation at some time or another. The real point is whether the organisation adjusts itself to adequately handle the new situation in time to avert failure to meet strategic objectives or not. This seems to connect with the bifurcation principle since failure to amend the organisation to meet changed environments or even changed objectives could result in an increasing number of problems with an increasing "inability" to solve them. Hence the situation could be expected to progressively degenerate; possibly to chaotic consequences.

An integral aspect of an organisation is the culture in which it resides, or which it creates, and the cultures with which it interfaces; these are soft aspects. It is therefore important to define culture and to try to accommodate to accommodate it.

An interesting definition change has been formulated by Kristian Kreiner(71) in which he expands the sphere of culture from:

- the underlying, often subconscious, foundation for peoples thinking and acting(the traditional approach);

to

- the surface and manifestations of such thinking and acting in organisations.

This latter definition has been utilised in this thesis in the sense that cultural characteristics are considered to be perceivable. It is therefore assumed that the pattern recognition approach and subjective characterisations will include significant cultural contributors.

As with environment it is not clearly defined; there are a number of descriptors including the one finally selected and reproduced above.

The research indicates the difficulty of defining the environment and the conflicts that can be generated within a company working in the development field; the latter evidenced by the number of different systems which have been devised to measure performance and risk. The need to limit progress to "small" finite steps and the concept of intervention is concluded. It is interesting to note that one of the interviewees stated that the best R & D results were obtained in a commercial environment due to the sense of urgency that was prevalent. He also stated that real progress did not take place in small steps but in the odd "jump"; he acknowledged that preparation for the "jump" had been well established in those cases that were successful.

As mentioned above the overall project planning consists of sequential events many of which are inter-dependent. In fact to meet the timescale many events are carried out in parallel thus receiving inputs as they proceed rather than at their commencement which would be the ideal, lowest risk, case. Hence the number of interfaces, and their criticality, are increased.

An example of "problems generating other problems" is as follows. During one of the projects discussed in annex 6 a critical high frequency payload diode failed to pass the qualification test programme. This meant another manufacturer had to be selected and the ten month programme restarted. The impact was enormous since the total payload and the satellite platform integrations were delayed. Due to the multiple and complex interfaces the entire project end date slipped. The rework situation introduced even more criticalalities into the programme due to the increased implementation of parallel activities to "strain" to meet the project planned, and contractually incentivised, completion dates. The perception of a number of managers during the qualification programme of the original diode was that "everything would ultimately be ok because the product comes from Japan"! The European competitor had failed to convince several managers even though the Japanese gave carte blanc agreement to meet all requirements without full justification. A number of managers felt very uneasy about this but their perceptions were not heeded. The whole issue fundamentally relied on the perceptions of one or two managers that the Japanese product would succeed; finally it failed and the European product succeeded. This affair was a kaleidoscope of "soft" controversies.

The above example is submitted as being rather typical of events that occur in many projects.

It is also submitted that the Law of Requisite Variety, proposed by R.Ashby(84), is applicable. This states that anything interacting in the world is subject to disturbances tending to upset its recognisable features. They can only be distinguished if a compensating response can be generated for each disturbance nullifying the change that would otherwise result. Hence it is concluded that "only variety can absorb variety". The variety of the controller must match the variety of the controlled.

It is thus contended that since the total possible variety of a situation will rarely if ever be matched, or agreed, by the managers experience, knowledge and perception it is likely that additional problems will be generated due to the evolution of unrecognisable features. This situation is compounded by organisational, cultural, and soft issues in general.

5.3.4.6 "The steady state becomes non-linear with many open loops".

This point basically refers to the difficulties of knowing what the actual status is in a complex system due to the large number of interfaces, the limitations of standard reporting mechanisms, and the dynamics of the overall project scenario.

With the proliferation of problems as mentioned in 5.2.4.5 and the, erroneous, representation of the project by static networks it is considered self evident that many areas of unknown will exist. Unknown or undefinable situations can only be open loop, non-linear in nature concerning the amount of time and resources needed to complete them.

From the analysis of the project documentation, see section 5.2.2., the following conclusions have been made.

"Unless the reader is very well informed it is impossible to judge the importance of the "statements of doubt" in the Project Progress reports(PPR). Even for the informed reader, the relative risk of this or that problem is not indicated. In fact the PPR almost seems to be an invitation to the customer to ask certain questions, in certain pre-selected areas, where the contractor probably has an answer "on hold".
This is of course a rather serious statement. It is probable that the contractor does not use this as a deliberate tactical ploy but rather adopts this style of behaviour because it has typically "always been done like that." Having made this "disclaimer" the author has known project managers who have always done their best to delude or confuse the customer to cover up their own intentions or errors....or insecurities. Such project managers have also had the tendency to restrict, or share, information with their own corporate management, and their teams! The Quarterly Executive Report(QER) contains practically no information concerning risk; it having been specially prepared for "unlimited distribution" and particularly to possible future customers. Hence corporate reliance on such a report, possibly to use it also as an input to another strategic plan, would probably be a waste of time; or very illusionary. It is clear from the above and the interview inputs that a more rigorous method of reporting is required. The orbit problems of project B were extensive and can, in hindsight, be traced to early brief references

in the reports."

The above indicates the inadequacies of the reporting and information distribution systems. This could have serious consequences on the decision making and general management processes and, it is submitted, would contribute to the increase of unknowns, and therefore non-linearities, in the project.

The definition of an open loop system which is relevant to this thesis is:

- a system in which the definition or outcome of any of its elements either,

  1) cannot be completely defined, or,

  2) cannot be directly linked with a previously experienced "similar" item which had a successful result.

This definition naturally excludes closed loop systems since both the conditions 1) and 2) are not applicable.

Using the same rational, "margins" cannot be used in open loop systems.

It seems that critical elements of open loop systems are knowledge as well as data based.

The following points present some examples from current research.

a) Complexity is a property of a system arising from interactions of the system with its observer-regulator rather than being an intrinsic property of the system itself. Linguistic models can be used to avoid complexity.(90).

b) Most managers have decided to use heuristic rather than mathematical models i.e. problem solving by inductive reasoning. Four basic approaches to scientific truth: Liebnitzian; Lockean; Kantian; Hegelian.(90).

c) Quantitative model representation of complex systems is questionable. Language expresses ideas and beliefs. Formalism errs on the side of sameness and seeks to exorcise vagueness; functionalism errs on the side of difference and encourages us to look at the uses of vagueness. Silence may communicate what is beneath or beyond words.(91).

d) Probability theory studies statistical inexactness, due to the occurrence of random events, and fuzzy set theory studies inexactness due to human judgement.(91).

Once again the domination of behavioural, soft, issues has been indicated.

In the "Analysis of Daily Records", see chapter 5.2.5, all the critical items that caused turbulent and chaotic conditions were identifiable as open loop systems prior to commencement of phase C-D i.e. they were either embedded research or inadequately defined managerial systems.

5.3.4.7 "Without risk indicators and intervention the achievement of the project strategic objectives will not be definable nor predictable."

This point relates to the issues of:

- risk indicators,
- decision making,
- intervention, and
- project failure/success.

The Space business is predominately success orientated; risk indicators, as such, do not exist.

As described in chapter 4 the main indicators of "success" used in a Space projects are:

a) the maintenance of the schedule;

b) the number of Change Notices by which the contractors request more money or time, or both;

c) the parametric margins e.g. for power and mass;

d) the results of System level reviews;

e) the achievement of successful qualification;

f) the delivery of hardware and software;

g) the successful completion of tests;

During the past ten years the attitude of ignoring certain risk and failure aspects has gradually changed in the technical domain. It is unfortunate, and perhaps an indication of the magnitude of the inertia to change, that such changes have often been forced into effect only after the occurrence of accidents e.g. the failure of the shuttle

Challenger.
A number of methods, tools, criteria and requirements now exist to define, evaluate and control technical, and to some extent programmatic, risk. They are still very weak in the man-machine interface, software, knowledge and data utilisation areas but progress has been made. The author has initiated some related research addressing risk and hazard analysis utilising data and knowledge bases, subjective judgement and expert systems. It is interesting to observe that every part of every electronic circuit is analyzed for all possible consequences of all possible failure modes(FMECA), at significant cost and time. An equivalent activity in the management and programmatic area has never been seriously considered to the knowledge of the author even though the "effective implementation" of the FMECA depends on the existence of such a system; hence one of the main drivers for this research work.

It is extremely surprising, to the author, that this in-balance is apparently not perceived to be paradoxical by the customer and contractor managements involved; in spite of the fact, from the orbit analysis(see annex 8), that 70% of all design related problems have been due to "inadequate failure mode consideration and the inability to test or simulate completely certain systems prior to launch".

It is suspected that the above orbit statistics were not known to the project personnel. This seems to be an example where relevant data was not available to the right people at the right time. This "open system" and "negative entropy" characteristic whereby decreasing the "local" entropy, i.e. by injecting the right data, in order to be able to increase order in a situation in which the complexity is increasing, would not therefore have been present. In these circumstances the projects can be predicted to become less successful.

The following extracts from the current research status indicates the major role of subjectivity and informal communication (soft aspects) in the way in which managers actually work and make decisions.

a) Managers:

- work at an unrelenting pace; their activities are characterised by brevity, variety and discontinuity; they are action orientated and favour oral media. They handle exceptions and regular work; and process soft information that links the organisation with its environment. The managers' programmes relating to decision making, information processing etc. remain locked inside their brains(18).

- spend as much time with peers outside their organisations as with subordinates and through such interpersonal contacts they emerge as the nerve centres of their organisations(18).

- at CEO level, decisions are made in small steps; particularly very complex ones to allow time to understand the problem(16,72).

b) Decision making in high velocity environments e.g. where the rate of change of product life cycles is high, is characterised by:

- analytical, rational, comprehensive, short term & fast processes;

- assessment of innovative, risky strategic alternatives with "decision execution-" and "implementation-" triggers;

- centralised power in the CEO but with high delegation to trigger points/ executives(21).

c) Strategy and the related decision making include the collection of objective and perceptual organisational data at multiple points in time as the strategy unfolds. The board of directors(an external coalition) may be dominated, divided or passive; in the two latter cases the lower management levels will get the opportunity to intervene and influence to their own ends. CEOs must respond to departmental power which can be direct; external environmental impact is seldom direct and the cause-effect relationship often unclear. Although CEOs often interpret their environment as it is perceived to exist, they may also create or enact an environment that is different from the one they have been experiencing(22).

d) Multiple goal behaviour of men and organisations has traditionally been approximated by single, unchanging, and technically manageable criteria; the results of psychologists and social scientists concerning multi(non-mutually destructive) goals has been ignored. These goals are not independent of the means used to pursue them. Dealing with such "incommensurables" as quality of life, education, etc.. can no longer be avoided. Many researchers are sceptical about mans ability to choose among multi-attributed alternatives- suggesting an interaction(23).

e) The public definition becomes an integral part of the situation(30) and cognitive dissonance, relating to the reordering of goals, is defined as being a direct function of the number of items the person knows are inconsistent with the decision(31).

Some of the principles relating to the above have been used in this thesis e.g. expert judgement and fault tree analysis. Part of the **intervenors role would be to ensure the implementation and utilisation of lessons learned**.

There are clear statements in the research which indicate that where an incremental approach has been used success has resulted. This point is acknowledged by one of the interviewees but he made the additional observation that to succeed significantly with respect to others major jumps were necessary. These major jumps far exceeded an incremental step. The same person made the comment that really successful R & D should be performed under conditions of stress e.g. something must be achieved by a certain date. There are also a number of statements that the strategy must fit the environment. This rather ambiguous since, as mentioned above, definitions of "strategy" and "environment" are not well agreed. The issue of incrementalism, traceability and feedback is mentioned increasingly and related to successful organisations. Correlation is not made with linear, non-linear, closed or open loop systems as has been done in this thesis. There is also the point that the borderless company is on its way; this conclusion was made from a survey, world wide, of 12,000 managers. This is interpreted to support the contention in this thesis that the border between a company and its "environment" is not representable by hard lines. In this thesis it is defined as the locus of the perceptions of the managers within that company.

Previous research has identified a connection between "incrementalism and traceability" and "success". This is an important support for the incremental approach which is one of the thrusts of this thesis.

Only one reference has been found that actually mentions feedback mechanisms being based on indicators; this is stated to be an ideal case(36).
There are many references concerning the subjective appraisal or perception of risk and the fact that allowance must be made for such differences. This is rated as a positive support of the hypothesis.

There is also the strong support that when two functions were learned under different conditions the subject erred in the direction of allocating more resources to the subject learned under less uncertain conditions. This supports the brain - chaos theory where we always try to relate something to a familiar aspect i.e. something we have experienced before. A point is made here that the interest of the intervenors was more in the phenomenolgy of the situation than in the cybernetics of control. In saying this, Checkland et al reject many types of modelling including VSM.

In the Project Implementation Profile method thirteen factors were written down which account for the variation of project success. At the top is a "clearly defined project mission" or, in the terms of this thesis, the "statement of risk". Lower down in the list are "monitoring and feedback", "communication", and "perceived quality". These points all support the hypothesis and the thesis in general.

There are a number of references to perception; emphasising that one must take account of perception and that it is a major element in early failure.

There are also a number of comments relating to the unpredictability of the future.

The above notes indicate the concern of a number of researchers with the lack of understanding, and consideration, of what organisations, and their environments, are and hence what risk actually means e.g. organisational safety is only apparent after an accident. Some researchers have clearly referred to the need to advance incrementally with a brief mention of indicators and feedback. Uncertainty is defined as the "unknown unknowns" which is congruent with the thinking in this thesis. There are a number of references relating to "perception" and behavioural aspects, and in particular the main contributors to project failures are stated to be:

- perception ambiguities;
- communication and feedback problems;
- planning and phenomenological(150) issues.

It is also interesting to note the occasional analogy to some aspect of "living systems" e.g resident pathogens. In general this synopsis indicates that this thesis represents a "natural advance" of a number of research directions that have already been identified and to some extent initiated and substantiated.

The necessity for intervention was demonstrated in projects C and D. In the former case, ESAs intervention was actually requested when the prime contractors perception of the situation was that a major crisis, beyond his powers of resolution, existed. This seems to clearly indicate a situation of chaos i.e. systematic relationships existed but only randomness was perceived.
For project D the intervention occurred on a regular basis due to the convention of an independent ESA Director General "oversight" committee. The effect of this intervention was, finally, to expose the high risk of this project and it was finally redefined. This particular project commenced as an European national project with a very high "national prestige" profile. The resources required then became too high for a single country to finance and ESA adopted the programme, with multi-national

participation and funding. The unwritten strategic objective still seemed to be the national prestige and deluded the perception concerning the magnitude of the technical problems and the corresponding lack of resources. The written strategic objectives only were used by the oversight committee.

The above examples illustrate two quite different situations where intervention was necessary in order to maintain, or protect, the strategic objectives. The problems in both cases was that the interventions came too late to avoid significant unnecessary expenditures.

5.3.4.8 "The perceived unstable project evolution is analogous to a flow condition moving from steady state to a state of turbulence and ultimately to a state of chaos as the flow rate is increased."

The aspects of perception, bifurcation, turbulence and chaos are the main issues addressed by this point and are central to this thesis.

Many references refer to perception; it is becoming a central theme in the research. A model of "brain perception" has been devised(93, 105) and is adopted in this thesis. It fundamentally states that the brain will always relate every new or different perception to a previous experience even if the resulting relationship is not correct. It seems clear therefore that a bifurcation may, or may not, be recognised by someone or it may even be invented where it does not exist simply because experience in the brain does not exist to indicate otherwise.

It has been well documented that **the process of defining the nature of a problem is dependent upon the histories and backgrounds of those responsible for defining the problem.** (42; plus, Bruner and Kresch 1950; Hayes and Simon 1977; Herden and Lyles 1981).

Perception is affected by the presence of a distorting medium and is processed by something which has certain limited capabilities. A general uniformity of nature is both necessary and sufficient to justify inductive reasoning.(68).

From the work of W.J.Freeman et al(91) it is apparent that chaos exists in the brain, and in fact is an essential factor in enabling the brain to cope with the enormous amounts of information presented to, or perceived by, it. Perception is defined as NOT the copying of an incoming stimulus BUT a step in a trajectory by which brains grow, reorganise themselves, and reach into their own environment to change it to their own advantage. This "own advantage" point is important; it implies that the brain will "convince itself" in order to satisfy e.g. hunger, thirst, sex ....which is clearly correct. The relationship between executives decision making and their "needs", from psychological, material, moral needs and conflicts, thus becomes clear(er).

There is now an established scientifically accepted model of brain perception which involves experience and familiarity and a constant conflict between out of balances primarily due to the existence of experiencal knowledge resident in the brain. Therefore the brain will always relate every new or different perception to a previous experience; even if the relationship is not correct. In other words the reinforcement given by experience to a stimulus enables a selection and identification, of that particular stimulus to be made. In the absence of experience no selection is possible.

The functioning of living systems according to the principles of chaos is documented, although not extensively proven, by numerous authors.(121, 131, 133, 134, 135, 136, 137). The involvement of chaos in the functioning of the brain has been substantially commented in this thesis e.g. chapters 3.11, 3.14 and 5.44, with associated references to the literature.

The concept of bifurcation whereby "changing one parameter can cause the system to move from steady state(equilibrium) to a point where the equilibrium splits in two, these bifurcations then come faster and faster, and then the system becomes chaotic(152, 153)" seems to fit the actuality of business, and project, behaviour very well.

From the interviews, see annex 6, it is clear that project managers and project controllers have often experienced feelings that "things are speeding up", crises are increasing, and "there are so many problems on so many fronts that we really don't know what to do". This seems to indicate that the authors so-called transition from something resembling steady state through turbulence to a chaotic state does exist; at least in the perception of the main players.

The observation has been made(152, 153) that "chaotic dynamics discovered that the disorderly behaviour of simple systems acted as a creative process. It generated complexity; richly organised patterns, sometimes stable and sometimes unstable, sometimes finite, but always with the fascination of living things."

The documented statement(152) that "dynamical instability is the average of a measure of the rate of growth of small deviations" seems to be very appropriate.

The above, from the experience of this author, describes project situations. Life can be tranquil, steady state and apparently linearly extrapolatable for a certain period and then suddenly, often from an "apparently insignificant" source, everything becomes turmoil with "tiger teams" being formed to deal with potentially catastrophic problems. **The situation has become non-linear**. Panic situations frequently develop and managers "throw money at the problem", see annex 6 for interviewees affirmative comments, on the basis of "solve quickly now and thus avoid more serious impacts later in the programme". This approach can be very damaging since the turmoil may actually spread due to the predatorial effect of the "throw money at the problem" approach depriving other areas of necessary resources.

For this author the science of chaos has provided the only realistic conceptualisation of project and business life as they really are; from his own experience, that of the interviewees, and from the project and case studies.

The analyses of actual project data carried out in chapter 5 are submitted as real evidence of the existence of steady state conditions evolving to turbulent and eventually to chaotic situations; and the presence of problem increase via bifurcation or "doubling" mechanisms. In particular Figs. 1 through 16 should be addressed.

The notes 124 through 130 provide a summary of the status of the science of chaos at the time of writing this thesis.

5.3.4.9 "The movement from steady state through turbulence to chaos occurs due to bifurcations which increasingly multiply if their reactions are allowed to proceed unhindered".

The main issues involved here are:

- problems will occur and will multiply due to interaction effects,

- the problem evolution can only be stopped if intervention takes place.

All of the projects studied commenced with turbulent periods relating to the political situation, the mission definition, the establishment of industrial consortia, and the agreement of contract conditions. With one exception, the projects studied then exhibited relatively steady state periods which every now and then erupted; usually due to technology developments going wrong. The further into the project life cycle that these eruptions occurred the greater the proliferation, or bifurcation, of the effects. This is bound to be the case due to the increasing "closeness" and interdependency of all the project pieces as they approach the time when they are all integrated together. Many of the problems causing the eruptions originated in "embedded research". Most of the latter were identified at the commencement of the project but were inadequately considered in the planning and costing; usually due to political and company (future) survival pressures. In these latter cases the intervention and control, by the top management at ESA and industry working in league, seemed to be determined to formally commence the journey towards their strategic goals irrespective of the realism of the starting situation. This point is evidenced in the interviews where it has been conceded that a "dummy price" was used in order to be able to start the contract. Once the project was started, and ESA committed, the contractors worries were essentially over due to the softness of the ESA contract conditions; it was almost impossible for a contractor to lose money. He could only lose a proportion of the profit! Due to the annual budgeting situation on the ESA side it was essential to commit funds within the financial year; the alternative was to risk permanent loss of budget. Since the ESA project staff are paid out of the project cost to completion budgets the commencement of projects was also essential for the retention of ESA departmental staff; this eventually reflected the ESA top management survival and authority. The above thus indicates a rather vicious "catch 22" situation. It is however probably representative of industrial environments in general. The output of this thesis is thus considered to be applicable to more than just the ESA-European industry scenario.

Certain aspects of these points from the hypothesis are therefore considered to be axiomatic due to the connection of practically everything with everything else in the total project planning. Therefore if, for example, a small design detail or the delivery of a small part is not completed on time then the complete project will suffer. The omission of those two completions will increasingly effect other tasks and procurement due the to synchronised and inter-dependent nature of the design, manufacturing, and build processes.

5.3.4.10 "The high risk consequences can be avoided if the bifurcation patterns, involving both hard and soft aspects, can be initially identified, and maintained current, thus permitting restriction of excursions to the turbulent and chaotic states by utilising risk indicators and intervention".

This point of the hypothesis considers the growth of small deviations, which generate dynamic instability(152), as being similar to the bifurcations identified in the science of chaos. It is then considered that the increases in bifurcations form definite patterns that are identifiable; as the number of interacting bifurcations increase, the transition from a rather steady state situation to one of relative turbulence will be clear.

The conclusions from the research that quantitative methods are not adequate is a solid foundation block for the "direction" of this thesis i.e. the only valid approach that can be made to encompass programmatic dynamics, non-linearities, and hard and soft aspects, is one which is qualitative.

The following comments relate to the characteristics of organisations and indicate the dominant role of "soft" aspects:

a) ideas can be interventions(34);

b) a major reason for organisational failure is the isolation of R & D from the corporate functions(36);

c) cultural perceptions shape managers(115);

d) successful organisations tend to have traceability "back" to previous work which had some similarity with the current work, monitoring and feedback must be built in(44);

e) organisations are political systems composed of constituencies of interest(75).

As with closed loop systems relating to complex systems, open loop systems have also not been directly mentioned. References in this research assessment again refer to the inadequateness of mathematical models. Most of the research on open loop systems deals with fuzzy mathematics, probability theory applications, and expert systems. There is a clear conclusion, made a number of times, that quantitative methods are inadequate. In fact, most of the open loop statements deal with definitions and the possibility of this or that method being applicable to different situations. In this area a significant amount of philosophical discussion is taking place and informatics modelling techniques using fuzzy algebra, subjective judgement etc. are under consideration.

Fundamental to this hypothesis is the concept that organisations can be self organising i.e. the pattern relating to the control of the bifurcations can become more orderly and therefore certain developing risk situations could be averted. This apparent violation of the second law of thermodynamics is only possible with the injection of negative entropy.

This thesis submits the achievement of a reducing entropy situation in the following manner. If data, hard or soft, received by a programme is valid and current i.e. relevant and timely, and the programme has, and uses, the capability to apply the data, then the programme problem solving ability will increase, the problems will decrease, the risk will decrease, the orderliness will increase, the complexity will decrease......and therefore the entropy will decrease.

It is thus an essential feature of defining intervention that the entropy status, qualitatively and relatively, is known; an increasing or decreasing entropy can thus be deduced. The criticality of 'the right data at the right time" is thus paramount.

The following points have been selected from the bibliographical reviews as key elements in support of the above statements.

a) An open system is where the stability is in dynamic equilibrium; in which continuous change occurs yet relatively uniform conditions prevail, like the conditions in a pool beneath a waterfall.(63)

b) Both negative & positive feedback, in the form of individual & species behavioural patterns, are involved in maintaining the overall dynamic equilibrium of the community.(63).

c) The objective of everything is survival; feedback is involved everywhere.(63).

d) Cognitive functions have to be learned. "Seeing" has to learned during a critical period of post natal development.(93).

e) The developing brain ought to be considered as a highly active and primarily self containing system which, when born, already possesses substantial knowledge about the structure of the world into which it is going to adapt itself. Thus when the brain is born and confronted with a dramatic expansion of accessible environment, it poses a number of precise questions to this environment with the purpose of optimising & adapting its internal structure to reality.(93).

f) The closed, highly interactive system.(93)

g) The cause of developmental errors is suggested by the particularities of the self-organisation process.The possibility must be considered that the brain does not formulate the right questions or does not ask with sufficient insistency to obtain answers.(93).

h) The character of a sociobiophysical system may be strongly affected by sudden changes in its subsystems or the systems environment e.g. the advent of new technology.(65).

i) Self organising systems are concerned with circularity, recursiveness, & self-reference.(104).

j) Memory and consciousness can be readily separated.(138).

k) Learning is not how people feel, but how they think.(139).

l) Information is not only produced by dissipating the degrees of freedom in a system, but also by increasing resolution in systems with few degrees of freedom.(138).

m) The large scale behaviour of complex systems, often hidden by fluctuations, can be interpretated in terms of an organisational scheme for all underlying events.(63).

n) The presence of periodic solutions implies the presence of steady states.(180).

o) A chaotic system can be locally unpredictable, globally stable.(153).

p) A complex system can give rise to turbulence and coherence at the same time.(153).

The above statements clearly identify the predominating role of feedback, the learning process, the dynamics of the situation, and environmental interaction in the brain. These characteristics are key elements in the thesis.

The subject of "risk indicators" as such has not been found in any of the research reviewed to date; it has been alluded to by implication.

Risk is mentioned in various references, as indicated below, but the definitions are not clear and not standardised.

The following points are presented as being particularly important to the validation of the thesis.

a) Organisations tend to be blind to the importance of events that could signal disaster(36).

b) Subjects appear to reconstruct the meaning of inconsistent labels so that they fit the "learned" relations(50).

c) Behaviour in organisations was seen, by Checkland et al, as following from human intentions and only to be understood in terms of the perceptions and meanings that correspond to them. The interest of the intervenors was in the phenomenology of the situation; less in the cybernetics of control (103).

d) Risk is known unknowns; uncertainty is about unknown unknowns(57).

It is recommended that some risk indicators are constructed in the form of "trees"(see figs.0 and 00, page 93); for example for the ITT, the Bid, and for the duration of the project. The trees should be based on:

- spacecraft functions such as guidance, navigation;
- interfacing hardware and software;
- contractually linked companies, with their products;
- financial aspects; essentially penalties & incentives.

Each risk indicator node should also be identified according to:

- its location with respect to all influencing open loop systems;
- whether it has multiple interfaces, with other equipments for example;
- its consequences on the spacecraft mission, finances, schedule;
- the resources required to reduce or contain it.

5.4 Conclusion.

In section 5.3 the validity of the hypothesis has been examined in detail using all the knowledge and data collected in this research programme.
It is submitted that the results of the data analysis in this thesis indicate that the hypothesis is valid. With such a small sample and lack of some detailed information it is not possible state more.

The author is convinced that the science of chaos is applicable and this contention is supported by the limited data analysis provided in this thesis. It appears to be the only branch of science that can address, in an integrated fashion, deterministic and behavioural, linear and non-linear, aspects.

Chapter 6. <u>The METHOD*.</u>

* To distinguish the "Method" proposed in this thesis from other methods it is always written with a capital "M" thus: Method.

6.0 General

This Method has been developed to facilitate the application of the results of this research.

The basis of this Method is the thesis hypothesis and the results of the data analysis.

It is pertinent to recall that the objective of the thesis, and therefore of the Method, is to enable the pragmatic definition of the role of intervention in strategic change.

It is also important to restate that this thesis presupposes the existence of an a-priori statement that defines the risk that the project objectives will not be met. It is also assumed that the customer and contractor have accepted that "risk".

This statement could take the form:

"the probability of the space vehicle successfully completing its operational mission shall not be less than 0.8(80%)".

This implies that the customer accepts a 20% risk that the required performance, for the mission time specified, will not be met.

A review of research to date indicates that a significant contributory cause of project failures is the absence of such statements or goals(88).

The Method thus fundamentally addresses the identification and management of risk; strategically.

A number of aspects of the Method have not been "proven" by the author but are used because they represent the only explanation known to the author that "fits" or "describes" certain "observed" circumstances.
The invocation of the "science of chaos" and "non-linearities" are the prime candidates. It is noted however from the results of the data processing, see chapter 5, that a substantial amount of supportive research and field evidence exists.

In this thesis the aspect of intervention relates only to the intervention in the project managers business, at all levels, by a separate authority.

A conclusion of this research is that the intervention function is considered essential in order that proper risk containment measures can be defined and implemented, and the dynamics of the business world can be accommodated during the project life cycle. The purpose of the Method is to define the role of the intervenor in the management structure of a development project.

The intervenors role has direct and indirect aspects; it must never visibly usurp the authority or responsibility of the project manager.

Prior to the commencement of a project it is the role of the intervenor to note the availability of all the necessary management tools, experienced people, established management methods and communication systems i.e. the means, methods and rules.
The intervenor would attend all high level negotiations, strictly as an observer, and would have carte blanche authority to visit any co-contractor or vendor, or attend any meeting, at his discretion; prior to and during the project life cycle. These aspects of the intervenors role are termed indirect and would generate a form of psychological awareness of a possible direct accountability.

It is important to appreciate that intervention can also be caused to happen by presenting information in such a way that it, the information itself, becomes the intervention function. It is part of the role of the intervenor to ensure that such "information initiated intervention" occurs where necessary.

During the compilation of this thesis, twenty eight POSTULATES have been written down; they are listed in Annex 1. These postulates are required to be used in the application of the Method as "checkpoints" at each review, and particularly during the evaluation of the Bid.

In a similar manner examples of fourteen RISK INDICATORS have been listed in Annex 3; they should be used as "guidelines" during the evaluation of project bids, reports, reviews etc. when defining risk indicators.

Two fundamental issues define the role of the intervenor; they are:

1) perception, and

2) the incremental approach.

These will now be discussed in more detail.

Figures 25 through 27E present an overview and flow chart of the Method.

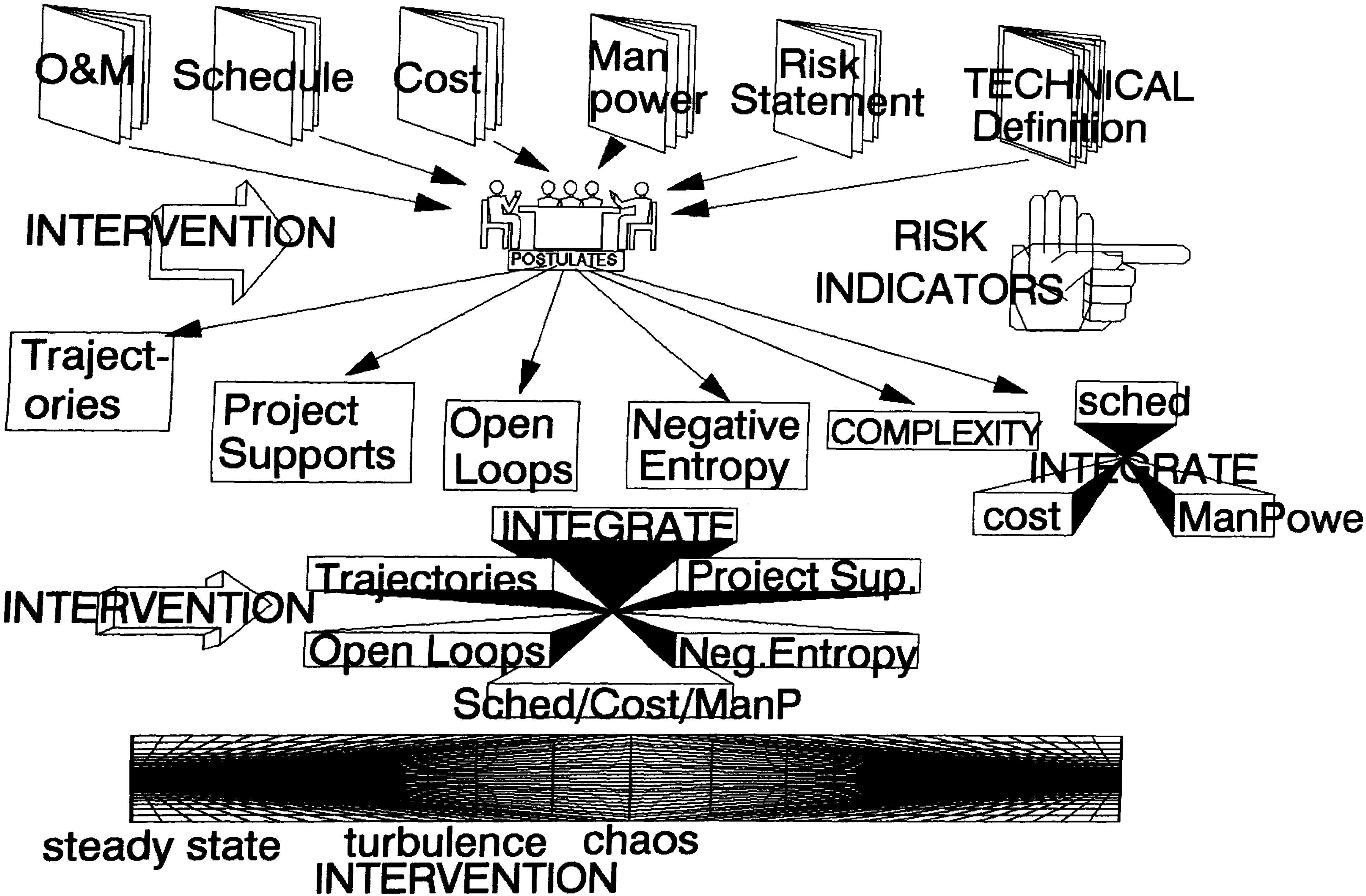


Fig.25: Method Outline

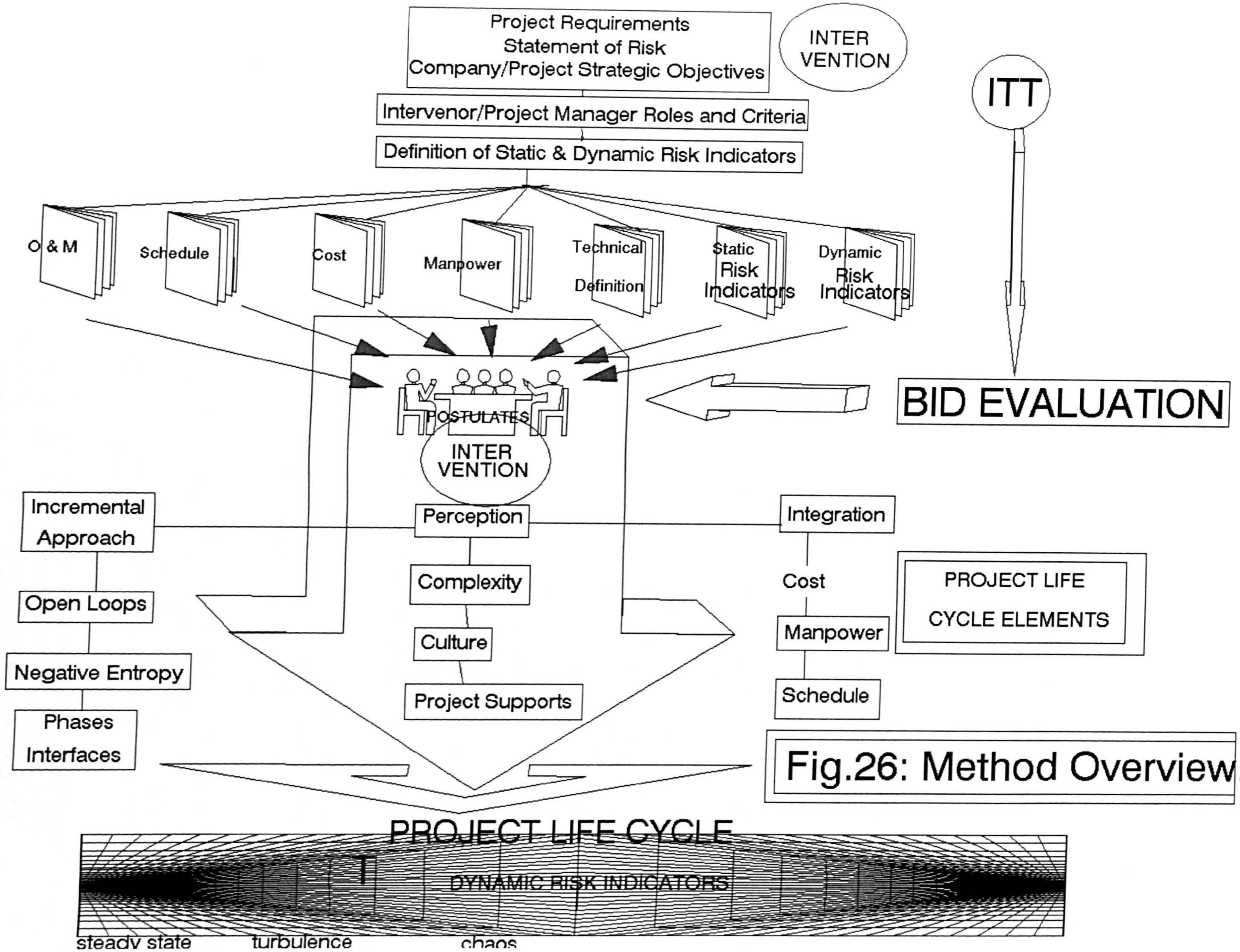


Fig.26: Method Overview.

The figures show the current typical method of presentation of a Bidders proposals, consisting of segregated information in book form. The Method requires that this information is evaluated with respect to trajectories, project supports, open loops, negative entropy, and complexity. It is required that the resources, cost and manpower, are combined such that they can be assessed as a total entity.

The Method then requires that all the above evaluated and combined data are integrated onto three-dimensional charts to enable judgement of proper resource provision for all areas of concern. Finally the Method requires the assessment of the dynamics of the project and the classification of activities as steady state, turbulent, or chaotic.

The advantages to be gained by applying this Method over the current way of conducting business in development projects, are outlined in chapter 7.

6.1 Perception.

Perception covers such aspects as the availability and usability of information; and the distortion of information as it is "processed" by different individuals. Hence the Method requires that all information is presented such that the risk which it contains can be perceived by the project management. One of the clear conclusions of this research is that information seems to be presented, in many cases, such that the risk elements that it contains cannot be understood.

The Method requires that all resource, cost, and schedule information, supplied by a bidder or a contractor, are presented in 3-dimensional(3-D) plots in an integrated and synchronised fashion.

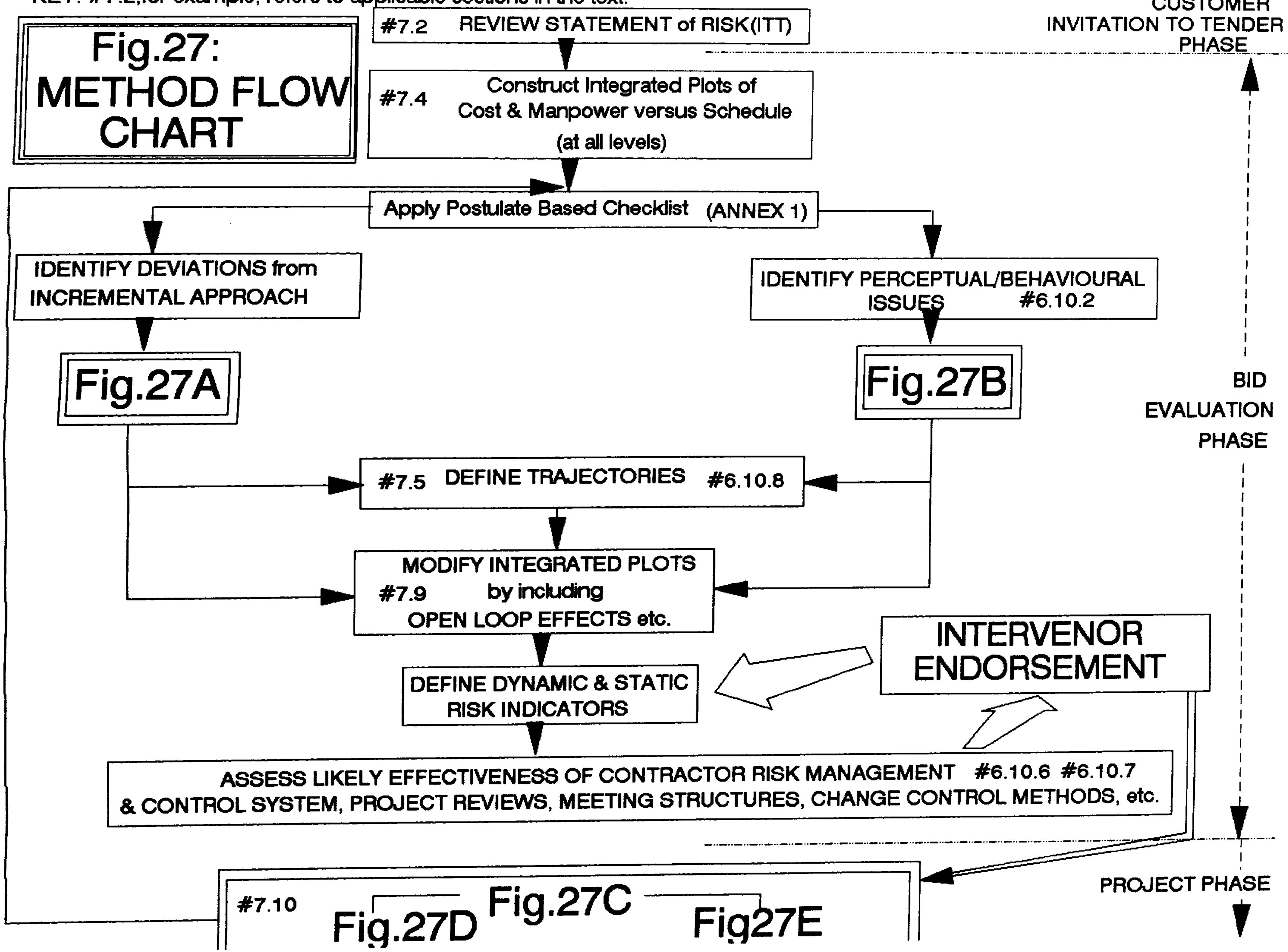
A flow chart of the main steps in the Method is shown in Fig.27 through 27E.

The 3-D plots must be correlated with the perceived risk assessments, by the local technical and management staff, of the aspects of the project or product under their responsibility.

In order to judge the value, or the existence of bias due for example to the lack of adequate experience, the personal and professional particulars of the top engineers and managers involved must be submitted and the 3-d plots annotated reference their impact.

It is also necessary to evaluate the effects of cultural differences particularly at interfaces; this could have short and long term effects. In this respect it may be problematic to have Jewish and Arabic persons interfacing

KEY: #7.2,for example, refers to applicable sections in the text.



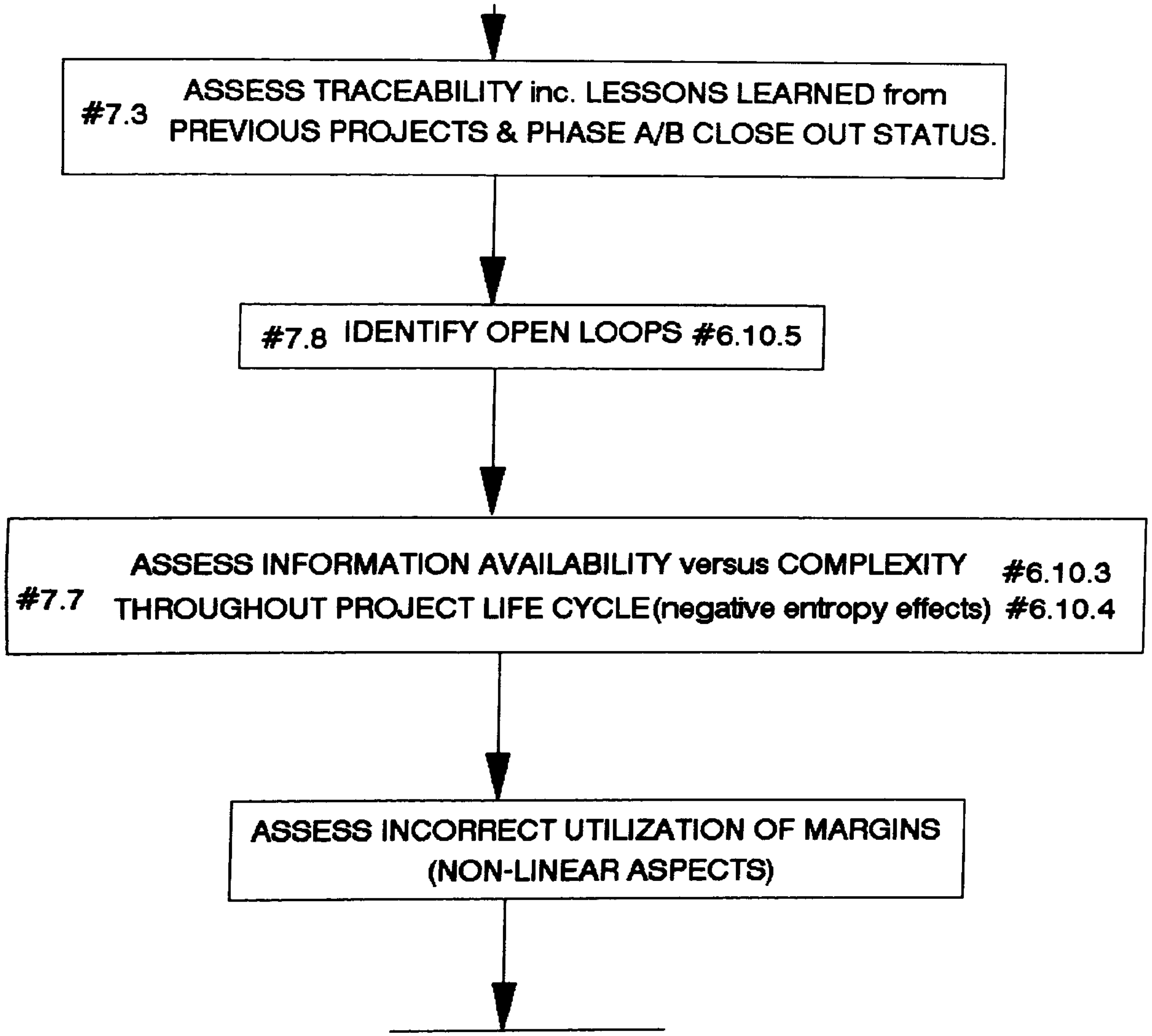


Fig.27A: Method Flow Chart; BID EVALUATION PHASE.
(DEVIATIONS FROM INCREMENTAL APPROACH)

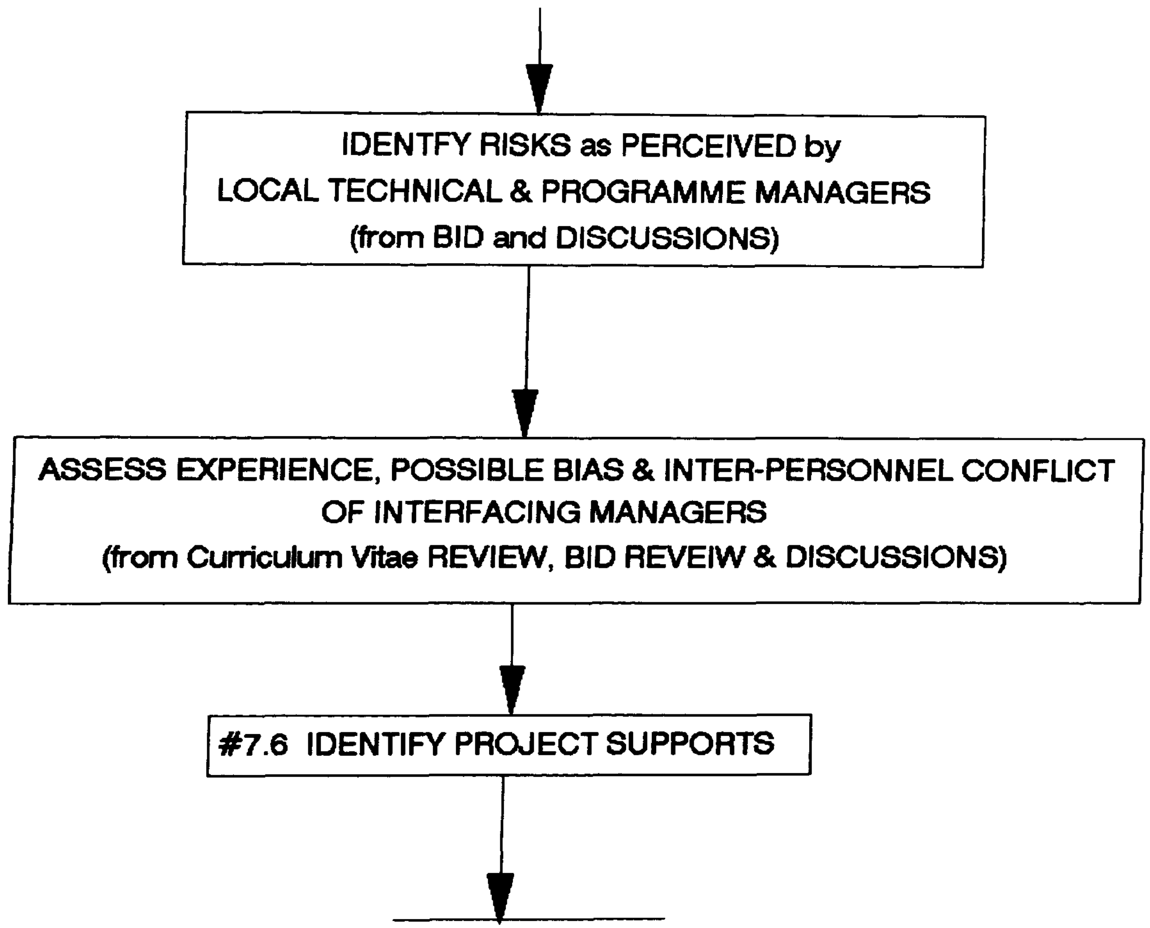


Fig.27B: Method Flow Chart; BID EVALUATION PHASE.
(PERCEPTUAL/BEHAVIOURAL ISSUES)

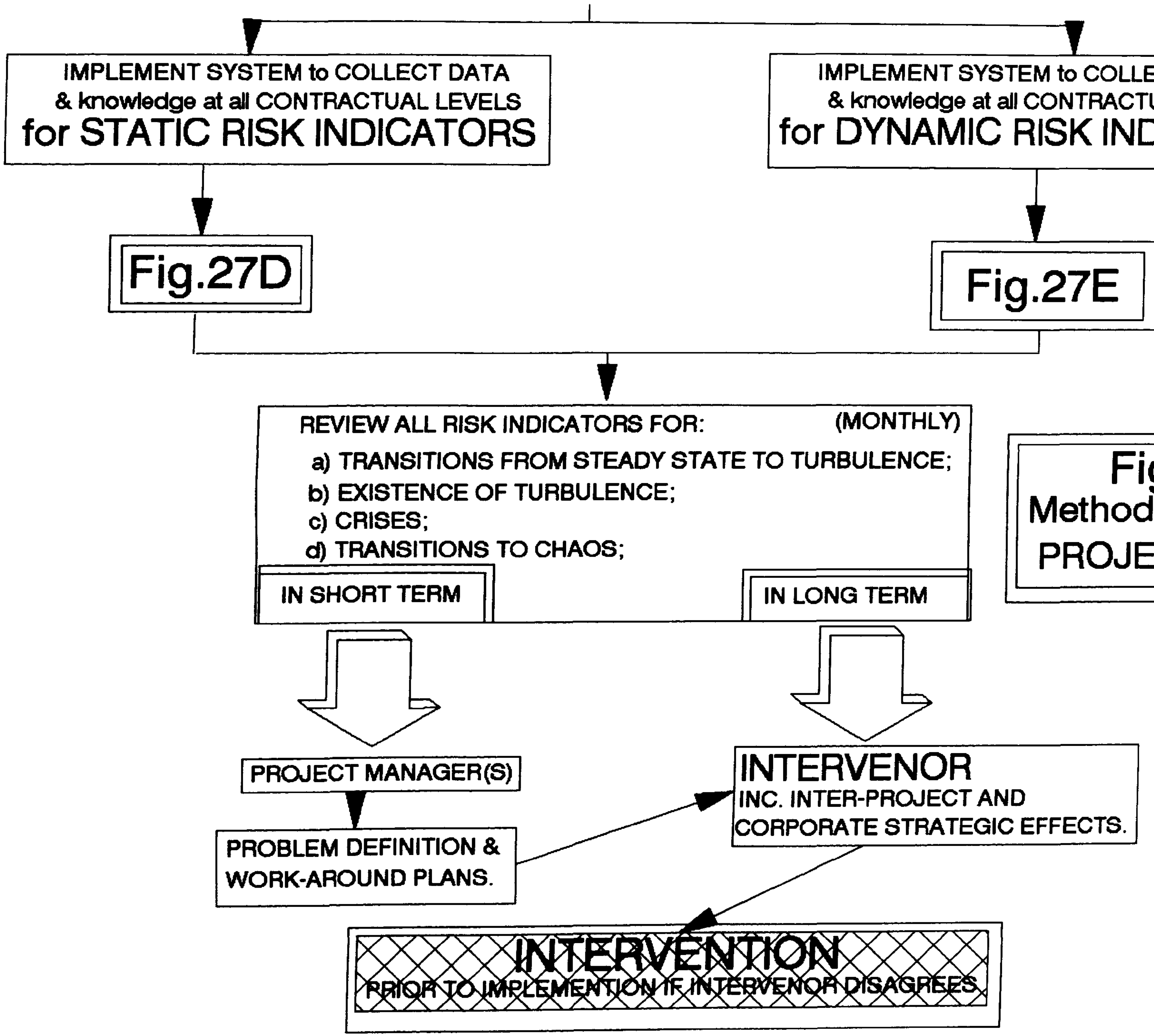


Fig.27C:
Method Flow Chart
PROJECT PHASE

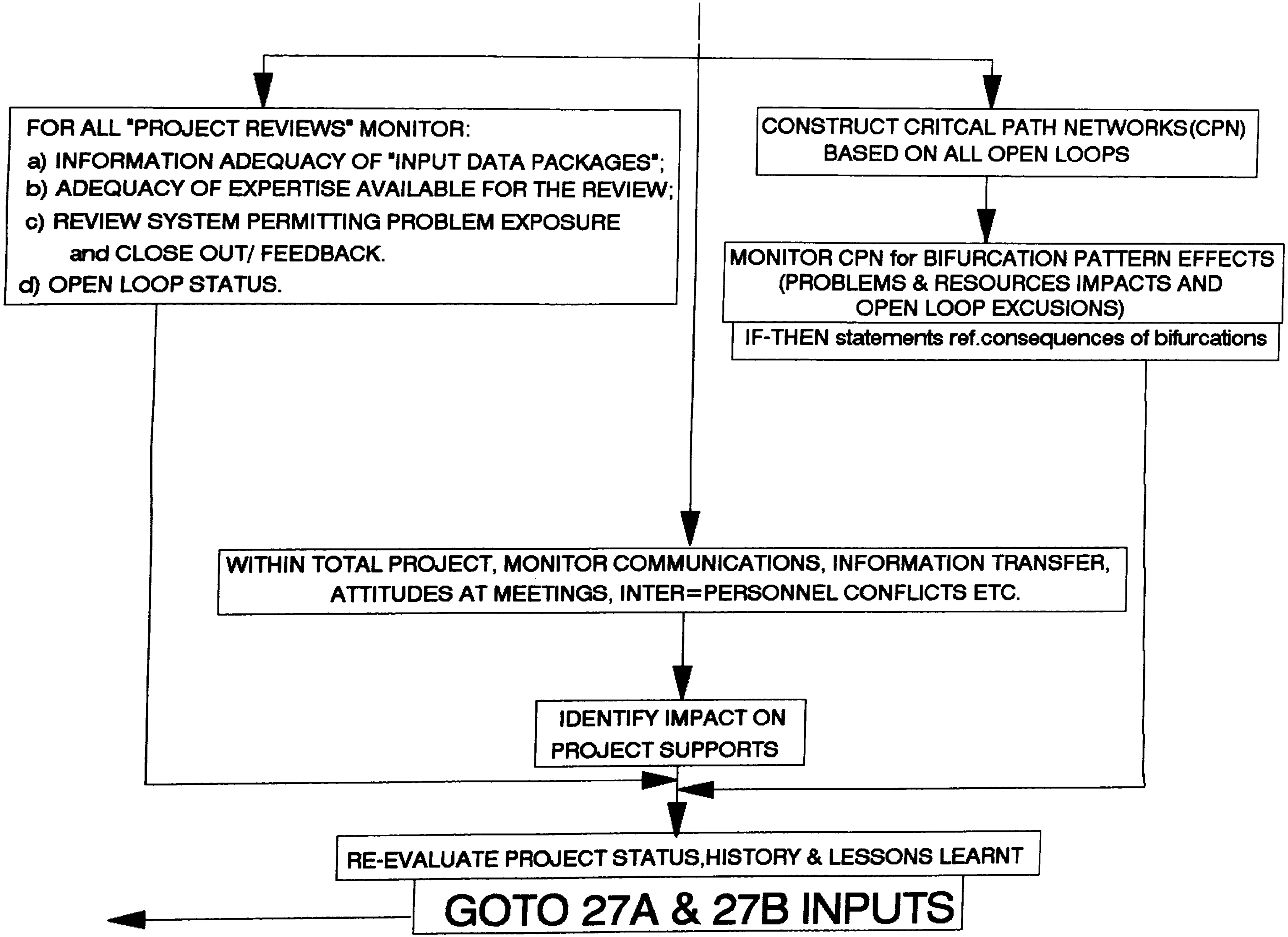


Fig.27D: Method Flow Chart; Project Phase. (STATIC RISK INDICATORS)

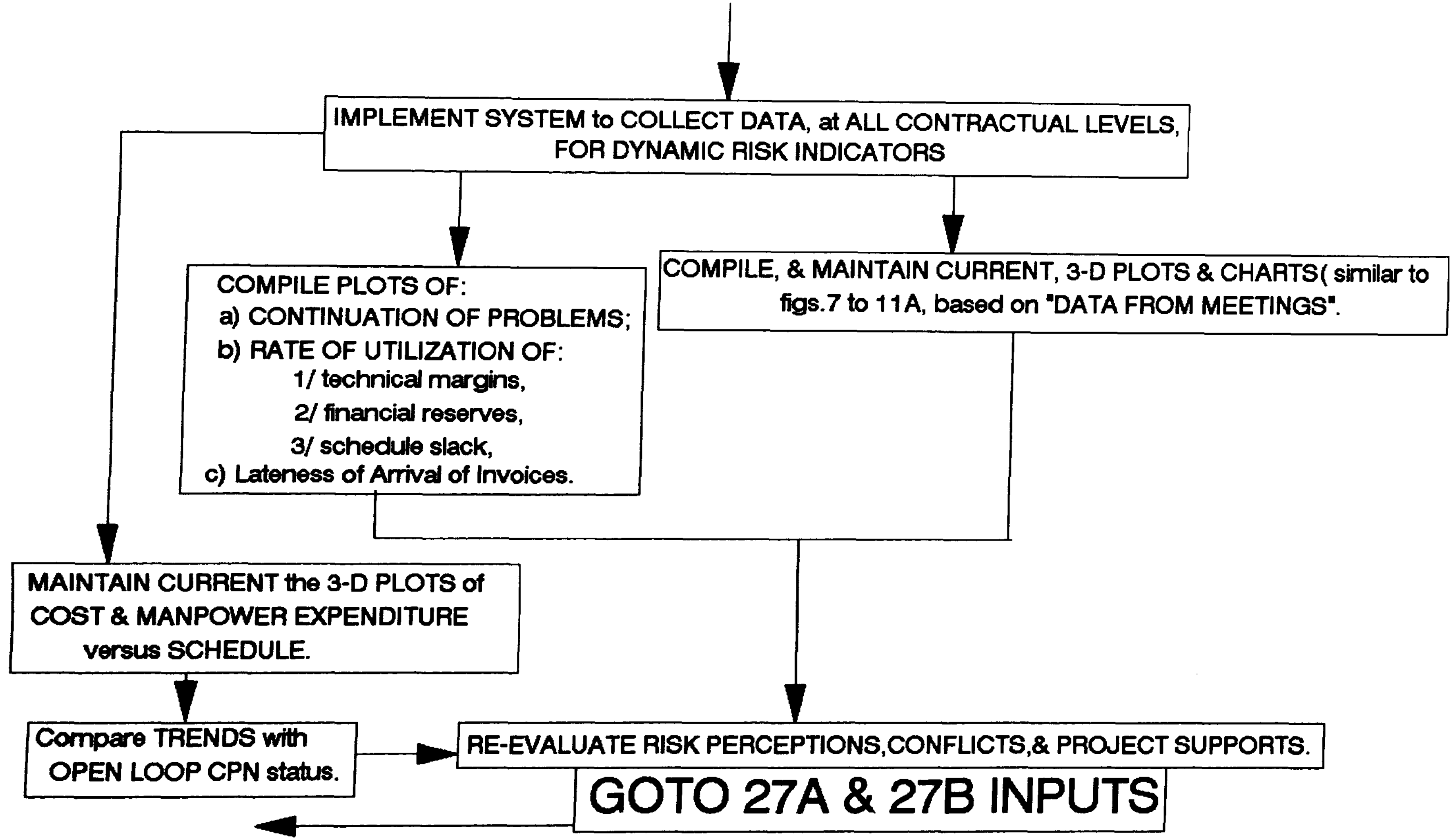


Fig.27E: Method Flow Chart; Project Phases. (DYNAMIC RISK INDICATORS) with each other.

It is the intervenors responsibility to perceive the longer term strategic influences, both internal and external to the company, on the project.

In order that the project can perform efficiently it must maintain the characteristics of an open system i.e. through the use of negative entropy it can establish increasing order with increasing complexity. As far as the intervenor is concerned this translates to the receipt of the right information at the right time such that the right staff are available to understand and implement the appropriate messages. Research and experience have shown that many development projects do not have this capability and hence the increase of complexity, amount of input data for example, causes crises to occur.

The Method also requires that an open loop does not exist concerning the learning that may have occurred from previous work. Thus it is required to establish a "lessons learned" culture such that past experience is examined and any lessons learned are passed to the next project.

6.2 The Incremental Approach.

The ideal situation for the intervenor is where all new design and build activities, for example, can be directly correlated with previously successful work by the company and personnel now involved.

Where such traceability cannot be established an open loop situation is considered to exist and an increased level of risk.

The accurate prediction of the future is considered to be impossible; this statement is considered to be a postulate.

Since the future cannot be accurately predicted and since the objective of this work is to minimise the escalation of risk in the "future" it is necessary to establish a method by which some confidence can be obtained of how problematic the future is likely to be.

The approach adopted in this thesis is twofold.

The primary method of assessing the future risk in a project is to review the planning for the onset of turbulence and chaos. Complimentary to this "pattern recognition" aspect is the incremental approach which entails proceeding forward in "small" increments such that the connections, or interfaces, between the succeeding increments have sufficient commonality to characterise, to the extent possible, the new increment in terms of the old (well understood) increment. This incremental approach should also enable the onset of non-linearities, leading to turbulence and chaos, to be:

a) assessed, during the project definition phase and,

b) detected, during the project implementation phases.

This "characterisation" process is essentially the identification of "delta" risk aspects of the new increment and establishing closed loop systems to enable those deltas to be contained. If a closed loop system cannot be defined, for example when a non-linear mode is encountered, then the particular aspect moves into the open loop system domain; see section 6.2.1, annex 9, and fig.34(page 189) for the definition of open loop as used in this thesis.

A number of researchers have reported on the importance of "previous familiarity with some aspects of a new situation".
This point is particularly poignant with respect to software developments since the discipline itself is relatively new and it has an accelerating development environment. A researcher in this field (110) has stated that one of the main differences between successful and unsuccessful programmes is that the former had "done it, or something like it, before".
The incremental part of the overall approach thus depends on the traceability of certain "risk sensitive" parameters, or attributes, from one increment to the next.

The intervenor is very concerned about departures from the incremental approach and would label such aspects as high priority risk indicators.

The overall incremental approach thus includes the following:

- risk dimensioned increments;
- transition from linear to non-linear modes;
- intervention definition, and rational for application including warning and control limits;
- static and dynamic risk indicators including project objectives and parametric sensitivity;
- positive and negative feedback including growth and decay aspects;
- human analogy concept.
- entropy and orderliness connections including the project-environment symbiosis that then becomes a natural consequence;

- integrated application of the approach to the total system.

- definition of strategic change;

6.2.1 Open Loops and Non-Linearities.

As stated previously the entire project, or business, "universe" is considered to be controlled by human beings, and therefore by their "brains". The brain functions on the basis of perception and perception functions on the basis of feedback; see chapters 3.11, 3.13, 3.14 and 3.15. Therefore, since the actual project environment is "continuously dynamic", all aspects of a project, and its environment, are considered to consist of feedback systems i.e. closed and open loops.

It therefore follows that if a particular system is not a closed loop system then it must be an open loop system. A closed loop system, as stated before, is linear and essentially everything is known about it such that reacting to the feedback information enables control adjustments to be made that will correct the detected deviations.

It is considered axiomatic therefore that negative answers to those questions which would receive positive answers in the case of closed loop systems automatically identifies the system as being open loop.

Of the following nine questions the first seven are considered in this category. The final two questions, i.e. questions 8 and 9, are included for completeness concerning possible interactions of interfacing systems.

Hence in the Method, for all significant work activities of each phase, the following questions must be answered:

question 1: has the activity been done before by the contractors who are scheduled to do it?

question 2: is all the data needed to complete the activity available when needed; or is the outcome of the activity predictable?

question 3: is all the knowledge needed to complete the activity available when needed; or is the outcome of the activity predictable?

question 4: are all the interfaces defined when needed? (this includes interfaces between phases; see section 6.4).

question 5: are all inputs, including other bits of HW and/or SW, available when needed.

their application is based on their gradual and predictable utilization with time.

In order to evaluate the risk potential where such traceability does not exist the project planning must be prepared in such a way that all open loop situations can be identified and graded.

Figures 28, 29 and 30 show the progressive modification of an example of a standard critical path network(CPN) to include open loops. The qualification test, failure analysis, life test and stress test are identified as open loops because the answers to questions 1, 2, 3, in section 6.2.1, are "no". This fundamentally means that the outcome of these activities is not known; they could all produce failure situations which could have serious project consequences. It will be seen that the final version, Fig.30, shows a completely different critical path than shown in with the conventional approach, Fig.28.

6.3 Intervention

The "overall management" of the project requires a synergistic co-operation between:

- the project manager
- the intervenor.

Each of the above have separate but complimentary roles which must be clearly formalised.

The **project manager** is hierarchically lower in the company than the intervenor. The project managers role is that of managing the day-to-day affairs of the project consortium. He is primarily responsible for the internal work of the consortium and for conducting the predictable or linear elements. He relates progress to the negotiated bid, including the resource profiles, as laid down in the project design and development plans; the latter constitute his strategic plan. The incentives and penalties relating to deliveries being on schedule, and milestone payments for "scheduled" reviews, are within the project managers responsibilities. The project manager is responsible for the design and development of the product itself.

The **intervenors** role requires him to be cognisant of the strategic significance of the project to the company and of the interfaces between the company and the external environment. His special areas of interest are the "open loop"/ "non-linear" aspects of the programme. He must try to anticipate whether resources will be adequate for these particular situations.
An area which is fundamentally the responsibility of the intervenor is that relating to perception. It is his job to

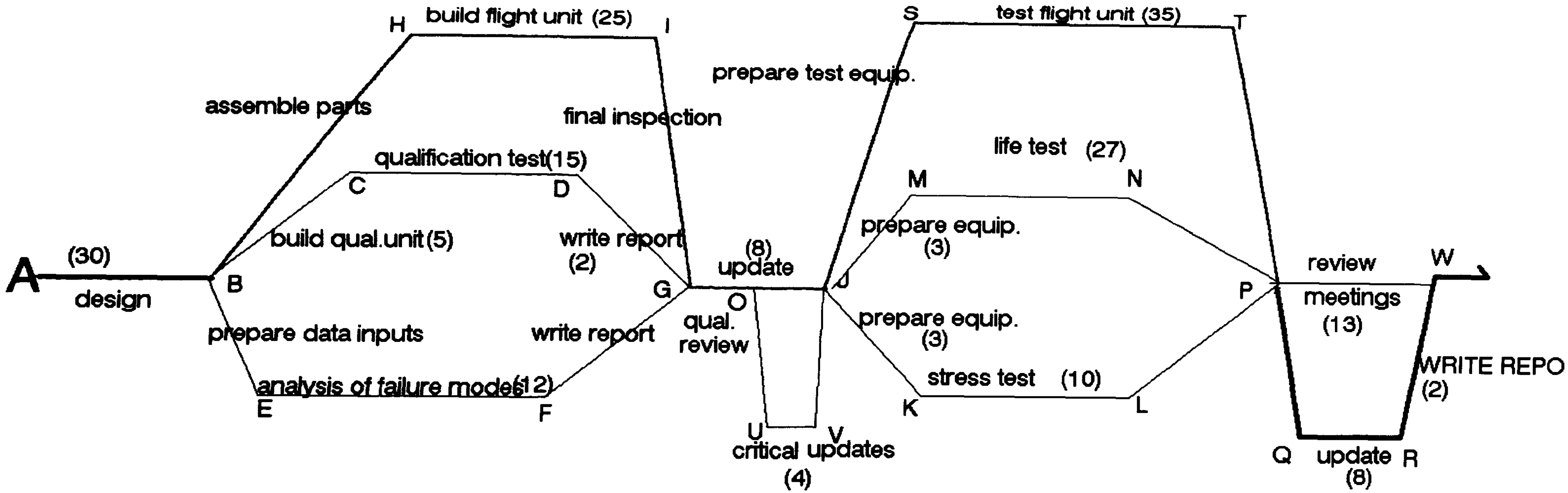


Fig.28: An Example of a Critical Path Network

NOTE:

1) The numbers in parenthesis() indicate elapsed time, in days.
2) THE FULL LINE INDICATES THE MAXIMUM TIME REQUIRED
3) THE NETWORK IS NOT TO SCALE
4) THE WORK PROGRESS FROM LEFT TO RIGHT
5) B ——Q e.g. = THREE TASKS NEEDED TO BUILD THE FLIGHT UNIT
(EACH TASK IS NOT IDENTIFIED SEPARATELY)
6) THE NETWORK DOES NOT SHOW RESOURCES

KEY:

—— = Critical Planning Path

QR = Qualification Review

c.u.= critical(max.risk) updates

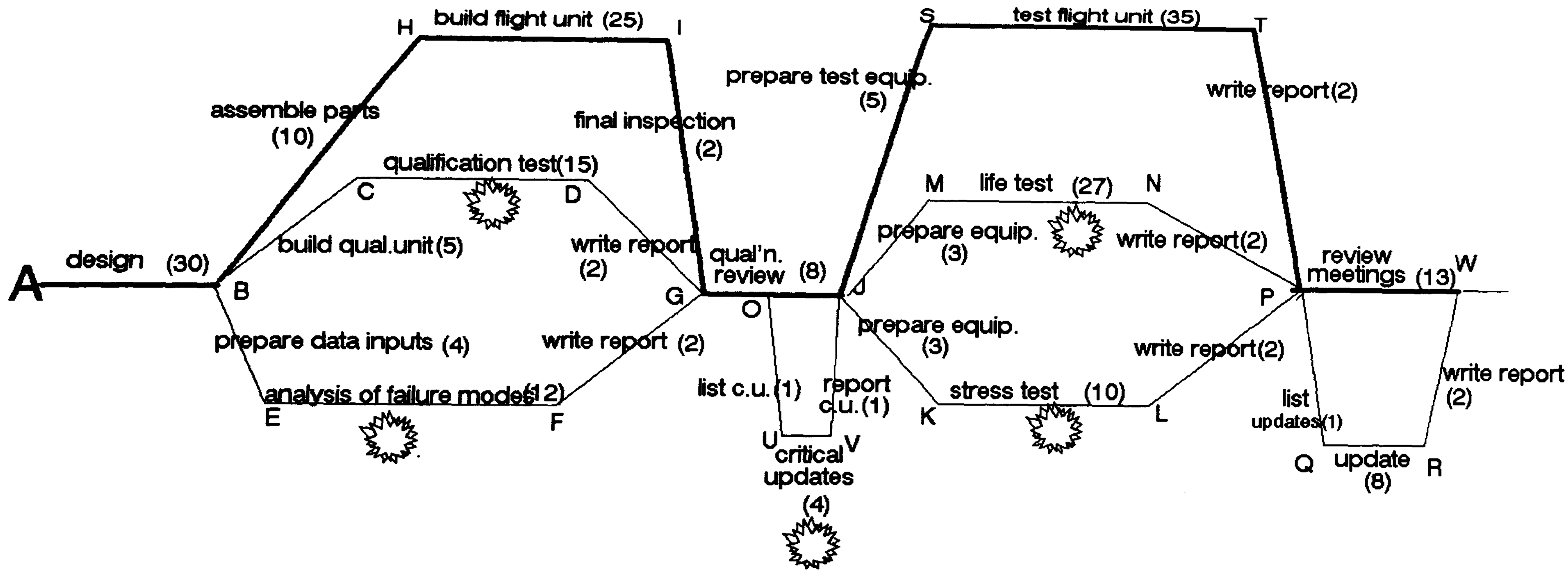


Fig.29: Open Loops Emphasised(from fig.28)

NOTE:

1) The numbers in parenthesis() indicate elapsed time, in days.
2) THE FULL LINE INDICATES THE MAXIMUM TIME REQUIRED
3) THE NETWORK IS NOT TO SCALE
4) THE WORK PROGRESS FROM LEFT TO RIGHT
5) THE NETWORK DOES NOT SHOW RESOURCES

KEY:

= Critical Planning Path

= Open Loop Activity

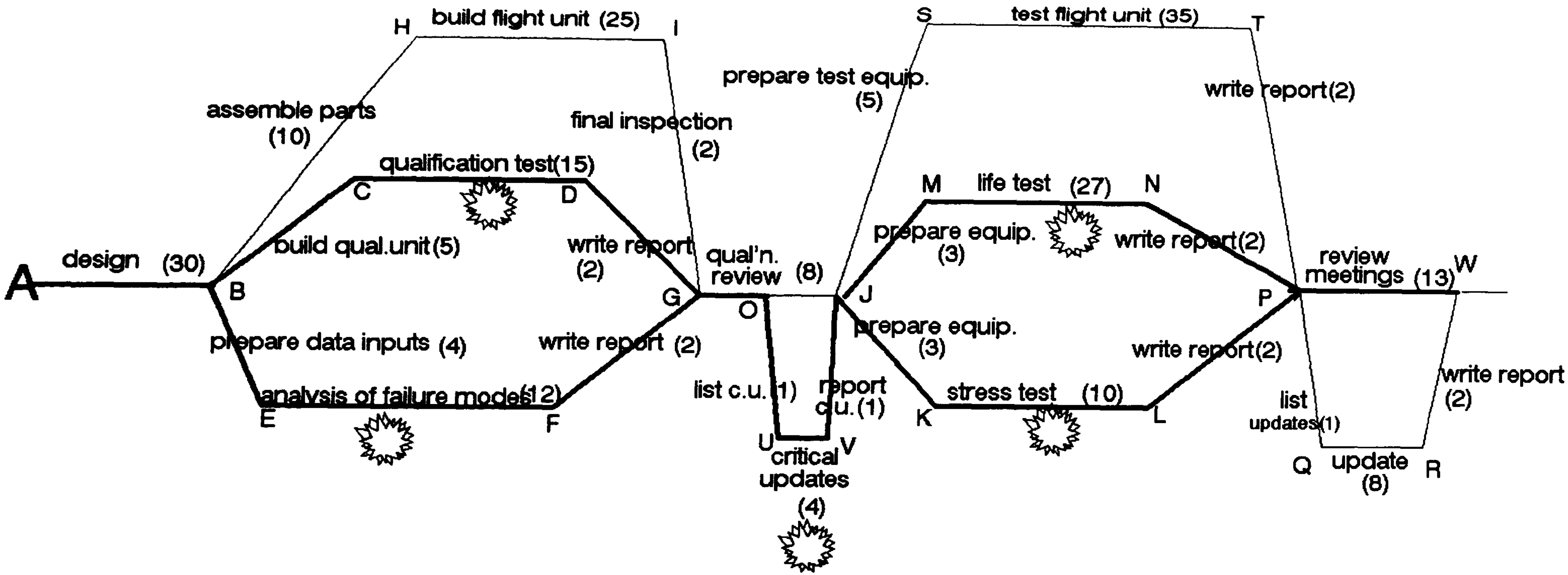


Fig.30: Open Loops Shown as Critical Paths(from fig.28)

NOTE:

1) The numbers in parenthesis() indicate elapsed time, in days.
2) THE FULL LINE INDICATES THE MAXIMUM RISK PATHS
3) THE NETWORK IS NOT TO SCALE
4) THE WORK PROGRESS FROM LEFT TO RIGHT
5) THE NETWORK DOES NOT SHOW RESOURCES

KEY:

= Critical Planning Path

= Open Loop Activity

c.u. = critical(max.risk) updates

assess whether there are perceptual biases present in the project consortia that could cause misinterpretation or incorrect judgement; this aspect includes the project manager and project team.
When major problems occur or a non-linear part of the programme is reached the intervenor moves from a standby to active participation mode. He will thus be involved in risk initiated reviews.
In assessing the bid the intervenor is responsible for agreeing the acceptability of the resources identified for the non-linear elements. The incentives and penalties relating to in-orbit performance are within the intervenors responsibility.

The intervenor is responsible for assessing the perceptual "peculiarities" of the contractor management team and also his own project manager and team.

In marine terms the project manager can be compared with the ships captain and the intervenor with the pilot; the latter to navigate the ship through difficult or badly charted waters. Clearly both are needed to accomplish the mission.

6.4 Activity Phases.

At all levels the project is assumed to be classifiable into the following four sequential "activity or process" phases:

1) DESIGN

2) MANUFACTURE(BUILD)

3) VERIFICATION(TEST)

4) OPERATION(USE)

Qualification is accomplished during the design, build and test phases.

The main outputs from the above phases are:

1) Design:

drawings; technology identification; parts definition; interface requirements;

2) Manufacturing:

the product itself;

3) Verification:

the product plus a test report;

4) Operation:

the product plus a user manual, including contingency(back-up) methods, and a product performance output.

The above outputs are **transferred** from one phase to the next. These transfer elements are discrete and are inspectable against "pass/ fail" criteria derived from the overall project objectives. At the end of each phase a scheduled "review" is required involving the project manager.

Each phase and its related transfer element are mutually inclusive and all are functionally serial. Programmatically they usually overlap to some degree and this is often camouflages problems relating to the lack of functional definition. The writer describes this situation as an example of "embedded risk"; this would be a particular aspect to be addressed by the intervenor.

Each phase requires its own specific types of resources. For example the design phase requires designers. There will be different types of designers; mechanical, electronic etc.

The resources include materials, machines, people(brains), data, knowledge, procedures, facilities.

Figure 31 shows the ideal, incremental approach where the phases are sequential and closed out before proceeding to the next phase. The figure also shows a feed-forward "lessons learned" activity which is part of the overall incremental approach and ensures the maintenance of the negative entropy situation. An intervenor would be quite satisfied with these conditions.

Figure 32 is representative of normal project conditions. Overlaps of the phases are shown with the consequence that, for example, the build of hardware and software commences before the designs are complete; hence open loops are generated. This situation makes the implementation of changes very difficult owing to the long processing times; due to the many contractual levels involved in the processing of change requests. There is also a tendency for problems to interact disadvantageously so that the actual design or build status at any one time is almost impossible to determine. Engineers and their immediate supervision are the first to become aware of these problems and discussions and meetings are triggered. These meetings thus constitute a dynamic risk indicator; see section 6.8.

The overlaps actually commence at the Bid and Bid Evaluation stages often initiating open loops which quickly multiply by interaction thus providing the onset of turbulent conditions. This is shown symbolically in Fig.33.

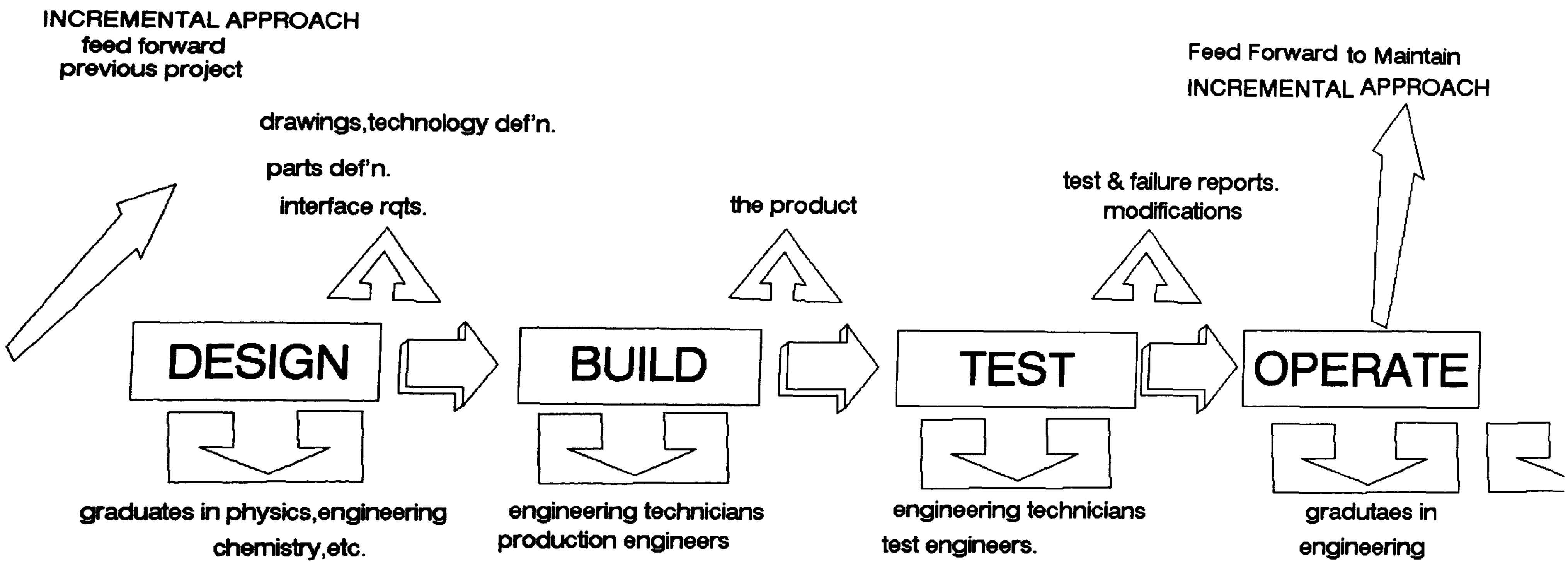
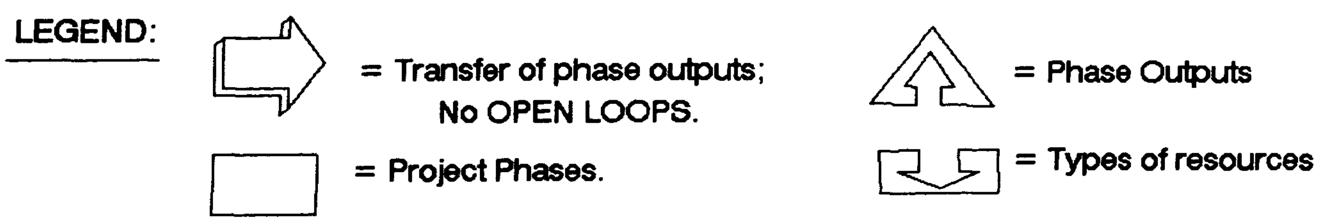


Fig.31: Ideal Project Phase Relationships.



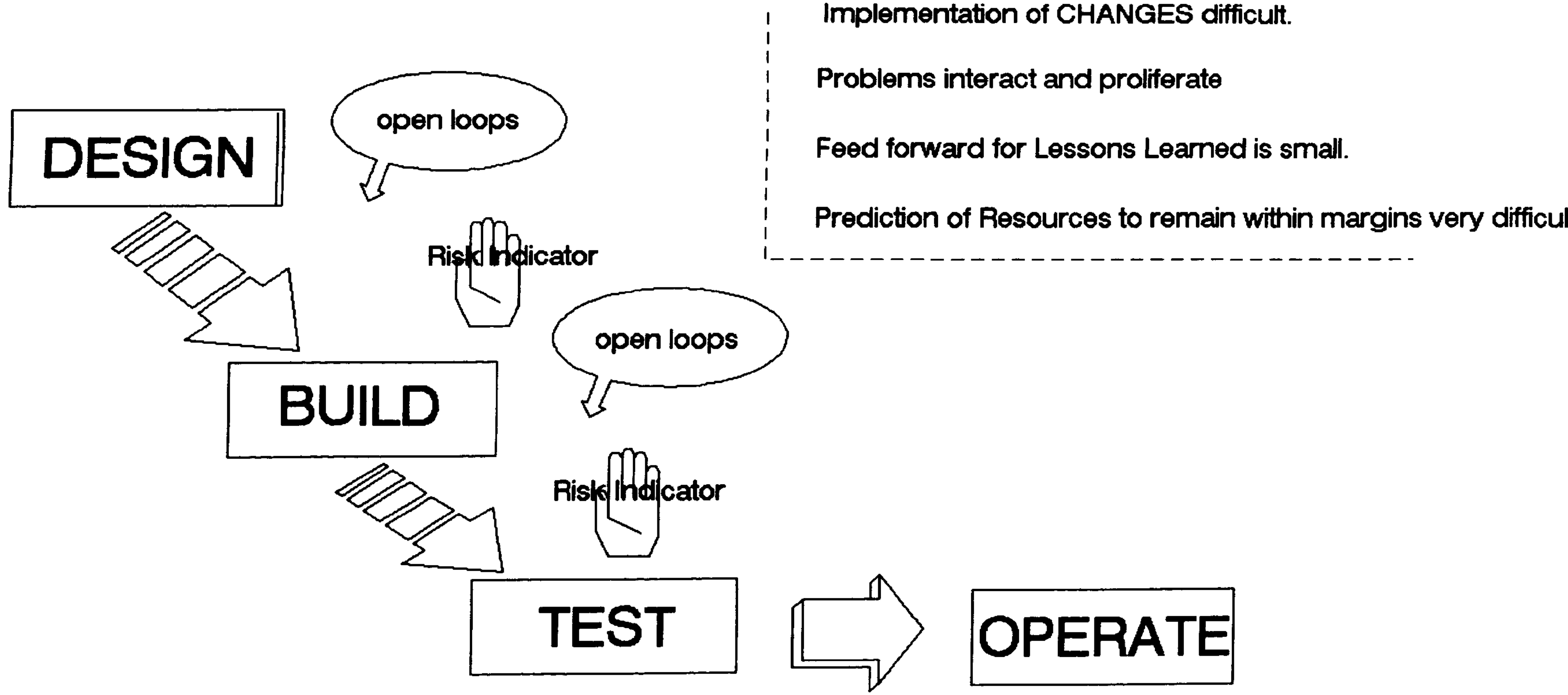


Fig.32: Typical Project Phase Relationships, in practice.

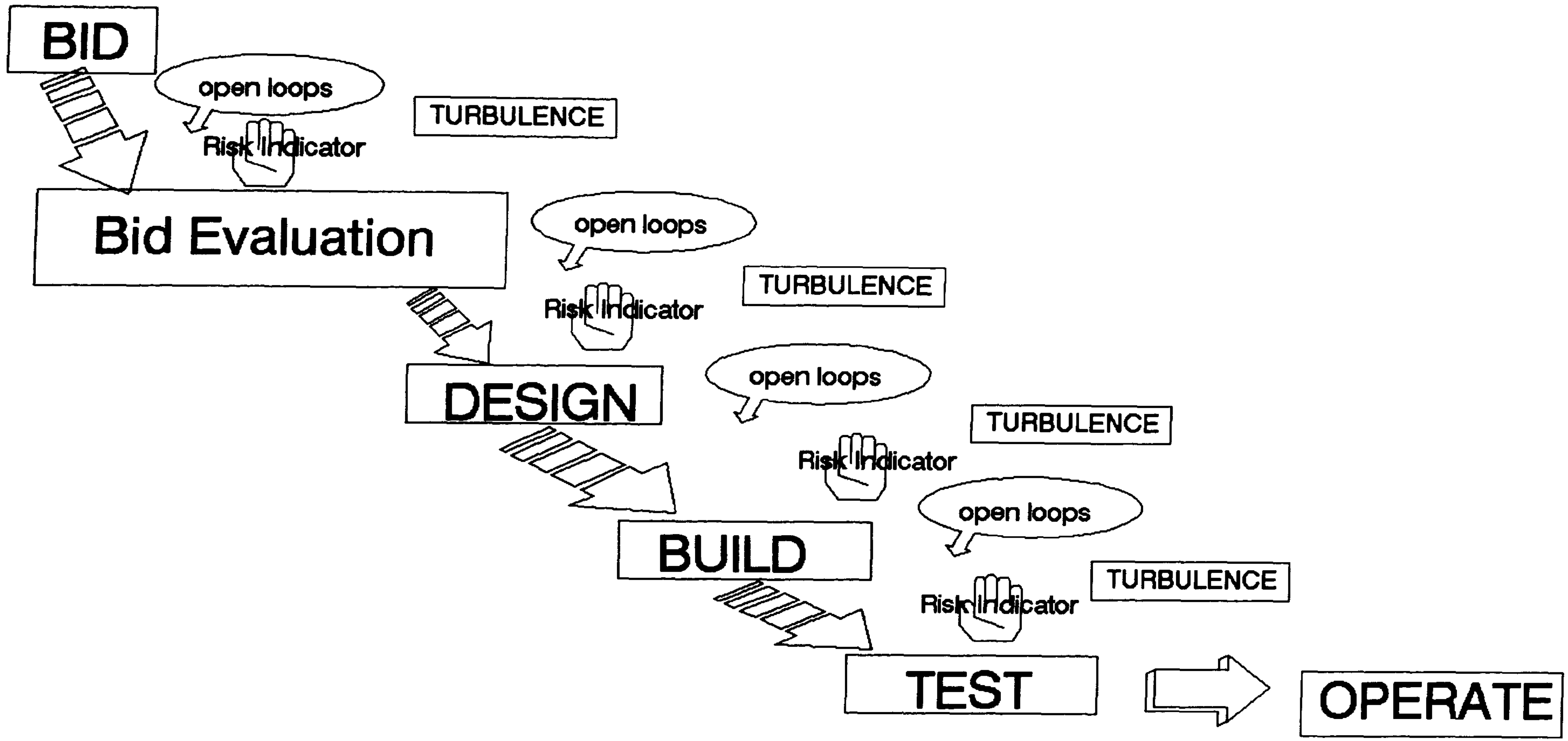
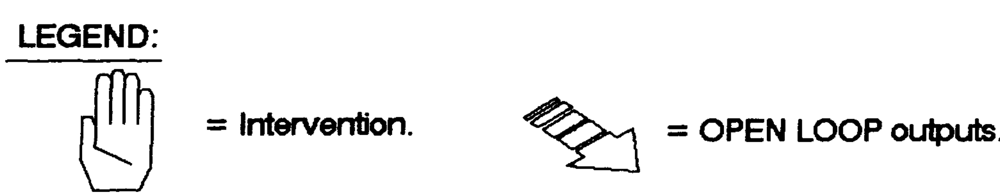


Fig.33: Indication of Open Loops causing Turbulence.



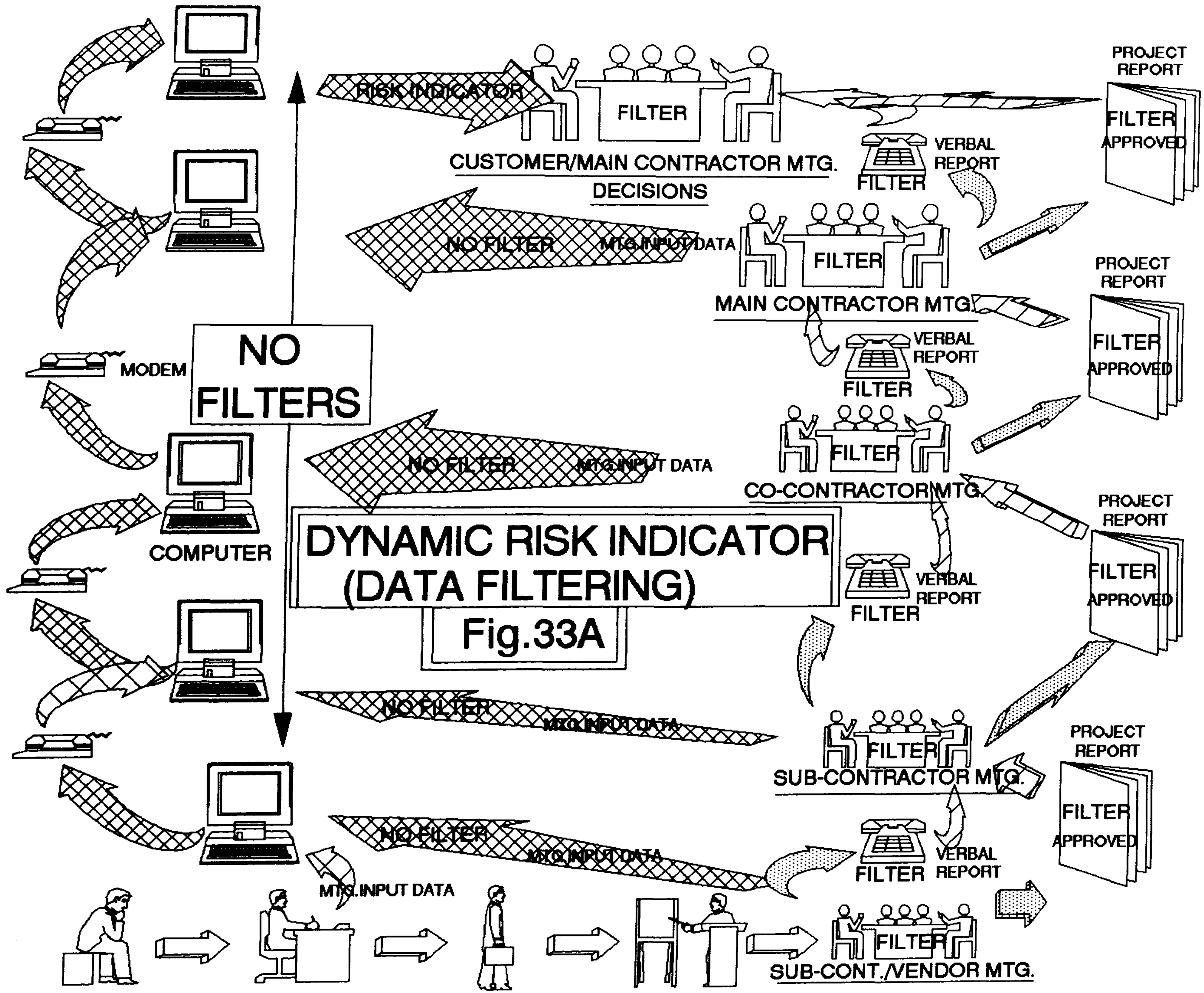

RISK INDICATOR
FILTER
CUSTOMER/MAIN CONTRACTOR MTG.
DECISIONS
PROJECT REPORT
FILTER
APPROVED
VERBAL REPORT
FILTER
NO FILTER
MTG.INPUT DATA
FILTER
MAIN CONTRACTOR MTG.
PROJECT REPORT
FILTER
APPROVED
VERBAL REPORT
FILTER
MODEM
NO FILTERS
NO FILTER
MTG.INPUT DATA
FILTER
CO-CONTRACTOR MTG.
PROJECT REPORT
FILTER
APPROVED
COMPUTER
DYNAMIC RISK INDICATOR
(DATA FILTERING)
VERBAL REPORT
FILTER
NO FILTER
MTG.INPUT DATA
FILTER
SUB-CONTRACTOR MTG.
PROJECT REPORT
FILTER
APPROVED
NO FILTER
MTG.INPUT DATA
VERBAL REPORT
FILTER
MTG.INPUT DATA
FILTER
SUB-CONT./VENDOR MTG.

Fig.33A

The project programme must be designed to enable the intervenor and project manager team to function efficiently. Adversial situations must be avoided hence a psychological contract, or partnership, must be established between the two elements.

There must be an "upwards" accountability from equipment design through sub-system and system to concept definition.

6.5 Project "Elements"

The elements which are considered to be the total constituents of the system, and supply inputs to the risk indicators, are defined in the following sections; they are either "hard" or "soft" as indicated.

6.5.1 Living Systems(soft).

The majority of the research to date portrays the "company" as functioning within an "environment", see section 3.9; this concept is then usually drawn as hard-line diagrams. From these diagrams, with their precisely defined interfaces, many researchers have deduced specific interactive relationships between the company and its environment, or customer, which are then used to classify all "company/ contractor couples" and predict the salient points of their future performance.

The author has not experienced the above characteristics and the data collected, albeit small, during this research does not evidence such precise classification.

In an attempt to commence the analysis at the most fundamental stage the author has initiated the process with the following "postulates":

- postulate a: all human beings are controlled by their brains;

- postulate b: all companies consist of, and are controlled by, human beings;

- postulate c: the environment consists of companies; and therefore human beings, and therefore brains;

- postulate d: the "totality" of the business world consists of the companies and their environments, and therefore of human beings and ultimately of "brains";

- postulate e: the "knowledge" and "selection(decision making) process" of the brain is a function of the "perception" of the brain;

- postulate f: a limit of "perception" exists for each brain;

- postulate g: the limits of perception constitute the traditionally defined "company/ environment" boundaries;

- postulate h: all companies contain, exhibit, and function according to, the characteristics of "living systems".

It is thus considered that all companies are living systems, and within themselves and with their interfaces with other companies, will experience such attributes as ego, insecurity, greed, bias, territorial possessiveness etc. They are self organising and adaptive. It has also been observed that a company has as many facets which, often differently, indicate its characteristics as it has interfaces; both within and external to the company. The attributes mentioned above, ego etc., are thus exhibited by individuals and by groups. The significance of the attribute to the recipient is a function of the perceived power or authority of the transmitter. As an example, a company official,with a certain "company" profile, would have far more authority on a local contractor than the chief executive officer; the latter would also have a company profile that could be quite different than the local official. In both cases persons who interfaced with the two persons would describe the (same)company in terms of the two different profiles and hence would define the company in two different ways.

It has been observed that companies exhibit "tribal" and "family" characteristics and that the strategy, campaign or "position" of a company will usually be defined and controlled by a very small number of persons; or even one!

It has also been observed that personnel are, to a certain extent, stereotypes of the culture within which they have made their industrial evolution. For example, a German will usually do what the boss wants, because he is "the boss". Similarly, a French manager will expect loyalty, obedience and reporting from his staff simply because he is "the manager". In the latter case it is likely he will form a small circle of "confidantes" around him with whom he will discuss matters; and no-one else. Postulate "g" defines the "periphery" of the company; it clearly depends entirely on individual and collective perception and can vary from day to day. This is essentially the dynamics of the situation.

The subject of perception is a major aspect of the model.

Perception is defined as the result of the brains modification of the observed reality.

The brain functions by comparing "sensed signals" with experience derived knowledge and selecting or interpreting an output such that no survival, ego or institutional criteria are violated. This "filtering" of the data results in the perceived image which becomes the reality of the particular person.

The inputs to the brain may be hard, soft, or a combination. Hard aspects refer to engineering rules, dimensions, quantities, laws, etc. and soft aspects refer to beliefs, culture, experience, personality traits, etc. Soft aspects also include "intentions" i.e. signals indicating an interest or intent by an enteral body but, as yet, nothing formal or defined.(see annex 2).

The following statements have been extracted from the work of De Bono and others:

- the history of experience gives us the boundaries of reasonableness;

- the purpose of the brain is to organise incoming information into a stream of steady state data; using patterns in a random manner. If something remotely resembles an existing pattern then the pattern will be used; even if it is actually not a good correlation;

- unstable states will be manipulated, manoeuvred, until they can be compared with a known pattern;

- perception works in an active information universe;

- provocation is necessary in self organising systems in order to temporarily move outside our experience.

The Method isolates the project management from such influences; they become the territory and responsibility of the intervenor. The intervenor is thus responsible for assessing the relevance of internal, within the company, and external hard and soft data to the project risk profiles and intervening as necessary in order to preserve the equilibrium and convergence of risk.

Strategic change can be linear or non-linear. The linear changes are often anticipated from extrapolations of baseline data. The non-linear changes are the real problem since they are not predictable, and can invalidate linear projections.

6.5.2 Closed Loop Systems(hard).

The five senses of the brain viz. sight, hearing, taste, touch and smell, all depend on feedback to function; they are closed loop systems. In general, the author has observed that managers endeavour to establish closed loop systems; even where they do not exist. The open loop system seems to be such an imponderable, such an initiator of insecurities and lack of control(not being "in charge") feelings, that it is avoided at (almost) all costs.

Contractually there are, in principle, conventions which cover non-closed loop systems. For example "time & material" contracts, but these either have "cost ceilings" or they apply for limited periods of time or function; in both cases the loop is not open for very long and they are very often enveloped by other closed loop contractual activities.

Notwithstanding the above, research activities are usually not governed by fixed price contracts.

In spite of the above statements there remains an apparent paradox since the preference for a fixed price contract means a commitment to meet the contractual requirements on time irrespective of the problems encountered en route. This seems to indicate that companies are able to establish effective risk management systems and yet the authors experience is to the contrary. However this paradox dissolves when one realises that with the time and material contract each and every expenditure may have to be justified to the customer. The contractor is thus faced with a trade-off between exposing his in-house financial manoeuvres, or trying to define the total risk of a programme before it begins. The authors experience on these issues, both as a customer and a contractor, is that contractors repeatable "hope" that they have:

- a) put sufficient margin in the fixed price bid to cover all eventualities and,
- b) for those problem areas that arise which exceed the margins they will be able to demonstrate that the issue is "out of scope" and therefore the customer must pay.

The alternative situation, with the time & materials or cost to completion contracts, is characterised by the exposure the contractor is compelled to make to afford the necessary visibility to the customer.

The customer running a (apparently) open loop time and material contract will in fact establish frequent financial reviews which essentially form a series of closed loop controls.

Of the two options, the fixed price contract is more often applied.

The overwhelming advantage of the closed loop system to the manager is that margins can be allocated to the parameters involved and the erosion of those parameters monitored to indicate the likelihood that the system will be within specification. This system also enables judgement to be made concerning the traceability and inter-dependence of the parameters and items involved and thus establish a heritage back to some known "defined risk" baseline. These advantages are registered here as being self-evident; they are, in the experience of the author, rarely applied completely.

The Method herein presented utilises the closed loop concept together with the definition of warning and action limits to indicate the approach of risk divergence e.g. the onset of non-linearities.

The difference between the Method being presented and current practise is that the Method requires the parametric margins include the resources they require in order that the margins converge to zero at contract completion. The Method also identifies the action limits, on the margins, as the warning limits for the intervenor; the latter would have additional action limits which could initiate the intervention function.

In general, intervention will be necessary when positive feedback in the closed loop systems is inappropriate or fails, or indicates a tendency to fail, to maintain the prescribed system progress.

Due to the empathy of human beings(brains) with, and the relative ease of managing, the closed loop system, a basic aspect of the model is that a careful analysis is initially carried out to identify, and where possible configure, closed loop systems. The remaining systems will thus be open loop which are much more difficult to control.

6.5.3 Open Loop Systems(soft).

Open loop systems in the context of this thesis relate to those areas where the solution to a problem cannot be defined. The main culprit in this respect is a non-linearity, for example "embedded research"; refer to section 4.2.2 for an explanation of this issue. In many cases other, apparently closed loop, systems interface with open loop systems thus causing the intervener to increase the criticality rating of a system.

Subjective judgement is usually used to "define" the risk. Unfortunately few rigorously defined systems exist; prestige, ego, and career considerations can bias the outcome to such an extent that the results are very questionable.

This thesis considers as "open loop" any system that involves a departure from the concepts of "traceability and incrementalism".(see #5.3 & annex 2). If, for example, a new technology is to be utilised then the system in which it is to be used would be considered to be:

- closed loop, if its evolution could be directly traced to technology which has given satisfactory service;

- open loop, if a "jump" or "gap" in the technology evolutionary path has occurred.

Margins and feedback cannot be applied to open loop systems. A programme which expects to reduce , or contain, its risk should include closed loop contingency plans or complimentary development activities to enable the convergency or divergency of the "problem" to be monitored by the intervener.

Since margins cannot be defined neither can the resources; hence the problem.

Many "soft aspects" tend to generate open loop problems. Providing the soft problem can be "sized" then a "closed loop surrogate" may be definable and an approximation to the incremental approach realised. For example the risk divergency caused by key staff departing at a critical programme time could be contained by organisational manipulations e.g.

1) duplicate staff,

2) financial or promotion award immediately prior to critical event,

3) sub-contracting with high incentives and severe penalties.

In each case the intervenor would need to be aware of the elements that would be needed to establish a closed loop; and then to be convinced that they could be implemented.

6.5.4 Open Systems(soft with hard aspects).

The subject of open systems is introduced and explained via a description of the functioning of the brain. This hopefully also clarifies the brain and living system concept with respect to the functioning of organisations.

The brain essentially functions by selecting from chaotic data based on experiential criteria; the output from this process is a convergence leading to a decision. The accumulation of experience generates progressively changing selection criteria; a growth trajectory takes place. As an example of the latter, a child is initially fire seeking but becomes fire avoiding after the experience of burning. If directly relevant experience is not available to the brain it will iterate its existing experiential data until an approximate "fit" is found and then select accordingly e.g. the first UFOs were selected as being "flying saucers".

Individual brains will try to make data sets converge using criteria which that brain understands i.e. has experienced; pattern recognition is involved.

The brain however has certain priorities which, if seeming to be degraded, will result in "intervention" and a probable change to the on-going event(s). Such priorities relate to thirst, hunger, sex, possession, security, etc. There seems to be a direct correlation on this aspect with organisational behaviour. The brain is self protecting, self surviving and ego-centric. The brain will distort the selection process to ensure that ITS perception of what it wants, it gets. This constitutes an intervention characteristic and "can" relate to the brains strategic objectives; one of which is surely to survive.

It is considered that organisations will be subjected to similar distortions by the "managing brains"*; conflict may well result from some of the distortion parameters and criteria.

The brain, and life itself, function as a self organising, OPEN SYSTEM.

* The implication of this statement is that the "managing brains" will be transmitting information which is tagged "this information is "hard" information due to my positional authority which is contained in company regulation "xyz", if the receiver of this information is "under my authority" then this information will override other data".....etc.

An open system is characterised by equifinality i.e. in contrast to equilibrium states in closed systems, which are determined by initial conditions, the open system may attain a time- independent state; independent of initial conditions and determined only by system parameters. In open systems, with transfer of matter e.g. people, materials, and energy e.g. data and knowledge, import of "negative entropy" is possible. Hence such systems can maintain themselves at a high level, and even evolve toward an increase of order and complexity; one of the most important characteristics of life processes. Open systems are particularly applicable to phenomena showing non-structural life interaction of processes. Living systems can be defined as hierarchically organised open systems, maintaining themselves or developing a steady state.(63).

It is considered that organisations consist of open, and open and closed loop, systems; linear and non-linear events. It is further considered that most organisations are not aware, or do not react, to these aspects. The "mix" of open and closed systems, their juxtaposition, and the "amount of openness" are judged to be a significant risk indicators.

For an organisation to be self organising, it must be coupled to another organisation i.e. the output is not a function of the original state or input but due to the action of some external factor which acts during the process of the system. Systems organising themselves by way of progressive differentiation evolve from states of lower complexity to states of higher complexity. Self differentiating systems that evolve towards higher complexity (decreasing entropy) are for thermodynamic reasons possible only as open systems i.e systems importing matter containing free energy to an amount over-compensating the increase in entropy due to irreversible processes within the system (import of negative entropy). However we cannot say that this change comes only from some outside agent, an input; the **differentiation within a developing organisation is due to its "internal laws of organisation AND the input"**.

Quantitative and qualitative data are also included in the model; the latter as subjective data being rendered into a quantitative equivalent using expert judgement techniques. It is considered that an increasing dependency on qualitative data will develop and hence the urgent need to understand how to utilise this data such that its entropic contribution is negative.

6.5.5 Complexity(soft).

On the subject of complexity, see also sections 6.6. and 6.7, it is the authors experience that initially, in a project life cycle (another reference to living systems!), the complexity is low; it then rises to a maximum at some point before design freeze (probably during the intense trade-off activity phase), and then gradually decreases. The problem with this general statement is that the complexity in the technical area probably does not coincide with the complexity maxima in the managerial, contractual and financial phases.
It is necessary in the above to differentiate between the complexity of soft and hard aspects and the inter-action between them. The actual existence of this point is shown in the analysis of the project data charts in section 5.2.5. It is considered that complexity is proportional to non-linearity.

6.5.6 Trajectories(soft).

Trajectories embrace aspects which:

- change as the project advances in time,
- represent the dynamic nature of the project, and
- can indicate an actual or potential

strategic change or increase or decrease in risk.

The main trajectories are defined as follows.

1) The progress of the project item along the "route" of the strategic plan.

   This trajectory can be defined in terms of milestones reached or passed, resources consumed, elapsed time etc.

2) The changes to the various margins.

   For example, erosion of the power, mass, and schedule margins.

3) The growth of brain selectivity.

   This trajectory can be defined in terms of the increase in knowledge (experience, training, lessons learned, new subject awareness, improvement of techniques e.g. man-management, decision making, time management etc.) obtained by individuals as they progress in and adjacent to the project; and the consequent broadening and increase in depth of expertise thus enabling "better"(more informed/less risky!) decisions to be made.

4) The changing perception of the "environment" (brain locii).

   This trajectory relates to the:

   - inter-personal contacts that are made,
   - inputs from media, libraries etc.
   - awareness of other strategic plans
   - assessment of the effects of inventions, discoveries,
   - cultural adjustments, etc.

6.5.7 Decision making processes(soft with hard aspects).

This point particularly relates to the consideration that decision making processes involve exchange of significant information, often in an informal mode, between the executives of companies. This point essentially calls into question the Core-Boundary model concepts mentioned in the literature; (see ref.110 et al.)

The author believes, from 20 years working in business, that a company as such does not have a characteristic personality or even a particular attitude for a significant period of time. However the persons working for a company, and representing it, do have a definite position and depending on their authority this "position or image" can be construed as the "position or image" of the company. Ones judgement of a company thus tends to be a function of the particular interfacing person.

6.5.8. Interventions(soft with hard aspects).

Interventions are considered to be either;

- direct, or

- indirect

Indirect interventions refer to those forces, pressures or influences that impose on our thinking processes from a myriad of sources; ranging from casual conversation to text book reading.

They often raise the spectre of something which could happen. As an example, suppose a British cake manufacturer "heard" that his nearest, but lower market share, competitor was about to be taken over by Sony, an electronics company with no apparent knowledge or interest in cakes. He would, nevertheless, probably be concerned and may start to consider what the new intentions of his competitor might be, before he is even sure that a merger, or an effect on his cake business, will take place. The gossip has thus created an intention, by someone, in the brain of the manufacturer who then treats it as an intervention; possibly effecting his strategic thinking and planning.(see annex 2).

6.5.9.Information(soft).

It is considered that information relates in its totality to either hard or soft aspects; examples of the former are laws of physics, dimensional measurements, hard line forms and shapes, etc. whilst examples of the latter are beliefs, culture, personality, experience, judgement, etc. Information is something which is "perceived"; it is therefore a variable. Not only is it a variable because of the effects of the perception process but, due also to the perception effects of "others", information can be significantly changed when it is transitioning.

6.6 Turbulence, crisis, chaos.

The real problem with the existence of open loops and non-linearities is that if they interface, and inter-react, with each other then very complex situations can occur. The problems can then cross contractual boundaries, involve a number of different companies possibly of different nationalities, involve different elements of the overall project thus impeding good work which is being done elsewhere, and so on. Some of the problems can cause design changes to be carried out elsewhere in order to protect the overall system "functional" objectives.

This situation is represented, via the science of chaos, by **the movement from a steady state(equilibrium) through a state of increasing "bifurcation", or branching, to a condition of chaos**. In the latter condition systematic elements do exist but it is extremely difficult to discern what they are. The existence of chaos will be entirely subjective i.e. perceptual. The movement from a steady, linear, controlled status through the onset of turbulence, which could be the result of anxiety, frustration, disappointment or discomfort, etc., to chaos could be a psychological or perceptual mechanism. One might say that turbulence and chaos exists, for a person e.g. a manager, if the questions are being asked:

- what should we do next?
- what is happening over there?
- if that fails, what then?
- is there anyone who really understands how this thing works?

Circumstances during which such questions as the above were asked actually occurred on project C; see section 5.2.5.4.

The circumstances are analogous to water flowing from a tap. As the flow rate is increased the water stream changes from laminar through turbulent to completely chaotic. In the turbulent condition it impossible to predict what will happen at any particular time in the future.

Hence during the Bid evaluation it is important to identify where the onset of bifurcation type activities could occur and then to prevent or avoid their occurrence. Once they occur the drain on resources to recover could well be disastrous. To meet this "avoidance" requirement the model requires the use of **risk indicators**; see chapters 3.6, 5.3.4.7, and 6.9.

6.7 Orderliness with Increasing Complexity

The method is based on the premise that since all companies are composed of human beings then the companies themselves behave in a similar manner to living, open, systems. This means that they have the capability to actually increase their orderliness as the complexity of their activities increases i.e. they are adaptive and self organising. This reduction in disorder, or entropy, is only possible if

negative entropy is injected into the system. The latter is only possible, without contravening the second law of thermodynamics, if it occurs locally whilst maintaining an increase of entropy at the overall system level. The model establishes this status by requiring that data and knowledge are supplied to the project in a very easily assimilateable form. This means that the right data and knowledge must be available at the right time and in a form that is understandable and useable by the persons who need it. This applies as much to basic design data as it does to data packages supporting design reviews.

6.8 Risk Indicators

Risk indicators inform the project manager and the intervenor whether their initially defined risk, that the project will not be successful, is likely to be exceeded. They should thus form the most important content of progress reports and reviews.

Risk indicators are defined as inputs to the project manager and intervenor which inform them whether their initially defined risk, that the project objectives will not be met, is likely to be exceeded. These inputs are related to the structure or pattern of events as they seem to be evolving in the project. Thus if two or more open loop, or non-linear, activities are inter-dependent then this would be an area where bifurcation could occur and hence would be nominated a risk indicator. Examples of risk indicators are the existence of embedded research, qualification activities, and perceptual biases.

The Method utilises **warning and control limits** associated with each risk indicator; these are established according to the rate of increase of the parameter being monitored and the criticality of the technology, equipment etc. within the overall project.

Risk indicators constitute a fundamental aspect of the model.

Risk indicators can be static or dynamic.

A static risk indicator is based purely on static or "snapshot" data; it provides a single picture of the flow status of the project at a particular time. An example of a static risk indicator is a PERT chart.

A dynamic risk indicator(see fig.33A) contains information on the increase or decrease of the flow rate(s) within the project. An example of a dynamic risk indicator would be a plot of the rate at which manpower is being used versus the rate by which a test is being successfully completed.

The message here is that risk monitoring must be "continuous" to enable assessment of the "continuously" changing project dynamics. This is supported from the research by the Law of Requisite Variety(59) which states that "only variety can absorb variety"; the variety of the controller must match the variety of the controlled.

In the model the risk indicators receive inputs from the project in its operational mode.

These inputs to the risk indicators emanate from the total system* which itself is considered to consist only of the project elements; these are described and listed in section 6.5.

* The total system consists of the project and its so called environment. A project typically consists of a number of companies in the form of a consortium with a lead(prime) contractor, sub-contractors, vendors, and a customer. The companies are formally bound together with the intent of achieving contractually defined outputs; the overall project goal is usually only the concern(responsibility) of the prime contractor; the latter is the only company with a direct interface with the customer.

6.9 Margins.

Margins are typically used on technical parameters i.e. measurable outputs from system equipments, and schedule. An "industrial risk" fund is often implemented.

A general rational for the definition and "permitted erosion" of margins is not known to the author. In his experience the margins are placed and their degradation monitored according to experience; they are often truncated when difficult situations arise.

In the method margins are only permitted on linear activities.

The "risk indicator - intervener" concept in this thesis depends on, and requires that, ALL margins relate directly to the resources required to fulfil the particular function concerned. This naturally requires an a-priori assessment of all problems likely to be encountered with an associated assessment of the resources to solve those problems.

The above concept also requires that "warning" and "action" limits are placed on the margins; the overall margins would thus be split into two parts. The intervener would only consider executive action when the control limit was reached, or tending to be reached. The project manager and the intervener would thus monitor the project according to the warning and action limits respectively.

This method of working would dimension every problem in terms of the resources required to solve it. This in turn would indicate the status of overall resource consumption and availability; and also the effect of lateral resource cannibalization. The moving averages of these values, and their extrapolations, would give a clear indication of the real risk; this is thus a priority risk indicator.

6.10 Criteria for Application of the Method.

6.10.1 General Comments

The following criteria must be applied to the project situation being examined in order to adduce the required outputs for application of the overall Method.

Perception would figure in this part of the Method.

6.10.2 Living Systems, inc. Perception and Environment, criteria.

1) Characterise each company, the combination of the prime contractor together with the consortium, and the customer, in terms of their dominant "human" attributes e.g. aggressiveness, defensiveness, etc. Consider the national characterisations that have been concluded by some researchers e.g. the French are predominantly thinkers, the British primarily people of action, and the Spanish primarily emotive.

2) Identify if companies are dominated by one or two persons and what their perception is likely to be; take their education and experience into account.

3) Assess the likelihood that key managers will put their personal aspirations before that of the project or company and the interface perception effect this will have.

4) List companies in the environment of each company and of the consortium; also other environmental influences and organisations both national and international inc. government.

5) Assess the probable interaction with, and perception of, that environment by the decision making perceivers in the companies, projects, and the customers; thus establishing the boundaries of the perceptions of the perceivers and what those environments "look like" to the perceivers. Hence certain salient points in the contractors and customers camps should be identifiable. This criterium includes the assessment of "how" the main players communicate; and how they obtain the information they believe in, and actually use.

6) Identify what the main dynamic aspects of the

environment are likely to be, as perceived by the main players, for the duration of the project. Rate of change of the environment, and distance of the technology being advocated from the state of the art, must be considered. Also consider the companies life cycles reference, for example, where they are in the communication satellite "product class" life cycle....if at all? Construct a trajectory of these aspects for the duration of the project.

6.10.3 Complexity criteria.

1) Identify the number of project interfaces.

2) Identify the number of different types of technology involved e.g. electronic, hydraulic, mechanical, etc.

3) Identify the number of different procurements i.e. using different suppliers.

4) Identify the number of state of the art, or "to be qualified" technologies.

5) Identify the number of specifications(requirement documents).

6) Estimate the total amount of data that has to addressed; and the likely effectiveness of the systems, inc. reviews, to assess it.

7) Identify the number of managers and engineers per 1) through 5) above.

8) Identify amount and availability of test facilities

9) Produce a "complexity against project time" profile based on estimates concerning the increase or decrease of complexity.

10) Identify the systems which are present in the project(s) to manage items 1) through 8) above. Failure and resource conflict situations should be considered.

11) Assess the maturity of the various companies concerning the work to be done and in particular the higher complexity aspects.

12) Asses the increase in maturity over the project life cycle.

13) Identify the number of different interfacing languages particularly where the interfacing language is not the mother tongue and where the internal language will be different than the interface, spoken and written, language.

14) Identify the different cultures involved.

15) Group all non-linearities.

6.10.4 Open System criteria.

Examine the self-organising (equi-finality) aspects of the companies and consortia i.e. the ability to achieve, or have already achieved, states which are not connected with the initial conditions and are determined only by system parameters. The objective here is to check that the "stability" of the project is in "dynamic equilibrium". If a project has the characteristics of dynamic equilibrium it means that as problems occur it is able to organise its resources in such a way that it can accommodate and solve or work around those problems whilst still maintaining its mainstream(strategic) activities. In other words the problems it encounters during its life cycle, which will usually be due to an interaction between sub- or co-contractors i.e. systems interacting with systems, can be solved using the organisational mechanisms and resources that it has at the time of the occurrence of the problems.

This requires analysis of the extent by which the companies are connected to other organisations which interact with them during the project. The interaction of the input data*, thus obtained, with the internal laws and characteristics of the company and whether the company is evolving to higher levels of complexity by making the "correct" differentiation between the two aspects, i.e. the input data and the internal laws, must be considered. Cultural aspects will be involved.
If the result is that the company is evolving to higher complexity and higher order, then the risk should be reducing and intervention is less likely. If more disorder, i.e. an increasing inability to cope with increasing complexity, is apparent then the likelihood of error will increase(risk indicator). An assessment of previous projects performance should provide most of the above information.

* The input data is very important. If it is clear that it directly relates to the project and is used to reduce problems, and therefore to reduce the disorder of the unsolved or unknown(open loops!), then it constitutes "negative entropy". Under these conditions the order of the project will increase even though the complexity will also be increasing. If such a system does not exist then the project disorder will increase, and also the risk; even with decreasing complexity. **This is a major Risk Indicator and requires intervention**. Warning and control limits can be applied to this risk indicator and implemented by examining the appropriateness, the useability(before the fact), and the effectiveness of use(after the fact) of the data inputs.

6.10.5 Closed & Open Loop criteria.

6.10.5.1 General: loop definition & criteria.

The definition of "loop" used in the context of this thesis is as follows:

" a loop relates to the resource flow(manpower and time) estimated as being necessary to "successfully" complete one or all of the following activities at any level i.e. from technology to system:

- selection(trade-off),
- design,
- manufacture,
- qualification,
- test,
- acceptance,
- assembly into the space vehicle,
- testing at system level.

The above constitutes a "loop" in the following manner. For each of the above activities specific resource flows have been estimated; these flows are checked at certain points and the values thus obtained compared with the estimated value at that time; this feedback completes the loop. Clearly the resource flow estimates are rather meaningless if they are based on significant assumptions due to the successful outcome of the activity being undefinable.

It is submitted, as mentioned elsewhere in this thesis, that the resource utilisation is something that occurs with respect to time and therefore has a "rate" and is a "flow"(see also the definition of "flow" in annex 9).

The combined flows of all activities in, for example, an equipment development programme are termed a "stream"; see section 5.2.5.1.2.4)

Loop Definition criteria:

Group all aspects of the project into "common loops" for evaluation as closed or open loop systems.

Examples are the "flows" associated with the design, build, verification and operational phases. If the "AOCS flow" is taken as an example then the first loop to consider is the AOCS design loop which consists of requiring a "yes" or "no" answer to the question, "is it certain that an AOCS sub-system can be designed, within all the constraints, to satisfy the specification requirements?". If the answer is positive then the process can be commenced; see Fig.34.

6.10.5.2 Closed loop criteria.

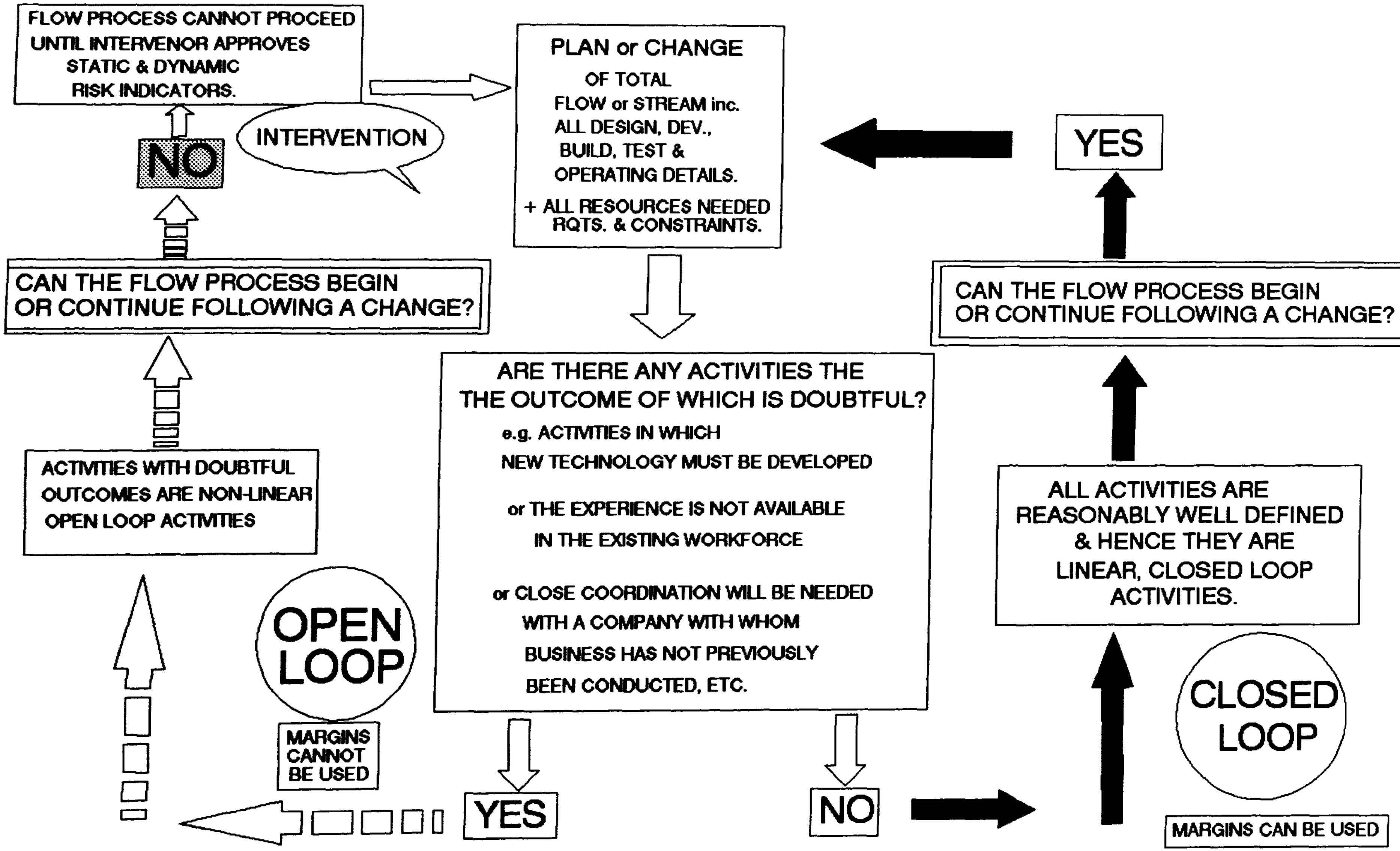


Fig.34: MODEL of OPEN and CLOSED LOOPS.

1) Identify, from the total list of "common loops", those loops for which the resources can be estimated with a high degree of certainty; these are classified as linear loops. Plot resources against project timescale (trajectory).

2) identify all loops for which margins have been allocated; plot margins as a function of project timescale; (trajectory).

3) Identify all feedback loops.

4) Identify warning and control limits for each closed loop; the warnings and controls relate to the possibility that the estimated resources will be exceeded before the final phase of that loop is completed. For all closed loops it must be possible to incorporate margins. Plot warning and control limits versus project timescale;(trajectory).

5) Overlay the closed loops for the duration of the project.(trajectory).

6.10.5.3 Open Loop criteria.

1) Identify, from the total list of "defined loops", those loops for which the resources cannot be estimated with a high degree of certainty.

   If, for a particular phase of the loop, there is a N%* or more doubt that the phase will be completed "free of significant problems", and those problems cannot be defined, then it must be classified as an open loop. Embedded research and qualification activities are automatic classification as an open loops.

   * The size of the number N depends on the criticality of the loop subject and would have to be agreed, with a rationalle, prior to ITT release.

2) Identify the type(s) of expertise needed to track and advise on the progress of the "unknowns"; all of which must be labelled "Risk Indicators".

3) Overlay the open loops for the duration of the project (trajectory).

6.10.6 Decision Making Processes criteria.

1) Identify main decision makers at project and corporate level, their qualifications & experience; also identify their main technical and contractual advisors.

2) Identify methods of making decisions; inc. extent of delegation, utilisation and sources of hard & soft

data. Consider the different perceptions involved. Include resource allocation logic.

3) Identify critical project supports.

4) Identify incremental and non-incremental aspects.

5) Identify Risk Indicators.

6) Plot risk indicators for the duration of the project. (trajectory).

7) Plot major decision points during life of project and risk profile (trajectory).

6.10.7 Intervention criteria

1) Identify interveners, by hierarchy; also their qualifications, experience, and relationship with the project manager.

2) Identify strategic plan, and objectives.

3) Identify interveners risk indicators; static and dynamic.

4) Identify critical project supports, for intervener.

5) Identify interveners warning and control limits. The interveners warning limits are the project managers control limits.

6) Identify interveners environment; and perception biases.

7) Identify interveners rational for intervention.

8) Identify resource allocation logic. This must include the various types of resource and the "learning curve" involved before new resources of a particular type can actually be utilised.; this aspect tends to make existing resources unique.

6.10.8 Utilisation of Trajectories.

The trajectories portray the expected dynamics of the project life cycle in terms of the various parameters considered.

As an example a rather unexpected trajectory was discovered during the project case studies. For one of the projects it was discovered that for the first eight years, of fourteen years in total, the procurement of components was not included in the main project planning. Hence the "planning trajectory" was missing possibly the most critical item and therefore did not portray the actual progress dynamics of the project.

6.10.9 Calibration.

The Method must be calibrated before initial use and recalibrates after every intervention.

Calibration points relate to the identification and definition of the "elements" for that particular project and the verification that after an intervention the element definitions are still appropriate.

Chapter 7. ADVANTAGES GAINED by USING the METHOD.

7.1 General.

This chapter outlines the advantages to be gained, and the currently experienced problems which can be avoided, if the Method is applied. The model outline and overview are shown in figs.19 and 20, chapter 6.1.

The outline follows the chronological course of a project from phase A to operation.

7.2 Statement of Strategic Objective and Risk.

At the conceptual definition point of the project an unambiguous statement defining the strategic objectives of the mission, the mission priorities, and the risk the customer is prepared to accept that the mission will not be successful, must be written down.

The intervenor must ensure that this is done in a complete and unambiguous manner, and understood by the main players.

This is almost never done and has been well documented, and experienced by the author, to be a major and increasing cause of problems.

7.3 Phase Close Out.

All outstanding items at the end of phases A and B must be clearly defined as open loops and integrated as such into the planning of the succeeding phase. Resources commensurate with the open loops must be included and areas of turbulence and possible chaos identified. All departures from an incremental approach must be defined; see figures 31, 32 and 33, chapter 6.4.

It is the responsibility of the intervenor to ensure that a succeeding phase is not commenced until the above has been established.

This aspect has never been applied in the experience of the author and has been shown in this thesis to be the cause of many problems that continued through the entire project life cycle. The problems from previous phases have often been short listed as being capable of resolution within the "next three months" with no additional resources.

7.4 Integration of Resources and Schedule.

The current methods of presenting vast amounts of segregated data render an understanding of the real risk situations almost impossible.

The manpower and cost data must be presented in an integrated manner with the schedule. Fig.36 shows an example of such a chart concerning manpower and schedule for the prime contractor and some sub-contractors. Such a chart would instantly inform management of high resource utilisation areas

The intervenor would use a chart such as Fig.36 and 37 as his first assessment of the viability of the project; this is a static risk indicator.

7.5 Trajectories.

Trajectories consist of aspects which change as the project advances and thus are indicators of some dynamic aspects. In general they are identified from static analyses of, for example, a companies previous record and then monitored to assess whether expected extrapolations are actually occurring. In this respect they are dynamic risk indicators.

By assessing, for example, the:

- maturity of the company e.g. its areas of proven experience;

- the companies utilisation of incremental approaches in its development activities e.g. does it have a lessons learned culture;

- the success and failures of the company including its market penetration, by its own efforts, product diversification, growth etc.;

- the propagation potential of problems across project phases, between equipment and sub-systems and system, and, possibly in camouflaged form, across contractual boundaries;

- the complete incorporation of all elements in each status reporting function e.g. the inclusion of all elements that have to be procured in the planning, and the inclusion of the "results" of all activities in the project reports;

- the "learning" that the project personnel are likely to obtain during the project life cycle thus increasing their ability to support the project and avoid the development of turbulent conditions etc.;

- the rate at which it replaces staff;

a better understanding will be obtained, before the project commences, of problematic interactions that might occur.

This constitutes a static assessment of dynamic mechanisms which could influence, or be directly involved in. the actual project life cycle.

7.6 Project Supports.

This aspect relates to the key persons across the project.

The Method requires that not only the experience and knowledge of the key persons are determined but also their ability to work together; to communicate, share problems, and motivate their staff etc.

The Method also requires that cultural aspects are carefully considered and inappropriate criteria are not applied. For example the Swedish and Italian cultures are quite different and cannot be judged using the same criteria.

Other aspects which have to be considered relate to language, vertical and lateral communication within companies, and familiarity with the standards and management methods being used in the overall project.

It is submitted that the application of "trajectory" and "project support" aspects would avoid many of the mis-understanding and false expectation problems that seem almost to dominate project life. The initial establishment of an accord between the main players in a project must realise a synergy which should avoid, or allow the early resolution of, many of the problems that occur today. The intention is to achieve something of a "family atmosphere"; this point is mentioned in several of the interviews.

7.7 Negative Entropy.

This point addresses the availability of data to all parties such that the necessary judgements and decisions can be made at the optimal times. This means that an essentially steady state level of order, communication, data collection and processing, and decision making must be maintained even though the complexity of the situation on many fronts will increase in a non-systematic fashion; tending to produce turbulence and eventually chaos.

Currently:

- reviews are often held with obsolete data,
- system information is restricted to upper levels of contractors, and
- the reporting of status is incomplete and, therefore, biased.

The unfortunate result is that the "steady state" outcomes are usually only cosmetic and camouflage increasing turbulence that suddenly erupts as chaos.

Application of the intervention Method should avoid these experiences.

This aspect is of paramount concern to the intervenor who would independently assess the data and knowledge sources, definition, flow, utilisation and control across the entire project. This activity together with the trajectories and project supports definition constitutes a major activated and responsibility of the intervenor during the bid evaluation and on-going project phases. The intervenor would not permit the proposal to be accepted, or major to take place, until he was satisfied in this area.

7.8 Open loops.

The identification of all open loops, on a continuous basis, together with their impact on resources is fundamental for the prevention of many of the currently experienced problems; many of which lead to strategic change due, for example, to their impact on schedule. The latter can be compared with the delivery time of a commercial product and the consequences of late delivery. Project C was "delivered" approximately four years late!

The definition of open loops, see section 6.2.1, and their utilisation has been explained in detail in the thesis and will not be repeated here. Open loops must be identified from the planning, CPN charts, and from the technical, organisation and management inputs.

Fig.35 shows a presentation of the open loops which have been identified from a review of the technical documentation of the project C proposal. The height of the histogram bars is proportional to the number and criticality of open loops in the various sub-systems; criticality relates to the system level consequences of an open loop.

Fig.37 presents the manpower profiles that the open loops shown in Fig.35 would require.

It will be seen that the manpower profiles originally submitted, see Fig. 36, would not envelope the manpower requirements ascertained from the technical evaluations shown in Fig.37. The bid would thus be defined as high risk in this respect.

Three aspects are mentioned here as specific examples of areas where open loop analysis would provide major dividends; they are:

1) embedded research: these are areas that are close to the state of the art and are non-linear concerning the prediction of time and resources needed to resolve the attendant problems;

Fig.35: Open Loops/Contractor-Subsystem

(Project C: criticality of open loops)

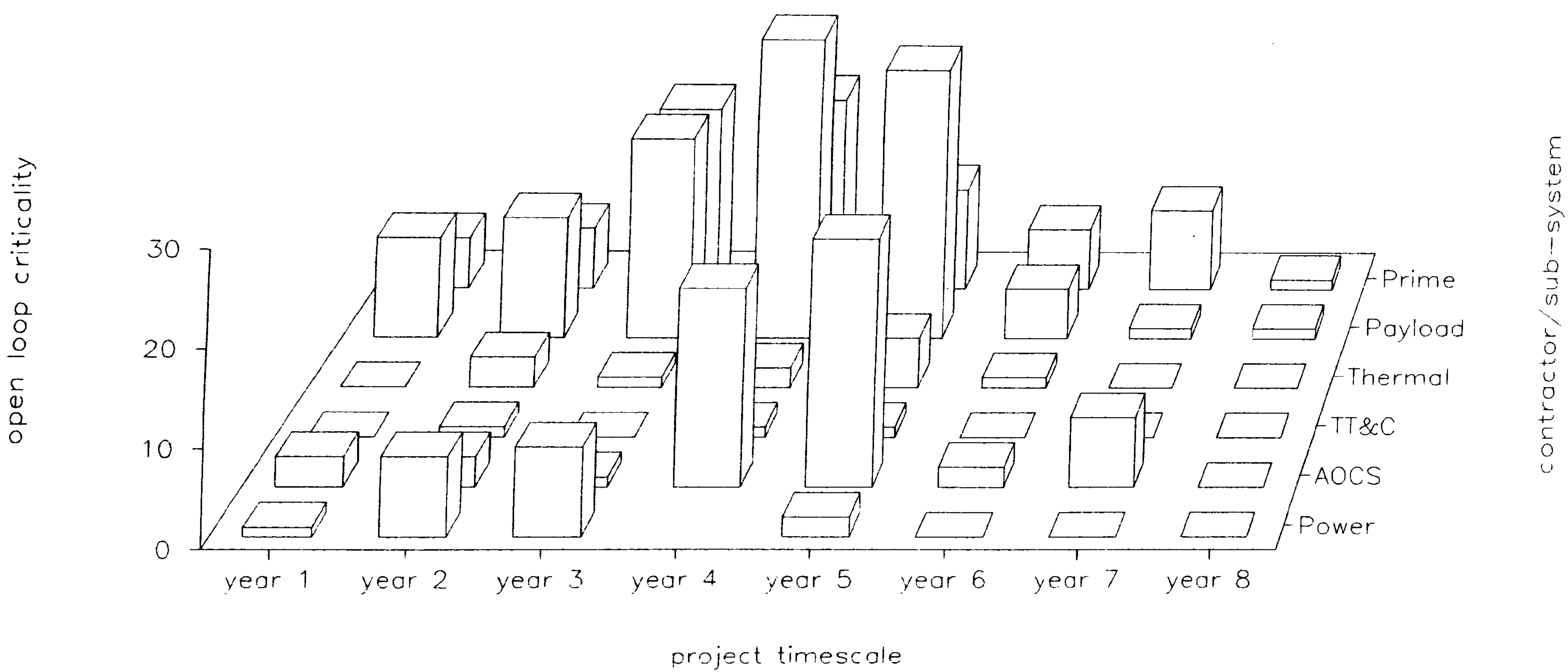


Fig.36: Project C Manpower Profiles.
(Original Submissions in Bid)

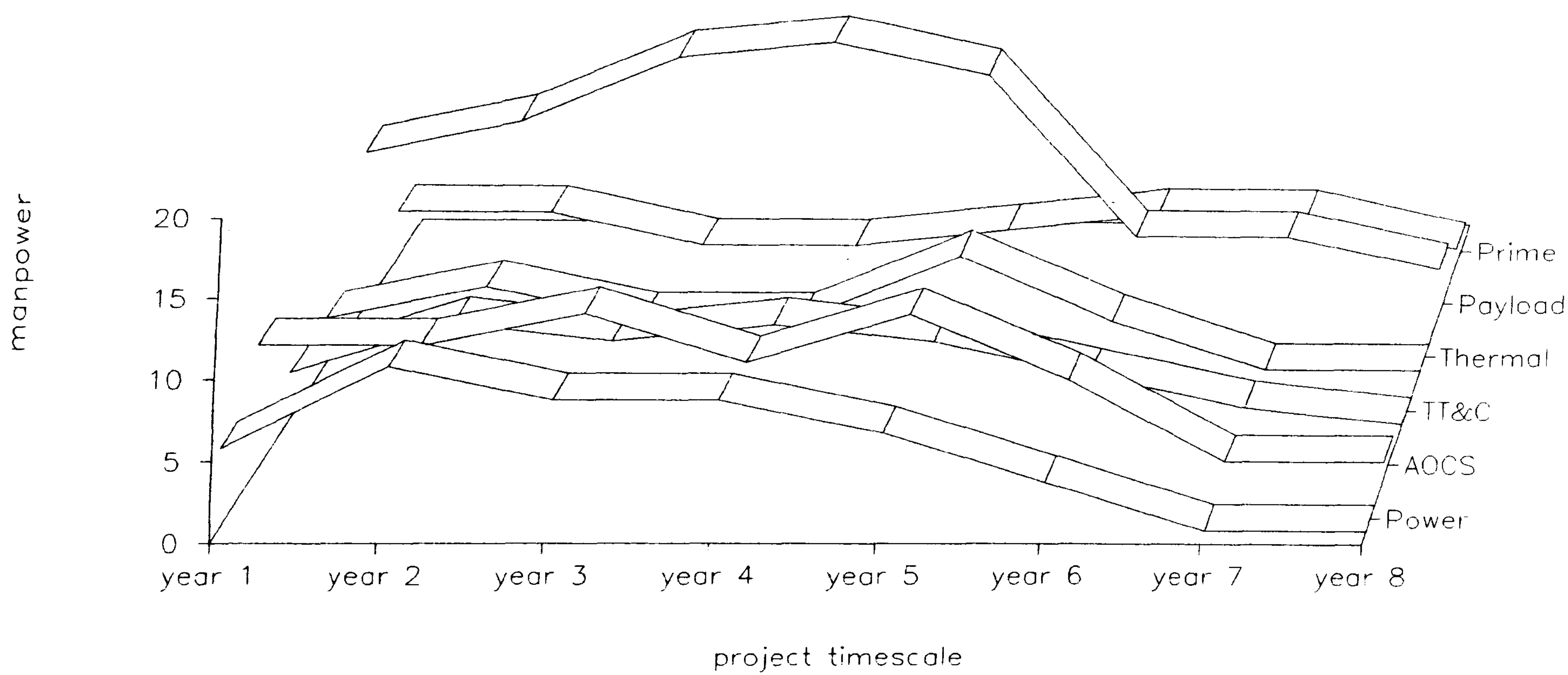
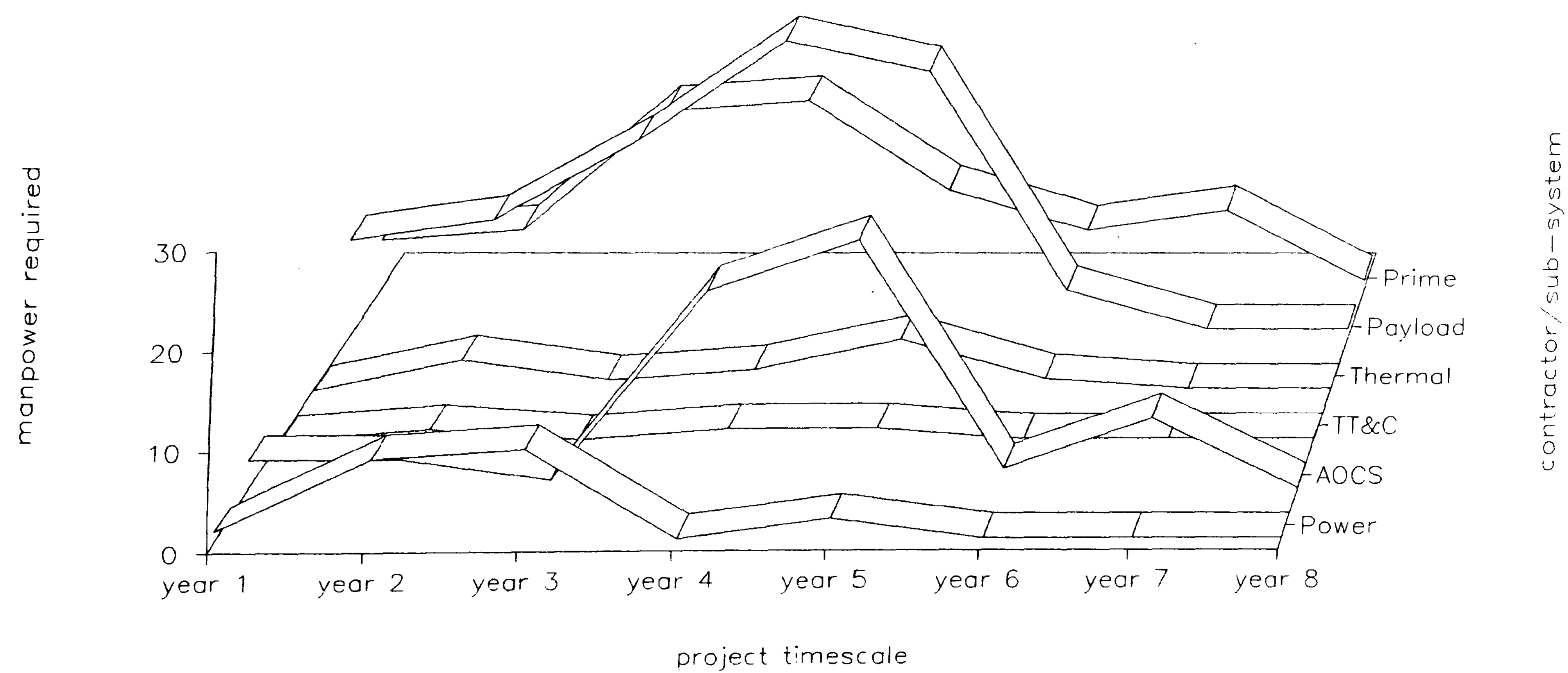


Fig.37: Open Loop Manpower Profiles

(Project C:Fig.**35** is basis of Profiles)



2) embedded risk: these are areas where the risk involved is not obvious e.g. the risk involved in the timewise staggering of the design and manufacturing phases across a project of:

a) many of the equipments,

b) many of the subsystems,

c) associated hardware and software activities.

This includes "negative entropy" related problems which thus tend to provoke the onset of turbulent conditions.

The replacement of key personnel is included in this category; the resolution of which, as required in the Method under the "project support" label, would be to arrange individual contractual, financial and career commitments to ensure that they remained with the project for as long as necessary. This latter aspect requires a new approach by companies to their staff recruitment and career policies.

3) Open Loop Planning.

This aspect represents a new method of risk presentation in the planning domain.

It is required by the Method, as an essential input for the intervenor, that a unique planning chart is constructed of all the identified open loops.

Hence it would then be immediately apparent where open loops interfaced with other open loops and the dependencies and consequences of those interfaces.

The development of such an "open loop" CPM is shown in Figs. 38, 39 and 40. It will be noticed that the final "open loop" plan is quite different than the plan that would be prepared using conventional methods.

Thus using the Critical Planning Network(CPM) technique which is used by many companies world wide, a static risk indicator is instantly available. It is vulnerable to negative entropy aspects.

From the project ground and orbit failure analysis, ref.section 5.2.4, the following specific open loop causes were derived:

1) undetected or ignored quality trends;

2) qualification invalidated;

3) inadequate failure mode consideration;

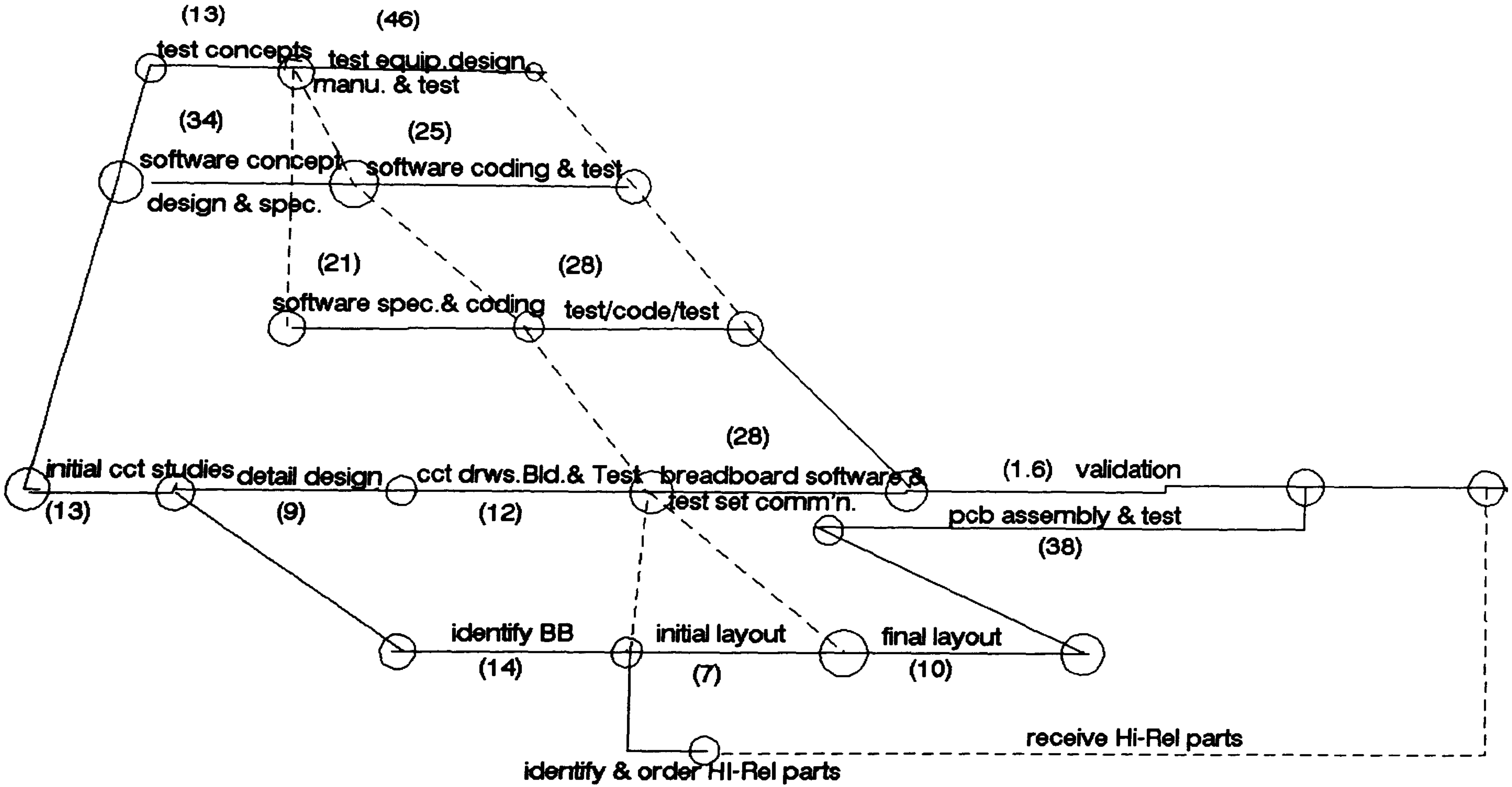


Fig.38: Actual Plan of the Design and Build of an Electronics Unit

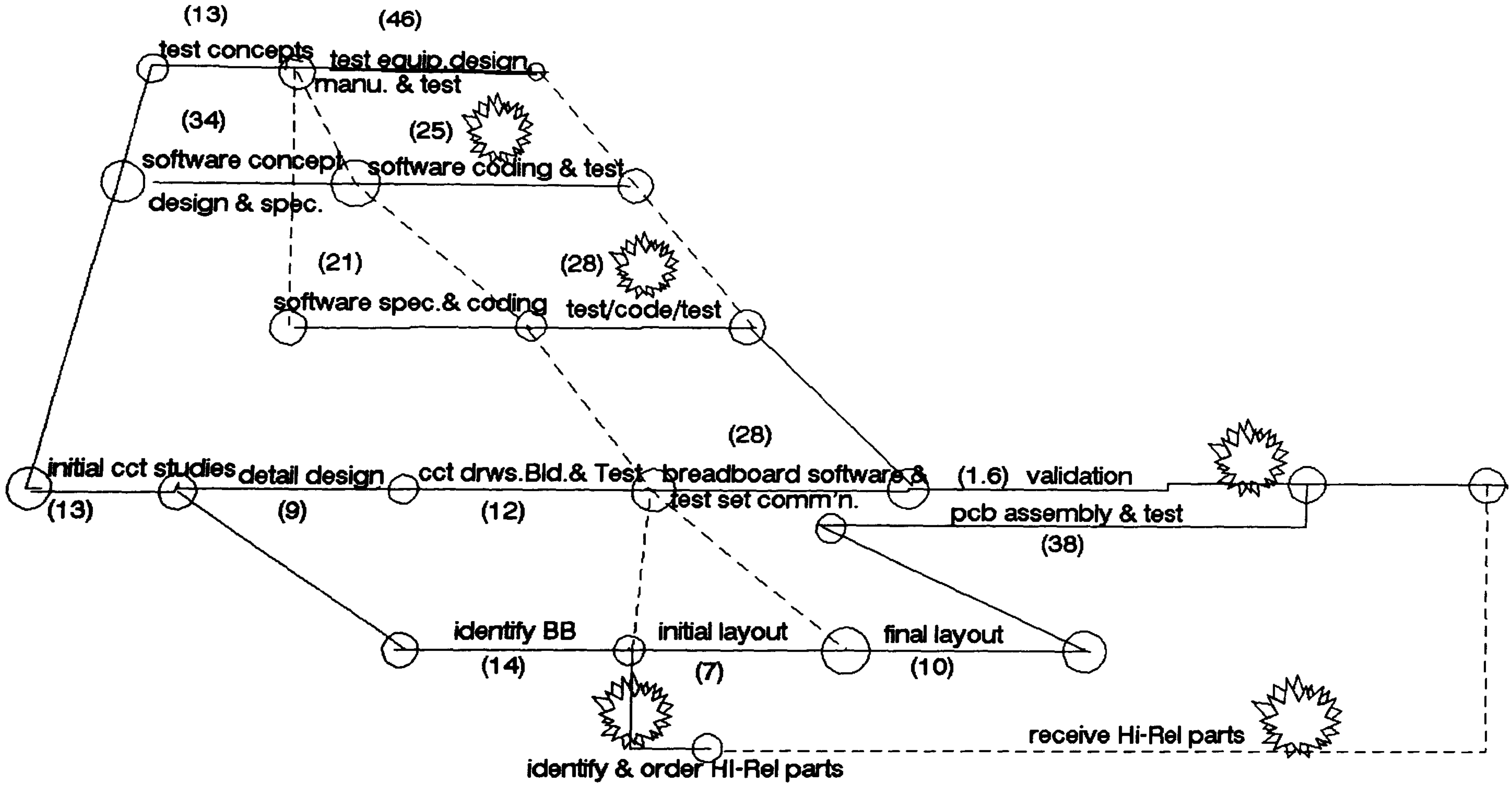


Fig.39 Actual Plan of Electronics Unit Design & Build with OPEN LOOPS identified

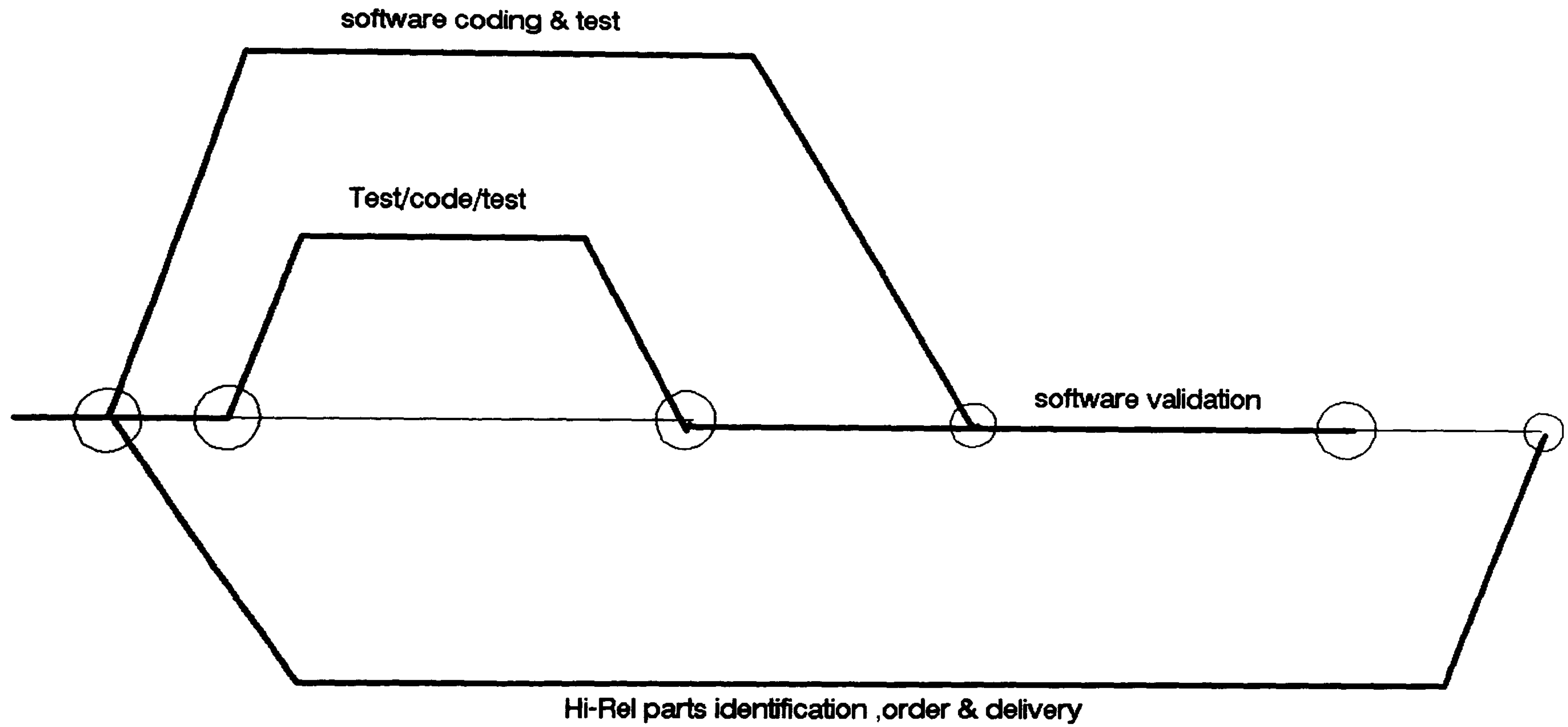


Fig.40: Representation of a Critical Path Network of the Open LOOPS shown in Fig.38.

4) inability to test or simulate;

5) failure scenarios poorly understood.

For different industries, other than the ESA-European industry business, specific open loop causes would have to be defined based on analysis of operational use, for example.

7.9 Integration of Resources, Schedule and Open Loops.

Having applied the above aspects of the Method it is then necessary that the intervenor and the project management obtain an integrated picture of all these aspects.

It is necessary to integrate the manpower profiles submitted in the Bid with the manpower profiles which have been deduced from an analysis of the technical documentation submitted separately in the Bid. With this sort of presentation a static risk indication is given of the capability and vulnerability of the project to the problems which are likely to occur. Thus, instead of the adequacy of the resources being a major concern and having to be supplemented between one and two years after the project begins, the whole business could be realistically assessed, and adjusted or cancelled, before contractual commitments are made. The intervenor would not permit a contract to be let until coherence had been achieved on the elements contained in this type of presentation.

7.10 The Dynamic Domain.

Once the project has commenced the intervenor must monitor the tendency of the situation to deteriorate and thus risk failure to achieve the originally specified strategic objectives.

The intervenor must use dynamic risk indicators in conjunction with static risk indicators for this function.

A number of dynamic risk indicators exist and will vary for the different types of development projects. The project is considered to essentially consist of flows of data and knowledge. A hardware item is covered by this definition since if it has not been defined in the project documentation then, as far as the project is formally concerned, it does not exist. Behavioural aspects are covered by knowledge flows; for example trajectory and project support aspects. When these data and knowledge flows are generally of a constant nature or velocity then conditions can be said to be relatively steady.
If the flow rates increase, accelerate, then there is a possibility for the onset of turbulence with the attendant increase of risk.

The intervenor is thus concerned with identifying those flows which could be measured and which could be used as dynamic risk indicators.
This research has identified a number of such indicators and they are listed below:

a) the frequency of meetings on specific subjects;

b) the rate by which parametric margins are used;

c) the rate by which financial reserves are used;

d) the rate at which schedule slack is used;

e) the rate by which invoices are submitted late to the payments authority.

It is shown, in annex 8 and figs.7 through 24A in chapter 5.2.5, that the frequency of meetings per subject indicates the dynamics of the situation and, with knowledge of the technical and contractual links and interfaces, interactive or bifurcative deteriorations can be assessed.

The model thus requires that different data and knowledge sets are submitted to the intervenors, at all levels, such that the frequency of meetings can be charted.

Hence the initial project conditions and the real time dynamics can be used to continuously assess the likelihood of the onset of turbulent conditions and the consequent departure from the strategic objectives.

Chapter 8. SUMMARY and CONCLUSIONS(DRAFT/15 Aug.1994)

8.1 Summary

8.1.1 General

The background to this research is the large number of development projects which have significantly exceeded their originally predicted budgets and schedules; even though specific and expert monitoring organisations have been established which have carried out extensive bid evaluations, programme reviews, and continuous "watch-dog" activities during the running of these projects.

This research, which was prompted by the above conundrum, commenced with the postulate that the future is unpredictable and converged to investigating whether intervention in development projects could ameliorate the risk, failure, and loss situations, both at the project and corporate levels, and if so what form it should take.

It became necessary in the research thus initiated to address the integrated deterministic and behaviouralistic aspects of organisations and to try to define a management system which would enable the dynamics of complex project situations to be pragmatically examined; and controlled on the basis of minimising the risk of schedule and cost overruns.

Following a bibliographical review of approximately two hundred references, it became apparent that classical methods which often assumed linear, and predictable, relationships between the dynamic elements in a project were not appropriate.
The only sector of knowledge that seemed to encompass the complex situations being examined, without making assumptions which were unacceptable in this research, was the relatively new "science of chaos"(152,153). The analogues that have been constructed in this research to represent, in a simplistic fashion, the project scenarios have drawn from the theory of chaos.

The conclusions which have finally been derived involve the use of dynamic and static risk indicators, the identification of open and closed loop systems, the need to establish a negative entropy situation as the project advances, and the understanding and utilisation of a number of patterns relating to the dynamic evolution and propagation of problems.

The dynamic risk indicators may be likened to the meteorological practise of "taking soundings" to determine what is actually happening in a complex storm front.
Hence the dynamic risk indicators have been based on, for example, the frequency with which certain problems or issues have been discussed at the various contractor levels

in an industrial project consortium; the latter typically consisting of eighty or more companies.

The concept of open loops is based on the fact that the outcome of many project tasks is not known, a priori, and cannot be predicted. An example is a qualification test which may result in complete failure of the article under test or design modifications that will require additional, unpredictable, time and resources.
This research has established that such events must be identified as critical and the currently used project(schedule) control systems modified accordingly. The open loop concept is shown in figure 41.

As the project advances its complexity usually increases with a high magnitude. It is essential that the initial state of order of the project is maintained even with the increasing complexity in order to preserve the characteristics of an open system. This is only possible if, locally, the entropy decreases since if it does not then increasing randomness will result per the third law of thermodynamics. The local decrease is possible, without violating the third law, since at the general or system level the entropy must still increase. This point relates to the research by requiring that information inputs to the project must be of the right type, at the right time, and to personnel who have the immediate ability to use the information; both deterministic(hard) and behavioural(soft) aspects are involved.

In conjunction with the risk indicators the research has identified four main types of patterns that exist in project environments and which must be used by the intervenor and project management, as relevant.

The four patterns are:

- pattern 1: the increase of the density and of peaks of the dynamic risk indicator "frequency of meetings" variable when plotted 3-dimensionally, with respect to "critical items" and "project time scale" on the other two axes.(see figure 43).

- pattern 2: the continuation, evolution and impact of certain problems throughout the project life cycle;

- pattern 3: the characteristics of the reduction of turbulence due to customer intervention by either increasing resources, increasing expertise available, agreeing schedule delays or cost overruns

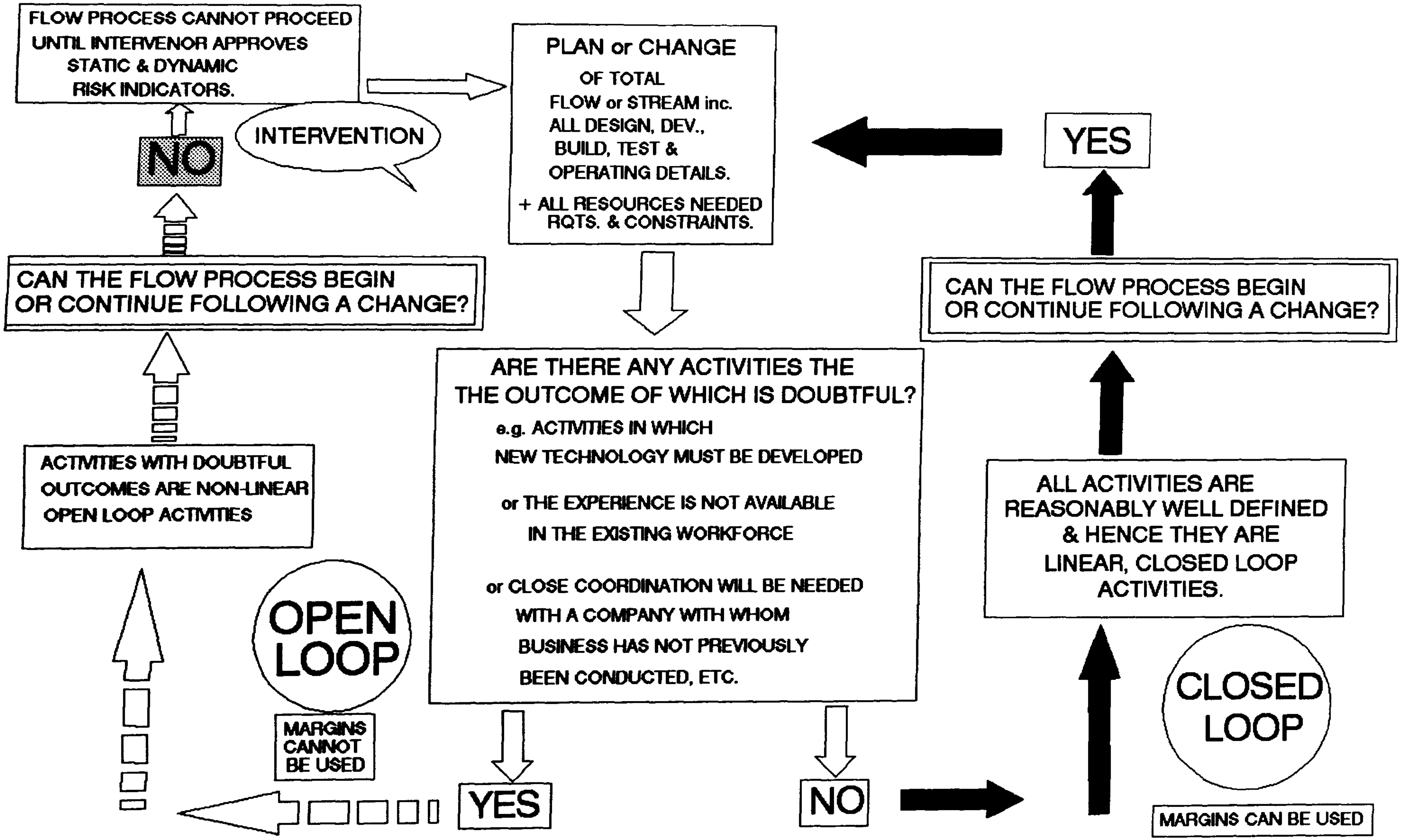
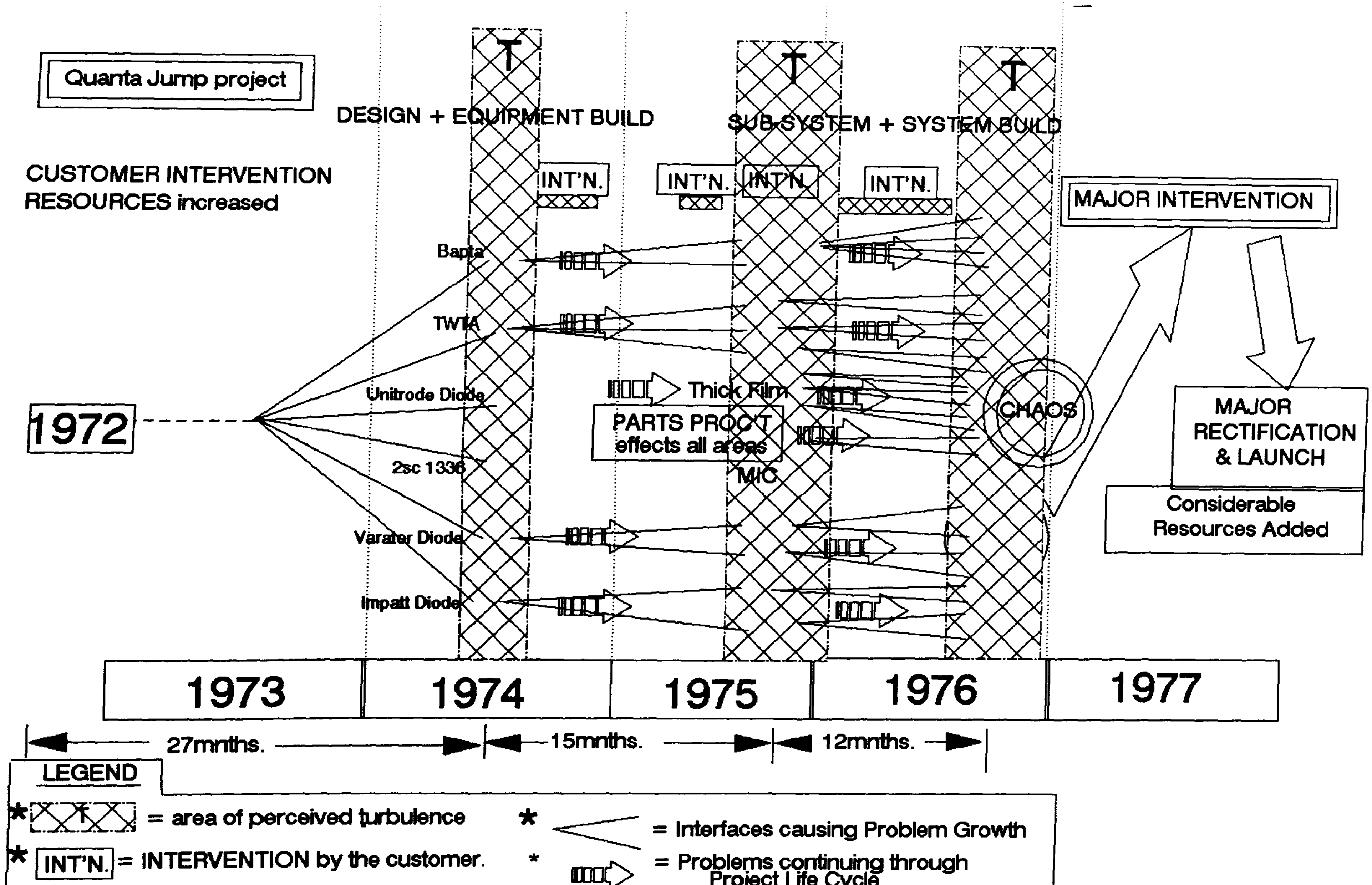


Fig.41: MODEL of OPEN and CLOSED LOOPS.



ACTUAL GROWTH of PROBLEM CONSEQUENCES due to INCREASE in NUMBER of INTERFACES as VEHICLE BUILD moves from TECHNOLOGY through EQUIPMENT & SUB-SYSTEM to SYSTEM LEVEL.

Fig.42 PROJECT "A"

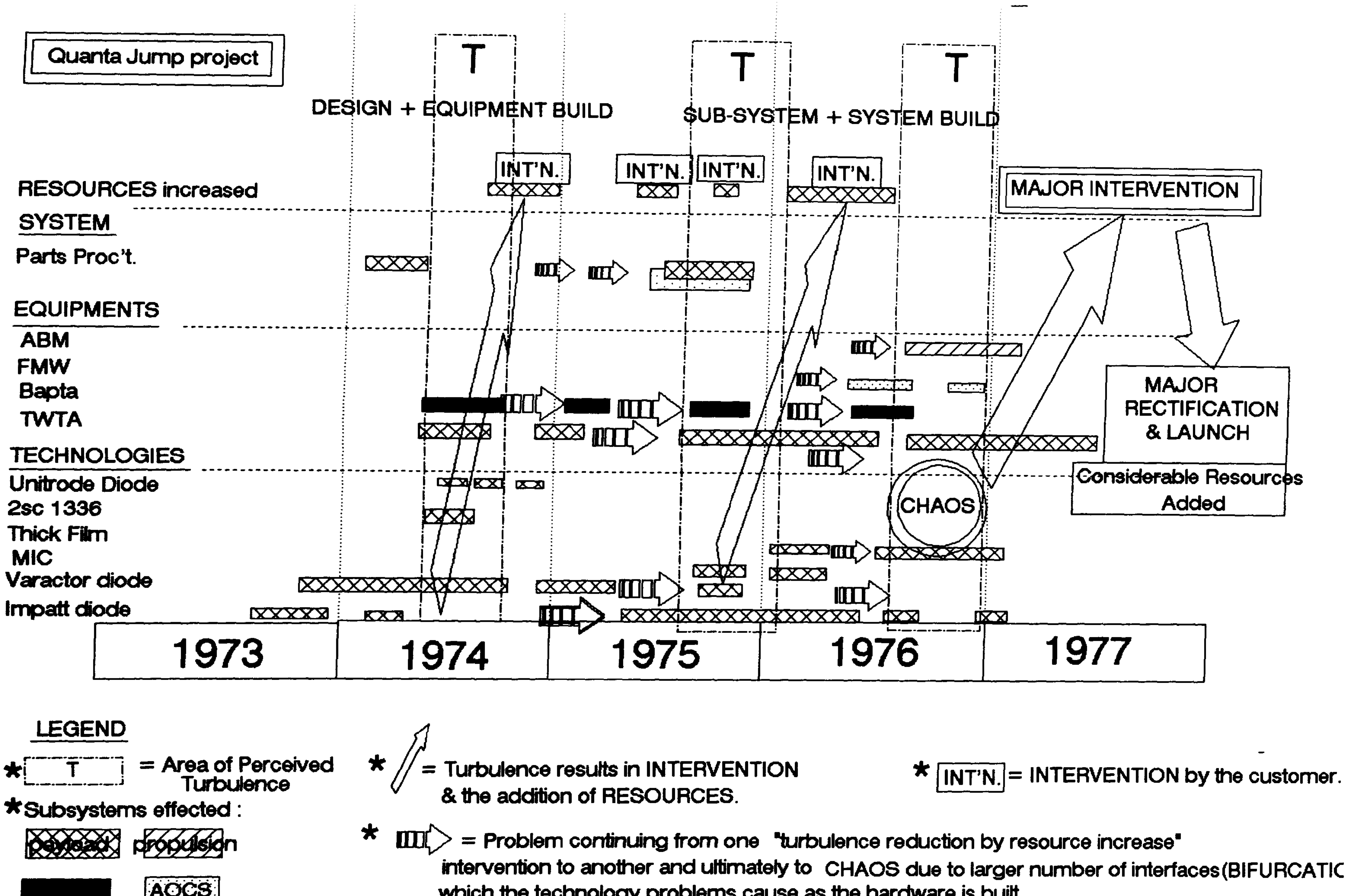


Fig.43 PROJECT "A" AREAS/DURATIONS/INTERACTIONS and TURBULENCE/CHAOS of MAJOR PROBLEMS

and in tacitly accepting risk sharing;

- pattern 4: the structure of the growth of problems producing a progressive splitting, or bifurcation, of the flows involved in the overall route of the project business.

Finally a method has been developed, termed the Dynamic Risk Management method, to enable a company to implement the results of this research. It embodies an "Intervenor" role with specific responsibilities and authorities at the project and corporate levels.

The above points will now be addressed in more detail under the following headings:

- complex projects;
- project turbulence;
- problem propagation;
- project chaos;
- the Dynamic Risk Management Method(DRMM);
- application of the DRMM;
- advantages of using the DRMM.

8.1.2 Complex Projects.

This research has basically addressed development projects which are characterised by the simultaneous interaction of a number of deterministic and behaviouralistic aspects. These interactions, due to their multiplicity and quantitative and qualitative nature, create other interactions which are not pre-determinate and which increase with time. The projects are thus, by definition, complex(104, 62).
Examples of deterministic aspects are quantitative technical and contractual requirements, costs per hour or per product, and schedule milestones.
Examples of behaviouralistic aspects are qualitative technical and contractual requirements since they require subjective judgement for their assessment, cultural and personality attributes, and educational and political biases.

The main characteristics of complex projects are that they are unpredictable and dynamic, with periods of great volatility; these aspects being the fundamental reasons why conventional project management methods are inadequate.

Conventional project management is essentially based on the following rather limited techniques:

- static snapshots of the overall project status which are usually:

    - obsolete when presented due to the length of time required to prepare them, and

    - inaccurate due to contractor "screening" of information before issue of the related reports at the various contractual levels;(see figure 53).

- status reports, and projections, of resource, cost and time expenditures versus performance and achievements in which the various functions are presented separately;

- schedule management prioritising on time-to-complete rather than an identification of "open loop" situations due to the unpredictability of the results of critical tasks;

- a lack of lessons learned feedback to minimize repetition of previous, and current, mistakes;

- dictatorial "egoistic" project managers who make many decisions based on "gut feeling" and the inputs from a few close colleagues, rather than being accountable within an established system with agreed criteria and roles; and,

- significant transgression of contractor and customer roles by the customer and higher tier contractors thus reducing the effectiveness of contractual penalties and jeopardising project and corporate strategic objectives.

8.1.3 Project Turbulence.

To investigate the dynamic aspects of complex projects four ESA development projects were examined in detail with respect to problems which had caused schedule delays and/or increased resource and cost utilisation; an examination of major decisions was involved in this investigation.
The objective of this investigation was also to expose, and hopefully identify means of rectification of, the problems of conventional project management methods.
In order to address the overall project dynamics it was necessary to identify attributes which contained accurate information of the actual project dynamics and which could be used in as near as possible a real-time mode.
The attribute finally chosen was:

" the number of times a particular issue was discussed at meetings at the various contractual levels".

Depending on the contractual level, from the lowest sub-contractor through the co-contractors to the prime contractor, then the number of times an issue was discussed was artificially increased, according to an arbitrary scale, to indicate that the issue was considered more serious as the contractor level increased.

For each of the four projects between 10 and 20 major problems were identified and the attributes relating to those problems plotted as points on two dimensional presentaion and as graphs on a three dimensional plot. examples of these plots, for project A, are shown as figures 42 and 43.
A total of over 2000 data points were plotted for the four projects.

Examination of the above figures indicates a disorderly picture of both clustering, in time, and height of peaks of the plotted attributes.
The general characteristic is of a "turbulent" nature with no obvious linearities or relationships being present.

This presentation of turbulent flows, with time, initiated the formulation of a general hypothesis concerning what actually happens to the various attributes in a complex project.
It was also considered necessary to write down a number of postulates which formed the basis of what we know, or assume, to be truisms of the project management scenario. The hypothesis and postulates are contained in the next section.

In addition to the detailed examination of the four ESA projects a number of customer and contractor managers and directors were interviewed to obtain subjective judgements of the value of conventional management techniques and how they actually operated with respect to information inputs and decision making.

From these interviews it was clear that project managers relied on a few colleagues as their main technical and administrative "project supports". It also became clear that cost and technical data were rarely presented in a truly integrated format and the concepts of risk indicators and open loops did not exist.

The analysis of the total data collected during this research also showed that systems for learning from the problems of previous projects are sparse. It also showed that although there was an awareness that certain problems could assume very damaging trajectories which would traverse the entire project life cycle, the usual action was to "throw money and resources" at the problem in the hope of an early solution with little regard for the longer term or strategic impact.

These aspects provoked the onset of turbulence and the escalation from turbulence to chaos.

8.1.4 Problem Propagation.

8.1.4.1 The Hypothesis

The following hypothesis, which has been validated in the thesis, outlines the definition and functioning of a complex project with an emphsis on the manner in which problems commence and propagate.

HYPOTHESIS:

" A development project, which is a complex, open system, commences from a **perceived steady state**, equilibrium condition. The planning representation of this condition, as used typically in industry, consists of a number of interfacing **static** diagrams. Strategic objectives are shown to be achievable within stated cost and schedule constraints; with **margins** in the technical domain and **reserves** in the cost area. An essentially **closed loop** situation is thus assumed as reflected by the majority of contracts being fixed price. Even the cost reimbursement and cost plus contracts have a maximum ceiling price so nothing is really considered to be open loop. As activity increases, the steady state is upset by problems which occur, **unpredictably**, here and there; their origins are primarily within, but some are external to, the project authority and responsibility boundaries. An interplay of **hard** and **soft** aspects exists within these scenarios. Due to the multiple, complex, and many common, interfaces, and the different **perceptions** by the involved parties, the problems generate other problems in a dynamic but still unpredictable fashion. The steady state condition thus becomes non-linear and many **open loop** situations begin to cause major deviations from the planned utilisation of resources.

Without **risk indicators** and **intervention** the project objectives will become increasingly vulnerable to the proliferation of problems; with resources being used in a fire-fighting mode but the basic causes of the problems will remain obscure. The time and resources required to achieve the strategic objectives are not then definable nor predictable; the project is going out of control and constitutes an increasing risk element. The above "perceived" increasingly unstable evolution is analogous to a flow condition moving from **steady state** to a state of **turbulence** and ultimately to a state of **chaos**, as the flow rate is increased.

The inter-state movement takes place due to **bifurcations** which increasingly multiply if their reactions are allowed to proceed unhindered.

As an example, it is sometimes the case that a single problem at a low technical, functional, level can effect the entire project.

The **high risk consequences** can be avoided if the bifurcation patterns, involving both hard and soft aspects, can be continuously identified; thus permitting restriction of excursions to the turbulent and chaotic states by utilising risk indicators and intervention. This constitutes the role of intervention in strategic change"

8.1.4.2 The Postulates

The following postulates are considered to be truisms that apply to the management of complex projects and are thus considered as not requiring proof or validation.

POSTULATE 1: The degree by which the reliability and safety and hazard analyses are not concurrently used in the design process needs to be represented by a risk indicator.

POSTULATE 2: Soft aspects can constitute major potential risk generators and must be assigned risk indicators.

POSTULATE 3: The terminology generalisations progressively being used are considered to be significant contributors to the difficulties concerning the definition and control of risk.

POSTULATE 4: The use of technology which has been developed in well defined, and traceable, incrementally advancing steps would avoid the inherent risk of the "quantum jump" approach.

POSTULATE 5: The failure to identify, and the lack of proper definition of, embedded research, in development programmes is a major risk contribution.

POSTULATE 6: The outputs of "failure mode and hazard analyses" constitute risk indicators.

POSTULATE 7: The non-utilisation, or utilisation in a non-timely manner, of failure mode & hazard analyses can be the cause of major risk.

POSTULATE 8: the definition and implementation of a "ranking" system for critical items would enable them to be used effectively as risk indicators.

POSTULATE 9: A properly structured problem definition system requiring intervention when problem consequences reach a certain, a-priori defined, magnitude would enable risk profiles to be defined; and, with additional measures, to be controlled.

POSTULATE 10: The ability of the panel members and panels chairmen to become familiar with the review material is critical to defining programme risk.

POSTULATE 11: An assessment of the risk involved in the progressive loss of the vehicle performance would enable a better cost/ schedule optimisation during the design and operational phases and more realistic risk management to be implemented.

POSTULATE 12: If the total resources are calculated on the basis of producing parametric performance(inc. the associated margins) and similar relationships are established relating to performance and profit (including incentive/ penalty effects) then the parametric margins could be used as risk indicators. It should be noted that the "resources/ parameter calculation" would involve ALL contributing activities to the achievement of the performance e.g. design, qualification, testing, etc.; hard and soft aspects and the interactive effects of different margins would also have to be included.

POSTULATE 13: If the strategic plans of the product user community and the technology developers are monitored by the related corporate management

AND,

the project is designed for technology insertion, and a wide range of possible applications of the product are kept open as long as possible

AND,

the "project supports"(see section 7.6) are established and maintained for the project life cycle,

THEN,

risk in this area would be minimised.

POSTULATE 14: If political and economic trends, at the macro level, are monitored and utilised in the compilation and update of Space strategic plans then overall risk will be reduced.

POSTULATE 15: The absence of the opportunity to exercise direct executive authority, on the project, by an intervenor using the design review board recommendations is considered to seriously diminish the effectiveness of the design review.

POSTULATE 16: The characteristics of the reactions of a company or a project are analogous to those of human being(s); some correlation exists with equivalent phases of their respective life cycles."

POSTULATE 17: The primary strategic decision making processes in companies and projects involves exchange of significant information, often in an informal mode, between the executive core elements of companies.

POSTULATE 18: All interventions can be defined as being: direct or indirect.

POSTULATE 19: The significance of the environment to the company/ project is due to its, the companies, perception of the environment as consisting only of intentions and interventions.

POSTULATE 20: A strategic change occurs when, in the absence of an intervention the continuing application of a positive feedback control mechanism fails to maintain the strategically predicted growth.

POSTULATE 21: Unrealistic perceptions, and consequent implementation and intervention, will produce an unpredictable effect on the situation. Realistic perception will produce a predictable effect. The former will tend to instability, waste, randomness; the latter to equilibrium, efficiency and growth.

POSTULATE 22: Intervention re-establishes realistic perception i.e. to define the characteristics of an intervention, negative feedback must be applied until positive feedback can maintain growth to achieve the objectives.

POSTULATE 23: OBSERVATION is a function of:

focus

visibility

view angle

scan rate.etc.

POSTULATE 24: The observed or sensed information is subjected to processing within the perceivers reference frame in order to produce perceived information. The reference frame contains hard and soft references. Examples of the former are company and national laws; examples of the latter are retained knowledge, educated techniques, beliefs, morals, intelligence.

POSTULATE 25: Reference frames constantly change.

POSTULATE 26: All reference frames tend to be different; to some degree.

POSTULATE 27: Reference frames can be biased, skewed, forced or constrained to produce perceived information with certain predominating characteristics; e.g. fear, objectives, reward, penalties can provide such bias.

POSTULATE 28: Organisation are dynamic to varying degrees and consist only of open and closed loop systems.

8.1.5 Project Chaos

Even a cursory examination of the the variables and forces which exist in a large industrial development project creates the impression of a myriad of "things that can go wrong"; many of which, it would seem, could seriously reduce the prospect of the project being successfully concluded. It is also clear, even from this brief inspection, that many of the elements are unpredictable and are likely to occur in an apparently random fashion.

The science of chaos attempts to deal with just such imponderables. It has established that situations which appear to be completely random may in fact not be random but may possess an underlying pattern or shape. This latter condition is termed chaos. Chaos can be thought of as pulling apparently random data into visible shapes whereas truly random data remains spread out in an undefined mess. Hiding within a particular chaotic system could be more than one stable solution.
A chaotic system can be locally unpredictable but globally stable. Changing one parameter can cause a system to move from steady state to a point where this equilibrium condition splits in two; these bifurcations then become faster and faster and cause the system to become turbulent

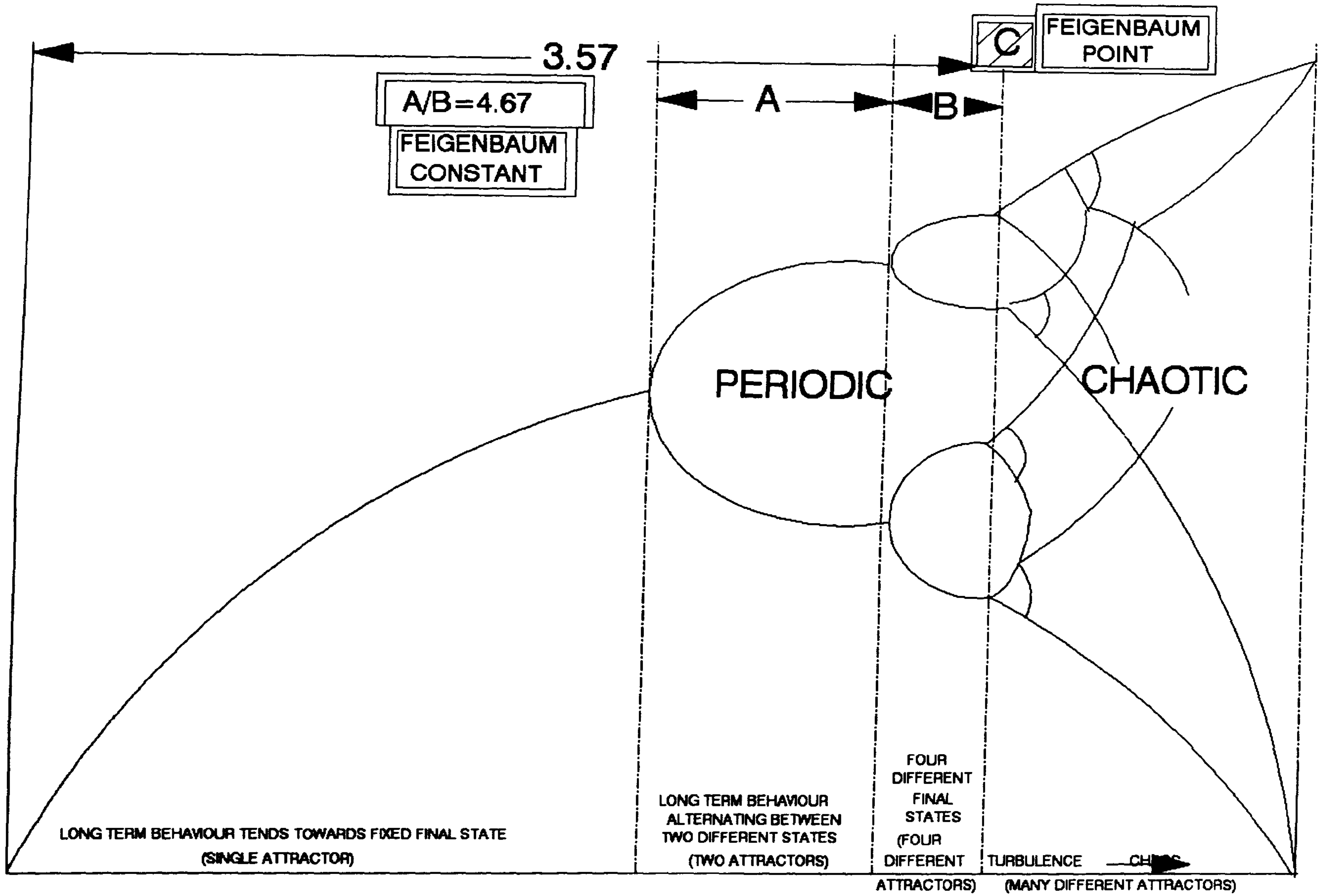
and eventually chaotic. This "bifurcation" phenomenon was discovered by the American physicist, Mitchel Feigenbaum, to obey certain universal laws under particular conditions; these are represented by the so-called Feigenbaum diagram.(153). (see figure 44).

The above aspects of the theories of chaos seem to fit the project scenarios very well and have been used in this research.

Following the realisation that classical concepts were inappropriate for this research it was decided to commence the research at the basic element involved in the whole business i.e. man.
More specifically the functioning of the human brain was used as the starting point and then extrapolated to projects and organisations as the inter-functioning of a number of human brains.
The latest theories of the functioning of the human brain are based on it processing data according to the theory of chaos(93, 140).
The brain functions as a self organising, open system, and selects from inputs of chaotic data based on experiential criteria. However the brain will prioritise on survival factors even to the extent of distorting inputs and will always endeavour to "fit" an input with what exists in its experiential knowledge base, even if the "fit" is rather obscure or even totally incorrect in absolute terms, e,g, UFOs are "flying" "saucers". (63,93,97,153,).

The assessment of the functioning of organisations in terms of the interactions of "brains" which function as mentioned above has been used in constructing the behaviouralistic aspects of the Dynamic Risk Management Method which is outlined in chapter 8.1.6.

From the detailed analysis of the four ESA projects, covering the past twenty years, it has been found that steady state, turbulent and chaotic periods exist per project and that the trans-periodic excursions can be initiated via bifurcations of the project "data and knowledge streams" or "flows".
Symbolic representations of these bifurcation processes, based on the Feigenbaum Diagram concept, and covering the development of technology and systems are shown in figures 44 through 49.
These bifurcation relationships constitute an important pattern for the understanding and control, or minimization, of the development of turbulence and chaos in a project. In the thesis a connection has been established with the latest research work on decision making and the initiation and generation of problems.(197 through 203, 208,211,212, 220, 221).
Figures 50 and 51 show how the bifurcations have occured on an actual project at various stages during the project life cycle and the corresponding development of turbulence and



NO INTERVENTION

Note: This is a symbolic presentation not a graphical plot.

FIG.44: CHARACTERISTICS of the FEIGENBAUM DIAGRAM

Note: This is a symbolic representation; y-axis has no scale.

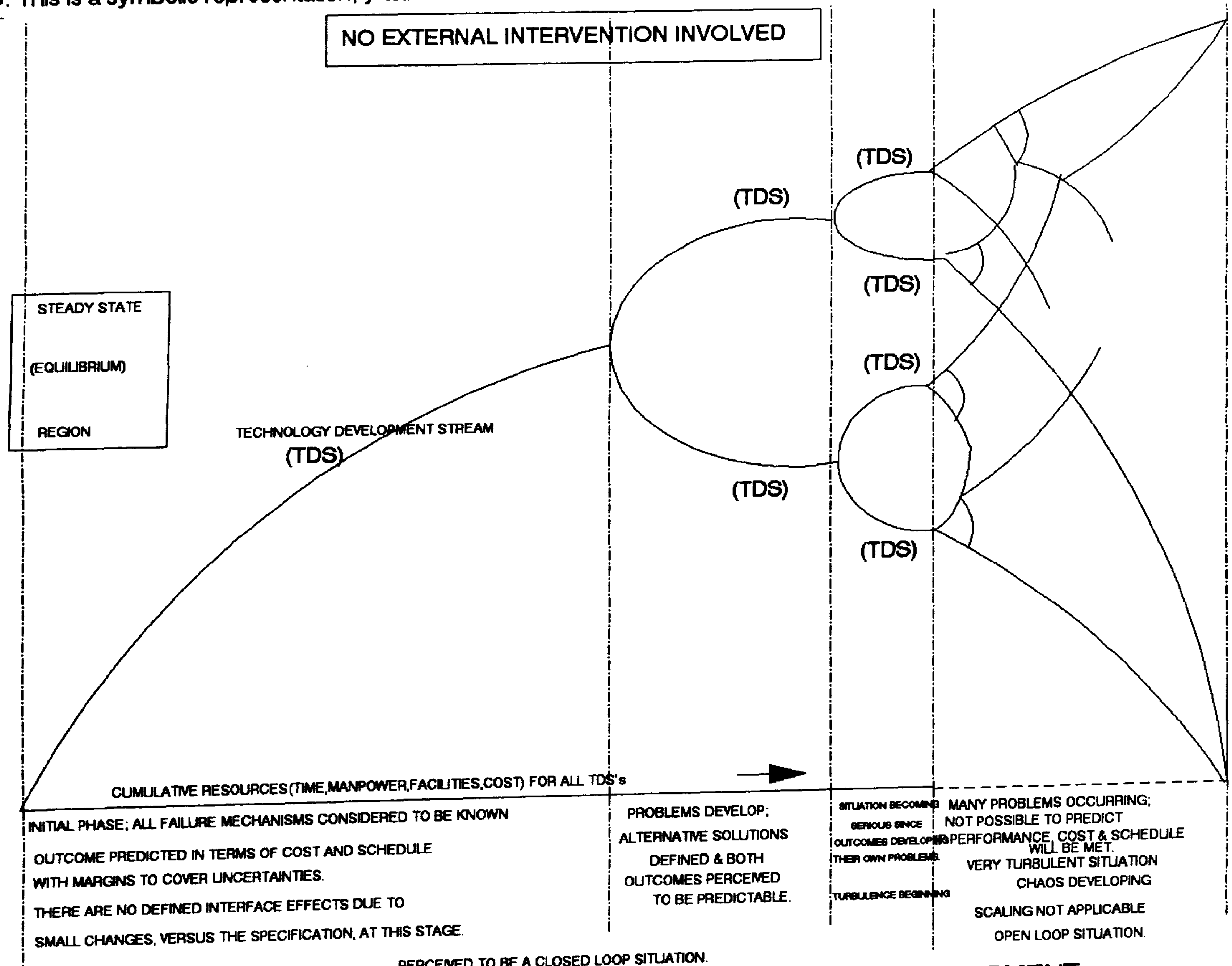


Fig.45: PROBLEM PROPAGATION APPLIED to TECHNOLOGY DEVELOPMENT

Note: This is a symbolic representation; y-axis has no scale.

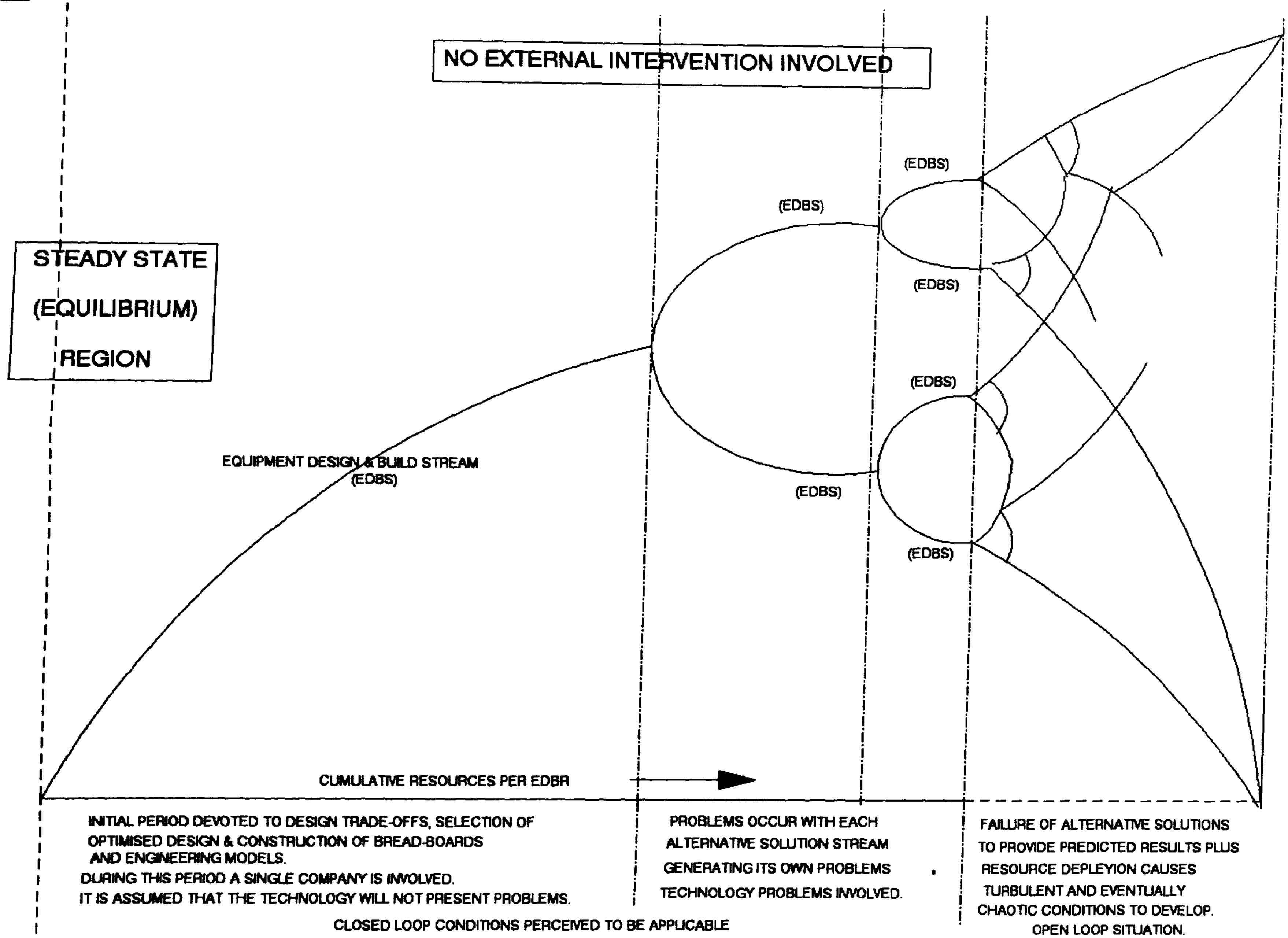


Fig.46: PROBLEM PROPAGATION APPLIED to EQUIPMENT DEVELOPMENT

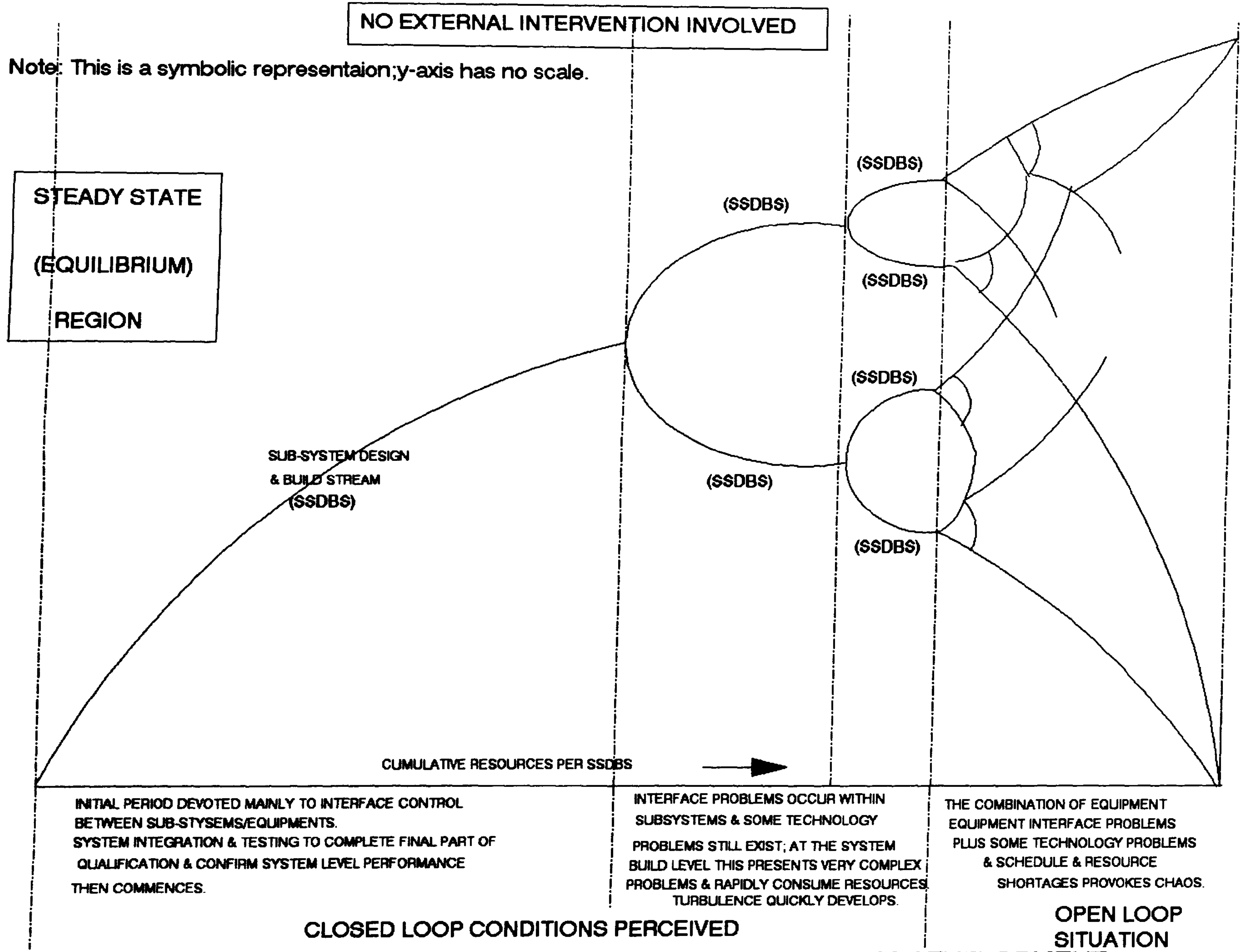


Fig.47: PROBLEM PROPAGATION APPLIED to SUB-SYSTEM DEVELOPMENT

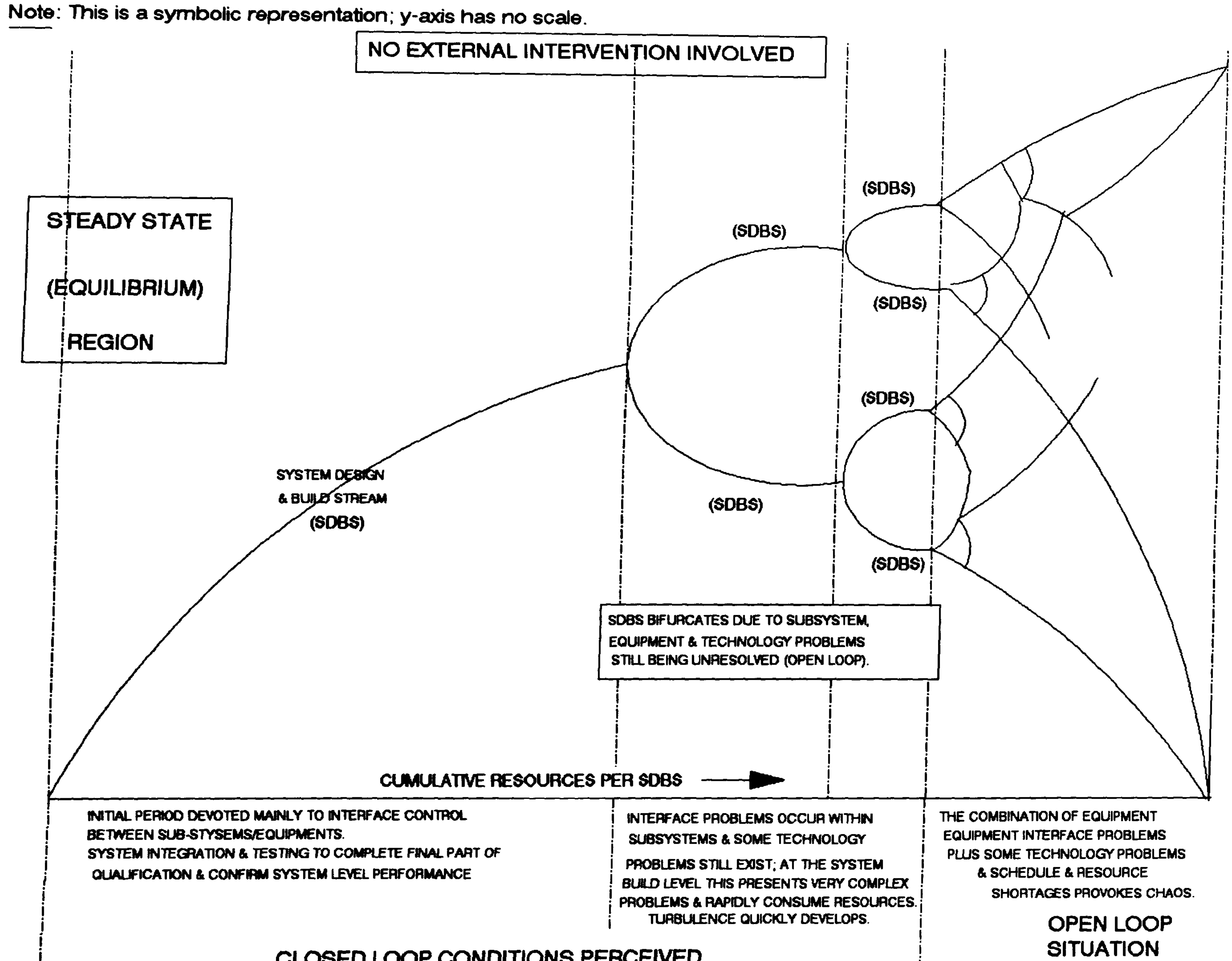


Fig.48: PROBLEM PROPAGATION APPLIED to SYSTEM DEVELOPMENT

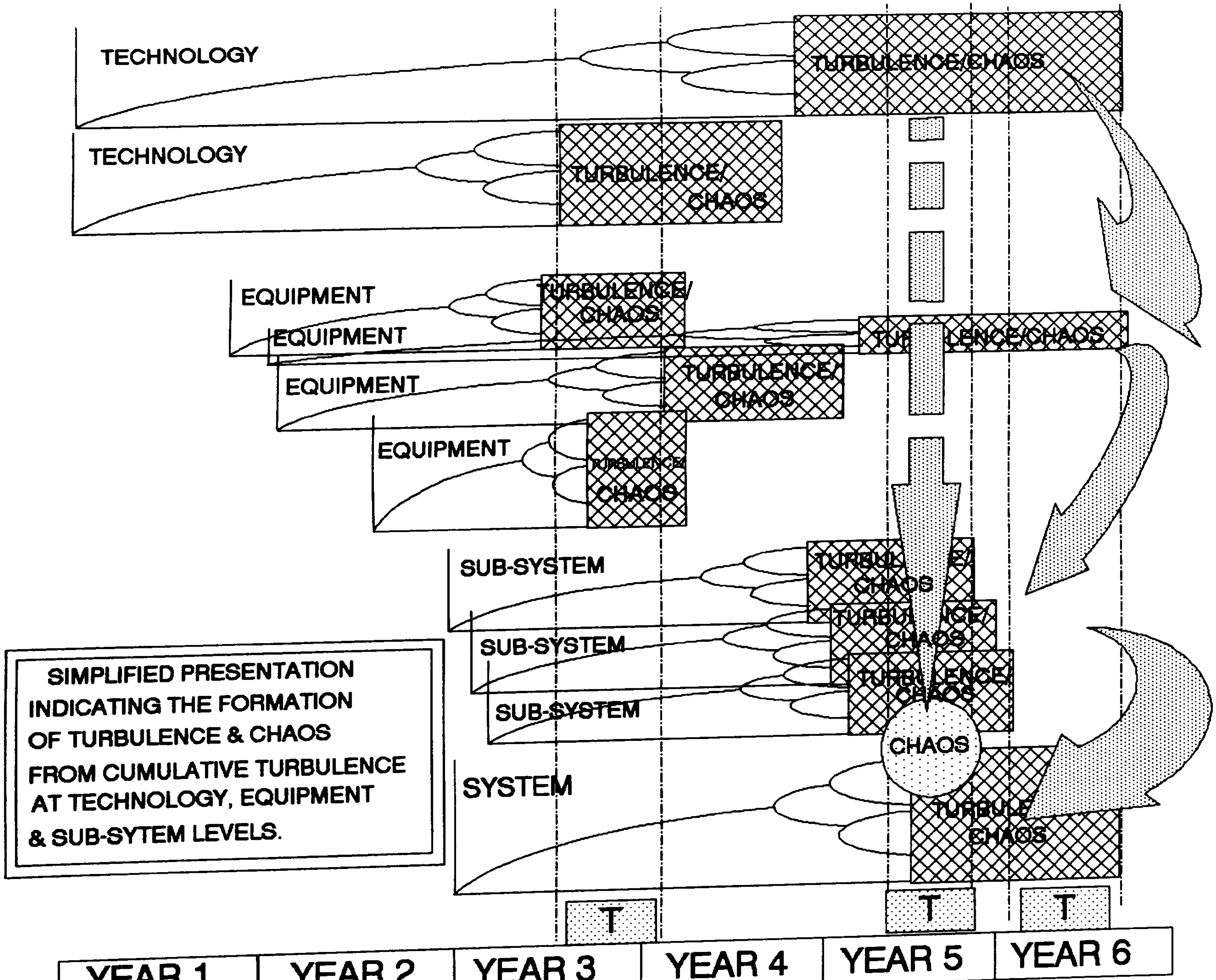


Fig.49: PROBLEM PROPAGATION DIAGRAMS APPLIED to PROJECT LIFE CYCLE

chaos. Figure 52 contains information of the specific technical problems which "bifurcated" and also the interventions by the customer in order to increase resources, or schedule, to return the project to a (quasi-) steady state.

8.1.6 The Dynamic Risk Management Method(DRMM)

From the analysis of data and knowledge collected during this research the DRMM has been defined. The DRMM requires the presence of an "intervenor" in the overall project-company corporate infra-structure with specifically defined reporting and decision making responsibilities with respect to both the project manager and the company corporate director(s).
The fundamental objective of the DRMM is to identify and control those dynamic entities that could cause the project to move from steady state to turbulence. The prevention of such excursions should minimize the cost and schedule overruns and enable a more realistic assessment of the impact of changing strategic issues. This objective is achieved by ensuring that relatively accurate data on all critical problems is available in almost real time to the appropriate management authorities, see figure 53; under the watchful eye of an active and authoritative ombudsman type intervenor who is indigenous to both the project and corporate organisations.

A major outcome from this research is the creation of static and dynamic risk indicators; they are briefly defined as follows. An example of a risk indicator in a spacecraft functions tree is shown in figure 54.
Dynamic risk indicators must give information of the actual dynamics of the various variables which are operating within the project. Their selection requires expert knowledge of the particular project subject matter concerned and they must be continually monitored by the project manager and the intervenor during the project life cycle. It is also concluded that when all open loops are identified prior to the start of a contract they can be compared with the actual open loop situation which develops as the project proceeds and rectification action can then be optimised across the whole system. This would avoid the "fire-fighting" management tactics so often practised at this time.

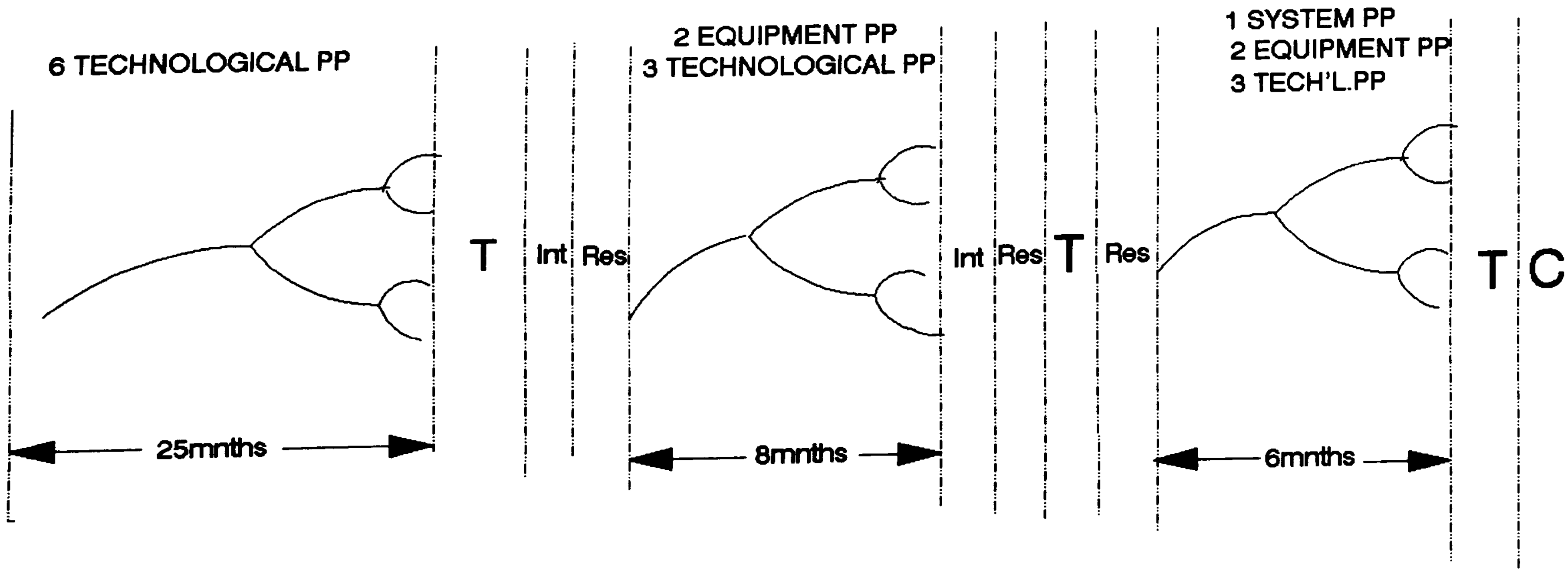
Examples of such dynamic risk indicators are:

- the **frequencies** of meetings on particular subjects;

- the **rate** by which parametric margins and financial reserves are used;

- the **rate** by which schedule slack is used;

- the **rate and trend** of the lateness of arrival of



LEGEND:

T = TURBULENCE. Res = RESOURCES ADDED(BY CUSTOMER).

Int = INTERVENTION. C = CHAOS.

mnths = months of project life cycle. PP = Problem Propagation paths.

Fig.50: Project A; PROBLEM PROPAGATION SIMULATION.

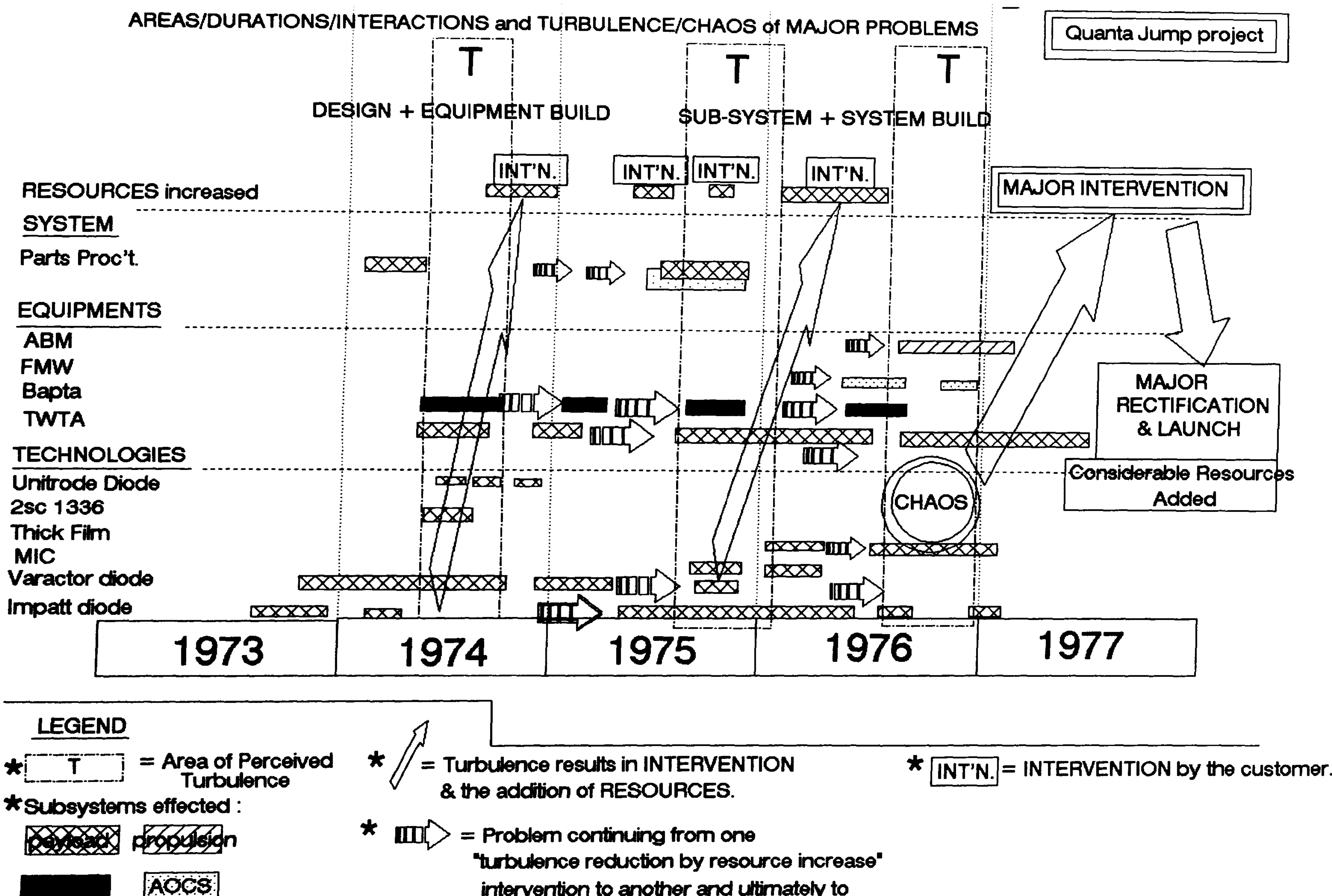


Fig.51 PROJECT "A"

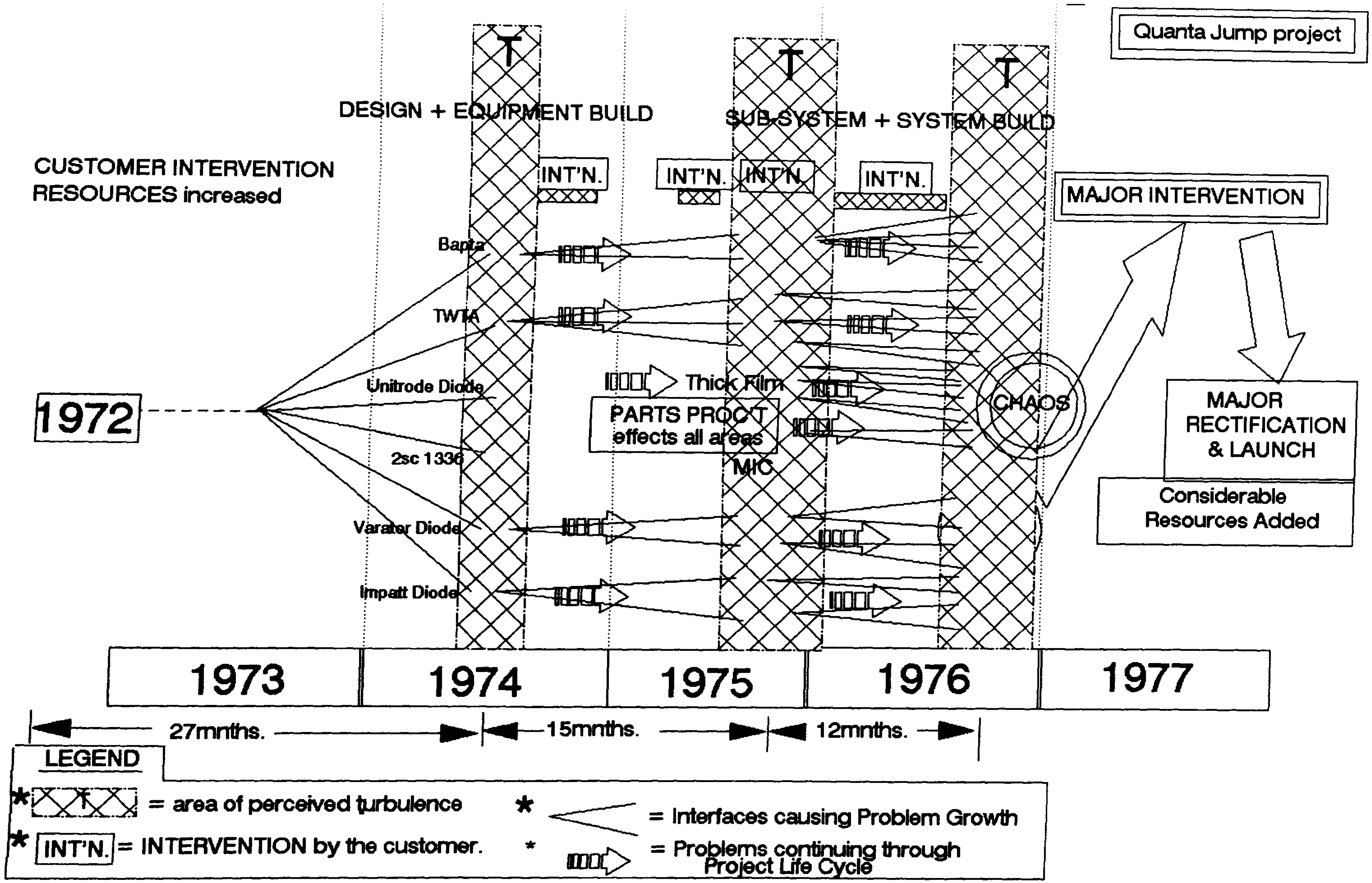
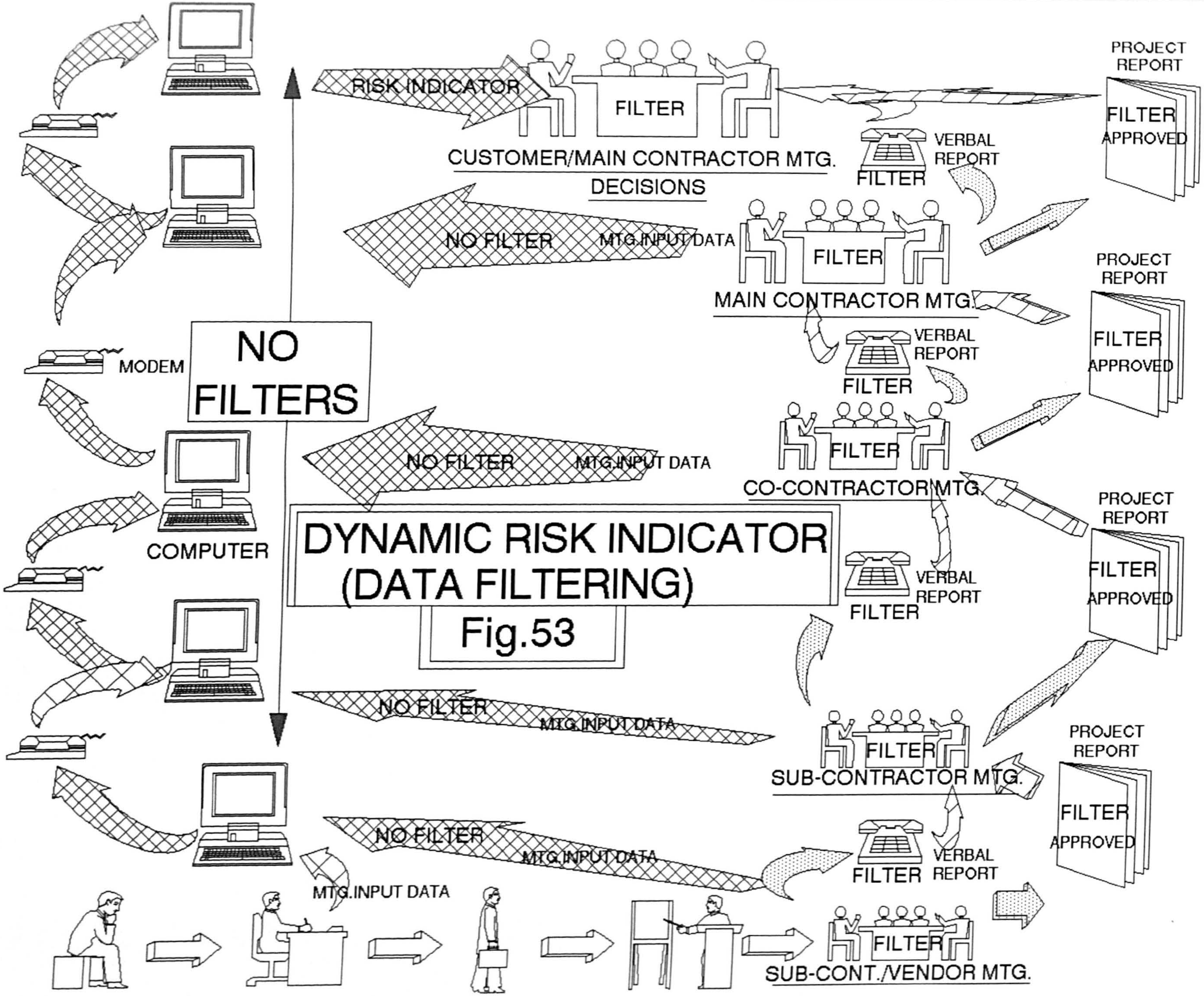


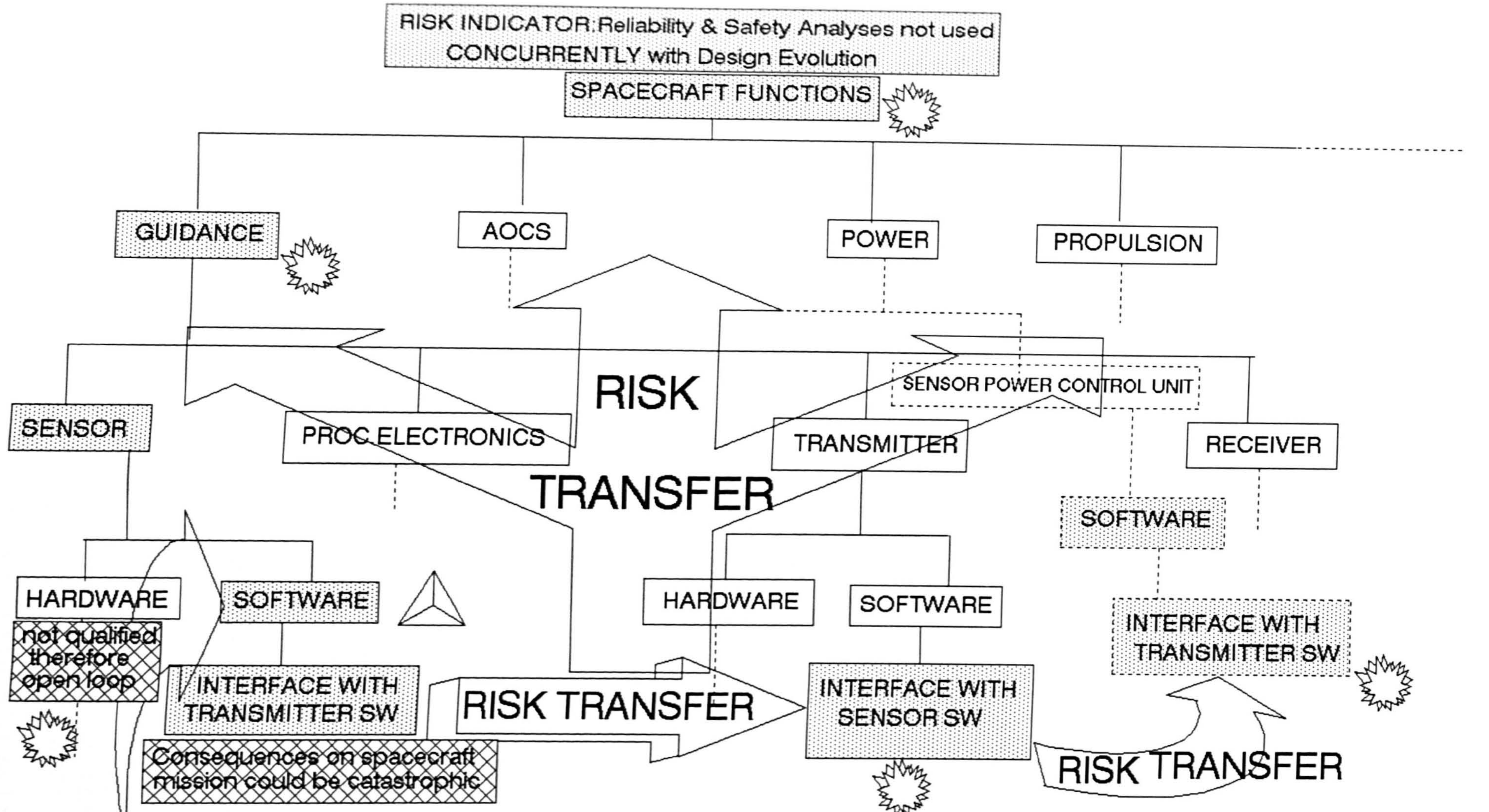
Fig.52 PROJECT "A"

ACTUAL GROWTH of PROBLEM CONSEQUENCES due to INCREASE in NUMBER of INTERFACES as VEHICLE BUILD moves from TECHNOLOGY through EQUIPMENT & SUB-SYSTEM to SYSTEM LEVEL.



DYNAMIC RISK INDICATOR (DATA FILTERING)

Fig.53



RISK INDICATOR NODE; hardware open loop already exists. The Software Design is proceeding without R & S analysis

The result is VERTICAL & LATERAL RISK TRANSFER thus placing many subsystems & probably the system at risk; open loops ( ) are thus being CREATED

Fig.54 EXAMPLE OF RISK INDICATOR in SPACECRAFT FUNCTIONS TREE

invoices, for payment, at the customer.

Static risk indicators are composed of data giving snapshots of the dynamic project conditions. They are limited in usefulness because they are usually obsolete before issued, because the compilation time tends to be disproportionately long.They also usually contain data which is inconsistent; either in extent, accuracy, currency, detail or objectiveness.

Examples of static risk indicators are;

- standard CPM schedule charts;

- project status reports;

- design,qualification and test review proceedings and reports;

- trend analyses.

An overview of the DRMM is shown in figure 55; the DRMM itself is defined in figures 56 through 62.

The Method focuses primarily on the following aspects:

1) the agreement of a statement of the projects mission and acceptable project risk, by the customer and contractor;

2) cost, resources and performance data being presented and monitored in an integrated fashion;

3) evaluation of the project documentation and plans, at project commencement and during the project life cycle, in such a way that open loop and negative entropy situations and static and dynamic risk indicators can be defined;

4) characterisation of key project personnel for perceptual bias;

5) identification of hard and soft aspects;

6) definition of the role of intervention utilizing the four patterns that have been identified during this research.

8.1.7 Application of the Dynamic Risk Management Method(DRMM).

It is very important that the DRMM is applied at the commencement of a project i.e at the initial conceptual phase and that, at that time, the role of the intervenor is fully understood and agreed, and the dynamic and static risk indicators identified.
The application of the DRMM represents a cultural change

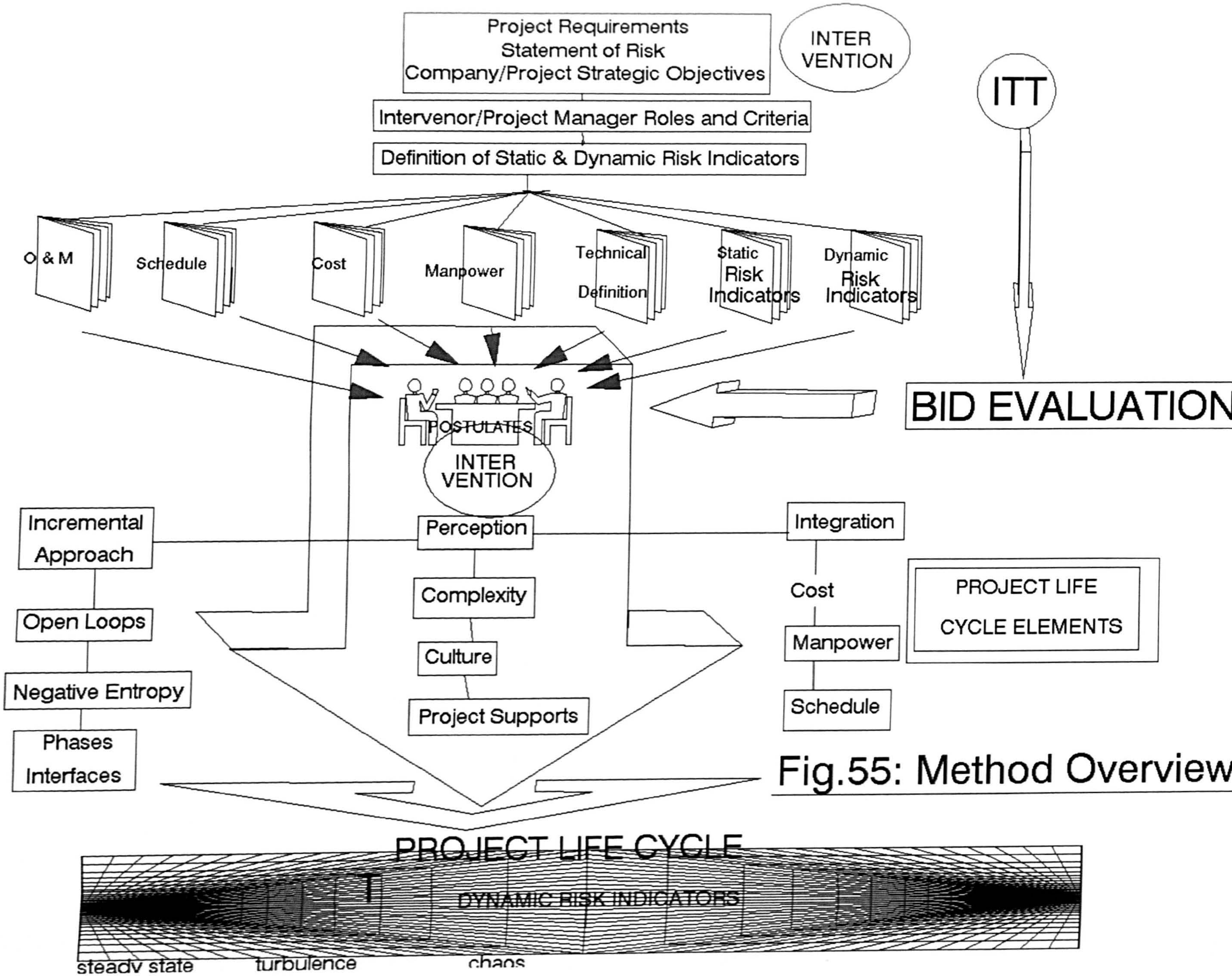


Fig.55: Method Overview.

KEY: #7.2, for example, refers to applicable sections in the text.

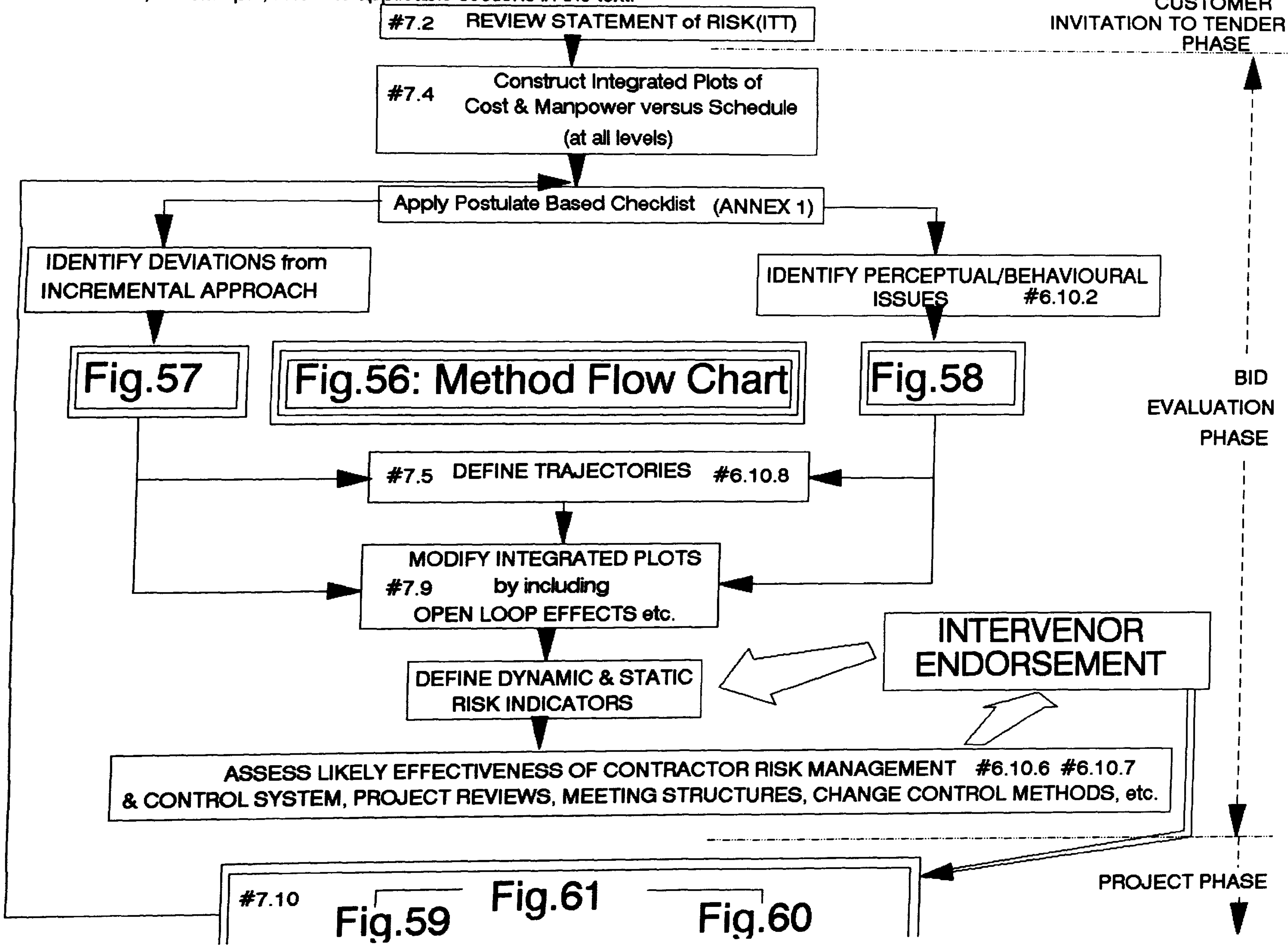


Fig.56: Method Flow Chart

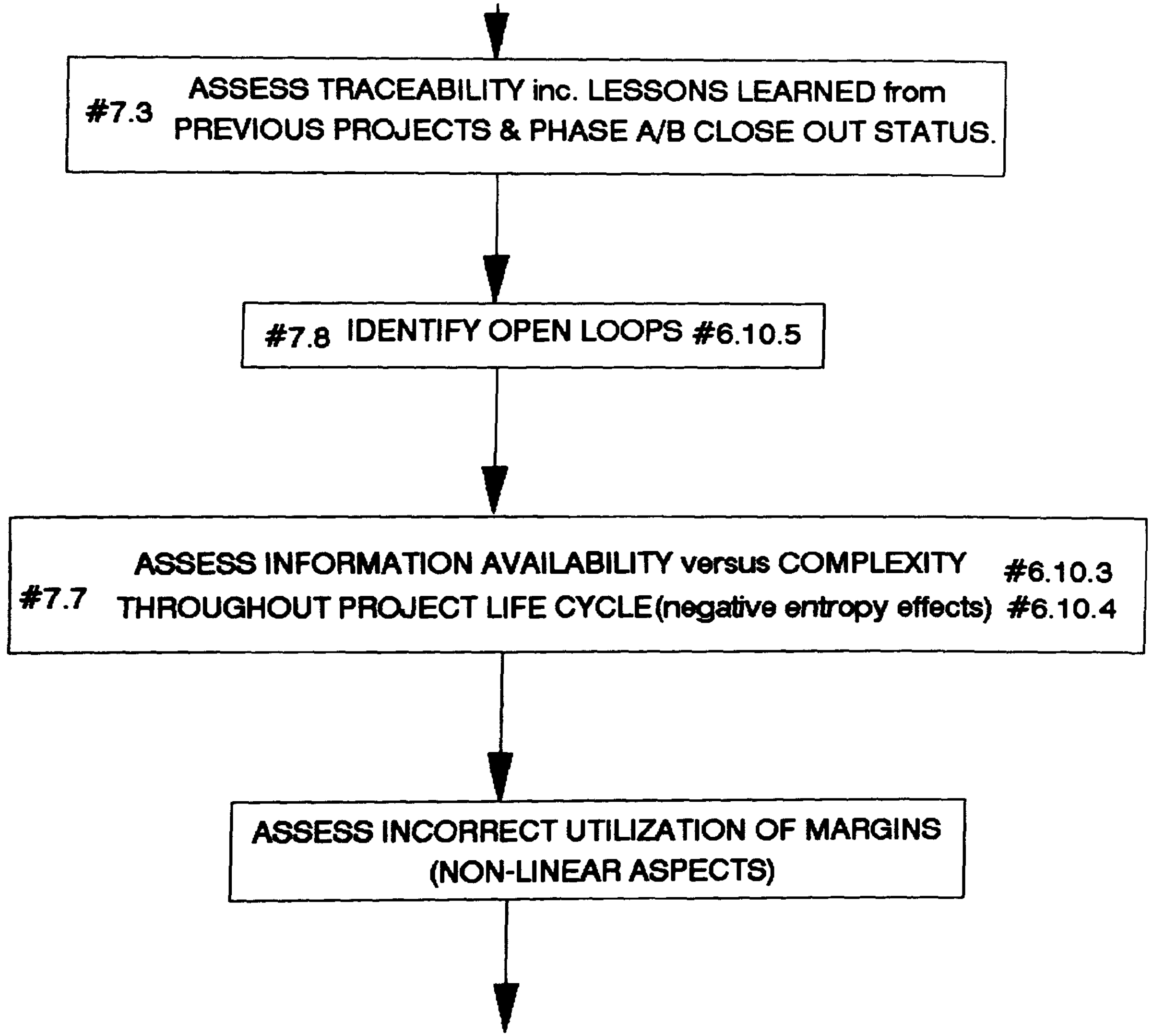


Fig.57: Method Flow Chart; BID EVALUATION PHASE.
(DEVIATIONS FROM INCREMENTAL APPROACH)

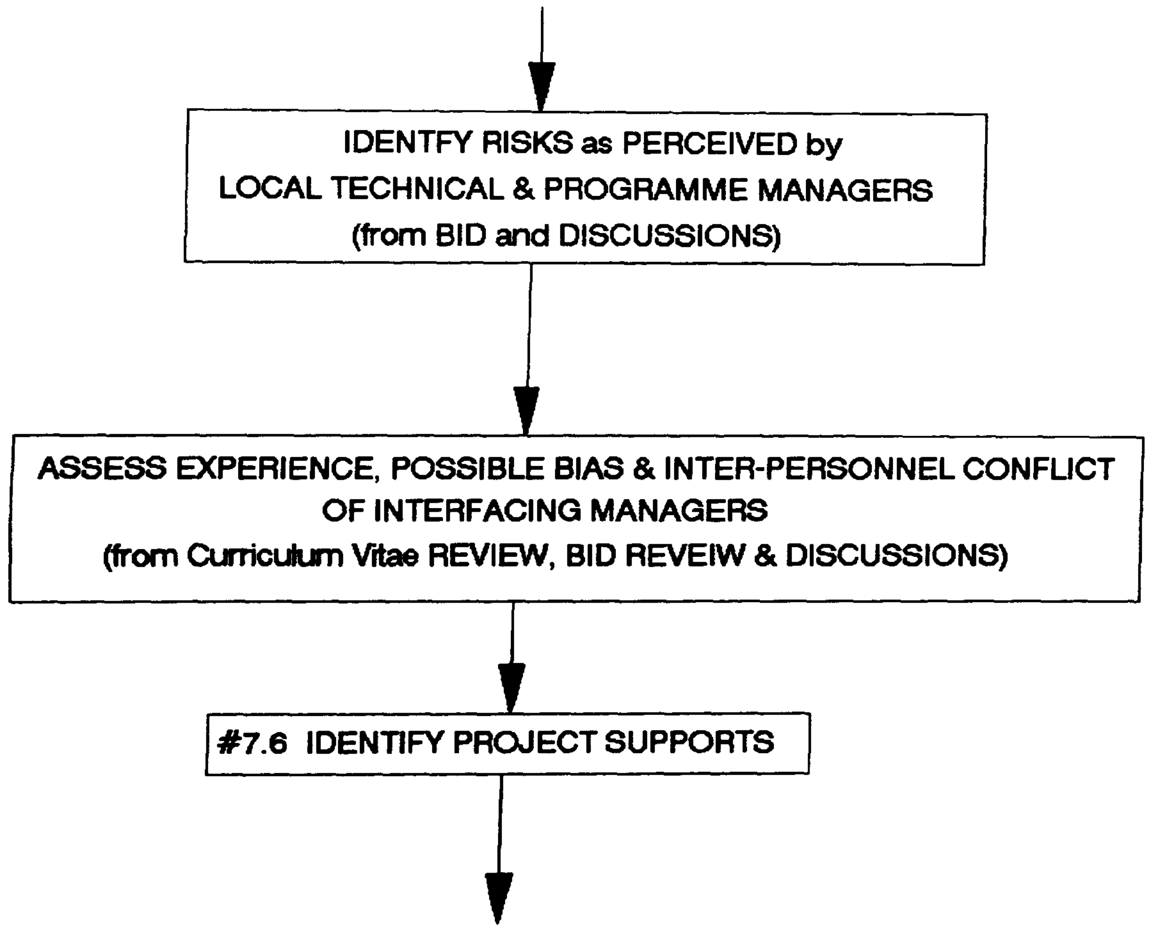


Fig.58: Method Flow Chart; BID EVALUATION PHASE.
(PERCEPTUAL/BEHAVIOURAL ISSUES)

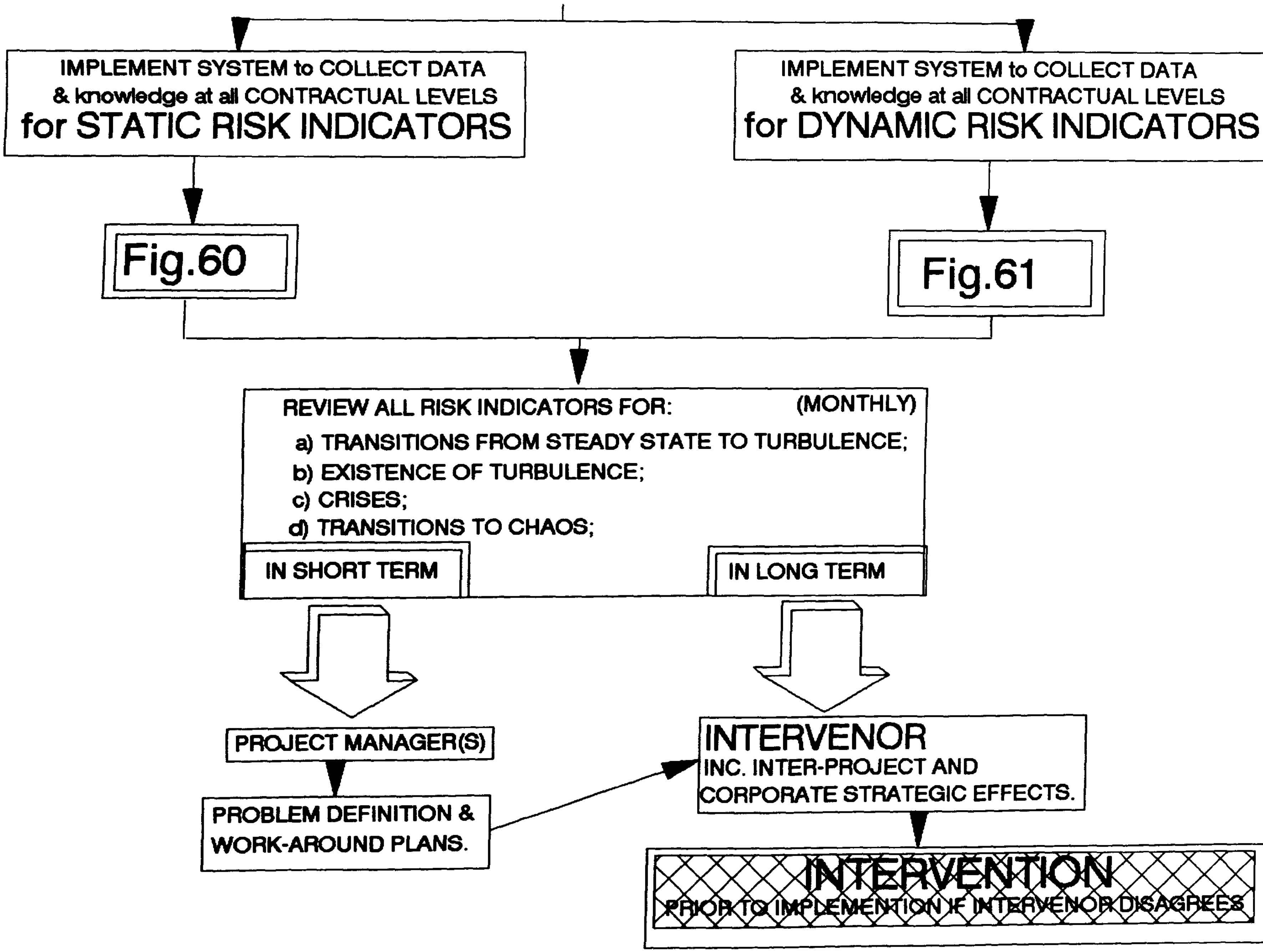


Fig.59: Method Flow Chart; PROJECT PHASES.

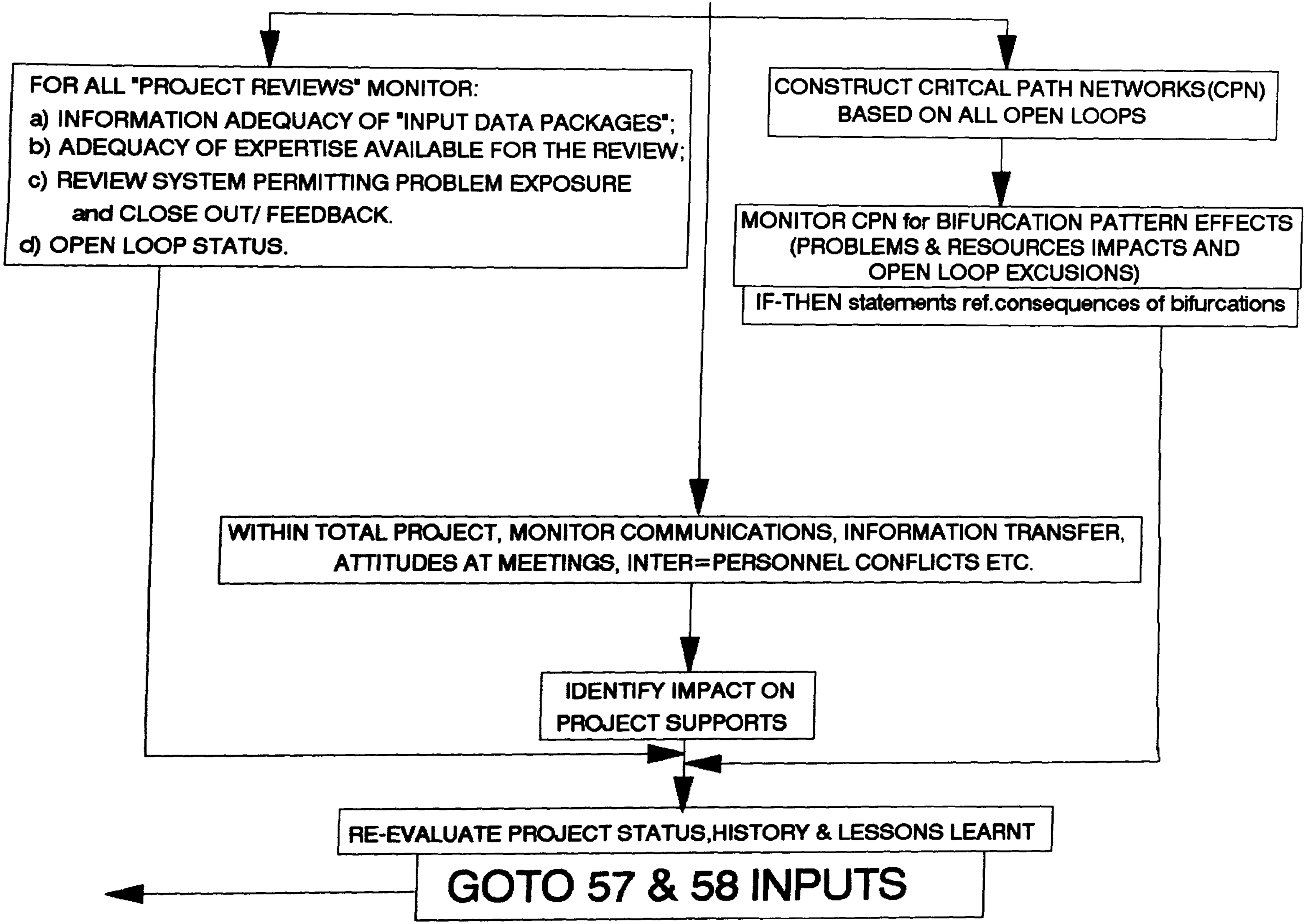


Fig.60: Method Flow Chart; Project Phases. (STATIC RISK INDICATORS)

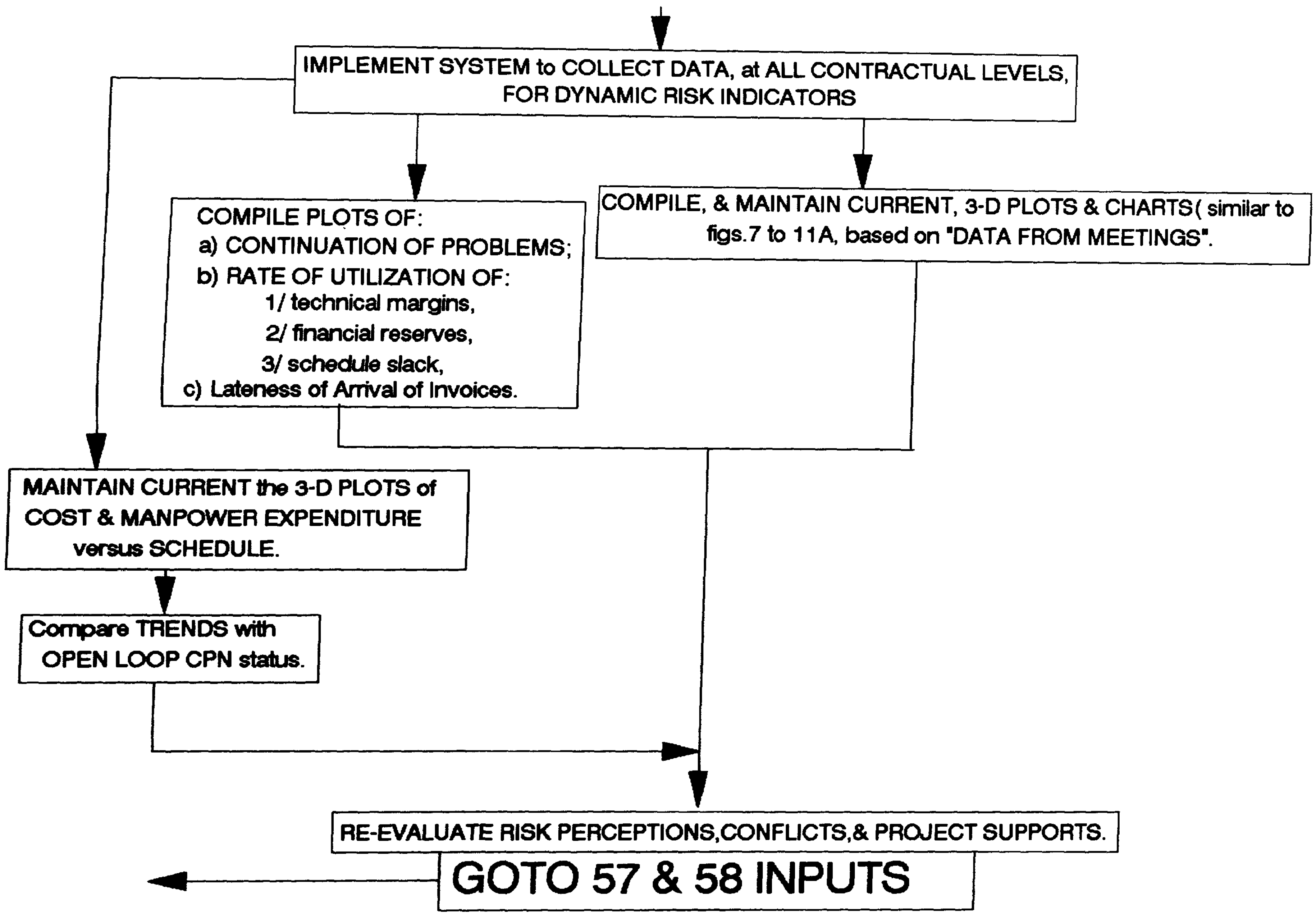
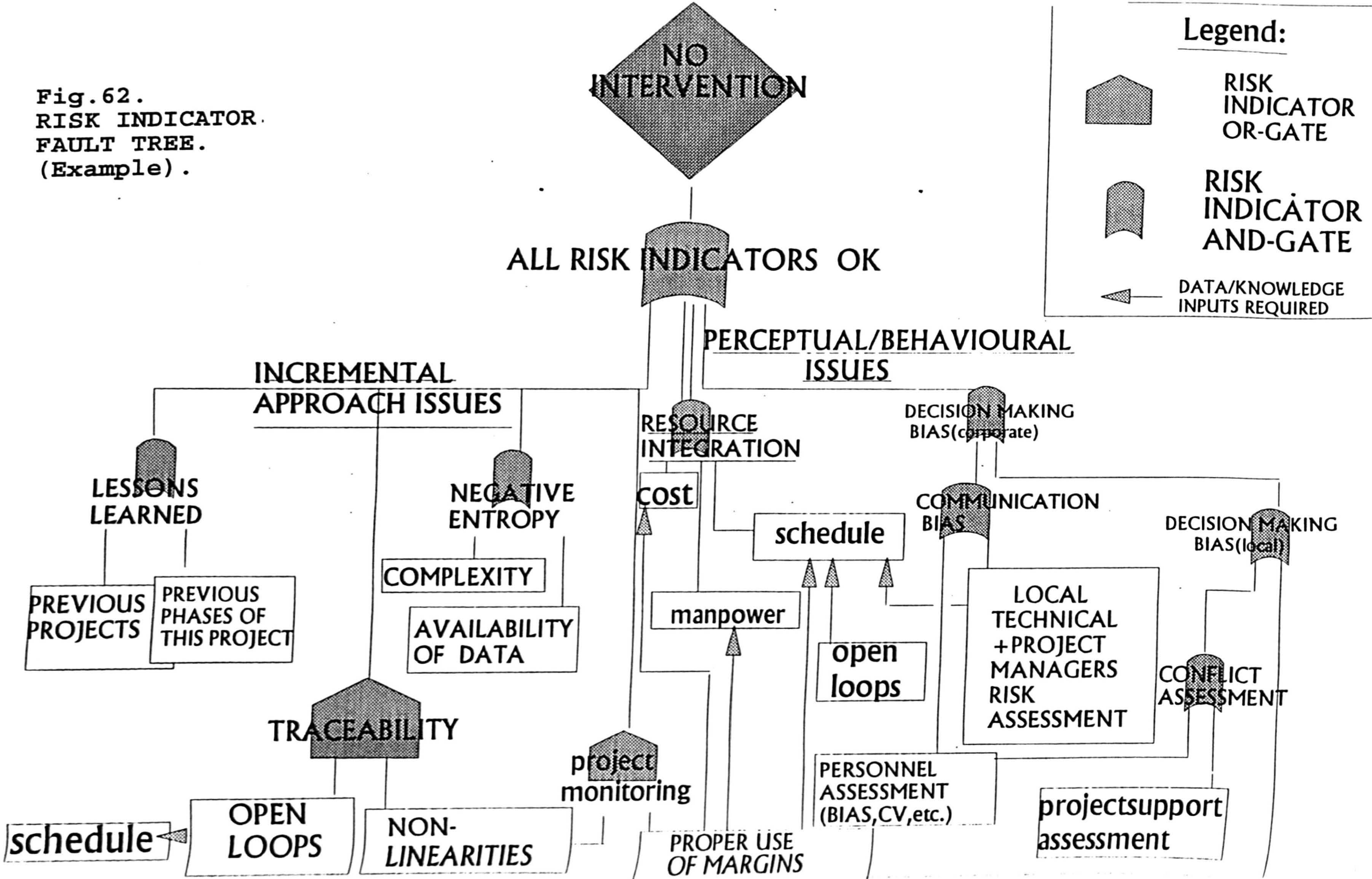


Fig.61: Method Flow Chart; Project Phases. (DYNAMIC RISK INDICATORS)

Fig.62.
RISK INDICATOR
FAULT TREE.
(Example).



for customer and contractor management by requiring project managers to establish a contract with their respective intervenors, under the aegis of the relevant Directors, involving the sharing of the decision making, the adoption of the data integration, open loop, and risk indicator concepts and the implementation of the DRMM itself.
The execution of such a contract would require that every contractor feeds information on all problems and issues, as they occur and then as they are discussed at meetings, directly into a computer network according a contractually binding format; see figure 53. Such "open house" data and knowledge transfer would be new in the formal sense but not new in actuality; it already exists in cost plus contracts as an auditable activity.
Contractual terms and conditions would have to be redrafted with the emphsis on penalisation of contractors for not properly implementing the DRMM rather than on deliveries and performance achievements five to ten years after award of contract.
The accent with this new system is that information on problems and issues is available to the project managers and intervenors authorities as it is generated and hence the developing "storm fronts" can be charted during their evolution rather than after they have done their damage.
The basic elements that application of the DRMM is seeking to remove are those associated with information distortion and cover-up to protect careers and contracts, and the expensive, and sometimes irreversible, erosion caused by late attention to problems by the proper persons.

In the DRMM environment the project would be controlled by the DRMM rather than by the whims of a few "key" individuals. This does not mean that a mechanistic system would be in control but simply that everyone "could" be accountable, to the intervenor, and the rules of the DRMM would have to be applied. The latter cover such aspects as presenting all open loops on the planning, preparing data in an integrated form, not proceeding from one project phase to another with non-permitted open loops, monitoring all risk indicators for the possible onset of turbulence, etc. One method that could be used, at all contractor levels, is the risk Indicator fault Tree; an example is shown as figure 62.

The adoption of such a system releases more time to be available for consideration of the actual problems themselves.

Current methods of identifying where the main risk areas are in a project are characterised by conflict between the various groups involved in the assessment of, for example, the review data packages. These conflicts are often caused by varied and ambiguous presentations of data and an inability, or even a prohibition, to correlate cost,resource,schedule, and technical performance inputs. With the DRMM approach these problems are, by definition,

avoided; the intervenor would not permit the review to commence or continue under such circumstances.
Hence the main areas of risk would become self evident when the 3-dimensional presentations,of resources, schedule and performance, from the contractor were compared with similar presentations prepared by the project and review teams. Figure 63 contains such a plot showing the contractors assessment of the manpower needed over the project lifetime for each of the major technical subsystems for a space vehicle project. Figure 64 shows the same project but with the manpower needed according to the opinions of the customer review team; this plot includes open loop effects and subjective(experiential) judgement by the review team members. A comparison of figures 63 and 64 reveals a number of areas of concern which would immediatley be apportioned dynamic risk indicators.

The vulnerability of the DRMM to creating tensions and conflicts between the project manager and the intervenor is largely dependent on the terms of reference for both positions being written in a complimentary fashion clearly identifying project success as the goal for both; the latter is interpreted as performance and deliveries on-time and on-cost. Personalities would be very important but the "perceptual/behavioural" arm of the DRMM should accomodate that aspect.

However, the effect of implementing the DRMM would require a particular type of organisation.
In order that the DRMM could be implemented efficiently the organisation in which it resided should have the following characteristics. It should be function and goal oriented with command by respect and achievement rather than by hierarchy and positional authority; and it should have a lessons learned, open information availability and debate, and self (positively) critique type culture. Information technology would contribute significantly to enable the contractor networking of dynamic risk indicators and effective use of lessons learned to be established. In general the organisation would be based on the team approach with the attendent synergy enabling frank exposure of concerns and hence security to those members who made mistakes.

8.1.8 Advantages

In industry and commerce at this time one of the greatest demotivators is that of frustration caused by lack of proper data sets at the right time to the right persons. This frustration escalates into the management domains as decisons are having to be made with very inadequate inputs. These frustrations and incorrect decisons occur in atmospheres of conflict, miscommunication and distrust due to personality, cultural, educational, corporate and political differences. All of this is happening within a technological revolution in which complete societies are in

Fig.63: Manpower/contractor/year
(1000s man-hours)

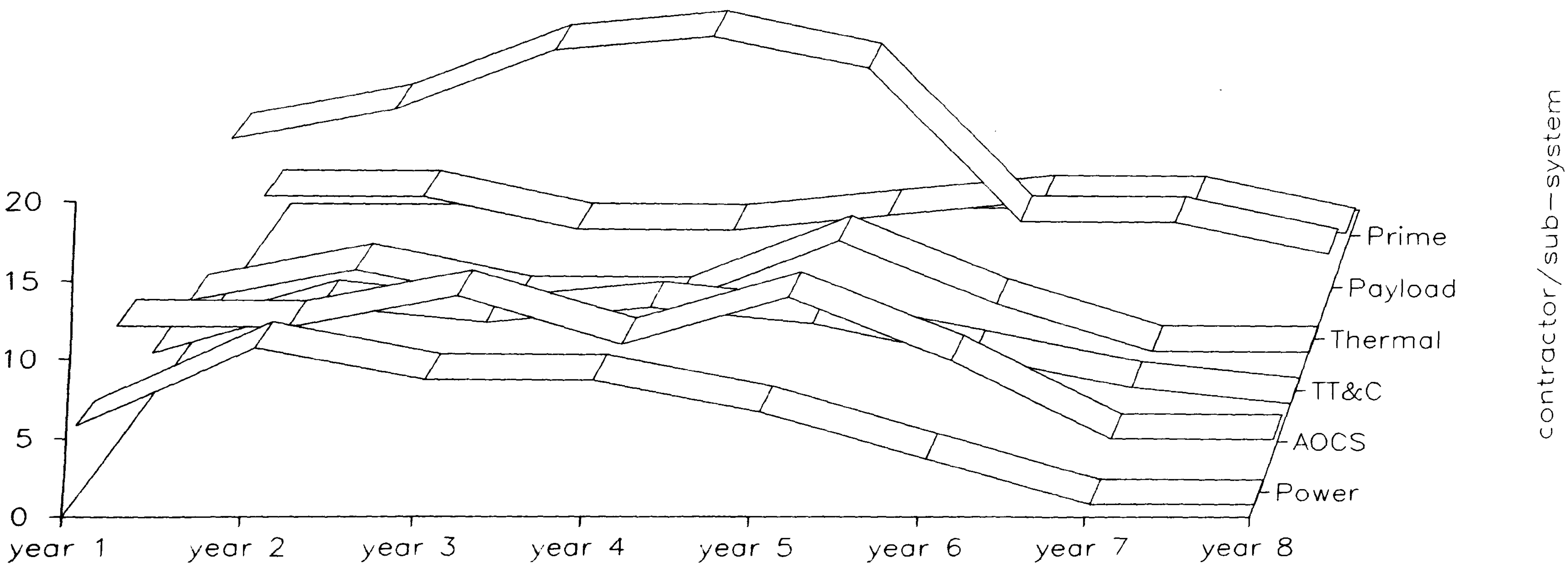
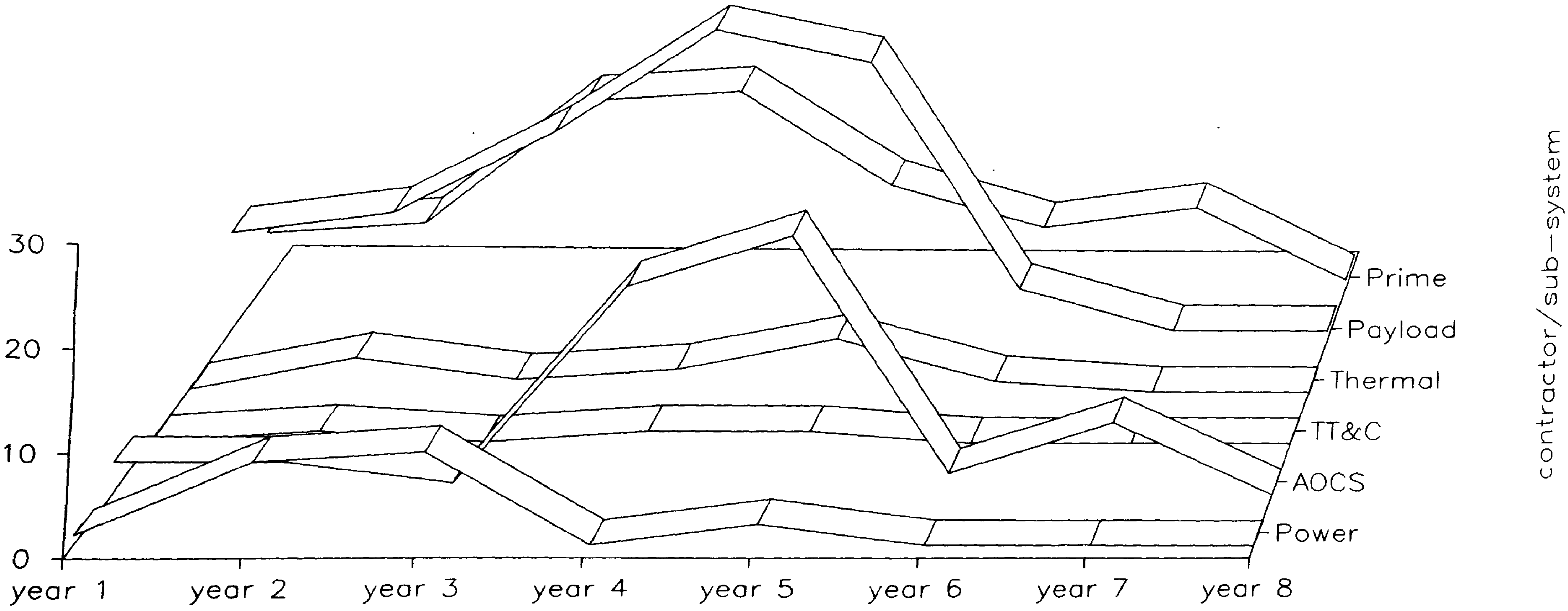


Fig.64: Main Open Loops Profiles
(manpower rqts. per open loop area)



danger of being isolated simply because they do not have an adequate level of computer technology in order to be able to properly interface with their more advanced peers.
Hence the complexities AND the, hard and soft, dynamics are increasing; rapidly.

The DRMM is an attempt to establish some coherency into the above scenario by dealing with the dynamics as they actually exist.
The main advantages of the DRMM will be that the players in the complex projects will be able, for possibly the first time, to avoid many of the frustrations, conflicts and wrong decisons mentioned above.
If todays meteorolgists attempted to forecast our weather using current project management methods, which are based on static presentations and models, then we would have to be "all-weather" equipped every time we left our habitats.

In terms of assessing the real cost and time overruns that would result from the use of the DRMM the following comment is made.
Utilisation of the DRMM approach would make the estimation of project costs and timescales more realistic. Also more time could be spent addressing the really important issues; in a timely manner.
In the authors opinion, using the DRMM approach, the timescales for projects A, B, and C would have been extended by approximately one, one, and two years respectively and each of those projects could then have been completed for the updated pro rata costs. Similarly, project D would never have been started.

8.2 Conclusions.

8.2.1 Boundary Conditions.

The author's review of the state of knowledge, involving approximately 200 references, has revealed that many separate avenues have been researched but very little integrated systems analysis has been done. The result is that the behavioural aspects seem to have received relatively little attention but, from the results of this research, they seem to be prime, and probably the dominating, elements. The situation today seems to be rather fragmented with no clear direction in which to proceed.

This particular research has utilised the results of the above review together with an analysis of experiential data, involving over 1200 data points covering a 20 year time frame, and an analysis of the operational environment, involving over 900 data points.

From this research, which involved the complete system of man, machines and environment, it is submitted that the hypothesis, see section 8.1 above, has been validated; see sections 5.2 and 5.3.

It is also submitted that a purely quantitative approach to the subject matter is inappropriate and that the significance of "assumptions" must be more clearly defined.

It is felt to be particularly important that unrealistic assumptions are not made concerning:

- the availability of data and computational systems to the average industrial manager;

- the correlation of small sample research results to management and risk situations in general;

- interface effects;

- the absence of positive feedback mechanisms and hence the apparent insignificance of small problems.

It is also considered to be very important that **more "systems level" field research is done by actual managers** i.e. by persons who have lived through the agonies, frustrations and glories of real business, and not mainly by disinterested observers.

8.2.2 Specific Results of this Research.

The final conclusion of this research is that it is essential to incorporate an intervention system as part of the overall management structure of a project.

The fundamental reason is to ensure a disinterested identification and implementation of static and dynamic risk indicators in order to avoid, or minimize, turbulent and chaotic conditions. Turbulent and chaotic conditions usually consume resources at very high rates thus directly threatening the achievement of strategic objectives.
The intervenor would be organisationally positioned between the project management and the company corporate management and would hence be sensitive to both company and project strategic issues. These strategic issues would be included in the definition and utilisation of the risk indicators.

The specific role of intervention is:

1) to ensure that a statement of risk relating to company and project strategic objectives, for the project, has been properly defined, understood and accepted by the contractor and the customer;

2) to ensure that sufficient and properly defined dynamic and static risk indicators, and the related pattern assessments, are being implemented, see chapter 5.2.5;

3) to ensure that cost, schedule, manpower and resource utilisation data is presented in an integrated manner incorporating open loop and negative entropy effects, and is adequate;

4) to executively intervene, via the project manager, if he considers that turbulent situations will evolve to chaos instead of being resolved to steady state conditions;

5) to refuse contract commencement, or continuation from one phase to another, if unacceptable open loop situations exist or proper open loop analysis has not been done and implemented;

6) to ensure that project supports are adequate and deleterious interaction is minimal;

7) to identify, from inputs from company level risk indicators, changing strategic aspects that impact on the project statement of risk and objectives.

The research results that have led to the above conclusions will now be outlined. A Method for implementing intervention in the overall situation is given in chapter 6; advantages to be gained by applying the Method are addressed in chapter 7.
The results outlined in this section have been obtained from the analysis of data which has been collected by the author whilst he was immersed, and executively involved, in the environment wherein the data was created. Risk was a major issue, see chapter 2. The author thus felt the pressures which certain events produced, experienced, with

fellow managers, losing control of situations due to insufficient, inaccurate or too much data and knowledge, and suffered the helplessness of not being able to understand certain situations because they were so complex; and therefore not really knowing what to do next. These subjective experiences were real and certainly contributed significantly to the decision making processes.

This research has collected field data in the European Space business environment and particularly involving the programmes of the European Space Agency(ESA), a multi-government organisation; see chapter 4.
This environment is not representative of purely commercial business, where market forces dominate. However, due to ESA striving to enhance the competitiveness of European industry in the international "open" markets, competitive and non-competitive industries do exist in the ESA domain. Hence the results of this data analysis in conjunction with the assessment of the current state of knowledge, see chapter 3, are considered to be applicable to business in general.

It has been concluded that subjective, personnel and management issues rather than technical issues dominate a project life cycle although they are often triggered by events that occur in the technical domain; see chapter 5.

The author has found no research to date which realistically represents the above actual life scenarios in their totality; see chapter 3.
So many assumptions, idealizations, static representations of complex dynamic situations, and general extrapolations from specific experiences have been made that the results bear little relationship to real life.
The scepticism which many managers levy at much of the management and risk "river of knowledge" mainly relates to their inability to correlate it with, and therefore use it in, the ruthless commercial project environments wherein they succeed and are promoted, or fail and become non-entities. The existence of these threats can encourage a project manager to conceal,or not to expose which is rather less negative, the increase of problems and "temporary" loss of control. This is a good reason for establishing some form of intervention.

This research has extracted from mans current learning those areas of knowledge which seem to "most realistically fit" the actual experiences, scenarios and results which constitute project life. Assumptions have been made and the phrase "this has been the experience of the author" has been used once or twice as the only real justification for proceeding in a certain direction.
The lack of rigour of this small subjective sample approach is clear. However, it is also clear that hypothesis must start somewhere and at the moment more data of the type presented in this research does not seem to exist.

It has been concluded that the business environment is totally dynamic and consists of "flows of things which require the expenditure of resources"; the latter embraces money, manpower and time.
The identification and analysis of these "flows" are fundamental to this research. The flows have velocity and force, or influence, and they can be linear or non-linear; the latter cannot be predicted. Most flows are, or become, non-linear. The non-linearities may not be immediately self-evident since they may take the form of second or third order effects. In the presence of positive feedback even third order effects can grow to become dominating issues. It has been shown in the analysis of the four projects that positive feedback mechanisms frequently exist; this has been evidenced by the persistence and growth of "low-level" technology problems, such that they have eventually threatened the success of the entire system. A non-linear flow means that the successful outcome of that flow cannot be stated with any degree of certainty. Hence if such a flow is presented, in a form recognisable as such, to a commercial customer by a potential contractor, then the customer would probably not approve its commencement due to the uncertainty that the product thus produced would function properly.
This assessment of the output and then using it at the input to decide whether or not to start the flow, or continue if used during the flow process, thus constitutes a loop with a feedback mechanism. Hence the non-linear flow represents an open loop process and an area of relatively undefined risk. In the context of feedback, it is noted that an apparently small problem can grow, due to positive feedback activity, and ultimately dominate, or even destroy, a project. It is desirable, for the intervenor, that negative feedback mechanisms exist in problem situations so that the problems will eventually just die out.

An important conclusion from this is that the extensively practised management method of apportioning "margins" to certain parameters at the beginning of a project and then monitoring the reduction of those margins as an indicator that the project is proceeding satisfactorily, or not, is valid only for linear, closed loop systems. Currently this method does not discriminate between linear and non-linear systems. In fact the margins are usually defined in a completely arbitrary manner, see chapter 5, and can be so large that they force non-optimal design and manufacturing and can actually increase project risk i.e. cause turbulence to occur earlier.

The flows within the project are initially in a relatively steady state. This means that events are occurring and behaving more or less as expected and are considered as being under control and predictable. At certain times problems occur and the flow in one area may slow down, with

respect to other flows, or interact with them; the planning is upset and management insecurities increase. When the problem occurs a work-around plan is usually implemented; the flows have now been split, since the work-around plan will consume resources in order to solve the problem, whilst, at the same time, attempts will be made to maintain the primary flow on schedule.
This simple model of "flow/problem/work-around-plan/restructuring of the primary flow" seems, in the experience of the author, to apply extensively to the business world. Furthermore, if a problem develops in the work-around plan, then another work-around plan will be implemented; and so on. In a large project with many contractual layers, a number of advanced technologies, culturally different persons involved, and several procurement phases, this "flow doubling" process occurring in many areas can be very extensive and quickly generate confused situations. This subject is discussed in detail in section 5.2.5.

As demonstrated in project C, the use of advanced technology which carries out many functions autonomously can become so complex that no one person really understands how the complete system works under all operating conditions. This situation is an invitation for problem bifurcation and open loop propagation under positive feedback conditions.

The above problem proliferation changes the steady state project scenario to one in which it is very difficult to define and control the various open loop situations which may develop. An additional problem is that some managers perceive the seriousness of the different problems quite differently, or even disagree that some issues are problems at all. A turbulent situation has then developed and there is a danger that it will continue or even worsen if decisive action is not taken.

This can be due to the persons involved in the work-around plans being in tunnel vision and thus tending to apply the same rationale which originally initiated the problem; instead of using lateral thinking to cover new ground. It can also be due to so many problems occurring at the same time, and the actual or potential schedule and resource depletion pressures being so great, that the managers brains experience overload and thus the control and executive elements of the project develop their own turbulence.
The situation will now be perceived by many of the managers as chaotic; they really do not know what to do because they do not understand the fundamental problems.

This research has shown, see chapter 5, that in order to curtail the evolution of turbulence and the continuation of chaos it is necessary that intervention in the day-to-day project business takes place.

It has also been shown that if the subject matter of a project has evolved from previously relevant and successful work in an incremental fashion, such that each interfacing increment preserves an essentially closed loop status, then the chance of turbulence occurring is low. On the other hand if quanta jumps are made in a project's subject matter, compared with what has happened previously, then the chance of turbulence occurring is high, due to open loop effects.

The basic differences between the incremental and quanta jump approaches are that in the latter:

1) the flow rates may have to achieve high velocities thus preventing proper interface control, verification, establishment of adequate margins, and close-out of problems;

2) the flows will probably experience significant doubling;

3) the flow rates may become very slow or even stop.

It is submitted that the above characterisation of project and business scenarios is realistic and can be represented using the science of chaos. It is hypothesised that representations and predictions can be made using period doubling and Feigenbaum diagrams; see section 5.2.5 and Figs. 1 through 19. This means that the onset of conditions which will be very difficult to manage, and will certainly increase project risk, can be modelled and are, to a certain extent, predictable.

These representations and predictions are only possible providing **"specific project information"** is collected in a particular manner to provide "dynamic and static risk indicators". The latter are essential to define the role of intervention in strategic change, pragmatically.

The identification and definition of risk indicators is submitted as a fundamental contribution of this research and will now be discussed prior to continuing with a description of the above mentioned specific project information.

It was hypothesised earlier that since the flows within a project can become so complex, for example unpredictable non-linear flow interactions being interpreted in various and unpredictable ways by managers due to the different experiential development of their brains, it is necessary to obtain information from these complex flows themselves as they develop. In other words, it is necessary to probe the flows themselves and obtain the outputs from the brains involved in trying to control those flows. Probes must be established which travel with the flows to provide information on the local circumstances and at higher levels to cover wider interactions; the global dynamics of the situation would thus be covered. The manner in which the above has been accomplished in this research has been by examining the minutes of meetings involving engineers/ lower management, middle management and top management for four projects. The number of times particular items have been discussed, noting the salient points addressed in each case, have been recorded on a spreadsheet with 5:3:1 scaling factors to differentiate the importance, in terms of perceived risk impact, of whether it was discussed at top, middle or lower management level. Hence, if a certain issue was discussed once at each of the three levels it would receive a rating of nine. This would indicate that the perceptions of the complexities, or risk, involved were such that it was immediately referred up to top management after only one discussion at the lower and middle management levels; a very unusual situation. The content of the spreadsheet has then been plotted using a three dimensional(3-D) graphics presentation to indicate any patterns or clustering etc.; see chapter 5, Figs.7, 12, 17 and 22. Further analysis of the 3-D plots, and related notes, has enabled areas of turbulence and chaos to be identified; see chapter 5, Figs.8,9,13,14,18, and 19.

From the above, and a validation of the thesis hypothesis, see chapter 5.3, it is submitted that the "probe information" described above constitutes dynamic risk indicators and, when selected and presented appropriately, will give warning of the onset of turbulent conditions.

Dynamic risk indicators must give information of the actual dynamics. Their selection requires expert knowledge of the particular project subject matter concerned. It is also concluded that when all open loops are identified prior to the start of a contract they can be compared with the actual open loop situation which develops as the project proceeds and rectification action can then be optimised across the whole system. This would avoid the "fire-fighting" management tactics so often practised at this time.

Examples of such dynamic risk indicators are:

- frequencies of meetings on particular subjects;

- the rate by which parametric margins and financial reserves are used;

- the rate by which schedule slack is used;

- the lateness of arrival of invoices, for payment, at the customer;

Static risk indicators are composed of data giving snapshots of the dynamic project conditions. They are limited in usefulness because they are usually obsolete before issued, since the compilation time tends to be long.They also usually contain data which is inconsistent; either in extent, accuracy, currency, detail or objectiveness.

One of the problems with business today is that it is almost exclusively based on static risk indicators, without taking into account their limitations and underlying assumptions. Also, internationally used planning techniques do not usually identify open loop activities and link them together to produce a project-wide open loop activity scenario; see chapter 6, Figs.26,29,30, and chapter 7, Figs. 38, 39, 40.

In conjunction with the risk indicators the research has identified four main types of patterns, see chapter 5.2.5.1, that exist in project environments and which must be used by the intervenor and project management, as necessary.

The four patterns are:

- pattern 1: the increase of the density and heights of the dynamic risk indicator "frequency of meetings" when plotted 3-dimensionally with "critical items" and "project time scale" on the other two axes.

- pattern 2: the continuation of certain problems throughout the project life cycle;

- pattern 3: the reduction of turbulence due to customer intervention by either increasing resources, increasing expertise available, agreeing schedule delays or cost overruns and in tacitly accepting risk sharing;

- pattern 4: the structure of the growth of problems producing a progressive splitting of the flows involved in the overall route of the project business.

The "specific project information" mentioned above relates to the definition of the environment, perception, the availability and integration of data, and project supports. These aspects will now be addressed.

Many management treatises define companies and their environments in the form of hard line diagrams with, for example, circles representing companies and larger circles representing the environment. The circles often overlap to varying degrees indicating cooperative or adversarial relationships between companies and/or the environments.

This research has not substantiated the above approach but has concluded that the environment of a company is a function of the perception by the authorities within the company of what is going on around them and whether they are able, or feel inclined, to use that "awareness". The environment is concluded to be dynamic and a perception of it may change from one moment to the next.

The effective or interactive environment of a company is thus defined as the "the locus of perception" of the authoritative managers of the company; the latter are those who have signature authority concerning "flows", and senior strategic advisors.

Every aspect of the project life cycle, and indeed a persons life cycle, is dominated by "perception". When situations are assessed, trade-offs considered, work-around plans constructed or decisions made they are all dependent of how the involved persons perceive the information available to them. It is submitted that perception is an intermediate, or end, point of communication. A person's perception of the information of which he becomes aware is a function of, for example, his ambitions, relationships and competition with colleagues, culture, religion, education, family status, personal feelings of security and competence, and state of health etc. In other words the data received by a persons sensors, e.g. eyes, ears and nose, will be processed in a brain which has been "conditioned" by its experiential development based on the above attributes. In fact the brain seeks information mainly by directing the individual to look, listen and sniff(183). The brain will then assess the information presented to it giving priority to familiar and non-threatening data. Based on the particular conclusions the brain will direct the person to react in this way or that. It is interesting to note that the latest theories identify the functioning of the brain as chaotic, and perception as a step in a trajectory by which brains grow, reorganise themselves and reach into their own environment to change it to their own advantage(183).

This research has concluded that perceptual biases, which could develop or exacerbate risk situations, must be avoided. It is proposed that the historical and psychological profiles of the interfacing project authorities are compared with each other and with the project objectives and life cycle characteristics at the commencement of the project; and monitored during the project life cycle. Related problem preventative action can then be taken to reduce the probability of it transitioning steady state flow into the turbulence domain.

Since the assessment and decision making elements of projects are the brains of the people involved it is submitted that projects are essentially living organisms. Also since a unique characteristic of living organisms is that they are capable of creating more order from less order it is submitted that projects intrinsically also have this property. It is further submitted that projects are open systems since information, energy and materials can be exchanged with adjacent projects or environments. An open system also has the characteristic that its stability is in dynamic equilibrium; in which continuous change occurs yet relatively uniform conditions prevail.

In order that the above can occur it is necessary that the project must receive negative entropy; how else can expanding and increasingly complex conditions become more orderly! The answer to this paradox - in order that the third law of thermodynamics is not contravened - is that entropy can decrease locally but the overall system entropy must still increase.

It is submitted that a negative entropy adjustment can occur if a project receives exactly the data it needs when it is needed and has the resources, including persons(brains), available to process and implement it as required to prevent turbulence developing.

Hence a project development plan can be scrutinised, both prior to and during its implementation, to identify when negative entropy adjustments will probably have to be made, and their definition.

Furthermore, entropy increases i.e. increases of disorder, can only be realistically assessed if data is presented in the same mode that it occurs in the project life cycle. For instance it is self evident that during the project life cycle manpower, resources and money are utilised, approximately, at the same time i.e in an integrated mode. In most contractor Bids these three elements are usually presented separately and in such a voluminous and inconsistent manner that correlation is impossible; see section 5.2.2, It is thus not possible to determine the credibility of possibly the most critical aspect of a Bid; nor to monitor it.

It is concluded that an intervention must occur if negative entropy and data mode correlation aspects are not present in a project protocol.

From the interviews, the documentation reviews, the review of current research and the author's experience there has been almost unanimous agreement that the main supports in a project are the key persons i.e. the persons who form part of the project management team plus individual experts with whom those persons are familiar and on whom they rely for specific expertise.

This aspect emphasises, once again, the importance of perception and subjective judgement; and the necessity for a formally defined role for intervention.

8.2.3 The basic contributions of this research are considered to be:

- the consideration of **hard** and **soft** aspects in an unpredictable environment which can result in chaotic consequences i.e. where non-linear, often irreversible, modes predominate;

- the identification that all companies function primarily as **open systems** and that they therefore have the ability to increase the degree of orderliness in the company even though the complexity of its work is increasing;

- the utilisation of the concept of **negative entropy** in the form of "the right data, at the right time, to the right people" with an appropriate feedback to establish a closed loop;

- the identification that differences in **perception** by the key players in a project are a prime element in the vulnerability of a project to increasing risk; it is concluded to be an essential aspect of the role of the intervenor;

- the definition of the environment as the perceptual limits of individuals;

- the definition and utilisation of static and dynamic **risk indicators and related patterns** with their supporting infra-structure of **open** and **closed loops**, **key persons as project supports, and trajectories**; the latter relating to such aspects as increasing personnel and company maturity, increasing company market share and product range;

- the limitation of parametric **margins** to linear, closed loop activities; and their definition in terms of resources;

- the combining of the **project manager** and **intervenor roles** in a partially separate and partially combined manner to realise an essential synergy of these two functions;

- the utilisation of the "growth of **turbulence and chaos**" patterns to predict and monitor project activities;

- the identification that **embedded research** often exists and is a cause of serious open loop situations;

- the discovery that certain entities in the project **flow**, have a certain velocity, and their **acceleration indicates an increasing risk situation**.

- the **definition of criteria** to enable the identification of **when** the project work situation is likely to move from a steady, manageable state to a fragmented, bifurcative state and eventually to a state of chaos.

ANNEX 1

POSTULATES.

The following postulates were formulated during the research associated with this thesis.

POSTULATE 1: The degree by which the reliability and safety and hazard analyses are not concurrently used in the design process needs to be represented by a risk indicator.

POSTULATE 2: Soft aspects can constitute major potential risk generators and must be assigned risk indicators.

POSTULATE 3: The terminology generalisations progressively being used are considered to be significant contributors to the difficulties concerning the definition and control of risk.

POSTULATE 4: The use of technology which has been developed in well defined, and traceable, incrementally advancing steps would avoid the inherent risk of the "quantum jump" approach.

POSTULATE 5: The failure to identify, and the lack of proper definition of, embedded research, in development programmes is a major risk contribution.

POSTULATE 6: The outputs of "failure mode and hazard analyses" constitute risk indicators.

POSTULATE 7: The non-utilisation, or utilisation in a non-timely manner, of failure mode & hazard analyses can be the cause of major risk.

POSTULATE 8: the definition and implementation of a "ranking" system for critical items would enable them to be used effectively as risk indicators.

POSTULATE 9: A properly structured problem definition system requiring intervention when problem consequences reach a certain, a-priori defined, magnitude would enable risk profiles to be defined; and, with additional measures, to be controlled.

POSTULATE 10: The ability of the panel members and panels chairmen to become familiar with the review material is critical to defining programme risk.

POSTULATE 11: An assessment of the risk involved in the progressive loss of the vehicle performance would enable a better cost/ schedule optimisation during the design and operational phases and more realistic risk management to be implemented.

POSTULATE 12: If the total resources are calculated on the basis of producing parametric performance(inc. the associated margins) and similar relationships are established relating to performance and profit (including incentive/ penalty effects) then the parametric margins could be used as risk indicators. It should be noted that the "resources/ parameter calculation" would involve ALL contributing activities to the achievement of the performance e.g. design, qualification, testing, etc.; hard and soft aspects and the interactive effects of different margins would also have to be included.

POSTULATE 13: If the strategic plans of the product user community and the technology developers are monitored by the related corporate management

AND,

the project is designed for technology insertion, and a wide range of possible applications of the product are kept open as long as possible

AND,

the "project supports"(see section 7.6) are established and maintained for the project life cycle,

THEN,

risk in this area would be minimised.

POSTULATE 14: If political and economic trends, at the macro level, are monitored and utilised in the compilation and update of Space strategic plans then overall risk will be reduced.

POSTULATE 15: The absence of the opportunity to exercise direct executive authority, on the project, by an intervenor using the design review board recommendations is considered to seriously diminish the effectiveness of the design review.

POSTULATE 16: The characteristics of the reactions of a company or a project are analogous to those of human being(s); some correlation exists with equivalent phases of their respective life cycles."

POSTULATE 17: The primary strategic decision making processes in companies and projects involves exchange of significant information, often in an informal mode, between the executive core elements of companies.

POSTULATE 18: All interventions can be defined as being: direct or indirect.

POSTULATE 19: The significance of the environment to the company/ project is due to its, the companies, perception of the environment as consisting only of intentions and interventions.

POSTULATE 20: A strategic change occurs when, in the absence of an intervention the continuing application of a positive feedback control mechanism fails to maintain the strategically predicted growth.

POSTULATE 21: Unrealistic perceptions, and consequent implementation and intervention, will produce an unpredictable effect on the situation. Realistic perception will produce a predictable effect. The former will tend to instability, waste, randomness; the latter to equilibrium, efficiency and growth.

POSTULATE 22: Intervention re-establishes realistic perception i.e. to define the characteristics of an intervention, negative feedback must be applied until positive feedback can maintain growth to achieve the objectives.

POSTULATE 23: OBSERVATION is a function of:

focus

visibility

view angle

scan rate.etc.

POSTULATE 24: The observed or sensed information is subjected to processing within the perceivers reference frame in order to produce perceived information. The reference frame contains hard and soft references. Examples of the former are company and national laws; examples of the latter are retained knowledge, educated techniques, beliefs, morals, intelligence.

POSTULATE 25: Reference frames constantly change.

POSTULATE 26: All reference frames tend to be different; to some degree.

POSTULATE 27: Reference frames can be biased, skewed, forced or constrained to produce perceived information with certain predominating characteristics; e.g. fear, objectives, reward, penalties can provide such bias.

POSTULATE 28: Organisation are dynamic to varying degrees and consist only of open and closed loop systems.

ANNEX 2.

INTERVENTION, "SOFT" ASPECTS & INCREMENTALISM.

The following notes were made following a period of reflection on the nature of intervention. They are included to hopefully clarify a number of aspects which are more briefly covered in the main body of the thesis.

a) Intervention.

There seem to be two types of intervention; the EXECUTIVE & NON-EXECUTIVE types.

Intervention is also either "DIRECT"(company/ man initiated) or "INDIRECT" (environmentally/ external- to-the- company initiated). Hence a 2 * 2 matrix should make it possible to classify all types of intervention.

The executive type consists of an actual activity such as a policemen holding up his hand to stop the traffic.

The non - executive type is an implication that an executive intervention MAY take place. For example, the policeman standing in the middle of the road about to raise his hand when HE JUDGES the time for intervention to be appropriate.

In both the above instances a motorist would feel an effect; in the latter he may or may not take some kind of action. Consider also your reaction when you are driving in a very tranquil, relaxed fashion and you "see"(perceive) a police car, or an accident on the other side of the road, or an ambulance overtakes you...with or without its siren going! Whatever happens you have been subjected to an intervention.

Similarly the traffic situation could intervene on the strategic plan of the policeman e.g. a car could breakdown thus preventing the policeman from controlling the situation, or he could suddenly develop a very bad migraine, etc.

c) Incrementalism.

The policeman model also permits an analogy with "INCREMENTALISM".

It would be impossible for any of the drivers to predict exactly when the policeman will intervene. It is important to realise that in a connected ("dependent") configuration of roads the intervention by a policeman at any location will effect the overall traffic "environment". A prediction of the optimal strategy to use to get from A to B quickest thus becomes practically impossible even for this very simple model.

" An Intervention ANYWHERE, will cause a strategic change SOMEWHERE."

The INCREMENTAL concept requires that the driver concerned ("the company under consideration") establish indicators before he starts the journey which will enable him to make decisions as the journey proceeds such that he will get to his rendezvous on time e.g. he may have to park the car and take a train or walk in order to achieve his objectives. The incremental approach would also not permit him to use a relatively untried vehicle e.g. Sinclairs electric town car, due to the lack of traceability to a vehicle that has been proven, with an acceptable risk, to be capable of completing that particular journey. His progress would be monitored by his "chiefs" via the risk indicators and they may decide to intervene because their perception of the hazards indicated a higher risk than that of the driver. He may thus be required, by car radio, to leave the car and catch a bus.....etc.

ANNEX 3

RISK INDICATORS.

The following are examples of risk indicators; they have been extracted from the thesis.

RI 1: The degree by which the reliability and safety/hazard analyses are NOT CONCURRENTLY USED in the design process.

RI 2: Soft aspects because they can constitute major potential RISK GENERATORS. The hard/ soft interface must be addressed in the definition of the risk indicator.

RI 3: The terminology generalisations progressively being used because they are considered to be significant CONTRIBUTORS to the difficulties concerning the definition and control of RISK.

RI 4: The use of technology which has been developed in well defined, and traceable, incrementally advancing steps would avoid the inherent risk of the "quantum jump" approach. The lack of such an approach, even by degree, is a significant RISK INDICATOR.

RI 5: The failure to identify, and the lack of proper definition of, EMBEDDED RESEARCH in development programmes.

RI 6: The outputs of "failure mode and hazard analyses".

RI 7: The non-utilisation, or utilisation in a non-timely manner, of failure mode & hazard analyses.

RI 8: the lack of a "RANKING" system for critical items; which would enable all critical items to be sequentially listed according to their critical consequences

RI 9: The lack of a properly structured PROBLEM definition system which would require intervention when problem consequences reach a certain, a-priori defined, magnitude thus enabling risk profiles to be defined, AND, with additional measures, to be controlled.

RI 10: The degree by which panel members and panel chairmen are unable to become familiar with the review material. This is critical to defining programme risk.

RI 11: The absence of a system which permits an assessment of the risk involved in the progressive loss of the vehicle performance thus enabling a better cost/ schedule optimisation during the design and operational phases and the implementation of more realistic RISK MANAGEMENT.

RI 12: PARAMETRIC MARGINS provided that a system exists which requires that the total resources are calculated on the BASIS of producing parametric performance(inc. the associated margins); and that similar relationships are established relating to performance and profit (including incentive/ penalty effects). It should be noted that the "resources/ parameter calculation" would involve ALL contributing ACTIVITIES to the achievement of the performance e.g. design, qualification, testing, etc.; hard and soft aspects and the interactive effects of different margins would also have to be included.

RI 13: The absence, or degree of absence, of the following system:

The monitoring of the strategic plans of the product user community and the technology developers by the related corporate management

AND,

the definition of the project for technology insertion, and a wide range of possible applications of the product are kept open as long as possible

AND,

the "critical supports"(see section 5.1) are established and maintained for the project life cycle,

THEN,

risk in this area would be minimised.

RI 14: The monitoring and utilisation of political and economic trends, at the macro level, in the compilation and update of strategic plans.

ANNEX 4

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ANNEX 5

BIBLIOGRAPHIC REFERENCES AND NOTES
(contained in volume 1)

(This annex contains the authors notes from the stated references*; the note contains edited selections from the references which are considered particularly relevant to this thesis. The editing process has paraphrased but not changed the substance of the original reference.

*The references are listed in annex 4 and, individually as relevant, at the end of the Notes contained in this annex.)

ANNEX 6

INTERVIEWS

Notes from Interview with Contractor Project Manager

Qu; did any of the major experiences of your life, education, religion etc. have any effect on how you conducted your management?

Ans: management style is whether you are autocratic, discussing out the issues, or intuitive, etc. I think that every manager you work for has some impact on how you actually manage. the other thing that had a big impact on me was when I did a DMS in the early 1970s; this was very useful particularly after some years of industrial experience. I found it useful to stand back and look at the general management manner of the managers I worked for. At the end of it all I find I tend to rather analytical, a little bit intuitive, I tend to be very discussive with the members of the team; one has to take the team along with you to get the issues out, air the issues, rather than be autocratic. The team must be behind what you intend to do. I think the university system should teach you to be fairly logical in thought; I think that often splits out people who are able to manage and those who are not. A lot of engineers have very confused thinking; they will not take a problem and look at it from all sides and also accept other peoples views apart from their own. They seem to have a very confused view of life, are unable to break a problem down, probably because they were never taught to break things down. I don't know whether its something I inherited but I think universities should teach you do much more thinking.

Qu.: to what extent do you rely on experts?

Ans: I would trust some more than others; based on the results they had produced before.

Qu.: would you trust an expert you knew more than one you didn't know?

Ans: I would not necessarily not trust one that I didn't know but I would be slightly more wary but I might give him the benefit of the doubt; if things did not work out I would then be very cautious.

Qu.: you often cannot wait until you have experience of the work of an expert. Many of the projects had embedded research; how did you handle that.

Ans: quite frankly one often did not have much room for manoeuvre in decision taking in such programmes(ESA programmes). ESA had decided on certain development directions and one would have to move half a mountain to change their minds; even if you thought it was really wrong.

Qu: and now, in private industry, do you have the same limited decision making? If not, how do handle it, because now you are in very hi-tech....ref. experts etc.

Ans: far wider now. Well, I'm now in the microwave business but I'm not a microwave engineer. But I think you can pick up sufficient information over a period of time to be able to ask hopefully intelligent & searching questions to draw out whether somebody is trying to deceive you. At the end of the day, with apparently equally well presented but different expert arguments you have to trust your own judgement. For the projects A and B the changes made were quite small, in my view; your ability to make fundamental changes is very limited. One was very limited in moving a company in the consortium; their were certain commercial and contractual leverages but their was so much going on through the back door, politically and ESA involvement that its not like a commercial programme where there is much greater freedom, more scope for error, and more opportunity to make a profit. The fact that one has more scope does not necessarily mean their is more risk but more opportunity. The risk is opportunist. One of the things we have realised is that we must look at the subject of risk, particularly at the start of a programme and sometimes going down two sometimes three parallel paths. You will have a baseline and you will have two or three alternatives; but the time when you can afford to do that is at the beginning of the programme. Usually the problem is that if you go down one path,, hang your hat on it, and something fundamental happens such that it doesn't work then the programme really slips and its too late; you're down the chute. So what we're trying to now is to say well what are the risk areas in the programme particularly the perceptions/ protection because that is the direction we want go. We define risk as those areas that are undefined, things we haven't done before, we're not quite sure what the output is going to be, we think its going to work but their is a risk until you've actually done it, new process to qualify...and is there anything else we can do to back up that risk. On ESA programmes this is quite difficult to do because of the other constraints. Its a very conservative approach and one gets into the sort of situation where company X has been involved in the development, or the qualification on a previous programme, and they will therefore do the work on this programme BUT they may NOT be the best company the new programme. You often give way because you think you cannot fight the politics etc; but I think some of that is fundamental rot. I remember the day when the prime contractor accepted a company to integrate all the payloads, at a meeting at ESA HQ involving corporate management etc., which I was very much against but there was some very high powered poker being played by the company concerned, contractors & delegates. I then had to work like hell to try to make it work and we changed the prime contract to be on a cost reimbursement basis.

Qu: did you try to put people on the spot in order to obtain their commitments to the bid etc?

Ans: the bids were usually not costed out but addressed in terms of the technical options to meet the requirements; looking several different configurations, taking inputs from several different technical people, to look at seberal different technical solutions. We would then look at it financially and schedule-wise but in those days these aspects were secondary.

Qu: how did you interpret technical risk in terms of cost & schedule?

Ans: it was not very scientifically looked at. At programme management level all you could be concerned about was overall concepts, like the overall AOCS, TT & C, power concepts, I had to rely on the subsystem managers to look into individual areas of risk in the equipments etc. Putting the lower level managers on the spot ref. their tech. & cost & sched. inputs was relatively soft in those days (TM note: this illustrates a completely different perception by the contractor corporate manager) but much harder now. Financial aspects did not figure as high as they should have done, it was very much technically driven.

Qu: Do you feel ESA have a lot answer for; were we properly preparing European space industry for international competition.

Ans: Yes and No to those two questions. In my current job where I am involved at two levels lower down providing equipments for comsat my experience is completely different; and we also bid in to all the major prime contractors. Nowadays, my engineers are on the line reference the identification of the risks and then when considering the price we have to balance the risk against the competition; and make a profit. Starting at a lower level one is able to assess the technical risk in more detail. The penalties on thee company can be very high e.g. 10% of the price for 30 days lateness. Slight technical problems can usually be negotiated with the customer but schedule is very important; we usually have a good control/ understanding of the technical issues. Lateness on schedule also ties up the team for longer than bid and this costs a lot of money; lateness is a good way to lose money. The later you solve problems, particularly with nothing in parallel, the closer you are to really serious situations. Time was invariably lost at the beginning of programmes; "we've won the programme, relax....."...noting really done for six months.

Qu: did you have a strategic plan?

Ans: we certainly have a SP now; going out for 5 years but is updated every year; we were to it. It focuses the R & D and investment. At the space prime contractor it was not obvious, at the project manager level, that there was a strategic plan. In order, now, to assess risk in R & D we look at what the potential market is we're aiming for & what % we think we can get. In the near term the market is defined by the programmes we can see coming up, or trends that we see changing. In the long term it is often an act of faith e.g. with SAW filters we started the R & D in the early 1980s & have just landed the first contracts on Inmarsat; we were the only people too have the available technology. The returns in our business are definitely 5 to 10 years.

Qu: how did you initially size the margins(technical) that were used on our satellites?

Ans: they were sized to be the sort of margins you could live with throughout a programme of that nature; previous programmes were used. for a new programme we would say that margin looked about right based on very limited experience. the local managers probably tracked the margins.

Qu: how did you decide the resources necessary for a particular programme.

Ans: Difficult; you spoke to individuals with experience and finally decided this is the size of team to do the job. We don't do that now. On projects where we have a lot of experience we know from our cost/ price base the resources needed to make a similar type of equipment; we now what our bottom line is. We try for max. profit. The above is based on similarity; the first time one does something is more difficult then you have to do a bottoms up. You have to build it up from detail inputs. The difficulty is when you come to negotiate the price with the customer to KNOW what margins are in there, & what risk.

Qu: do you relate the strategic plan with margins? use feedback etc?

Ans: yes; its much more basic than using feedback etc. The whole business was developed by identifying niche areas where we think we have good margins and high return. We do not e.g. consider types of business for which we feel we are not suited e.g. high vol, low marginal profits.

Qu: if you compared a successful with an unsuccessful first time product what main characteristic differences would you identify?

Ans: it comes down to the quality of a few individual(TM comment: similarity here with the contractor corporate managers comments on project supports being key people") and trust/ knowledge of those individuals by management. There are other areas where things were not successful, we kept trying things again & again but they kept failing and again I think it comes down to the policy and quality of a few individuals. The old cliche " your people are your main resource" is very true so the lesson to learn is to choose the right people.

Qu: what are critical supports to a project?

Ans: in many cases its attention to detail in the type of business we're in; small community, problems become common knowledge very quickly. One cannot therefore afford to have area disaster. We must make sure the building blocks are very controlled such as the processes, the materials, the bits & pieces that go into the equipments etc. If you lose that control, through lack of attention to detail, you will have a lot of grief. You must not overdo it; you must not inhibit the innovative spirit to get the job done on time & ship it out. Striking this balance is difficult. You must keep the right people in the right areas; very important. I'm a strong believer in

PA/quality control but it must itself be controlled. It must be applied sensibly.

Qu: when did you decide to intervene?

Ans: usually via a general review of progress when one picked out an area as significantly diverging from what had been anticipated. The review which has been convened due to the occurrence of a problem is, by definition, an intervention. The problem was often because something was NOT happening.

Qu: at intervention your information set & level were different than the local sub-system(project) managers; did this cause problems, confrontation?

Ans: yes; sometimes it was necessary to involve the line department managers(the sub-system people usually had two bosses, project & line). A classic case of intervention where I arrived late with my expert; there were about 30 other experts around the table who agreed nothing was wrong but we think otherwise. We required a retest and the product failed. (TM comment: this manager believed his expert out of 30 others....why did the others not see the problem (ref.MAGE). Quite frightening that all these guys around the table, costing vast amounts of money to be there etc., were not asking the right questions or doing the right sorts of things. One wonders therefore if part of the problem in a large organisation is INERTIA.

Qu: how do you take the environment, which is changing all the time, into account.

Ans: the information I use in decision making depends on the problem to be solved; quite often it comes from outside the company. Intelligence for new bids usually comes from outside; you build a picture of the environment. You tap into as many sources as possible to maintain the picture. You have to decide when you have to make irrevocable decisions. We would probably bid to all primes in a commercial competition; with the bids tailored for the different nuances of the different primes. We also have to take the changing world situation into account; maybe we should team with people or continue our normal approach. One must not take too hasty a decision but you must not miss the boat.

Qu: did you measure the performance of the managers who worked for you.

Ans: historically in the prime contractor it was limited to annual reviews. Now its more frequent; assessment should be continuous...cannot wait a year. Historically, we found there was too much emphasis on individual work-package level; too much emphasis on financial aspects to the engineer can be too distracting..he's more interested in being hit over the head afterwards. He had the authority to spend but the controls were not, at the prime contractor, really there. There was great emphasis hitting the overspenders over the head but it didn't achieve very much. There was no external-to-the-project group auditing finances. Too much control does not achieve very much.

Qu: do you consider an organisation has certain characteristics/ behavioural modes?

Ans: yes; for example the Germans & Swedes were tough to negotiate a reasonable price but once done they would then get on and do the job, & were then easy to manage. The Italians however apparently readily agreed to a price but then debated it for evermore; very difficult to manage.

Qu: could one compare the functioning of an organisation with that of a human being?

Ans: Yes, partially but in a strong organisation the individuals grow into the company culture; the latter is quite a strong driving force in the company. The people have to buy into the fundamental culture of the company or they will leave or not be very happy; all dipoles are pointing in the same direction(TM comment; an interesting usage of microwave terminology when discussing organisations; see brain notes). But people may achieve the company objectives in quite different ways. My company has a real culture; we tried to write it down at one stage but found it too difficult. We really must believe we are the best. In large organisations there is a certain amount of fear; more than in small companies. People should feel free to express themselves; many people were afraid to talk freely. A big company like the prime contractor had many cultures, some local to personalities in charge of divisions for example.

Qu: do you think an incremental approach is important?

Ans: an organisation can only grow to a certain extent by evolution, entrepreurial jumps give real growth. A solid feeling will be achieved before the jump; maybe a company using a technology developed somewhere else; no jumps without some foundation. We found the most efficient R & D is done on the projects due to the pressure of meeting the deadlines. An achievement on a programme is worth infinitely more than "having something running in R & D". The driving factor to force the minds to focus to achieve the R & D result during the programme is the fact that the company may lose a lot money, and the individuals their jobs, if they are not successful; fear could come into it. The other problem is that R & D tends to put to one side because people are so busy on other things. managing R & D is extremely difficult. What we try to do now is organise things such that R & D is considered as an outside project & hence it has to meet milestones and will not just be put to one side under pressure from other areas.

Qu: did you get adequate feedback from all areas;

Ans: residents can help but are very difficult to manage. The real method to make sure you get the truth is to have a meeting and look into the "whites of their eyes"; with different cultures this can be difficult.. British dealing with Italians is bad enough; Scandinavians & Italians are worse. I think the problem with the prime contractor was that they didn't know where they wanted to go or what they wanted to be; the vision was missing. They seem to be getting it a little now; too late. The French are different; they set out and go for it. Sometimes they get it right, sometimes wrong; like Ariane 5 & Hermes etc. I work for personal satisfaction; this was most realised when I became project manager. What gave me most satisfaction was when I had control of project and brought it in on time.

Qu: what are the significant differences between Japan, France etc.

Ans: the main problem with UK has been the lack of money. Hughes is very successful because it has a very successful marketing machine and good technology; with good strategic planning. For example, the flip from spin stabilised to 3-axis stabilised; an overnight flip. Also big companies can get cheaper loan. I am surprised at how slow the Japanese have been; they are still only at the equipment level.

The trick is to be able to allocate the right resources up front to avoid fire fighting at the end. The big programmes fail because they don't do proper risk assessment at the front end. The difficulty of R & D is getting the right relative priorities for the various projects.

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Notes from Interview with Customer Project Manager(CPM).

A major experience that really effected how I thought about things afterwards was attendance at a management course when I was a graduate engineer working on a design project. This course was an "absolute revelation" and the I have applied the principles I learnt, since that time.....with, in my opinion, great success. My educational background was physics which I feel gave me an advantage over engineers, in the engineering field, due to the wider and deeper appreciation of the principles involved.

Question related to "what CPM wanted to put in the ECS ITT; the main subjects". I had noticed, as a member of industry and then of ESA, that previous ESA ITTs had the major fault of over specification which cost industry a great deal of time & money without any additional benefit to anyone. I was responsible for putting the project B ITT together in ESA so I sat back & formulated my own guidelines; there were no written ESA guidelines. So I asked myself what do we want the contractor to tell us so that we can assess his ability to do what we want. The first fundamental was to specify clearly & precisely & concisely exactly what we wanted, technically. We were buying goods & services from the contractor and this had to be specified precisely; this had not been done before. Previously ITTs had been grossly over-specified even down to nuts & bolts level; this was very improper. Also the contractual and product assurance area need to be defined; in a precise and simple manner which had not been done previously. I thus established the SP(system performance) specification which contained all the top level technical requirements; this system is now generally used.
The main Reviews were part of the management plan. I had the feeling that previously there had been too much control of the contractor at the working level and what we wanted to know was "when it came to paying him money, had he done the job sufficiently well to justify that payment". This needed key milestones and at those points we assessed his qualification for payment. These reviews must be pre-defined because they are part of his contract and the contractor relies on getting money at a review. In an ideal world one would like to have a contractor who would deliver what one had asked for in orbit, functioning perfectly, and

then payment would be made. This is clearly not possible with current European industry, the politics get in the way, and such aspects as ESA supplying the launch vehicle make it impossible to implement. Hence ESA has to satisfy itself before launch that the satellite is fit for launch. So political & logistical reasons prevent the ideal system being implemented. The actual number of reviews was reduced from previous arrangements. These reviews were "key reviews" for ESA because we had committed a launch date to our customer(Eutelsat) & key for the contractor because he need to know he would get money at a particular point in time.

I saw the role of ESA as "acceptance, or not, of the contractors status as presented at reviews; the release of funds for payment". The word acceptance carries responsibility with it; if ESA accepted something at a review then as far as I am concerned ESA had made a contractual acceptance. (TM note: in fact the ESA legal dept. do not accept this; they state that such ESA acceptance constitutes only "permission to proceed".).

ECS was not competitive. The ITT was only discussed superficially with BAe before issue. The ITT was for a fixed price contract; BAe had to tell ESA how much it would cost but I am sure they knew the ESA budget available for this work.

When I reviewed the bid I was basically checking whether he was responsive to our requirements. In some areas this is easy for example in agreeing the review timescale. For other areas it is more difficult and the contractor can only say I can meet your requirements by using these techniques or methods. In other words work has to be done to establish whether a requirement can be met. It is then up to ESA to assess the validity of these statements and this is often not easy; leading to a lot of negotiation. ESA has to make judgements; for example will a particular antenna achieve the gain stated by the contractor. We rely on experts for much of this judgemental work.

Assessment of the Bid to establish whether the contractor had defined his role to be complimentary to our as customer revealed that in some areas this had not been achieved. The contractor stated that he did not agree with some of the things ESA proposed and wanted them differently. This was then negotiated. After evaluation of the bid it was decided that the price was too high; certain areas must be cut. Difficult to identify any criteria that were used to structure the price cutting. The basic requirements reference Review milestones were kept.

The risk to the agency that we would not get what was required in the ITT was carried out using experts in each technical area. I listened to the experts and then stated whether I agreed but I made the final decision. A joint decision was really made. I trust more the expert whose judgements have previously been proved to be correct; therefore I trust more the expert I know. I cannot comment about two experts I do not know; this never occurred.(TM: perhaps, sub-consciously, only known people were reattained or consulted as experts...perhaps it was even a condition?).

NSSK (north-south station keeping)was discussed in the bid but not implemented due to no firm requirement from Eutelsat and the need to have maximum communications capability on board(NSSK needs more fuel); also ECS was to be used for TDMA broadcasts, no direct broadcasts. Both requirements needed large ground stations with tracking antennas and hence the need for NSSK goes away. Then Eutelsat became more knowledgeable & organised as a customer to us (TM: environmental perception change) and realised the ECS may not be limited to TDMA. In addition Arianespace was moving along the development line and was able to allow more ECS mass. This scenario convinced us that NSSK was possible and very desirable; hence we introduced the change.

There were a number of reasons why the project ended up being approx. 18 months late and significantly overcost. The environmental specification gave a lot of problems on project A(the previous, and first, ESA communication satellite). The technical envelope that we required the contractor to meet, as defined in the ITT, did not have the support of the ESA technical directorate nor the project technical engineers. Part of the reason for this was that Ariane had not flown to demonstrate the environment it would produce. Thus, in the ITT, we knew the environment was not adequately defined; we realised this was a risk but we took no steps to compensate for it. We took the position that these were the requirements against which the contractors price was a commitment. We knew there would be a problem if we changed it; we did change it, and there was a problem. There were also other problems but it is a great truism that if the customer changes his requirements then the contractor will try to take advantage of the situation to "justify" any delinquencies.

The term "risk indicator" is knew to me and a bit difficult to understand. I would prefer the term "unforeseen problem area".

An example of an unforeseen problem area is the following. Because of delayed budgetary release some equipment design was not left to the contractors choice; ESA imposed certain contractors on the prime to do ceratin work. This was in the ITT. For example, this company is developing a decoder, you will use it. This brought us into a risk loop with the contractor; the contractor said OK I'll use it provided the equipment works properly and delivery is on time, etc. ESA then has a shared responsibility. A different situation existed for those equipments which were selected by ESA and those which were unilaterly selected by the prime contractor even though they had very similar fixed price contracts. For the former when a problem occurred the prime came to ESA with his begging bowl and often received a sympathetic response. For the latter this practically never happened and a good management job was done. (TM: open loops!!)

Reference the "soft" and "hard" aspects, for example whether the management team would do a good job, we did think about and there is no difference basically between the two. The hard data is based on experience; whether what someone is proposing is feasible. For soft data its the same; a number of persons selected by the contractor were rejected by the agency because we, or our consultants, thought they would not be adequate..based on previous experience. One of the big criticisms of the project B programme was the changing of personnel; there was a lack of continuity. A number of people who learnt the project B business very well, were then presumably considered excellent persons by their management and moved off ECS. This was a clear increase in risk to ESA. In one case a proposal for a project manager was refused by me; I declared that if this person was appointed I did not want anything more to do with the project. The project manager was not appointed. A factor in this is the weak penalty clause in ESA contracts; the "other" contract with more severe penalties will take the best people in view of increased risk to the contractor.

On the subject of margins for example for mass, TT & C. These margins were defined based on experience. The contractor on project B tended to make larger than necessary margins, probably to protect himself more. The mass margins were tracked at the monthly progress meetings and at the major reviews; I consider that this was successfully managed for project B. We must realise that at the end of the day industry wants to make a profit and there are a lot of people in ESA who have not had industrial commercial experience and who tend not to appreciate the industrial commercial problems. Life would be a lot easier if everyone started from that premise.

Reference the intervention by corporate management during the phase C/D, e.g. because the project was not proceeding to the strategic plan, I do not recall any direct interventions. I did discuss a number of issues with corporate management.

Reference the definition of parametric margins in terms resources, this was never considered. I do not consider slack in the planning PERT as a margin. In fact there was no slack on the critical path for project B and therefore there was no "margin" on schedule.(TM: this is true because, by definition, the critical path is the listing of all tasks, and only tasks, which have to completed in order to reach the declared end point. Slack does exist however in the other task paths.).

If a qualification activity was not on the critical path then it would contain slack; this slack was judged to be correct based almost entirely on subjective judgement..experts, discussion and so on.

I considered certain key experts to be critical supports to the project.

My dealings with companies were with teams within the companies and certain individuals often tended to dominate; therefore an analogy with human behaviour is possible. There were definite cultural differences e.g. Italian companies we dealt with were known to be susceptible to strikes and the prime contractor often asked our support at meetings concerning Italian problems; the French were very difficult politically but technically very confident; Swedish & German were difficult during negotiations but then fairly straight forward.

In terms of the extent of influence of the corporate management on the team it seemed that the Italians were answerable directly if anything went wrong.

The QPRs(quarterly progress reports) were in the nature of something that had to written; people had to commit what was happening to paper. They were mainly for corporate use. The main information sources however were the co- & sub-contractor meetings which were attended by ESA as observers. The value of this knowledge was that we could say a-priori that an intended move by the prime contractor would or would not be endorsed by ESA when it was tabled at the formal level. For example, if you the prime present this at the next Review then we will reject it, so you might as well change now. It was of course up to the prime contractor whether he heeded that advice or not; there were a number of instances where he did. Although the contractor could have used this a-priori involvement of ESA to his advantage by refusing to be penalised if things went wrong, it being a joint responsibility due to the pre-involvement, he never did.(TM comment:PH & BE thought otherwise). (TM comment: A discussion on whether the prime contractors resource management was monitored by ESA did not produce much comment; it seemed to be a new subject. It seems to be clear that the ESA project management is primarily technical and schedule; one must recall that they are primarily fixed price contracts which do not require resource expenditure disclosures.)

The relationship between ESA and the prime was very smooth at the beginning of the project but not so good at the end; this could have reflected increasing scarcity of resources due to management problems, or other reasons.

During the Bid evaluation I had visibility of the cost, management and technical panel outputs. At this time, and only at this time, was an assessment of the adequacy of the resources made. We were however very sensitive the fact that the contractor had committed to put "adequate" resources on the project to make it successful, not to put so many men for so many years. We could jump up and down if we thought the resources were inadequate but we couldn't really do much about it.

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Notes form Interview with Prime Contractor Corporate Manager.

STRATEGY was determined by contracts from ESA; they were extremely important in providing prior technical background; R & D supported technical decisions which had to be defined in financial terms.
Technical people tend to be optimistic and so a very thorough confrontation review was necessary to try to put those technical people "on the spot" by saying to them "do you bet your commitment to delivering this product to the right technical standard at the right time?". This is not enough of course because the product has to be made for the right price. There is a FUNDAMENTAL PROBLEM of MAKING PEOPLE ACCOUNTABLE for their actions; at a price & time which is acceptable to the customer. Accountability was established right at the beginning of the project; in the bid phase during the completion of the ESA cost/resource forms, for example. Try to make the work package managers entirely responsible for their workpackages. In the negotiation stage between the general management and the performing departments one runs into the difficulty of, on the one hand, of their being willing to be accountable to certain budgets(both cost & time) and meet customer requirements. The INCLINATION IS TO WIN PROJECTS BY IMPOSING(inviting people to accept..) RATHER ARBRITARY CUTS, particularly in price; a BOGEY PRICE is thus created. This decision making(arbritary) by the CEO etc. is later discovered to have meant to the local workpackage manager that he IS OFF THE HOOK. The next stage was then to get the European members of the consortium around the table and then so-called "management cuts", again rather arbritary,

were made. These CUTS ARE BASED ON EXTERNAL DATA to the extent possible e.g. previous bids, parametric cost models; but its all now related to the bogey price. In the case of a private initiative project(multi-company but privately funded) we looked at the market and decided a mid-range satellite was needed and with our partner we proceeded; probably involving $40m from each partner plus government inputs. The price was built on previous satellite models (TM note: none of which were PV!!). This PV venture turned out to be quite successful. All the bids include a basic company profit.

I considered the ENVIRONMENT to be an international one. The data of the environment came from:

- reading previous bids;
- ESA inputs; valuable because it "represented European industry"(TM note: only the ESA perception of European industry);
- conversations; not that important but more important when they concerned the U.S.;
- discussions with US partners/ consultants (e.g. what chance os success did they think the bid had; what do you think Hughes are bidding).

In terms of establishing TARGETS or bogey prices most of the DATA CAME FROM EXTERNAL COMPANY SOURCES i.e. the external data was deemed to be more important BUT you have to believe your own people since they constructed their own prices against the bogeys; and you cannot check everything. The bids by the internal people have either implicit or explicit SAFETY FACTORS reference TECHNICAL RISK and one then has to try to reconcile these costs with what the market is saying is the market price. In the case of HIGH TECHNOLOGY(advanced, state-of-the-art) one tried to establish a fixed price contract with the sub-contractor. However since at least one sub. was half government owned the risk aspect was rather artificial.

The main RISK INDICATORS were the major milestones, and meeting the ESA requirements. In some programmes with high interest rates in operation, CASH FLOW became a major consideration. Also whether overrun on the total cost is likely. People are kept on programmes to safeguard and retain accountability. If running behind milestones then massive resources are poured in, in the belief that such action will avoid bigger problems later on. Hit the technical problems as quickly as possible. Hughes are very good at doing this(TM comment: Hughes are the most successful satellite company world wide and have PhD teams to "throw at problems").

Apart from regular reviews INTERVENTION by myself(PH) was at regular internal company reviews; initially monthly & then fortnightly. It was probably an error that I participated instead of observing since by participating many people considered that the CEO had assumed responsibility and therefore their accountability was ended...they were no longer responsible. Contrasted with the captain of a ship where the captain has the responsibility in the final analysis. Very easy to make such a mistake i.e. participate instead of observe.

If a customer directs you he assumes financial RESPONSIBILITY. In many cases whether the customer comments are taken as advice or contractual direction/ responsibility depends on many things: chemistry, trust, working togetherness. ESA had the definition of "acceptance" as "permission to proceed" without assuming any responsibility.

Concerning financial analysis the approach was rather INCREMENTAL in as much that previous projects costs were considered; LEARNING was thus involved. Unbiased people were imported to assess the realism of the cost estimating. Also one must do better second time around; great pressure in bidding phase.

CRITICAL SUPPORTS in the project were often PEOPLE. Some people fight like hell for you; they drive but they also lead. Local leaders will fight; you can depend on them. Some technical aspects are very critical.

SOFT & HARD data. There were always frictions between the forward line depts. and projects; continuous problems getting the line depts. & projects to work together...in-fighting. One was always trying to obtain a balance and making explicit changes to maintain that balance. The projects often milked the line depts. for good staff.

This manager was very keen on the TM concept of defining MARGINS in terms of resources.
When there is a particular problem then the man-hours must be worked out, at the project meetings, to get back on schedule; the Hughes system once again. It was done but to a limited extent. There was, & is, a severe lack of resources in Europe. Value of work done has to be assessed by the contactor; good for controlling the project.

Ref. OPEN LOOPS; in the contract between the contractor & customer one tries to arrange for as few open loop systems as possible. When they are present they should be time & material contracts etc. In defense & national projects a deal can usually be made with the govt. ref. open loop aspects i.e. when a problem occurs which was not foreseen. This is not the case with international projects.

Organisations are like FAMILIES. The CEO & his mates are the heads of the family; the performing depts. are the teenagers, they have to kicked back into line every now & then. Leadership, forgiving, understanding, accountability, are all present.

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Notes from Interview with Customer Project Manager(2).

This project manager is British with a degree in physics and industrial experience in the UK and in the USA. During his term of office on this project his age was in the late 50's.

Qu.
Can you tell me, first of all, how useful, really useful, did you find PERT for assessing future risks.

Response.
It is useful and perhaps that's the best way of describing its usefulness, assessing future risk. PERT: I was involved in one of the first projects to ever try to use PERT in aerospace and that was in 1976. PERT has been evolved, as you know, on Polaris and it has done a very great job for the U.S. Government and so we were doing a project for the U.S. airforce at that time, and they said, we are going to start to use PERT, please apply PERT to your communication satellite project, and I was working with two project engineers. I was the technical guy because nobody at that time knew quite how to represent the flow of hardware through engineering, through manufacturing, production control.We thus developed ways which are certainly what General Electric Company have been using ever since. The idea of PERT and of course at that time, that was PERT Time and there was also a thing called PERT Costs which I don't believe has been used very extensively. By that time PERT Time was seen as an absolute way of controlling, managing, predicting day to day activities on the project, and when I took over Olympus the PERT charts had been laid out by subsystem with that end in view; and I would have to say that as a means of controlling and managing day to day activities, I don't think it is very good because things happen too fast on a project, and you maintain a staff of six guys who are trying to update these charts all the time. By the time they get them updated and give them to the engineers, they say, that's old hat, that was last week, now its changed. So day to day was not a terrible amount of use but much longer term as you said, assessing future risk I think it is very good, because it is a disciplined way of putting together all the key activities that have to happen, the inter-dependencies in the long term, and it can show you a few things which you hadn't perhaps expected. Although, I have always maintained that the longer term PERT chart is really nothing more than the rather complex bar charts that we used prior to that time. And bar charts with inter-dependencies was what we were using before they invented PERT and that does really tend

to show you the same kind of thing. But anyway not to knock it, I would say PERT in the long term, yes, can be very useful and as you may know when I took over project C, the PERT slacks in the activities against the build state which had slipped from one year was showed as minus fifty two weeks.

Qu.
Did you establish to your satisfaction, or rather how did you establish, that sufficient resources when you took over were available i.e. manpower and costs, actual manpower, were available to bring the project in on time and on performance.

Response.
Well, there is no very simple way to do that. It took a long time, probably about six months, during which I visited a large number of the key companies looking at what was happening. And when something is not happening in time you have to decide whether it is due to lack of resources or lack of understanding what they ought to be doing. Basically it was visiting the companies, reviewing the tasks, looking at the plans and going down to real detail how many people you've got on this job, how many people you've got on that, and this we did over a period, as I say, maybe it was six to nine months. At that time there were sixty companies working on project C outside part suppliers. The task of the prime contractor in trying to manage a project like that as prime contractor was huge, and one of the biggest lack of resources that we identified very quickly was in the prime contractor. They had a totally inadequate project team. They had under estimated the management task of managing all these companies in eight different countries. As I say the answer to the question is, there is no very simple way to find out if resources are short, other than actually going to the companies reviewing in detail what's going on first, versus the plan.

Qu.
Do you feel that ESA exceeds its role as customer, that does it abrogate the role of the contractor.

Response.
Abrogate is probably the wrong word. I believe that ESA frequently does the role of the contractor, yes, but they do it virtually by default because as you well know ESA programmes are set up on the basis of contributions from countries. A certain company has to be the prime contractor because that's the only country that's prepared to put up the money. Another company has to be the payload contractor, because once again, that's the only country prepared to put up the money. This is regardless of whether that particular company has sufficient experience to do the job. So frequently, ESA as sure you well know steps in and does the job. Provides a tremendous amount of assistance to

the company. But again I am not sure this wrong. I have had these discussions with the Italian delegations over of course of the project C programme and they regard this as the role of ESA. Its a training role, so they are quite happy that the Agency has to move in and sometimes do the job.

Qu.
Do you think that makes a mockery of our bid system.

Response.
If you were to look at things in a totally black and white sense, yes, I suppose it does. If ESA were some agency in the United States placing a contract with a company like British Aerospace and if that company had performed like British Aerospace in the United States the contract would undoubtedly have been cancelled very quickly. But once again I come back to the role of ESA in Europe. We are not here to put companies out of business; our role is to assist European companies, and European countries in becoming competent and trained in space. So, although I used to get very angry about the fact, coming from the US as I did, that companies had taken and signed contracts with us to do jobs they were not doing properly. Nevertheless I understood and was informed and accepted that it was our role to assist them and in many cases as you well know we were actually forced to send teams of engineers to companies to actually do the work. Now that's a bit extreme but most of the time it was a question of management assistance but sometimes we actually sent engineers to do the work that they were unable to do.

Qu.
Do you think that has a positive "knock-on" effect for the next project.

Response.
You mean does the company become more competent? I think so, I am sure of it. I would have to look at the prime contractor, project A and project B satellites, we perhaps didn't have a very great visibility of the benefit they got from it. But they did, as you know, Skynet satellites for example and other derivatives of ECS for other customers. As I question that they were using management techniques that they had applied successfully on projects A and B. The project A/B series in the prime contractor was a success story. The company built a large number of satellites, far more than the project A/B series based on that, and I think based on the management technique they picked up.

Qu.
So you don't feel then that the role of ESA is similar to, for example the US company you worked for, reference its contractors.

Response.

Oh, its totally different, chalk and cheese. My old US company, for example is a totally commercial company and so as for any such company, it places sub-contract and the guy has to deliver. If he doesn't that's tough; they have got some pretty tough penalty clauses in their contract. I thought you were going to say NASA because NASA is a similar agency perhaps in the U.S. to ESA in Europe. Except that NASA again very largely would be far more commercial but I think they are far more inclined to assist a contractor in difficulty than just to simply cancel because the contractor that cannot do his job and the contract has to be cancelled, it reflects on the agency.

Qu.
You mean on the bid system of the agency.

Response.
Yes indeed, on the selection system, because if NASA places a contract and half way through the guy obviously can't do the job not only does the whole programme suddenly slip or maybe collapse but it reflects on the fact that NASA selected that company in the first place. So NASA will undoubtly give some assistance to U.S. companies but it probably only happens once. And after that they don't get a chance to bid again. In the commercial world I think both in Europe and U.S. its totally commercial. If you sign a contract you have got to deliver; if you don't, that's it.

Qu.
Could you give me some comments about predicting the future and so on. Could you give me some general comments on thoughts on dealing in a complex system such as project C with the unanticipated. I mean there is always the unpredicted, the unanticipated. Now we have got our static planning; as you have pointed out reference our PERTS and so on. When you went around, when you took over for example, there may have been a project manager before you who had certain ideas. Now you took over and found all the schedule slack. You said alright I'm going to do this, I'm going to go round and look at all this. In general do think the future is unpredictable? Can you give me some general thoughts on how you deal or think or say manage the unpredictable.

Response.
You're saying, how you manage in that situation? A prerequisite for being able to do anything really is to make sure that you have a highly competent team of your own. When things are going smoothly the project team really can just coast along just doing their job attending progress meetings and everything's hunky dory. But the reason you need to have such competent and experienced people on standby is for the inevitable problems. So as I say you need the team for when something unexpected happens and then you have to move very quickly. You have to have the ability to create a task force within the project team.

If it is a payload problem you put a payload manager in there. You immediately make sure he's got three or four guys with the knowledge of the technical area that's in difficulty. And you just write out to the company and you immediately find out what the story is. If it's design then you have to put design people on the job immediately; what we did was have ESA engineers practically living at the plant for maybe a few days, maybe a week, maybe sometimes longer than that. If its a production problem as it more usually was on Olympus we would have product assurance people there and we would get the prime contractor to put a resident team in. You are on a daily teleconference situation, daily faxes, daily teleconferences but you have got to get that team of the best possible technical people, you have got right on the job very, very quickly. That's why, as I say, its no good just having a competent project team of experienced project managers, project engineers, you must have senior technical people available instantly. This is not always going to work if you have to rely on a functional organisation to provide the technical people; they always will get involved but very often the guy you want is on leave for a week, he's on mission, or he's tied up with another project. So the project team must have its own competence to cope with situations like this.

Qu.
In other words for the unpredictable things in the future you have this stand-by reservoir, the technical aid. So are you saying there is no other way, that you see, of dealing with it?

Response.
Concerning predicting; we cannot. I mean the future is unpredictable, of course. Well, I described the classic situation when something goes wrong, when something fails a qualification test or something of that description and you immediately got to take action because without a doubt that particular equipment is on a critical path. Naturally everything you do in planning a project is to try to prevent situations like that happening. Everything you do in reviewing the design is to try to anticipate or prevent a serious problem developing in tests or in product assurance or whatever. So you are working all the time to try to solve a situation like that. I described what happens when it happens, when everything you've done has failed and somebodies gone wrong. Then you've got to get the team involved very quickly but of course it doesn't always mean that you can solve it with your own engineers. We've had problems of that nature on Olympus where what we had to immediately do was get another contractor involved. There are certain technologies which are very unique to certain companies and of course different types of travelling wave tubes on project C and we had problems with at least three of them. Then we had to place backup contracts for two of them and the original ones never flew. So that's a very specialized technology and what we had to

do in the case of one contractor, we immediately got to their top management and said the agencies got a serious problem on this project can we have your cooperation in setting up a backup contract. And we immediately got it. So you start at the top management level, they give you the green light to send a team out there, negotiate a specification very quickly, try to negotiate the schedule very quickly and come up with a replacement equipment and of course we had to do that on several occasions.

Qu.
Do you feel this, that's a very interesting point you mentioned, that you went out to get the green light as it were. We do have a corporate management. Do you feel that we should always have a layer of management above project management which can intervene at any point in time. Either, a) when it feels like it, or B according to a firm set of criteria i.e. agreed with the project manager a-priori.

Response.
No, I disagree totally with that idea. The project manager in the agency is given total responsibility and he must have total authority; the two have to go together. And I have got to say that in working for my Head of Department, with a few exceptions, I had that total authority. What is needed is for the layer of management above the project manager to be totally ready to jump in at the request of the project manager, to support him with the top management of the company and help him wherever possible. As I say although there have been a few exceptions generally my director did play that role and it does not work if he's there as it were taking action even against a pre-arranged criteria as it were over your head. You must call him in to support you rather than have him take independent action.

Qu.
I would now like to consider the scenario between yourself and the industrial project manager. How do you feel that should work, the intervention aspect.

Response.
Sorry, explain the intervention aspect.

Interviewer response When the project manager in industry is driving his consortium as you say. Now on top of him, if you like, you've got you with your team. Now at certain points in time you decided "I'm going to intervene". You have perceived that "there's a problem", you don't think they're doing it properly", whatever. So ESA(you) intervenes. How in general do you think that should be handled.

Response.
I always did it with, or through, or in conjunction with the project manager because in carrying the same argument

forward, he's in charge, we've delegated responsibilities to that company and he must be seen to be charge of his project. You must not under any circumstances bypass him or second guess him. This means of course, if he doesn't happen to agree with the course of action that you want to take, that you're going to have a lot of very hot meetings and a lot of hot discussions. Which we did on project C. Sometimes it involved actually involving his senior management not to bypass the guy but to get another level of judgement and experience onto the job. Once again we always managed to do it. It was sometimes rather stressful and of course you're terribly dependent on the experience of the project manager involved. If he's perhaps a little bit limited in experience, then you are going to fight a lot of battles, but then that's what we're paid for.

Qu.
I think you are in, as I've said before, a unique position, possibly in ESA, because you have all this industrial experience and many ESA project managers haven't had that; at least industrial managerial experience. So one could, and I think we often have, had a situation when the role is reversed where in industry you have a very experienced guy and a much less experienced guy in ESA. Now how would you see that situation?

Response.
That is bad news; for both parties.

Its a point I made several years ago when the recruiting policy of the agency topped at grade A2 engineers(junior grade; maximum age 35 years.). I made the point, it was in a presentation to Professor Lust(ESA DG at that time), "our job is to manage industry and we must be at least as competent as the people we manage". I have seen situations where a industrial manager in a meeting made an agency manager which much less experience look rather foolish because the agency manager did not understand what went on in manufacturing. He didn't understand the functions of product control inspection, the parts screening, the day to day management and manufacturing activities, process control. He didn't understand this task and he didn't really know what he was saying when he asked them to do something. This of course, immediately detracts from his image and it undermines his authority because industry realises that they've got more experience than he has and they can to some extent pull the strings but they don't respect him. Its highly important that in managing projects, and the programme directorate must basically do that, that you have people who have got a lot of experience and must have a lot of "industrial" experience. One of the problems in the agency in my view is that a lot of the most senior people in the agency don't have industrial experience. They have never functioned and succeeded as industrial managers. This is a handicap for them also. But nevertheless it certainly works at project level and you must have people who can manage. They are after all managing industry; they must be able to manage the guy they are talking to across the table.

Qu.
An old friend of mine, he left ESA sometime ago, he has now come back as a project manager in science. I had lunch with him the day before yesterday. He said, well, my first problem is dealing with all these people in ESA; they all think they're gods, each and every one of them. How important to the success of the project do you think this perception of respect is. The perception by the people working on the project; that here we have someone we can respect. Its a perception. You've mentioned cases where that respect is not there and in cases where it is. This is a soft aspect; its not something you can put on a PERT plan but possibly it could have as big an impact as, for example, somebody putting the wrong diode in, or soldering something incorrectly etc.. Do you feel that this is an important aspect, for a successful project?

Response.
Yes, it is important.
Two aspects; the first one is a sort of, as you might say, a soft aspect. It means that if you're respected by the contractor then your day to day contact with and your progress meetings will be smoother, more pleasant and more honest. That's a fairly simple thing. But the second aspect of it is far more fundamental, I think if you are seen as somebody less experienced than themselves, somebody who's judgement they don't want. Somebody where they feel their own judgement is better than yours, they are going to present you situations in which they have already analyzed the situation, analyzed the problem, decided on a course of action and they will present it as the only course of action they can take. In fact by the time they present it to you it probably is the only course of action they can take. On the other hand if they respect you they will want to have your opinion, they will want to get you involved earlier in their problems. So in a sense you'll know about things earlier, there will be a more open dialogue because they want your judgement. So that's very important.

Qu.
So lets assume now you are the director of the programme or programmes; I am going to introduce a term called risk indicators. We have indicators for all sorts of things in life but for possibly the most important thing, risk, we don't use that term. Its a fairly new term. The risk indicator simply means something that indicates if the risk is increasing; its something that I should look at in order to try to get a handle on the risk I am about to encounter. So lets assume that you are the director of a number of programmes, would you consider this respect aspect as being a significant risk indicator? If your appointed project manager was marginal in experience would you treat this as

a risk indicator?

Response.
Of yes, I would feel immediately that I'm going to have to spend an awful lot of my own time watching over his shoulder because I couldn't really trust him to know what he was being told. When somebody's describing a problem that they have encountered in, say an engineering model test or some equipment. He's got the viewgraphs out on the board and he's telling you what they did and what didn't work, the theories they got, why it didn't work, a course of actions that they are proposing to take. You very quickly develop an instinct for how serious it is, simply by studying the guy and his understanding of what he is doing and his attitude. There is a lot of psychology management. So if I'm a director and I've got a project manager without the adequate experience. I know he's not going to be able to do that or only in some instances. He might be able to do for some technologies but not others. He might be a babe in the woods when it comes to thermal or something else. So its going to constitute a risk in such a situation. You've got various things you can do I suppose; you can surround the guy with a lot of technical experts. You can say, tell me if something's going wrong and the project manager doesn't recognise it but I mean this is not a way to manage, its going behind the guys back. In fact the director doesn't have the time to do this, its management. Its a very significant problem I think.

Qu.
So, staying with this risk indicator thing for the moment. Can you think of anything else that you would put under that general heading of risk indicators. You've got a program starting right at the beginning. You're looking for things downstream that will indicate to you in advance, even the unpredictability of things happening. Now we've got one risk indicator which relates to the respect, which is a very good point. Can you think of anything else that you would use. Possibly the PERT diagram is something you would use as a risk indicator.

Qu.
I assume you are not talking about technical risks; or are you talking also about the maturity of technology and all that stuff.

Yes.

When you start any project you can break the whole thing down into subsystems and equipments. Very quickly, I think, most people would be able to identify just where the critical technologies are going to be. In other words where the difficult technology problems are going to be. You can probably identify 90% of them before you start the project.

You know that certain equipments are going to be tough. For example you are trying to build a frequency generator at some particular frequency that's known to be touchy. Later on there will be 10% of problems that emerge simply because of equipments trying to interface with each other and there will always be the unexpected. So technology risk I think is something that we probably do pretty well in the agency. I don't think we have ever really been surprised. I'm talking about project C. I think that technology problems we had were fairly predictable. O.K. I can think of some. I remember the tank design programme. There are unexpected things but the technology risk is generally fairly well identifiable at that time.

Qu.
How did you establish that technological risk? How did you establish in the bid phase that the resources where adequate? In the bid we have the PERT diagrams, the cost analysis computer print-outs, and then the man-power charts. Then you have the CVs(curriculum vitae) of the people. How do you establish that the resources, in total, are sufficient?

Response.
Well, you can only do it the hard way. I have to say I was not around when this was done on project C. Presumably we didn't dig deep enough because quite clearly the resources were not adequate. I think that to be fair technical resources were probably pretty good. What was missing and is frequently the case was the management abilities at the first, second, and third levels of management; immediate technical supervision, middle management, project management, I think there were just not enough experienced people in there, driving the resources.

Qu.
Could we detect that from CVs?

Response.
You can. It depends but you"ve got to know what to look for you in a CV. A guy might look great. He might have a first class honours degree and five years experience in some technology. He looks great but he's probably never ever got a piece of equipment through qualification and into a satellite.

Qu.
Should all these people be interviewed by ESA the bid phase; at least by the team?

Response.
Well, I don't think so. Certainly some key people should be. For example some of the sub-contractors managers don't have to be interviewed because they are already known. I think they should be, there are some certain key people but I'm not suggesting to interview every single engineer. But

the managers should be known. Oh yes, they definitely should be known and they should have a good track record. As I say its knowing what to look for in the CV and I think this was particularly true in the case of a particular contractor where they do have some very good engineers and very poor management. A solution there was to put in a bunch of very experienced people. The agency paid for some of them and we recruited a total of seven, very senior, highly paid technical, consultants as they are called today. They were of course, job shoppers way back. Five out of the seven were Americans from TRW. These were put into the one of our contractors teams. One of them for example was totally responsible for the one of the sub-contracts to the co-contractor, for one of the payloads. Another one was responsible for another payload. This was the level of the newly introduced people.

Qu.
They did a good job?

Response.
If they hadn't we would never have got project C built. So what was missing; the technical management aspect in that particular case. Many payload engineers did a pretty good job and the final performance of the payloads has been very good. We had some travelling wave tube failures which I don't believe we can blame on Alenia but the payload for example gave a higher performance than required by the specification. This was one of the reasons when we lost one of the solar rays and had to operate 3dB down the customers never noticed, because the performance of the payload was so much higher than the specification. So the engineers in Alenia are very good. That's true I think of most European companies the technical standard of engineering is very high.

Qu.
So under this risk indicator you see the maturity of the technology in which we discussed, the competence, experience of the management at various levels. Anything else that you feel is not in those two areas.

Response.
Well, one obvious one of course is what else is the company doing because it doesn't matter that they've got enough resources, enough managers. They will always trot them out when they want the contract. Six months later when they win some other contract they might take them off the project. So you've got to look at what their commitments are to other customers and other projects. You will always throughout a project fight the resource battle. You will always suddenly decide you are going to have a meeting with the top manager because they have put a whole lot of people onto some other project and you are starting to suffer.There is a constant battle watching over the company to make sure that they keep the right people on the job

once they put them there. That's a big risk.

Qu.
Going to back to something you said just now. You started saying something about when the project is running smoothly, the project meetings happen and that's O.K. Then we might get a problem and we put a tiger team in or something. Do you feel that, or how do you feel, if I can use the term that a project moves from a smooth, steady state condition? Do you feel it goes through phases such as first of all its smooth then it becomes a bit turbulent and then it becomes really turbulent, chaotic? Then something happens: you return it maybe to that stable position and then the whole thing happens again. Do you feel that sort of thing happens?

Response.
It does but the cycle is fairly rapid or it was fairly rapid in the case of project C.

Qu.
From steady state to chaos?

Response.
Yes, simply because there were major technical problems at one point in time that lasted for quite a long time during the development. So you might get one area under control but not the others and then other problems developed. It was rather like the Hydra and cutting off their heads; as soon as you cut one off another one grows. It was a little bit like that so there wasn't any very long periods of time when things were going smoothly.

Qu.
In one area you mean; or it affected all areas?

Response.
You mean subsystems; probably no. There were some technical subsystem areas that went along pretty smoothly but again not many. I remember TT & C (Telemetry and TeleCommand), which is one of the most mundane subsystems in most satellites. I remember a major crisis because we couldn't get the heat out one particular power transistor and the thing failed qualification. Then it failed again; it went on, on and on. And that was a subsystem that was supposed to be absolutely mundane and normal and we went to the States to buy the equipment simply because they had the technology and we didn't want problems. You can't ever quite say that things will settle down into a routine way. In fact if they do you are probably missing something. The cycle is very short, its a sort of monthly thing almost. I remember at one point the prime contractor management approached my director and said we want a meeting between the prime contractor team and ESA team because we've got so many major technical problems we actually can't handle them ourselves we want to form a joint approach with the agency.

They came to ESTEC with their project manager and his team. I had my team there with our director. They went through 13 major problems, which they described in detail, that they had on the project that they felt that were too much for them and they appealed for agency help because they did not feel that without the agency help that they could solve them in a sensible time. So given that kind of background I don't think there were many times on project C when things really settled down. Now if you are talking chaos which I think you are I wouldn't say we were in a chaotic situation all the time but we were certainly in a very highly stressed risk situation in many, many technical areas at the same time. Pretty well throughout the project and of course, continuing to include Kourou for the launch campaign. It never quite stopped on project C which was probably what made it quite unique.

Qu.
Do you feel that this, if I can stay with this, this movement, do you feel that it all starts at a certain point which is quite low in the overall organisation. You mentioned a power transistor; which is located in an equipment which, in turn, is located in a subsystem, which is part of the system. Do you feel that in most cases it starts at a very low level and you get a sort of branching that effects something else and then those things effect something else and it grows like a tree. Or do think there is some other mechanism or some other structure at work?

Response.
Its hard to see that but I know it would seem to be that way. The problems. I guess you could say we had two categories of problems on project C. One was basic design, coming up with a design that worked. Coming up a design that would survive in the environments. I think that the tank design was definitely in that category because the design that had been proposed and reviewed and accepted didn't work. They had to go back and start again. There were one or two areas like that. The other area was very much an environmental one and you could say this maybe supports your theory that it starts at a low level but the environments that all equipments that had to be qualified to were pretty severe and the acoustics were the worse. So the problem when it showed up in trying to get through qualification was always at a part level. Some part broke off or whatever. So you could say yes, in that sense it started at a small level and then of course the thing multiplies because suddenly you've got to try change the design in some way. Its no good putting the part back in just like it was before because its going to fail again. So you have to change the design again. You've got to build the equipment again or modify it and then you've got to test again and certainly that of course starts to ripple through the whole system. As any PERT network will tell you. Everything is on a critical path suddenly. So yes, that does certainly multiply in that sense but that's a

well known phenomenon.

Qu.
Let me go back to the things we have been saying. At a point in time BAe came here with 13 major problems. How can this happen with such an experienced team? They had by that time a lot of experience. A major established outfit like the prime contractor with experienced established codes. Most of the codes were established; we built them up every year from project A. How can it happen, we spent all that money on reviewing the bids; we spent weeks and weeks, months and months. We think we have nailed every problem and suddenly as you say, there's this enormous catastrophic situation as far as they are concerned; they can't handle it. How does that happen? What is the reason?

Qu.
I think I can describe how it happened but its hard to, not to get into politics and all sorts of company interplay. My own view is that the prime contractor was taken by surprise. They never and I have to deviate Tom at this point to something I don't think is really at all bad here but I have to tell why I think it happened. The prime contractor needed the project C programme; it was a large programme. Their project team alone was over 140 people for years. Now that's a very major injection of money into a company. It enabled them to maintain a very high base of engineering on a programme. It was a very expensive programme and at the same time they were making bids for Skynet, and Intelsat. It was a great prop for the company but they looked at the job that payload contractor had in managing four separate communication payloads, all of them fairly challenging. They had assessed in my view the payload contractor would not be able to cope and they were quite right. So all of the PERT charts that they told you about that showed minus 52 weeks slack were based on payload problems. And always whenever we said why are you not doing something on time it was always the payload contractor that was blamed: it was always the payloads. Now I have told you also that what we did then was to turn right around and we made sure that the payload contractor could do their job. We sent teams of engineers out to the payload contractor to write specifications and to write test requirements. We injected 7 very senior people into the payload contractor team and suddenly the prime contractor found that the payload programme was going along pretty well. They were late compared to the original dates but they were obviously going to make it; they were going to get there because we were forcing them to get there. Suddenly the prime contractor could no longer shelter behind the payload contractors slack. That's when they came to us, they realised they hadn't been paying enough attention to their own major problems and suddenly they were in trouble. I think the fundamental reason is that European Industry see's ESA as a very benevolent customer and when a 700 million dollar programme like project C

comes along they are only just to delighted to have it. That's how it happened. Now you could say why didn't we see it was happening. Well, we did see it happening but there is a certain amount of perception of what's going on; it happens in many of the project meetings. One of the fixes we made to project C in Kourou was to put in a safenet switch because something we had proposed three years previously. This was because we believed that the central electronics unit on project C was so complex that we could never quite guarantee that we wouldn't find ourselves in a situation where the satellite got locked up in orbit. The prime contractor assured us by repeated assertions that this could not happen. Finally they had a change of management in the prime contractor, and one of the engineers in the prime contractor went to the guy and said there is a mode of operation in which a failure could put us into a mode which we cannot get out off. We can't command it, that manager said. What can we do about it? He said we can do this. He said, its what ESA suggested three years ago. Why didn't we do it, the manager asked. He said, because we thought we were smart enough not to do it. The manager responded: what you have been guilty of is technical arrogance. The prime contractor management approached us and admitted it, they said we were guilty of technical arrogance, we can get into such a mode, which we can't get out off, we acknowledge that we have got to do something about it; they would make a maximum effort to come up with a design. They did that, the modification was incorporated in Kourou.

Qu.
I'd like to address the subject of perception. Do you feel that, in your life, your education, your past life and so on there are maybe one, two or three things that really effect your judgement when you make a decision? Let me give you an example for a moment. Lets say, you are you and I'm an Israeli and an Arab guy walks by the window, I could perceive enemy, as Arabs and Israeli's are always fighting. You see rather an attractive nice looking dark skinned guy. Now I perceive that because of my experience on the planet, that is the nature of the question. Do you feel for yourself there are any major issues that formed a very, very useful education, experience or something. You may have said to yourself "I'm going to keep that in my mind, and whenever I do something in future I'm going to relate to it". This could relate to good or bad experiences.

Response.
I think the thing that comes to mind most frequently in trying to manage a project is what I was talking about earlier; the psychology of listening to an engineer explaining a problem. I have a bit of a concern about engineers who are what I call paper engineers. As I say, they've got a first class honours degree, they've got five or six or seven years performing designs and very cleaver designs. They may have several patents to their credit. But

the only engineer who's word you can rely on, in my view and this is something that has conditioned me, is somebody who has actually been through the hardware programme. He's had on equipment, that he's had to get qualified. Design first of course and then qualified into a flight satellite. To the greatest extent possible "hands on experience". These guys I feel I can trust because they have done it. They know what happens. They know the problems of suddenly having to get purchasing, to going out to get new parts, production control has started into manufacturing, to get the box modified, to get it re-tested, to get it into the satellite, they have done all this stuff. The guy who hasn't will say, well we will do that in a week, the other guy will say, well it took us four months last time. These are the guys who really know how project works. So I had a lot of hands on hardware experience myself in my engineering background and worked guys in other disciplines who had the same thing. My manager at that time, this was in the General Electric Company was very, very insistent on not believing the paper engineers necessarily, he always wanted to back up from a guy who had done it, who knows what it took. So I developed that kind of feeling for an engineer.

Qu.
For a manager as well?.

Response.
Absolutely, When I say engineer, I mean engineer at all levels. So you could say if I see a paper engineer walk past the window that's my enemy. Its not my enemy, the guys very good.

Qu.
But not the guy you preferentially want?

Response.
Well, he's got a role to play but when you are assessing risk which is what you are doing, then you are making a judgement on what you are being told all the time. So I trust the guy who's got the hardware background. Its what I say.

Qu.
I want to talk a little bit about the environment. When you were at working in the USA, and now that you are here. What do you consider your professional environment to be?

Response.
Definitely management.

Qu.
Do you feel for example that the science satellites are part of your environment. Or that there is a prioritisation when you look at things. There is information; your brain

is receiving information. You are giving information or making contact with various things on the planet etc. How would you define this environment that you move around in?

Response.
Well, that's a very general question, I suppose I would have to say my environment is very general. You have to realise that my personal experience is perhaps rather odd because I was in Aerospace for, shall we say, the majority of the time. I was only with the US company Headquarters for a couple of years. I was with the US company in the U.S. and there my role was totally different. I was totally involved in industrial management issues. Management of a international organisation which had several locations, four in the United States, three in Europe. I was on the staff of the president of the group and the job was solving management problems and working with organisations in Holland and vice versa. So at the same time product selection was a problem. Product planning was done by commercial companies and they have to decide if its going to sell. So product planning is a major function before they ever undertake any kind of development. The difference in environment between the U.S. and Europe was such that Europe says the products that are good for the U.S. are not good for Europe, so there's product planning problems and my job as a staffer was to try to solve all of these things; work with the senior vice presidents in all areas. So for ten years I had a very different environment. I was working with very senior managers, I was exposed to all the senior management problems of a highly commercial company. Then I came back into Aerospace and I have been here now for eight/nine years. But that background is always with me, when I deal with some of these big industrial companies like the payload contractor. So I don't know whether I am answering your question but I see my environment far broader than engineering management. I don't particularly want to, its just there. I think once you've got knowledge you can't forget it. So I know what's going on in the halls of the company and sometimes it can be of assistance. It means that basically, as I say, the environment I suppose I feel I'm in is very much management and when I read aviation week and can see what's happening in some company I know very much what's go on. You can read between the lines very often.

Qu.
Where did the really good, what you consider to be really good, information come from. Did it come from the QPR(Quarterly Progress Report), did it come from the PPR(Project Progress Report), did it come from discussions with the project manager, did it come from discussions from your own team, did it come from their penetration of the sub-contractors, etc. The real information, that you really acted on. You really believed; what was its source?.

Response.

The latter two that you just mentioned. The progress meetings with the companies and the information from my own team coming directly from the sub-contractors, that's where my information came from. The regular prime contractor reporting was by comparison very glossy and superficial. It was useful but it was not the fundamental source of information from which I managed. It was my personal penetration into the companies they were managing and visiting and having progress meetings with there contractors. That's undoubtedly where the key information came from and I just have to mention that very often it would not even be known to the prime contractor; and then I always bought the prime contractor into it.

Qu.
Do you feel, if we put the PERT on the table, one could identify a lot of the tasks as being open loop. By open loop I mean they are non linear. One could say, well I know that task is going to start there but I am really not sure about the outcome, I am really not sure, for example, about the result of a qualification. But do you feel, that if one took a total programme plan, one could mark everything on there in terms of closed and open loops. Open loop by definition being non-linear and the closed loop being linear. That is, if you are half way through a project and you had used half the resources, then for a closed loop situation you'd say, I'm pretty sure that the end is in sight I don't need to worry about that any more. In fact one wouldn't worry as much about the closed loops as the open loops anyway. But do you agree with that concept?.

Qu.
I guess I would have to say no because I think if there was something open loop I would worry a lot about it. By definition a PERT chart has to show a coming together of a vast number of activities to a end point and show in the end that its on time. So everything really by definition is closed loop because everything you are taking into account must be completed before the project gets delivered, that's the idea. So something that's open loop means that there's an uncertainty there, which could place the whole project at risk. In practice you could probably be right there may be a lot of those activities that tend to be open loop but what your job as project manager is to make them closed loop. You've got to make them come to a termination, at a time when you need them.

Qu.
Could you develop that just a bit more. We have on our satellite projects margins and really we're talking about linear margins, We have mass, we have power; these are parametric margins. We say we are going to build a satellite for three tons; we have a capability for three tons from the launcher. So we stipulate, for example, a margin of half a ton and hence we must build the satellite with a target of two and a half tons. So when we go through

the programme we track it, we start off at the beginning with the half ton and we hope that by the end all the modification etc. will have exactly have consumed all the half ton; but not more. If of course there is some mass left over, that's a bit embarrassing as well. So that implies linearity because if we are half way through the project and we have used a quarter of a ton, half the resources, then we think fine we are on the ball. Do you feel that this utilisation of margins in a linear sense is really a rational management tool for the avoidance of risk?

Response.
No, I don't think so and I don't want to disagree with you but I don't feel that I ever applied linearity to those margins anyway. Because if you are talking mass margin for example, you make all sort of predications on what its going to be, based on experience. You generate a margin which you think you need based on experience. Then you start performing but the big steps come of course when you build something and after you've tested it and see what modifications you have to make. So the margin gets consumed in steps, it gets consumed when you have completed the Engineering model. It gets consumed then at the next stage at the flight hardware qualification. So by time you get by through qualification with that equipment you are probably just about there and there is maybe another year or two before you ever fly the thing. So its not linear its a step function. Certain steps which I think engineers recognised.

****

7.6 Customer Project Controller(1)

This project controller is Swedish with an industrial background in Swedish aerospace; his age at the time of this work was early 40's.

The following notes were made from extensive discussions; no tape recordings were made.

The projects were underpriced from the outset. This was realised but the detail was not available to enable firm definition.

The planning documents do not indicate risk; an engineering assessment is needed for that aspect. This was not available at the customer nor the Bidder.

In the Bid the technical content was not correlated to cost. Very much engineering experience and commercial knowledge is needed to assess the viability of the planning; and time and resources.

In general many organisations seem to be ill-equipped to evaluate proposals.

There does seem to be a pattern in the evolution of problems roughly resembling the transition from some sort of steady state through a turbulent/crisis regime to panic/ chaos.

Too much intervention can cause crisis to continue.

Many customers intervene in a very detailed manner; this is counter productive.

The responsibility of the prime is "watered down" by excessive customer involvement. In the customer there is often a "jockeying for Brownie Points" by obtaining information by this or that "intervention" means. In the excessive intervention environment many contractors are submitting CCNs(contract change notices) continuously thus resulting in cost overruns.

Contract must be static to provide a baseline; things must start, and be correlatable to, somewhere.

Risk cannot be judged "looking" at a plan.

In many instances situations are approved at the project level with the intention to look at problems later.

When many young people are introduced into a project the thinking is freer, more open and more lateral; less intervention from the experienced older persons . However, the experience is missing; this could prove expensive.

Margins are attractive mainly because they are so simple and everyone thinks they understand them.

Rate of disappearance os planning "slack" is important but is rarely plotted.
Open loops cannot be identified incurrent planning methods and is rarely considered as such.

In project evaluation exercises a liaison between planning and engineering etc. is essential but is really done.

On the subject of intervention and strategy it may be interesting to note that Brown Boveri is run from a small Swiss village by six executives and seven secretaries!

****

7.7 Customer Project Controller(2).

This project controller is Italian with an administration background; his age was mid '40s at the time of this activity. At one stage he was located at a major Italian co-contractor to properly implement project control. This involved long sessions with the engineers concerned. The following notes were compiled from several discussions.

Planning presents the size of the project; it provides an envelope of time and resources.

Planners are usually detached from the engineers.

Planning must be "lived with". Planning is a growing living thing that cannot be randomly accessed; it is important to know what went before in order to be able to "realistically" interpret what the current planning presentation means.

Planners must be technically qualified or technically knowledgeable in order to be able to communicate with engineers and senior managers.

Culture is an important aspect and is almost never addressed. (TM note: should Italians therefore evaluate Italian inputs, and so on ??).

The Bid evaluations are restricted to Master bar charts and sub-system reviews; this is insufficient.
Companies think in terms of targets; money. Engineers think in terms of manipulating test programmes etc.

The pressure generated by fixed price contracts within a company are very important vis-a-vis the risk aspect. Some of the major programmes have very substantial cost reimbursement elements i.e. non-fixed price. very often the contracts are cost reimbursement with a ceiling price. When the ceiling is reached. the company stops work.

It is necessary to have a planner plus engineer discussion for every task; margins and risk can then be properly communicated.
On the project in question there were a constant sequence of problems; and a number of industrial disputes.

****

7.8 Customer Project Controller(3).

This project controller is German with an engineering technician background; this means he is familiar with manufacturing methods and factory routines. His age at the time of the work was early '40s.

Many planning etc. inputsare received from contractors just to satisfy the customers requirements; not to really

contribute to the project success.
Contracts are often quickly signed by contractors because they know they are in an environment whereby they can obtain additional monies from contract change notices(CCN). It has occurred that ccns have been written BEFORE the contract has been signed!

A major cause of phase C/D problems are the mistakes and incompletions that occur in phase B.

Many contractors have knowledge of the overall money available by the customer well before they start bidding. The Bid therefore often reflects what is available rather than what is required. The deficit will hopefully be "made up" via CCNs.

The above customer assessments of the money needed for a project are often arrived at very arbritarily; often by persons without real commercial knowledge.

A "lessons learned" culture is essential; with data and knowledge bases.

The ESA ECOS system contains a lot of data but is not implementable for project work. It has some usefulness for Bids but is labour intensive to load and expensive; in terms of time and money.

At the moment very few industrial planning and management tools are integrateable.

Most problems can be isolated except those with multiple interfaces.

A major problem can be that the top(driving) custom specifications are "full of holes". This has caused a number of projects to rapidly increase in risk for the customer i.e. large payments to the contractor to cover the additional requirements as the requirements are completed.

Contracts have been in which additional senior staff were employed BY THE CUSTOMER to run some of the co-contractor areas.

A major "risk indicator" appears to be that of the customer project personnel, or even the contractor project staff, being too far away from the action.

Good contract negotiators are very rare.

****

7.9 Customer Project Controller(4).

This senior project controller is British with a civil service accountancy background; his age at the time of project involvement was early '40s.

The following notes were made from a short interview.

By experience, it is considered that payloads are more risky.

Risk cannot be assessed from PERTs and DCPs(cost planning).

It is essential to identify key equipments.

ESA ECOS never used extensively.

Customer role now that of supplementing lack of contractor expertise and resources; very little monitoring now.

The superposition of manpower and cost on the PERT would be very useful.

A good "risk indicator" is monitoring the invoices that are sent to the customer by the contractor. When the contractor fails to send invoices on time i.e at the pre-agreed points, then it can be confidently predicted that the related co- and sub- contractors are late and hence a risk rea has been identified. This relates particularly to fixed price contracts.

ANNEX 7
ORBIT FAILURE, ACCIDENT, and NON-CONFORMANCE ANALYSIS

Orbit Failure, Accident, and Non-Conformance Analysis.

This annex(7) contains computerised presentations of the outputs from a database, outline designed by the author, which contains world-wide failure and accident information appertaining to space vehicles. The information covers ground(e.g. test) and space occurring incidents and applies approximately to the past decade.

The presentations have been designed to be self-explanatory and each 3-d histogram contains explanations of the variables being correlated.

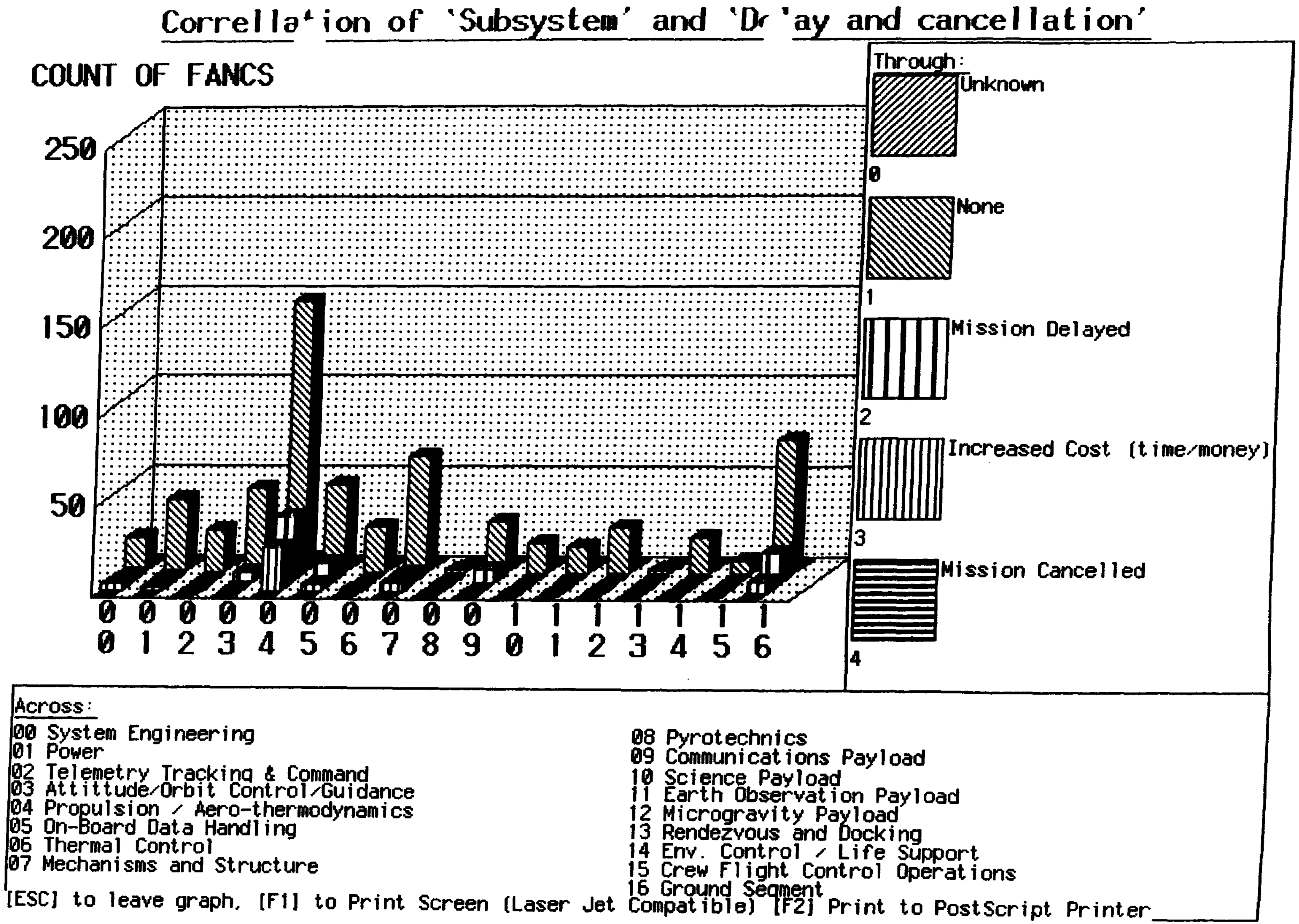
The results of an analysis of this data is contained in chapter 5.2.4 of volume 1 of this thesis.

The term "FANC" is an abbreviation of "Failures, Accidents, and Non-Conformances". This term embraces everything that "went wrong" with the space vehicle. Those FANCs that could have resulted from managerial, etc., errors during the project have been identified in the analysis. A major aspect that has been examined has been the extent by which the evolution and growth of problems which were initiated during the project, and in some cases caused turbulence and chaos to develop, continued to be present during the operational phase i.e. in orbit.

FIELD IN GRAPH: Delay and Cancellation:

The following values can be taken for Delay and Cancellation:

0	Unknown
1	None
2	Mission Delayed
3	Increased Cost (Time/money)
4	Mission Cancelled


Corrella'ion of 'Subsystem' and 'D' 'ay and cancellation'
COUNT OF FANCS
250
200
150
100
50
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16
Through:
Unknown
0
None
1
Mission Delayed
2
Increased Cost (time/money)
3
Mission Cancelled
4
Across:
00 System Engineering
01 Power
02 Telemetry Tracking & Command
03 Attitude/Orbit Control/Guidance
04 Propulsion / Aero-thermodynamics
05 On-Board Data Handling
06 Thermal Control
07 Mechanisms and Structure
08 Pyrotechnics
09 Communications Payload
10 Science Payload
11 Earth Observation Payload
12 Microgravity Payload
13 Rendezvous and Docking
14 Env. Control / Life Support
15 Crew Flight Control Operations
16 Ground Segment
[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer

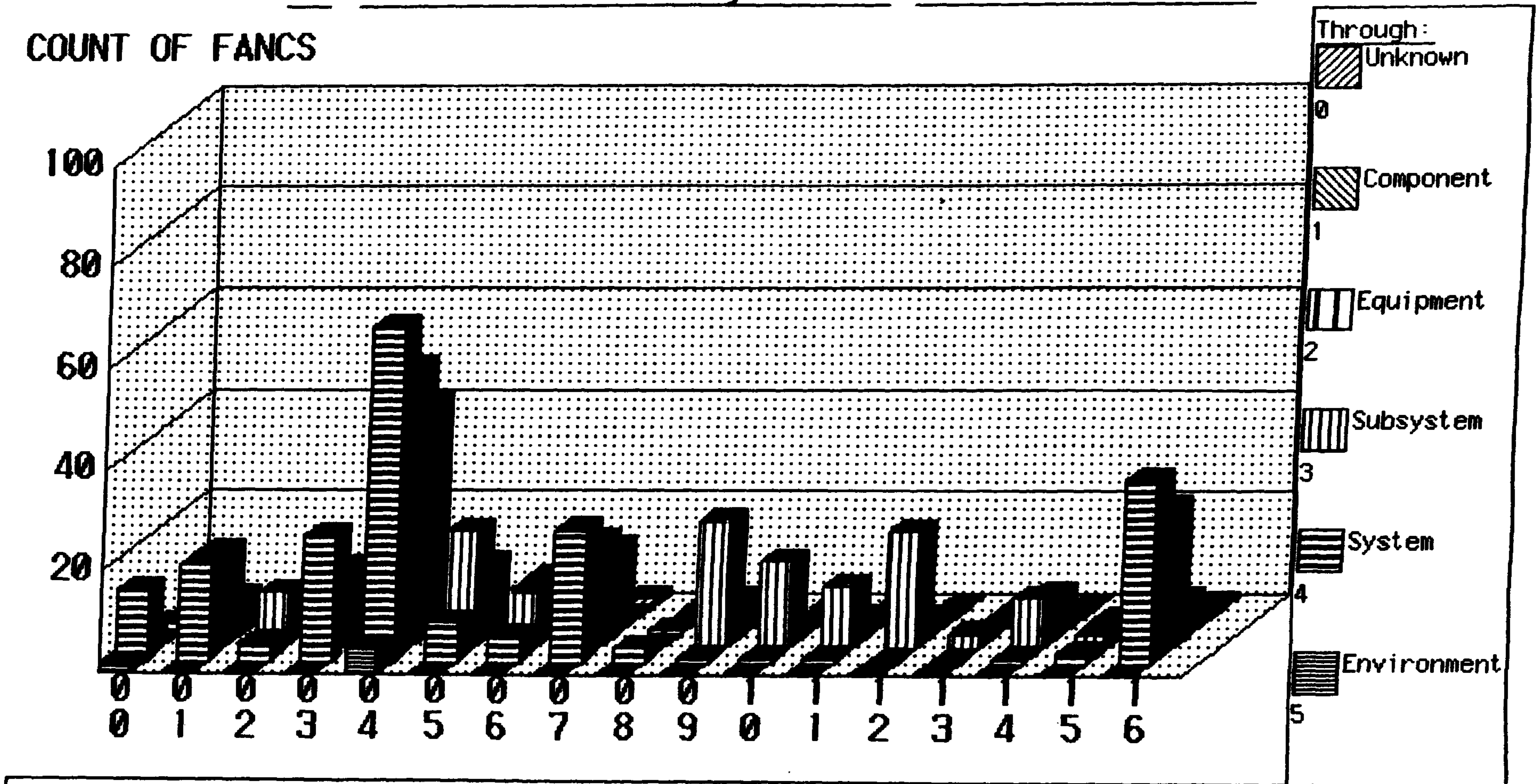
FIELD IN GRAPH: Localisation/Propagation

This parameter gives a measure of how far the FANC's influence goes beyond the point where it actually occurs. The most localised is the least damaging, the most propagating, the most damaging.

The following values can be taken for Localisation/Propagation:

0	Unknown
1	Component
2	Equipment
3	Subsystem
4	System
5	Environment

Correlation of 'Subsystem' and 'Localisation'



Across:

00 System Engineering
01 Power
02 Telemetry Tracking & Command
03 Attitude/Orbit Control/Guidance
04 Propulsion / Aero-thermodynamics
05 On-Board Data Handling
06 Thermal Control
07 Mechanisms and Structure
08 Pyrotechnics
09 Communications Payload
10 Science Payload
11 Earth Observation Payload
12 Microgravity Payload
13 Rendezvous and Docking
14 Env. Control / Life Support
15 Crew Flight Control Operations
16 Ground Segment

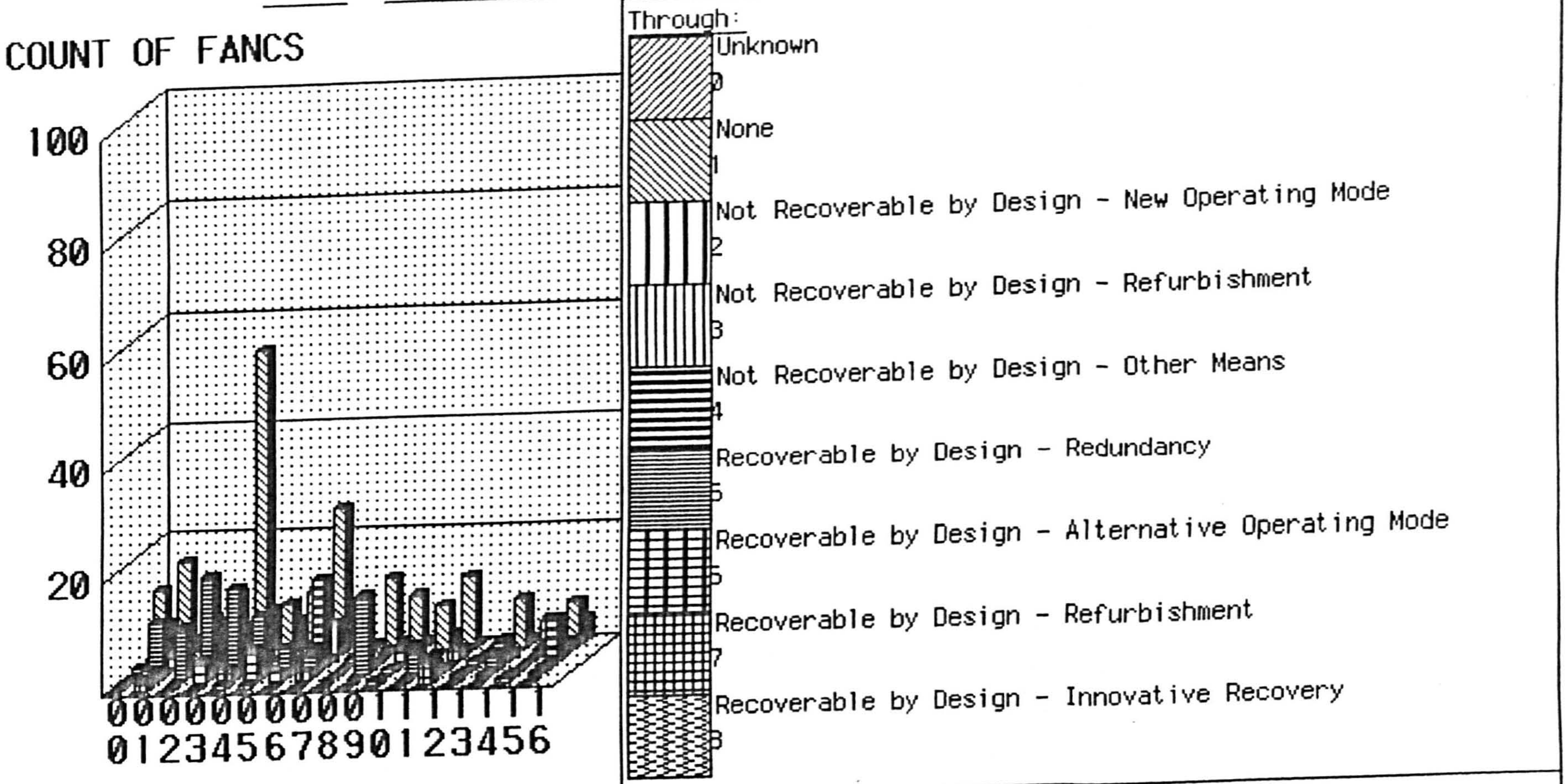
[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer

FIELD IN GRAPH: Recovery Type

The following values can be taken for Recovery Type:

0	Unknown
1	None
2	Not Recoverable by Design - New Operating Mode
3	Not Recoverable by Design - Refurbishment
4	Not Recoverable by Design - Other Means
5	Recoverable by Design - Redundancy
6	Recoverable by Design - Alternative Operating Mode
7	Recoverable by Design - Refurbishment
8	Recoverable by Design - Innovative Recovery

Corr'lation of 'Subsystem' and 'Recovery type'



Across:

00 System Engineering
01 Power
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03 Attitude/Orbit Control/Guidance
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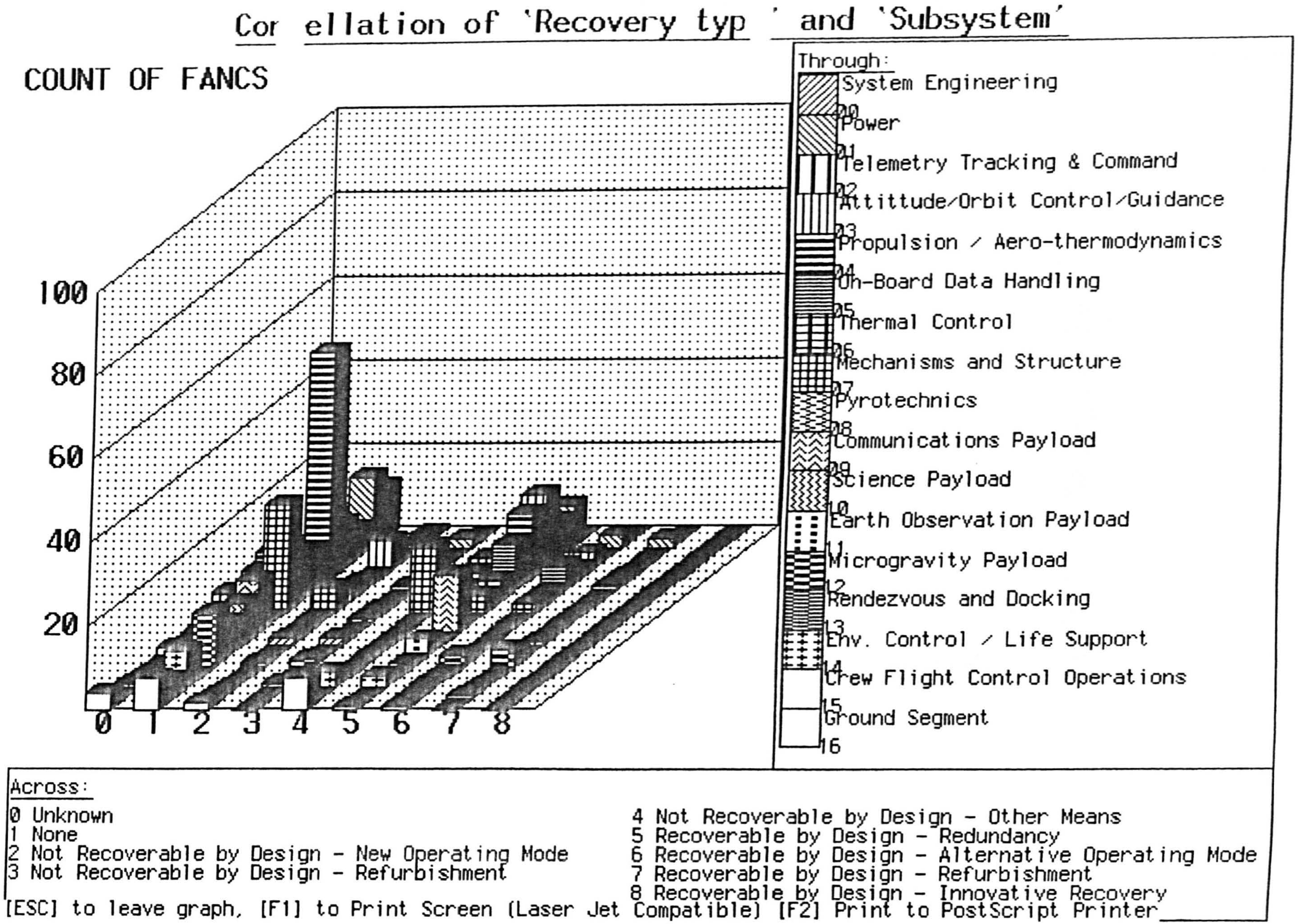
15 Crew Flight Control Operations
16 Ground Segment

[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer


Cor ellation of 'Recovery typ ' and 'Subsystem'
COUNT OF FANCS
100
80
60
40
20
0 1 2 3 4 5 6 7 8
Through:
System Engineering
00
Power
01
Telemetry Tracking & Command
02
Attitude/Orbit Control/Guidance
03
Propulsion / Aero-thermodynamics
04
On-Board Data Handling
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Earth Observation Payload
11
Microgravity Payload
12
Rendezvous and Docking
13
Env. Control / Life Support
14
Crew Flight Control Operations
15
Ground Segment
16
Across:
0 Unknown
1 None
2 Not Recoverable by Design - New Operating Mode
3 Not Recoverable by Design - Refurbishment
4 Not Recoverable by Design - Other Means
5 Recoverable by Design - Redundancy
6 Recoverable by Design - Alternative Operating Mode
7 Recoverable by Design - Refurbishment
8 Recoverable by Design - Innovative Recovery
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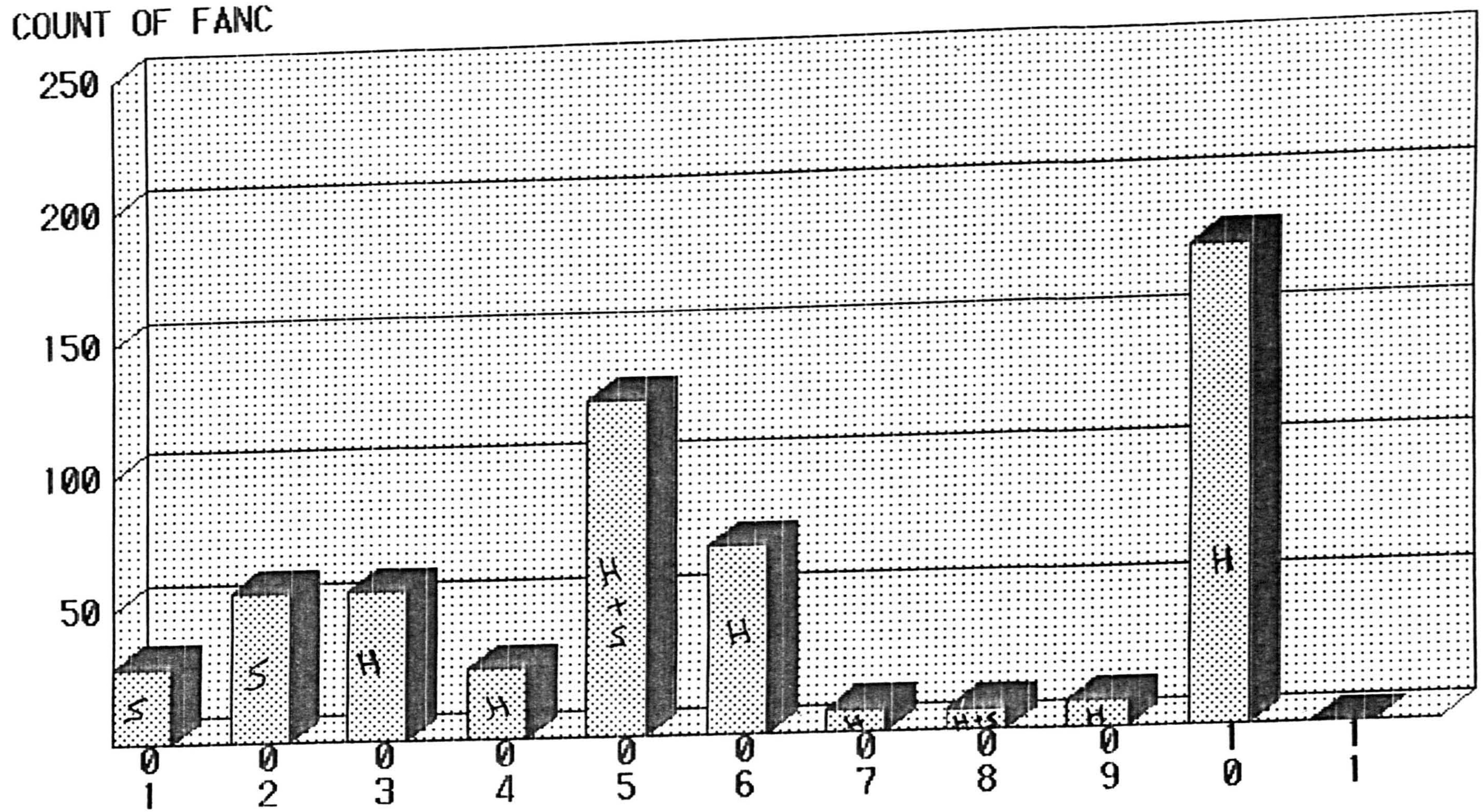
Histogram of Main Problem Area Headings

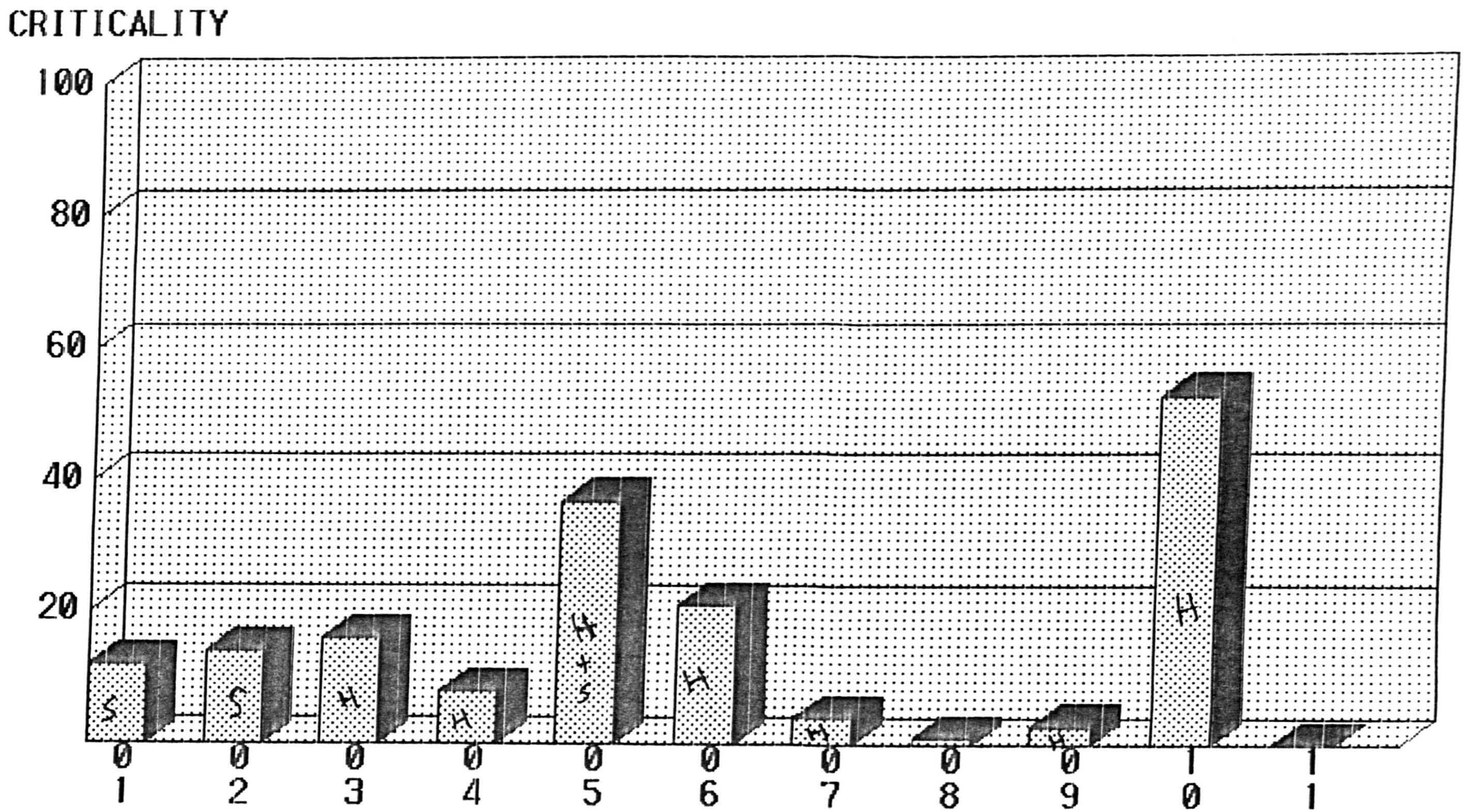
S = Soft
H = Hard



01 Management Issues
02 Human Factor Problems
03 Interfaces
04 Configuration Management
05 Quality Cont/Qualification
06 Design Issues
07 Contingency Analysis
08 Autonomy
09 Safety/Protection Features
10 Technology Issues
11 Trends

[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer

Criticality of Main Problem Area Headings



01 Management Issues
02 Human Factor Problems
03 Interfaces
04 Configuration Management
05 Quality Cont/Qualification
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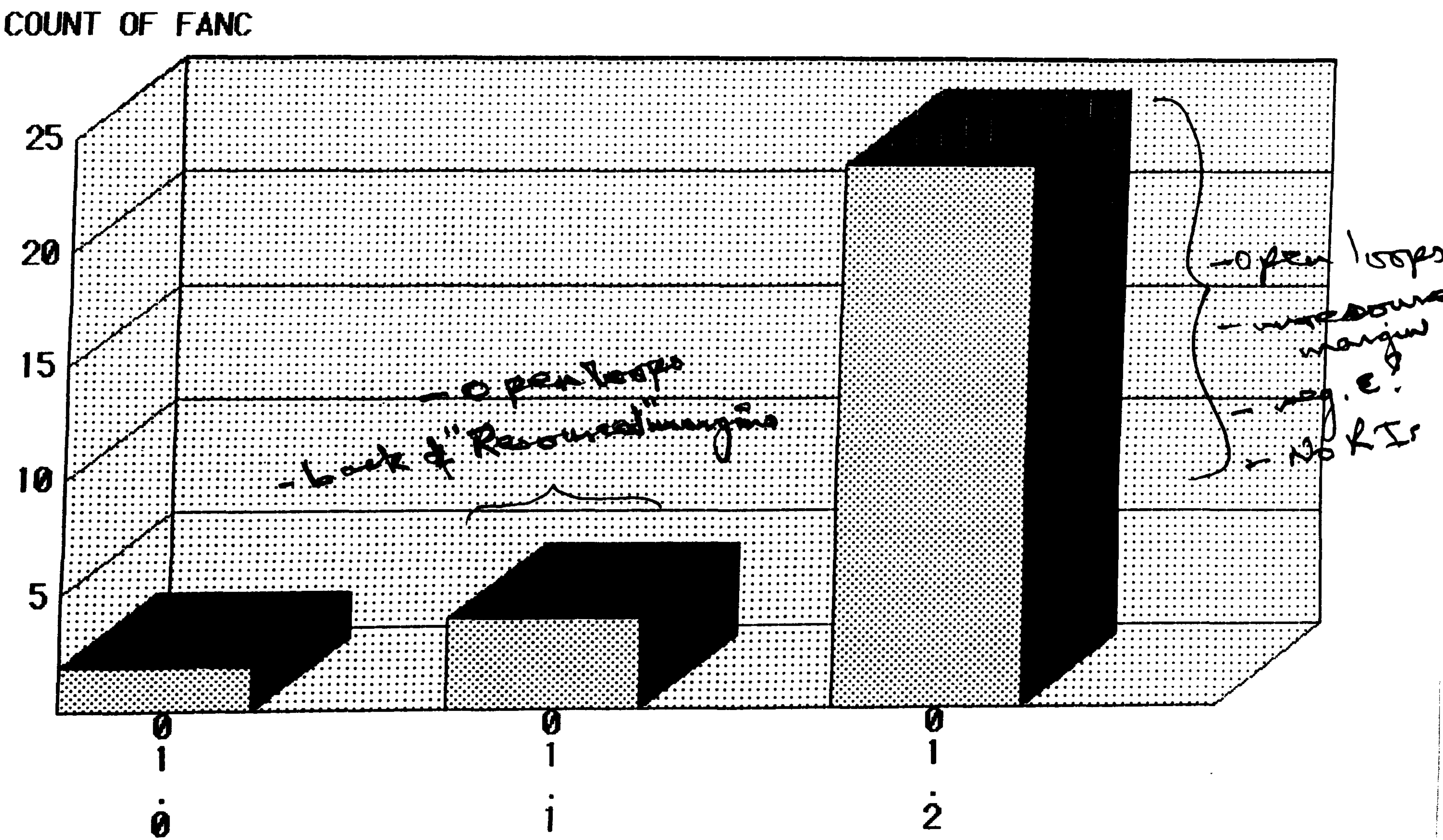
07 Contingency Analysis
08 Autonomy
09 Safety/Protection Features
10 Technology Issues
11 Trends

[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer



01.0 Unclassified - Management Issues

01.1 Unbalanced use of funds for problem solving
01.2 Programme Risk not properly understood/quantifiec

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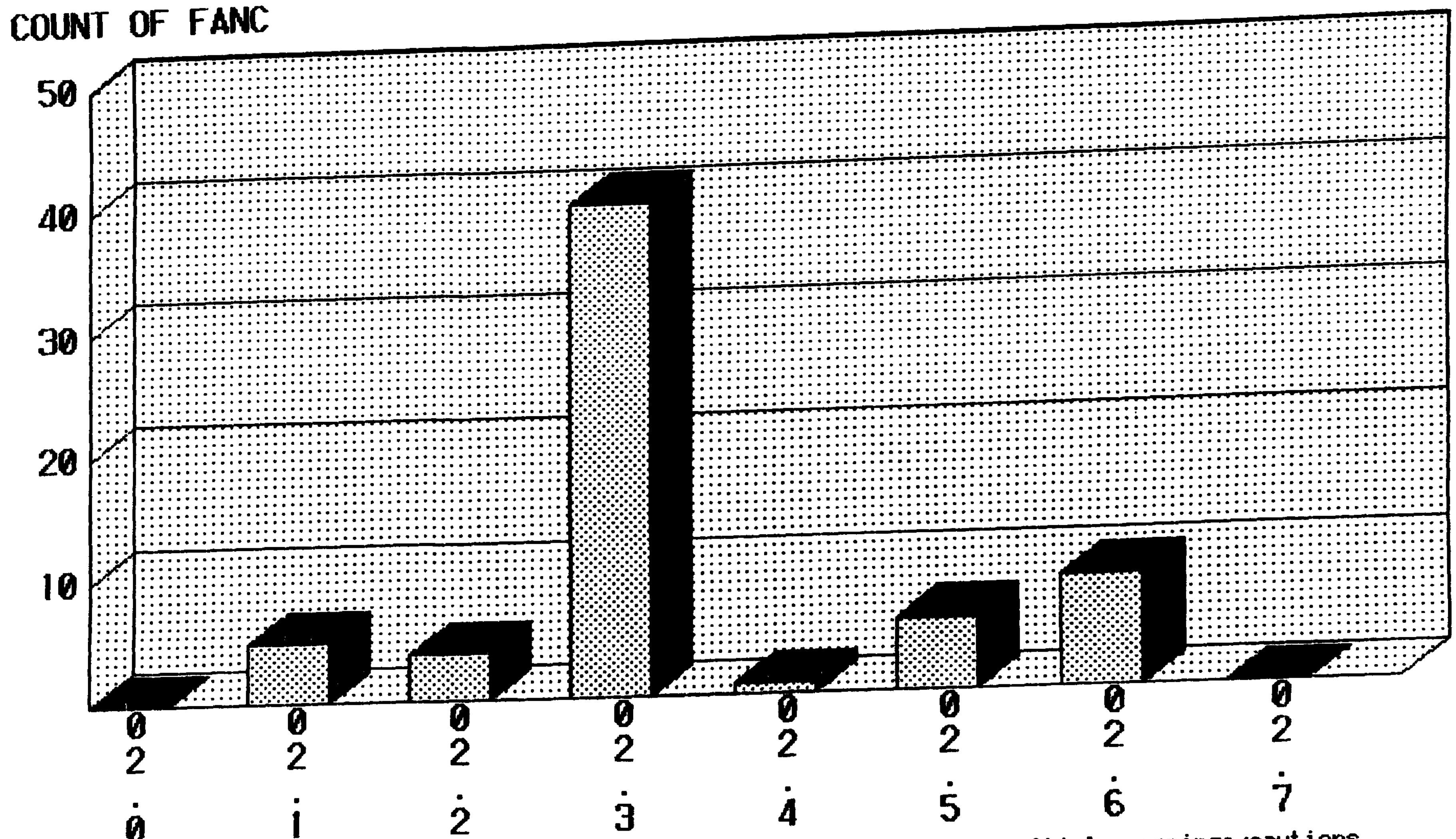
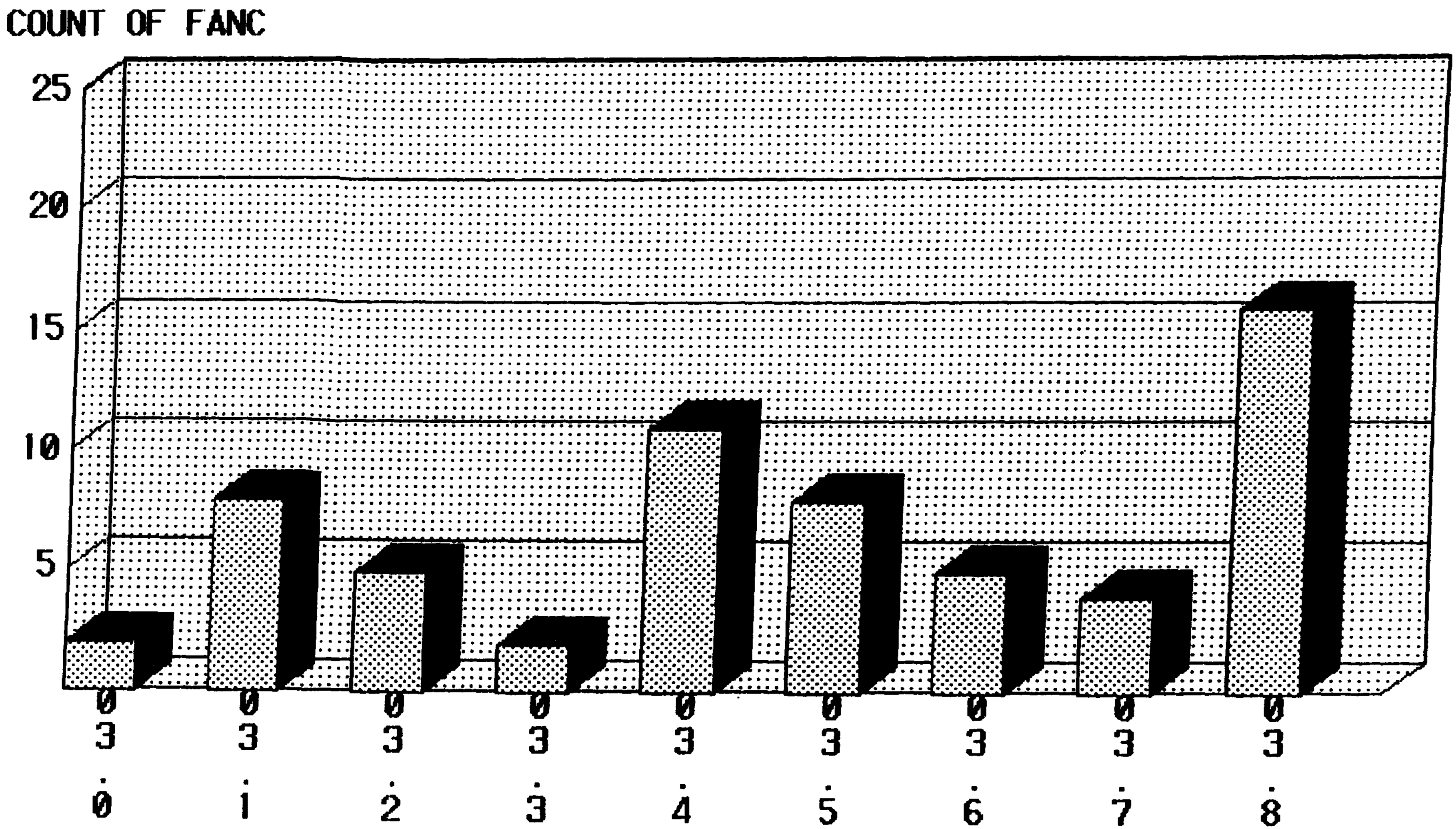
''istogram of Main Problem / ea Headings



02.0 Unclassified - Human Factor Problems
02.1 Satisfy objective (problem solve) in tunnel visi
02.2 Common Sense / Procedure conflict
02.3 Poor Human performance
02.4 Desensitized to multiple warnings/cautions
02.5 Workplace accidents
02.6 Procedure and Procedure change validation
02.7 Bias against good PA in action closures to a deac
[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer

Histogram of Main Problem Area Headings



03.0 Unclassified - Interfaces
03.1 Interface between phases: Launch Pre-sets
03.2 Single function / plural contributors (persons,
03.3 Dynamic geometry
03.4 Interfaces between subsystems
03.5 Interfaces between systems
03.6 Miswiring / cross wiring
03.7 Fuse Sizing
03.8 Mission Support Equipment Assurance

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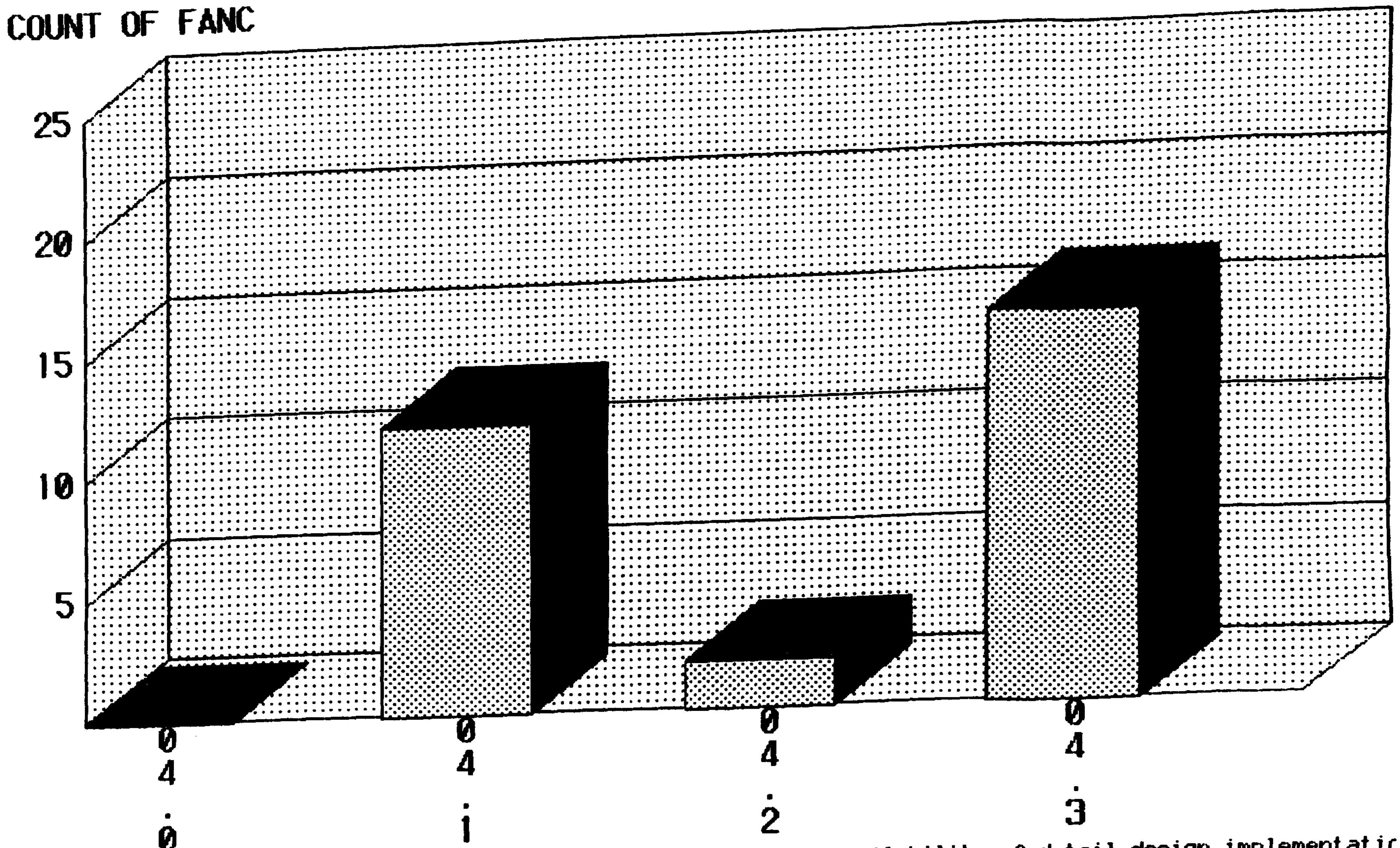
Histogram of Main Problem Area Headings



04.0 Unclassified - Configuration Management
04.1 Status & Consistency (incl. Software / hardware
04.2 Non - availability of detail design implementatic
04.3 Change Impact Analysis and Change Verification /
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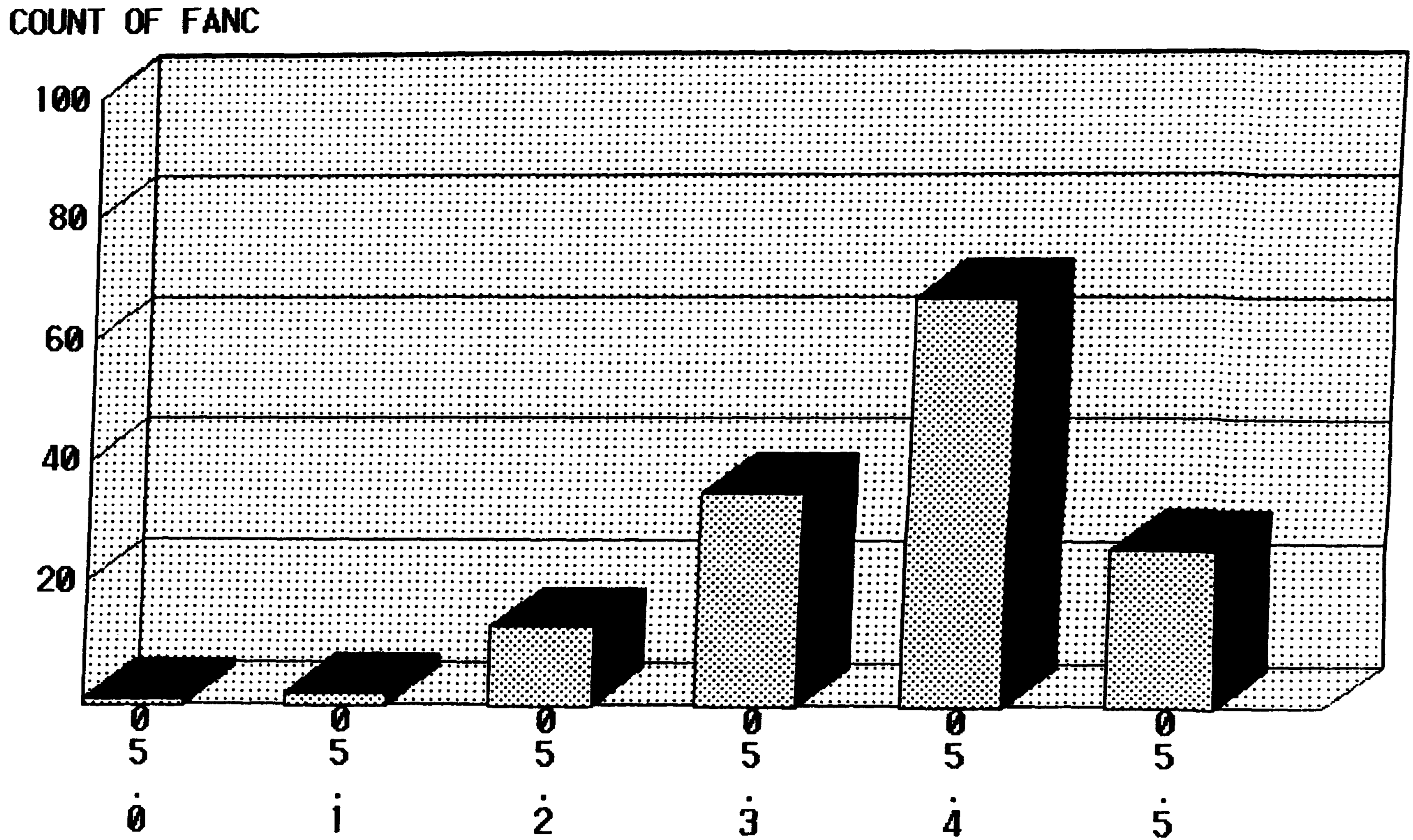
Histogram of Main Probl-m Area Headings



05.0 Unclassified - Quality Control / Qualification
05.1 Undetected Sign Errors
05.2 Undetected/Ignored Quality trends (e.g. Parts, C
05.3 Qualification invalidity
05.4 Repeat of known failure type
05.5 Product not fully testable / test not valid
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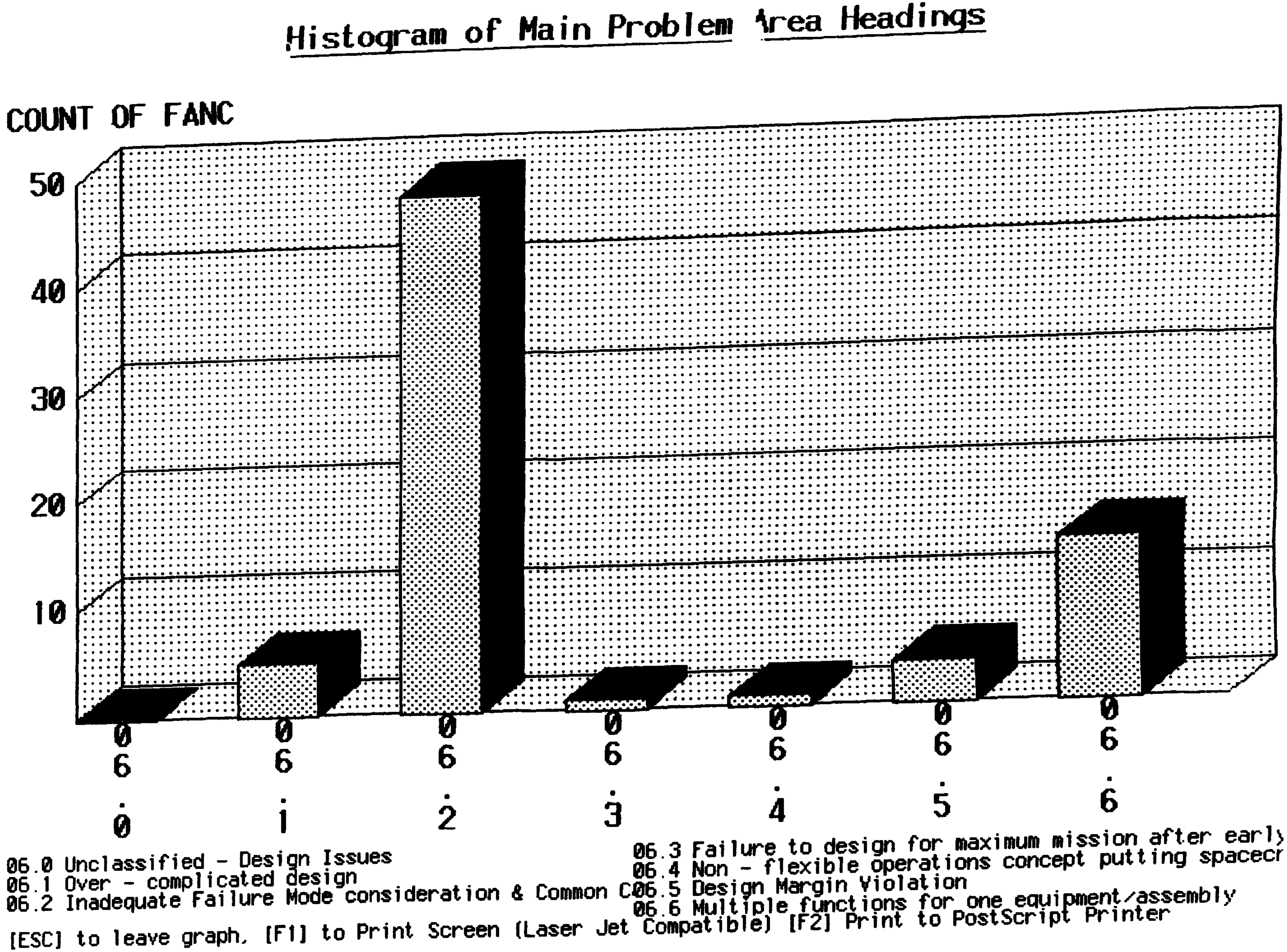
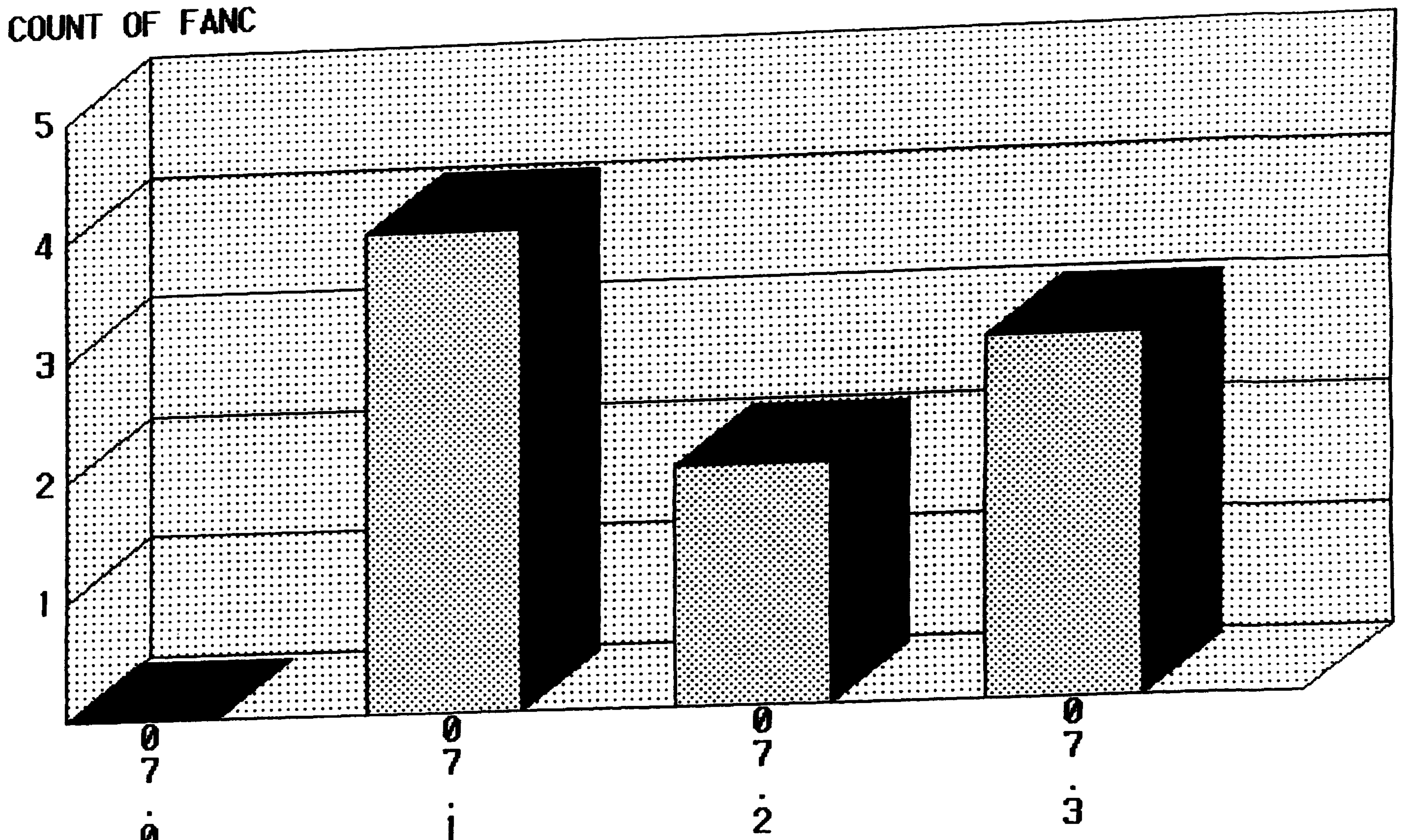
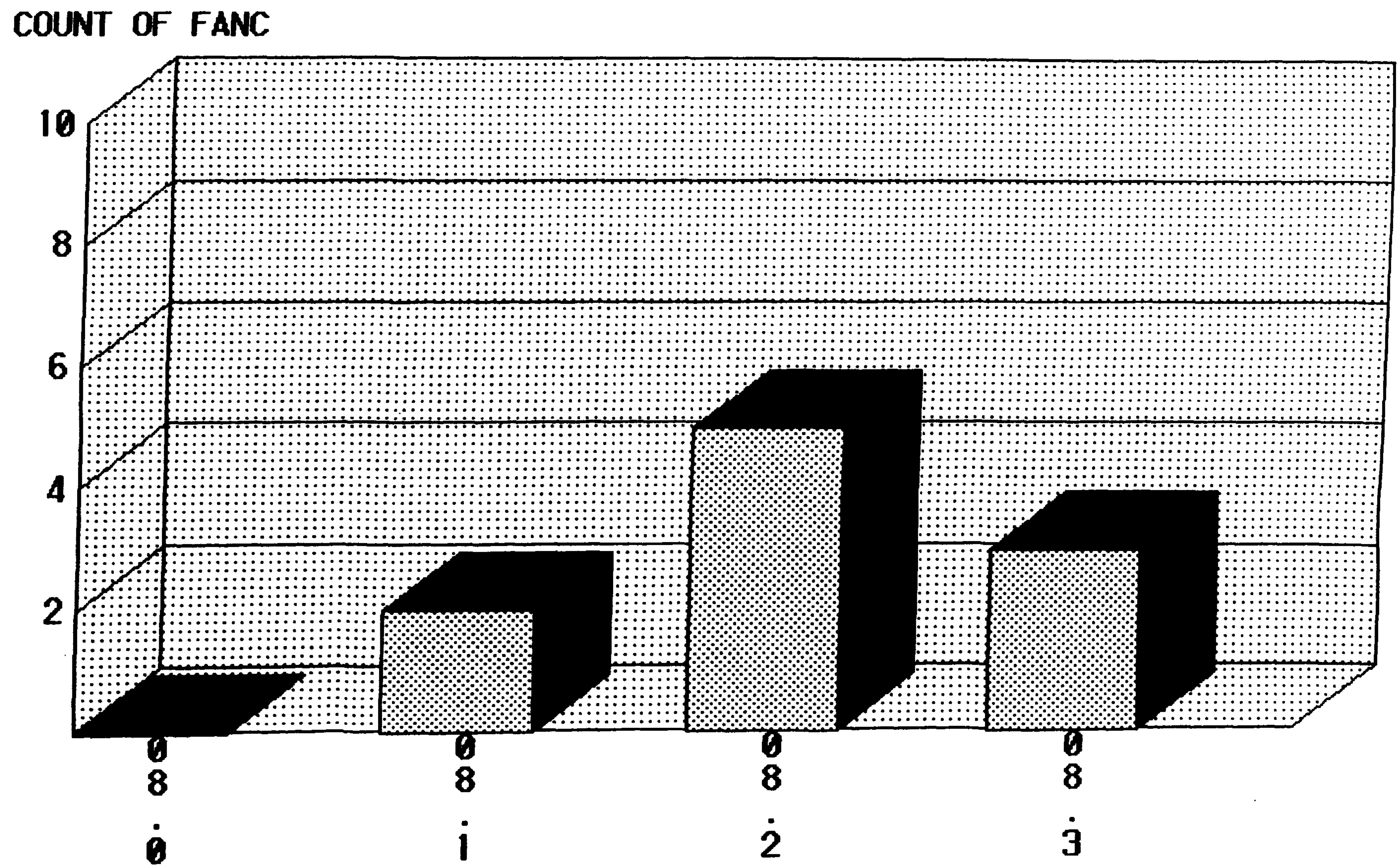

Histogram of Main Problem Area Headings
COUNT OF FANC
50
40
30
20
10
06.0
06.1
06.2
06.3
06.4
06.5
06.6
06.0 Unclassified - Design Issues
06.1 Over - complicated design
06.2 Inadequate Failure Mode consideration & Common C
06.3 Failure to design for maximum mission after earl
06.4 Non - flexible operations concept putting spacecr
06.5 Design Margin Violation
06.6 Multiple functions for one equipment/assembly
[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer

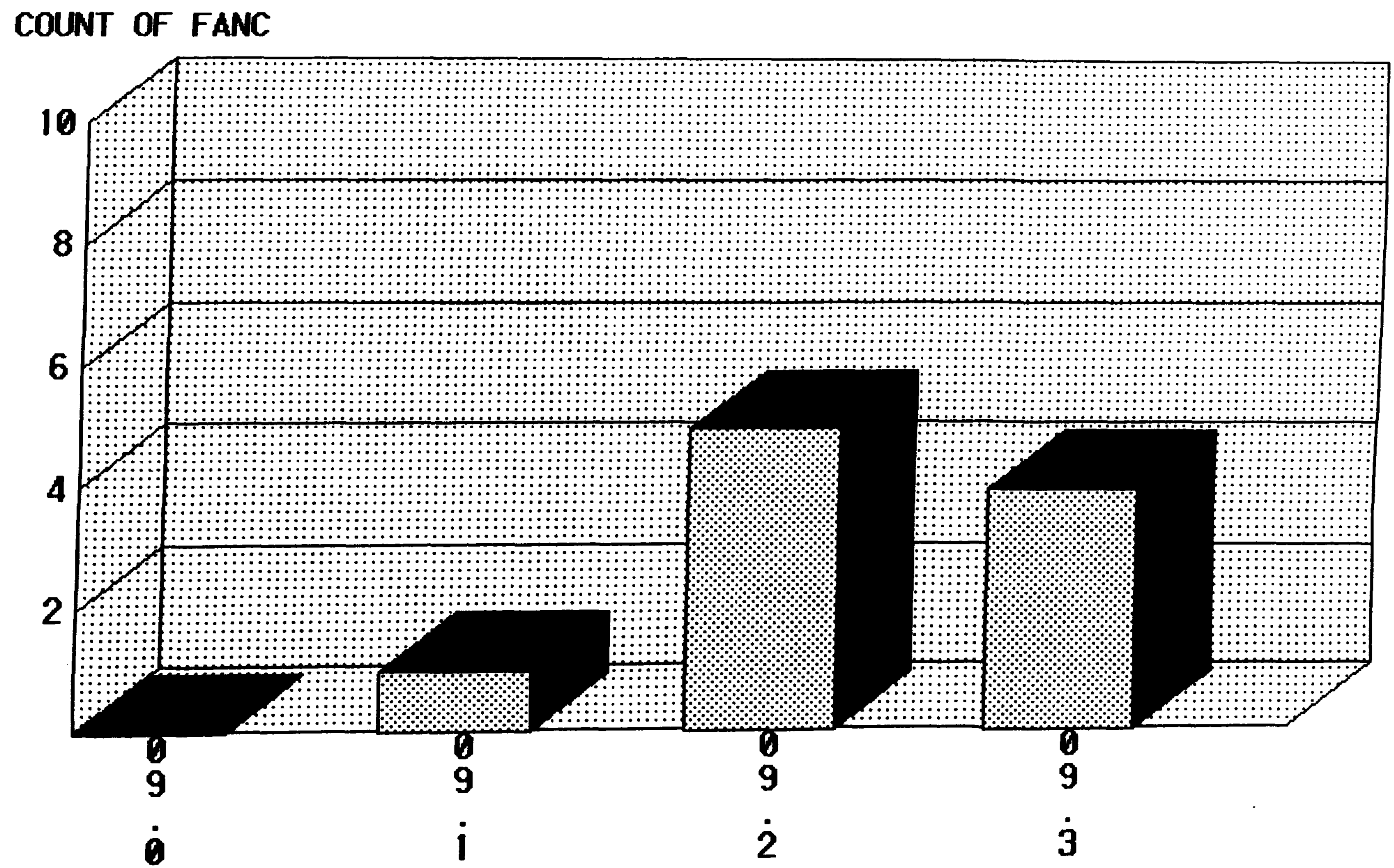
Histogram of Main Problem Area Headings



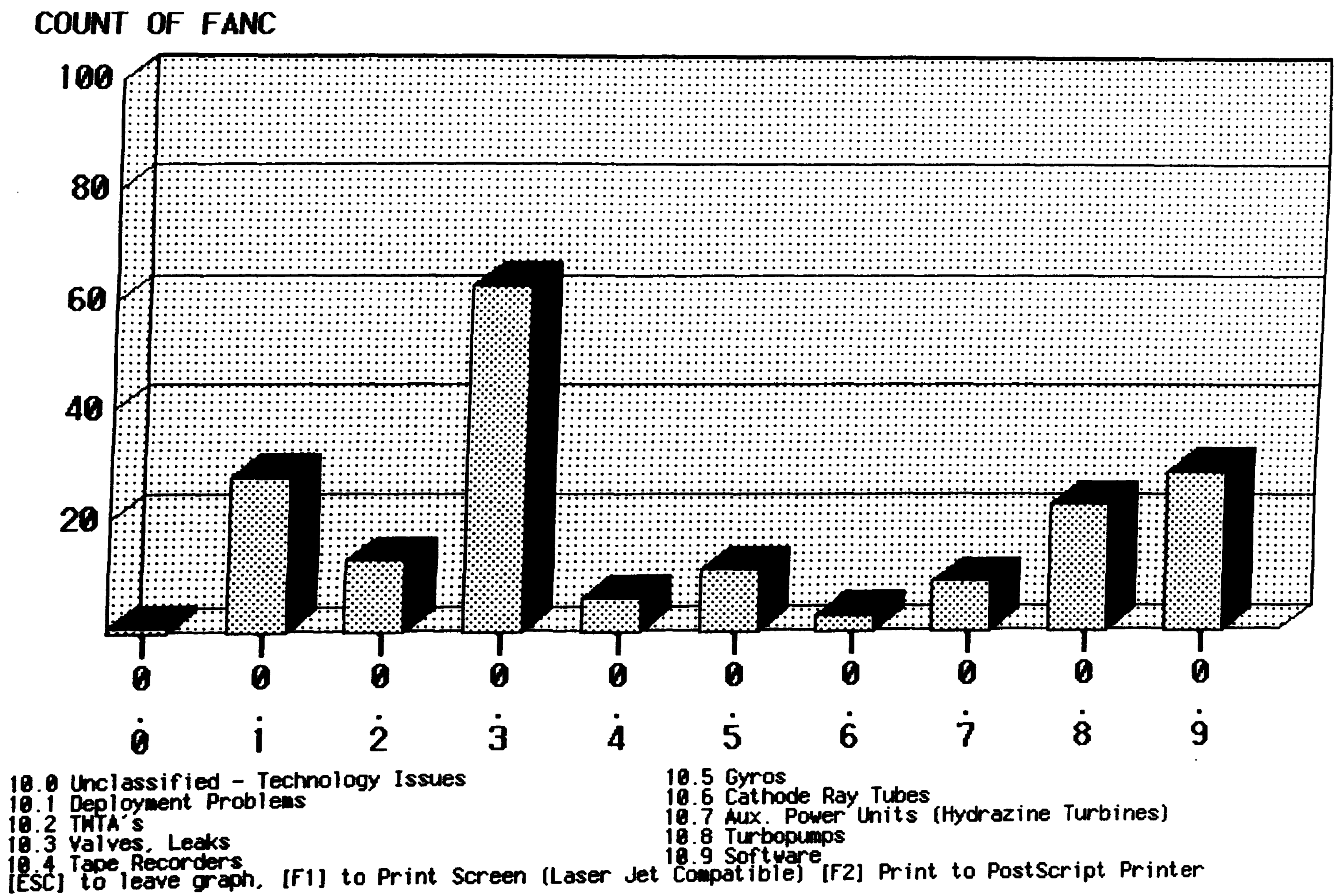
07.0 Unclassified - Contingency Analysis
07.1 Thinking beyond 'Eliminate Single Point Failure'
07.2 Safe Mode Deficiencies
07.3 Change Impact on Operations after in-orbit incide
[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer



08.0 Unclassified - Autonomy
08.1 Potential Over - Use beyond satisfying Mission N
08.2 Implementation: failure scenarios poorly underst
08.3 Implementation: inability to test/simulate fully
[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer



09.0 Unclassified - Active Safety/Protection Features09.2 Constraints: Not Act if triggering events do not
09.1 Function: Readiness - to - act / Response to tri09.3 Constraints: Permit Disabling; isolation from ott
[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer


COUNT OF FANC
100
80
60
40
20
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
10.0 Unclassified - Technology Issues
10.1 Deployment Problems
10.2 TWTA's
10.3 Valves, Leaks
10.4 Tape Recorders
10.5 Gyros
10.6 Cathode Ray Tubes
10.7 Aux. Power Units (Hydrazine Turbines)
10.8 Turbopumps
10.9 Software
[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer

CORRELATION: 3D graph from two selected fields

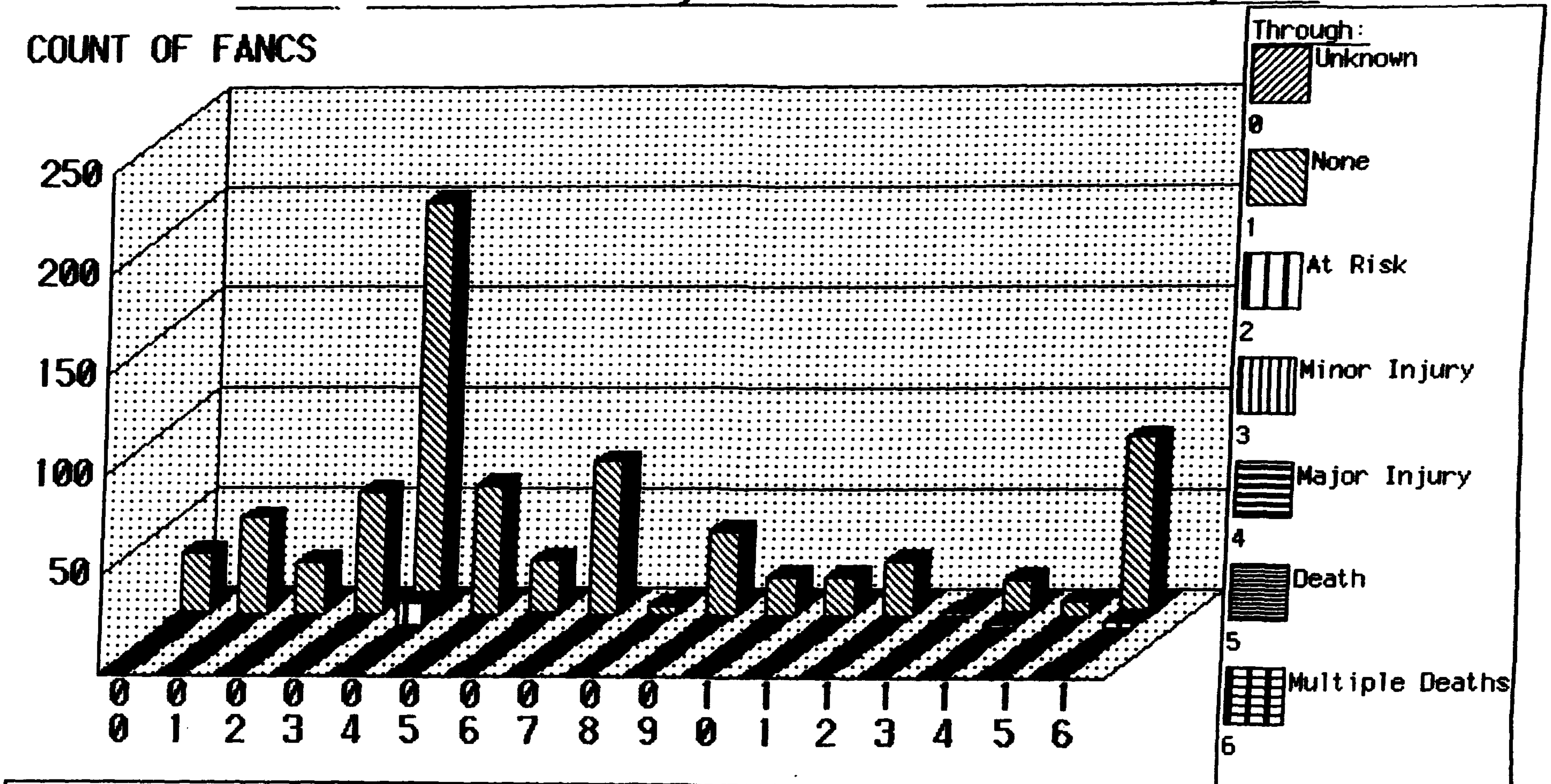
This graph shows how FANC's applicable to two User-Selected fields (for example Phase against Consequential Loss) are distributed. The vertical axis shows the number of applicable FANC's (Count of FANC's). The other two axes display the values which can be taken by each of the selected fields.

FIELD IN GRAPH: Human Life Impact

The following values can be taken for Human Life Impact:

0	Unknown
1	None
2	At Risk
3	Minor Injury
4	Major Injury
5	Death
6	Multiple Deaths

Correlation of 'Subsystem' and 'Human life impact'



Across:

00 System Engineering
01 Power
02 Telemetry Tracking & Command
03 Attititude/Orbit Control/Guidance
04 Propulsion / Aero-thermodynamics
05 On-Board Data Handling
06 Thermal Control
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16 Ground Segment

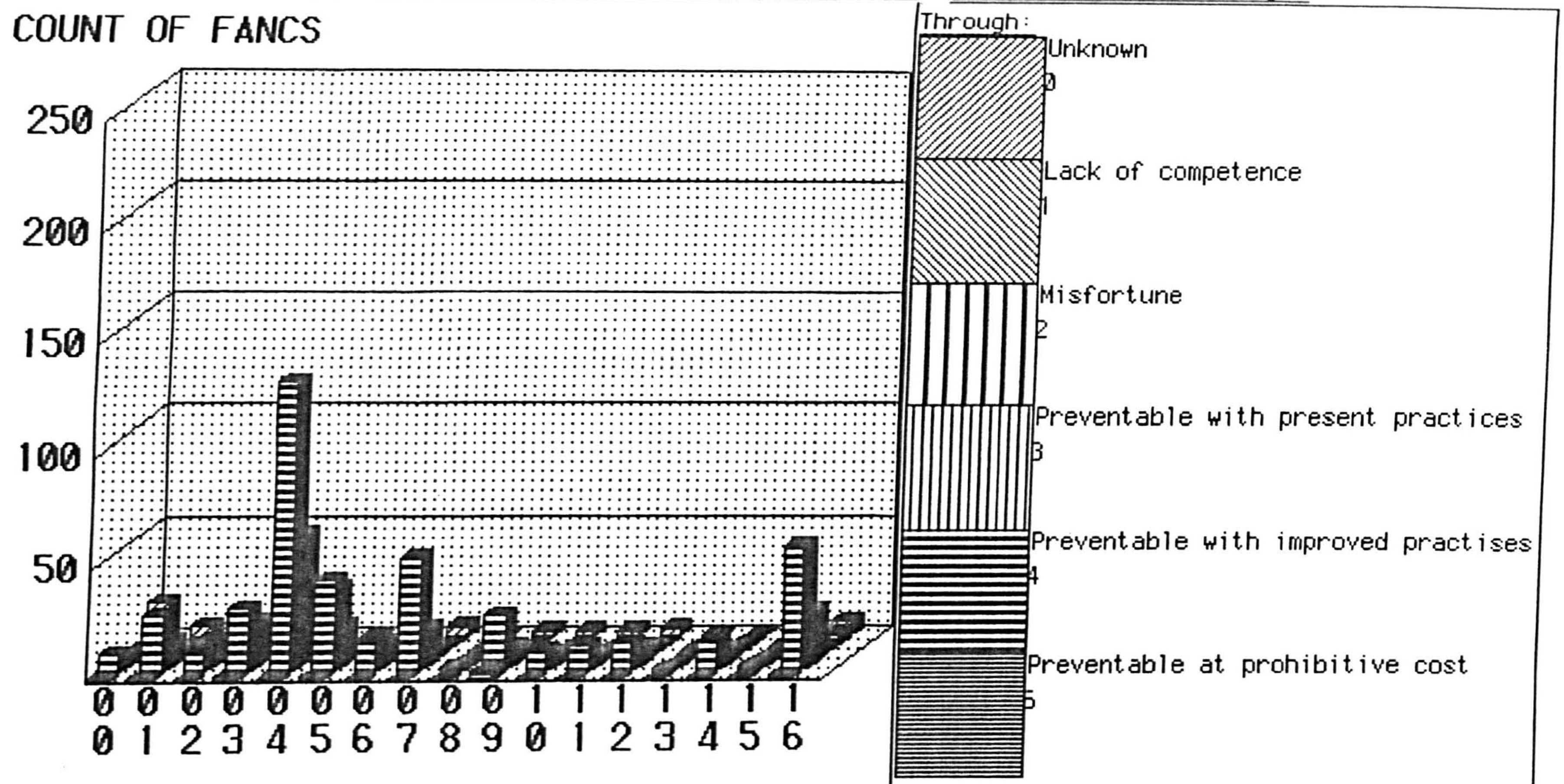
[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer

FIELD IN GRAPH: Preventability

Preventability is a measure of how readily the particular FANC should have been prevented. The assurance environment at the time and place where the FANC occurred is compared with ESA practices now.

The following values can be taken by Preventability:

0 Unknown
1 Lack of Competence
2 Misfortune
3 Preventable with Present Practices
4 Preventable with Improved Practices
5 Preventable at Prohibitive Cost



Across:

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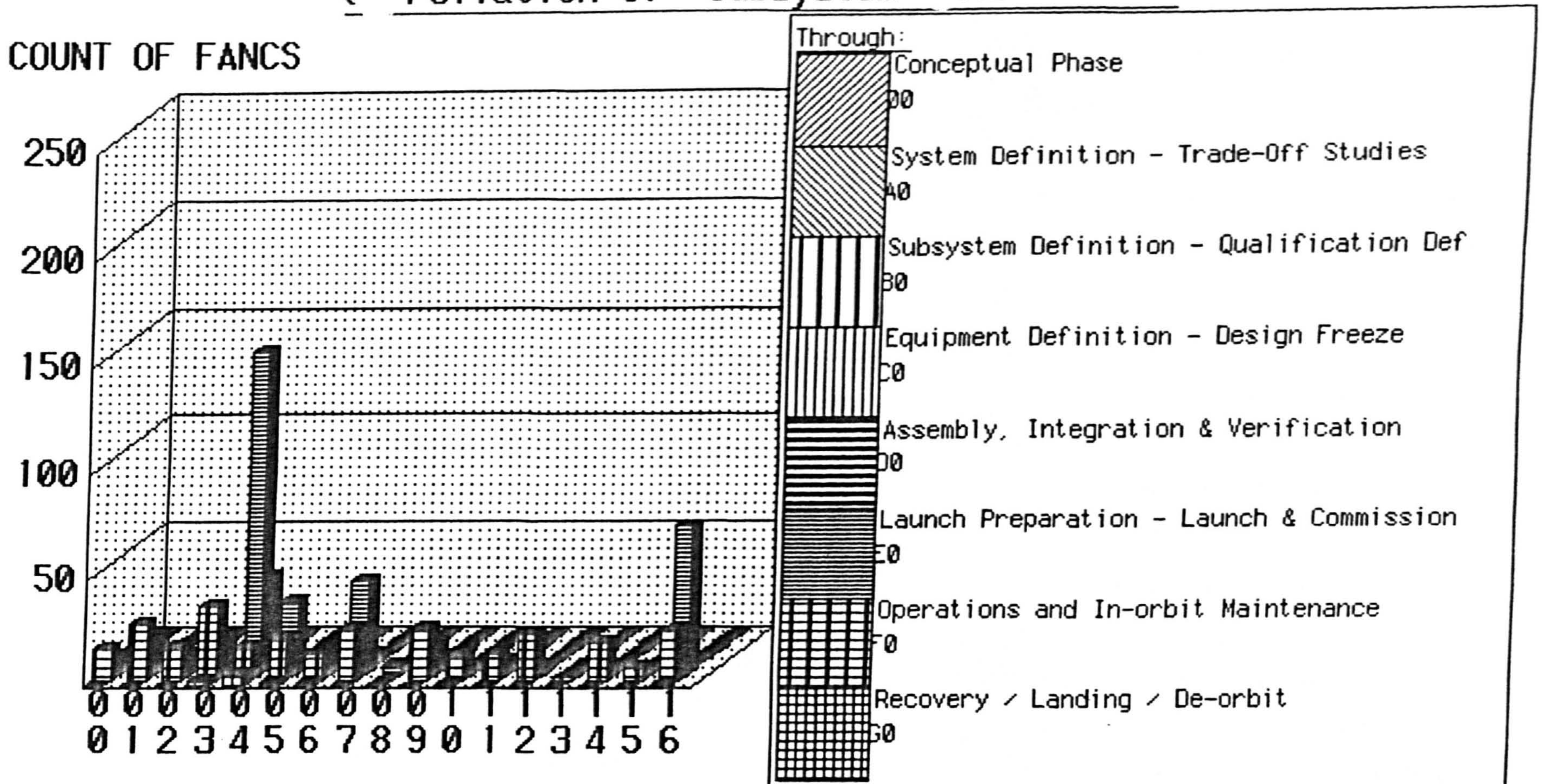
[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer

FIELD IN GRAPH: Phase

The following values can be taken for Phase:

0	Conceptual Phase
A	System definition - Trade-off Studies
B	Subsystem Definition - Qualification Definition
C	Equipment Definition - Design Freeze
D	Assembly Integration & Verification
E	Launch Preparation, Launch & Commissioning
F	Operations and In-Orbit Maintenance
G	Recovery / Landing / De-Orbit

C rrellation of 'Subsystem' nd 'Phase'



Across:

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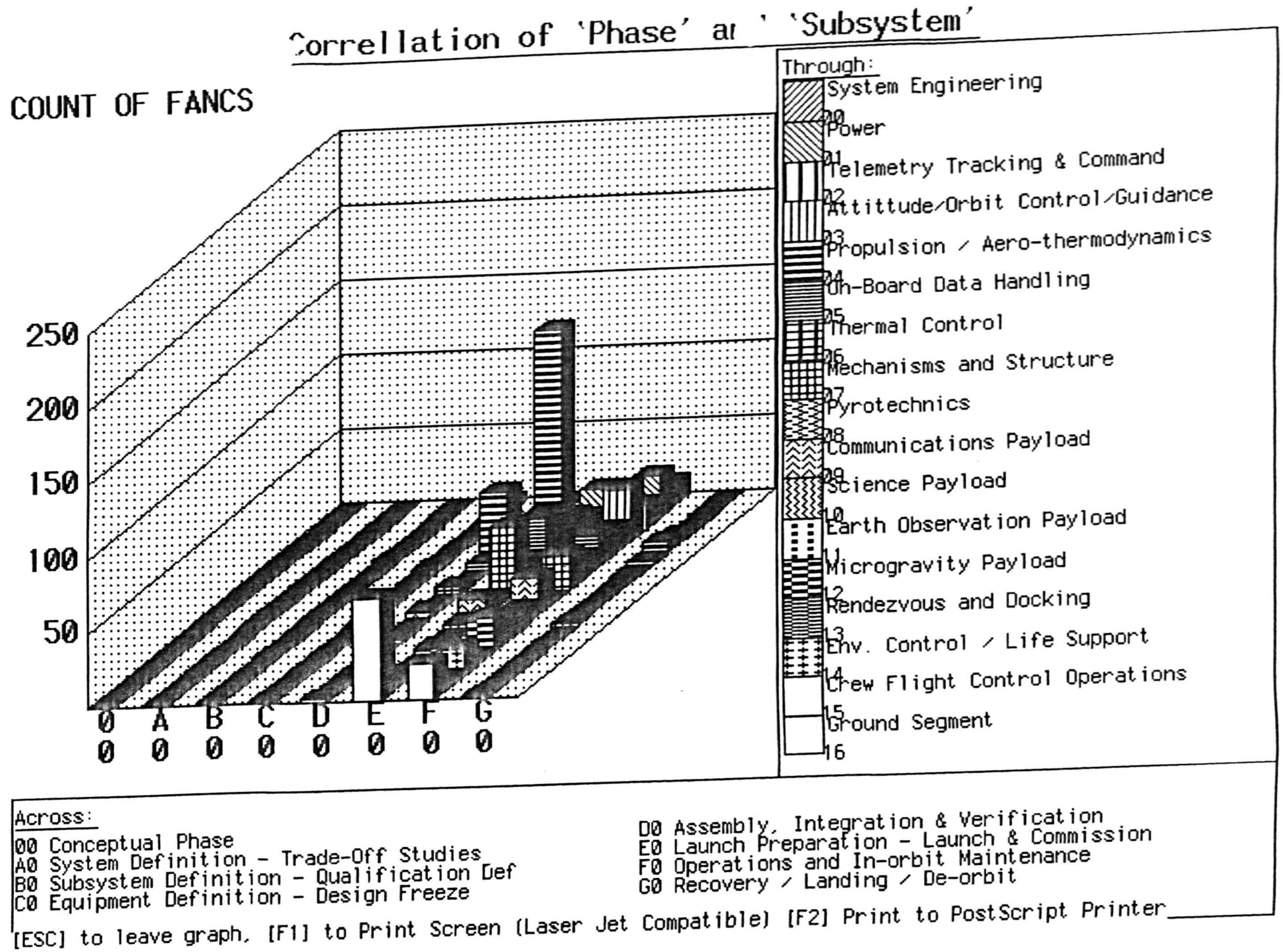
[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer


Correllation of 'Phase' a 'Subsystem'
COUNT OF FANCS
250
200
150
100
50
00
A0
B0
C0
D0
E0
F0
G0
Through:
System Engineering 00
Power 01
Telemetry Tracking & Command 02
Attitude/Orbit Control/Guidance 03
Propulsion / Aero-thermodynamics 04
On-Board Data Handling 05
Thermal Control 06
Mechanisms and Structure 07
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Earth Observation Payload 11
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Rendezvous and Docking 13
Env. Control / Life Support 14
Crew Flight Control Operations 15
Ground Segment 16
Across:
00 Conceptual Phase
A0 System Definition - Trade-Off Studies
B0 Subsystem Definition - Qualification Def
C0 Equipment Definition - Design Freeze
D0 Assembly, Integration & Verification
E0 Launch Preparation - Launch & Commission
F0 Operations and In-orbit Maintenance
G0 Recovery / Landing / De-orbit
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FIELD IN GRAPH: Mission Loss Actual / Mission Loss Unrectified

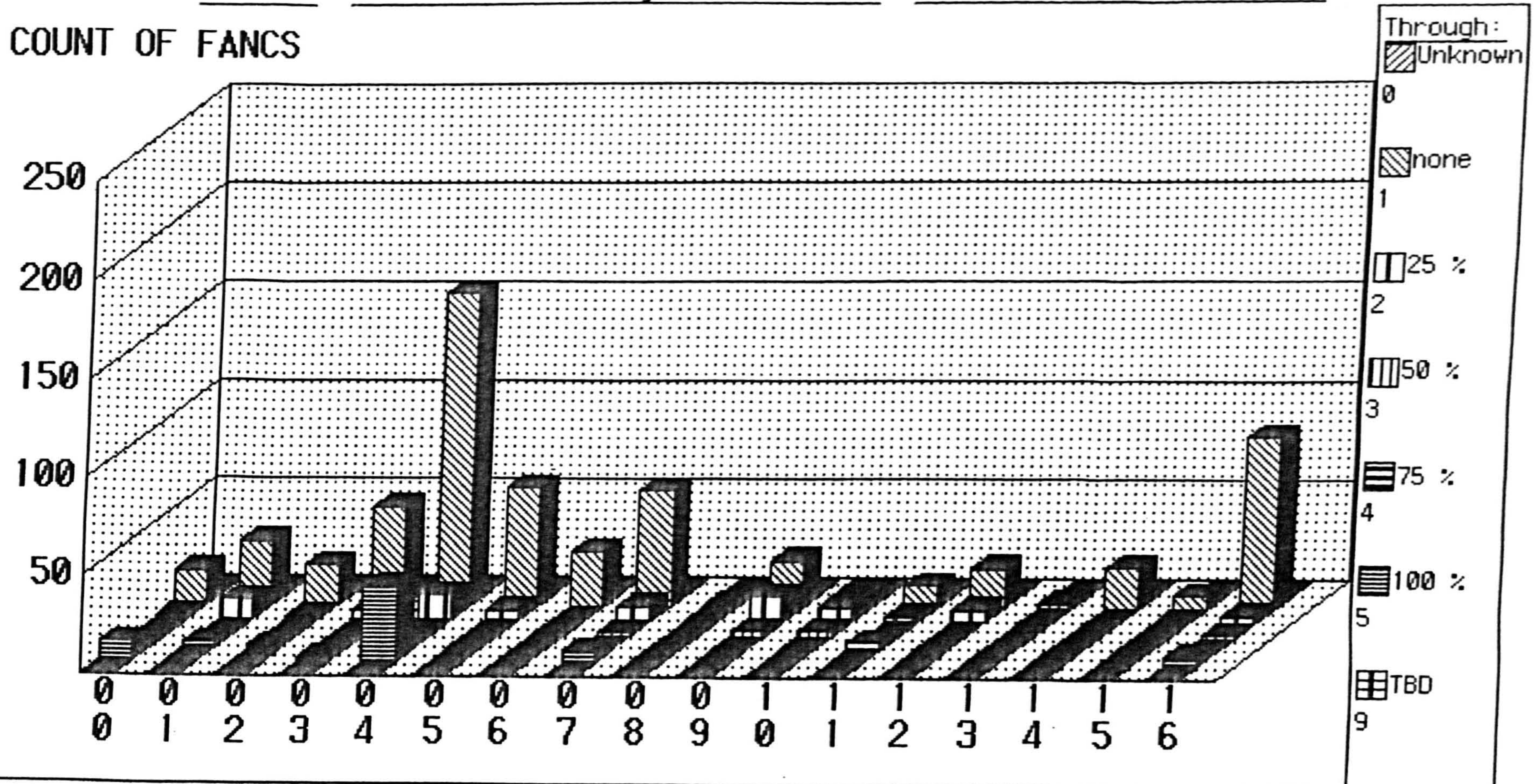
The Mission Loss Actual indicates the proportion of the Mission that has been lost by the presence of the FANC after any recovery action has been implemented. A FANC occurring late in a mission has little impact. A FANC occurring early can have a large mission loss only if recovery action is ineffective.

Mission Loss unrectified is the proportion of mission that would be lost by the presence of the FANC, assuming no recovery action took place (irrespective of whether recovery was possible). It is useful to compare this with Actual Mission Loss to gauge the benefits which recovery achieves.

The following values can be taken for Mission Loss:

0	Unknown
1	None
2	Up to 25%
3	Up to 50%
4	Up to 75%
5	Up to 100%

Correlation of 'Subsystem' and 'Mission loss actual'

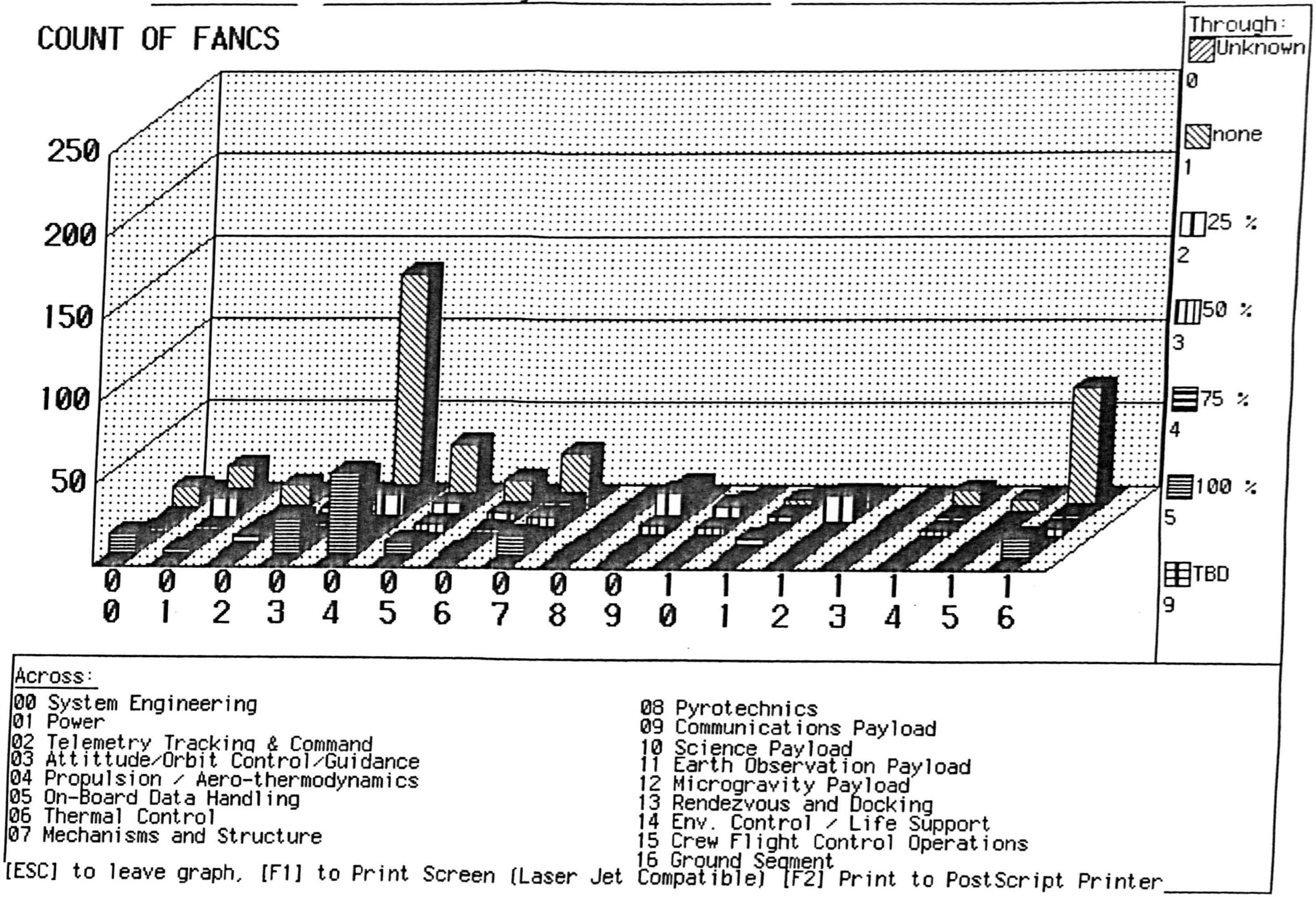


Across:

00 System Engineering
01 Power
02 Telemetry Tracking & Command
03 Attitude/Orbit Control/Guidance
04 Propulsion / Aero-thermodynamics
05 On-Board Data Handling
06 Thermal Control
07 Mechanisms and Structure
08 Pyrotechnics
09 Communications Payload
10 Science Payload
11 Earth Observation Payload
12 Microgravity Payload
13 Rendezvous and Docking
14 Env. Control / Life Support
15 Crew Flight Control Operations
16 Ground Segment

[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer

Corrella†'on of 'Subsystem' and 'Mi ;ion loss unrectified'

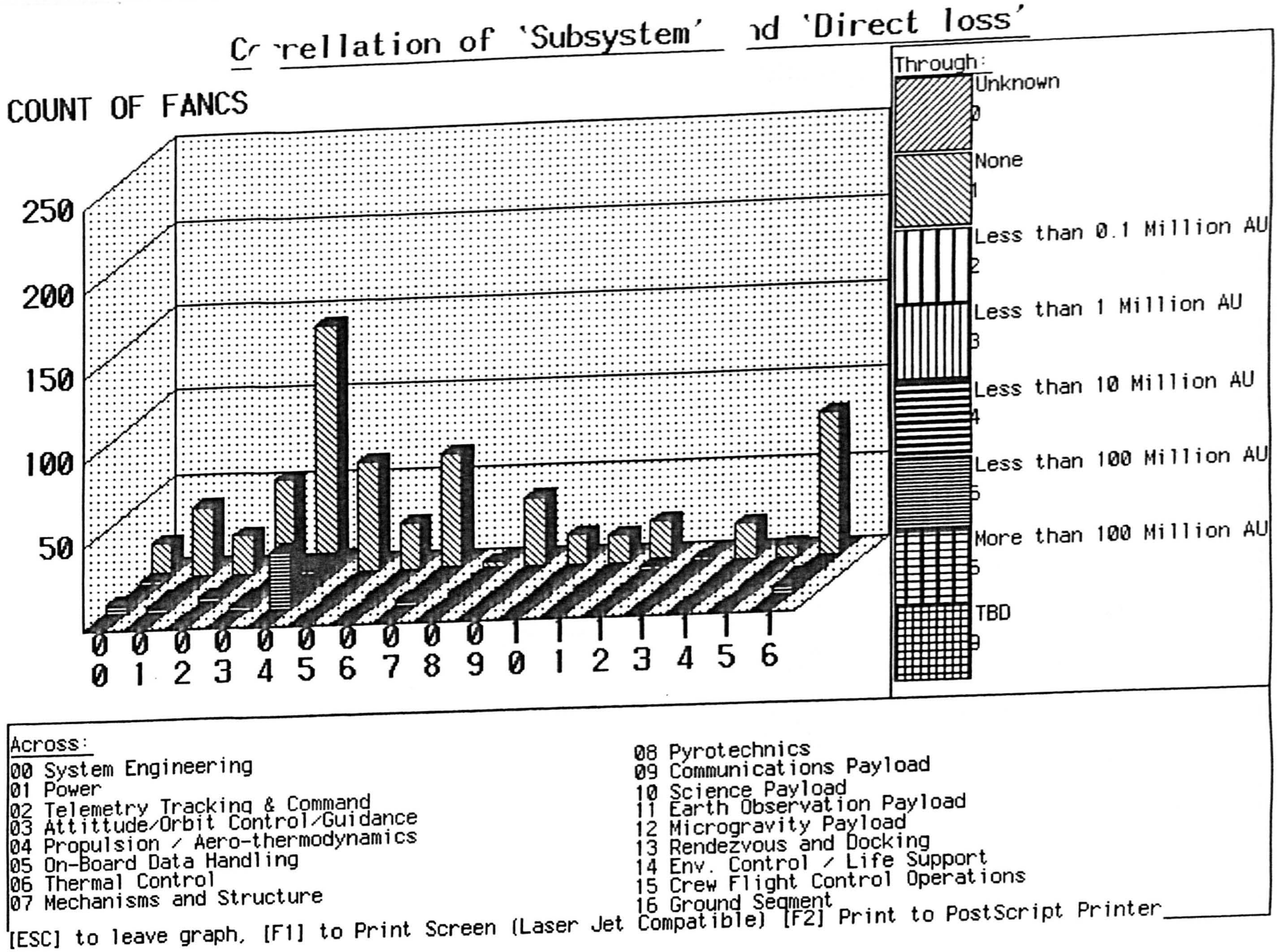


FIELD IN GRAPH: Direct Loss / Consequential Loss

Direct Loss measures the Financial (Asset) loss sustained within the Product in which the FANC occurred. It does not include any losses occurring to third parties or other parts of an overall system. Consequential Loss is a measure of the Financial loss sustained by products and third parties other than the Product affected by the FANC itself. It includes revenue loss and is the counterpart of the Direct Loss.

The following values can be taken for Direct Loss / Consequential Loss:

0	Unknown
1	None
2	Up to 0.1 million AU
3	Up to 1 million AU
4	Up to 10 million AU
5	Up to 100 million AU
6	Over 100 million AU


C rellation of 'Subsystem' nd 'Direct loss'
COUNT OF FANCS
250
200
150
100
50
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16
Through:
Unknown
0
None
1
Less than 0.1 Million AU
2
Less than 1 Million AU
3
Less than 10 Million AU
4
Less than 100 Million AU
5
More than 100 Million AU
5
TBD
9
Across:
00 System Engineering
01 Power
02 Telemetry Tracking & Command
03 Attitude/Orbit Control/Guidance
04 Propulsion / Aero-thermodynamics
05 On-Board Data Handling
06 Thermal Control
07 Mechanisms and Structure
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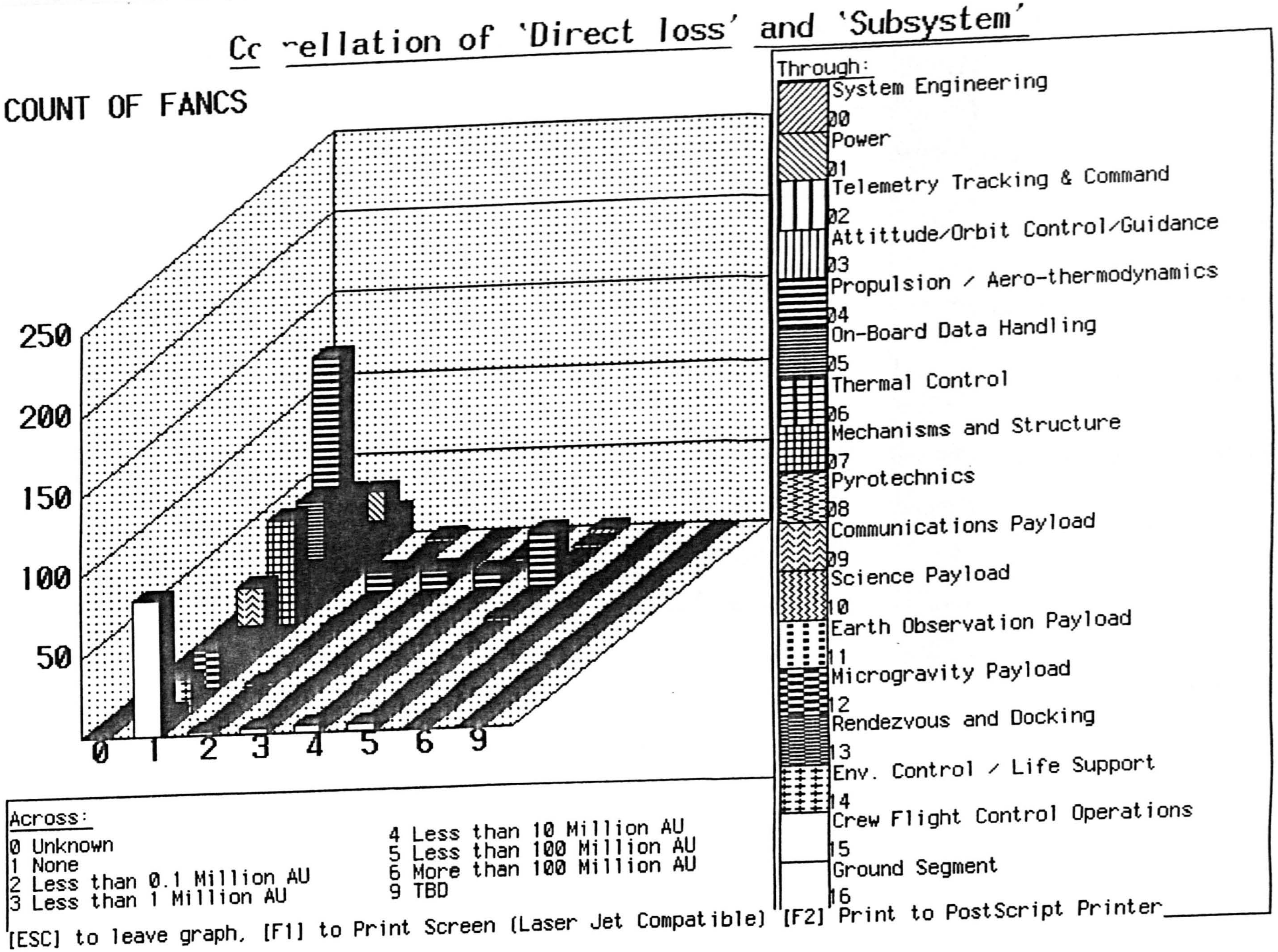
[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer



Cc -ellation of 'Direct loss' and 'Subsystem'
COUNT OF FANCS
250
200
150
100
50
0 1 2 3 4 5 6 9
Through:
System Engineering
00
Power
01
Telemetry Tracking & Command
02
Attitude/Orbit Control/Guidance
03
Propulsion / Aero-thermodynamics
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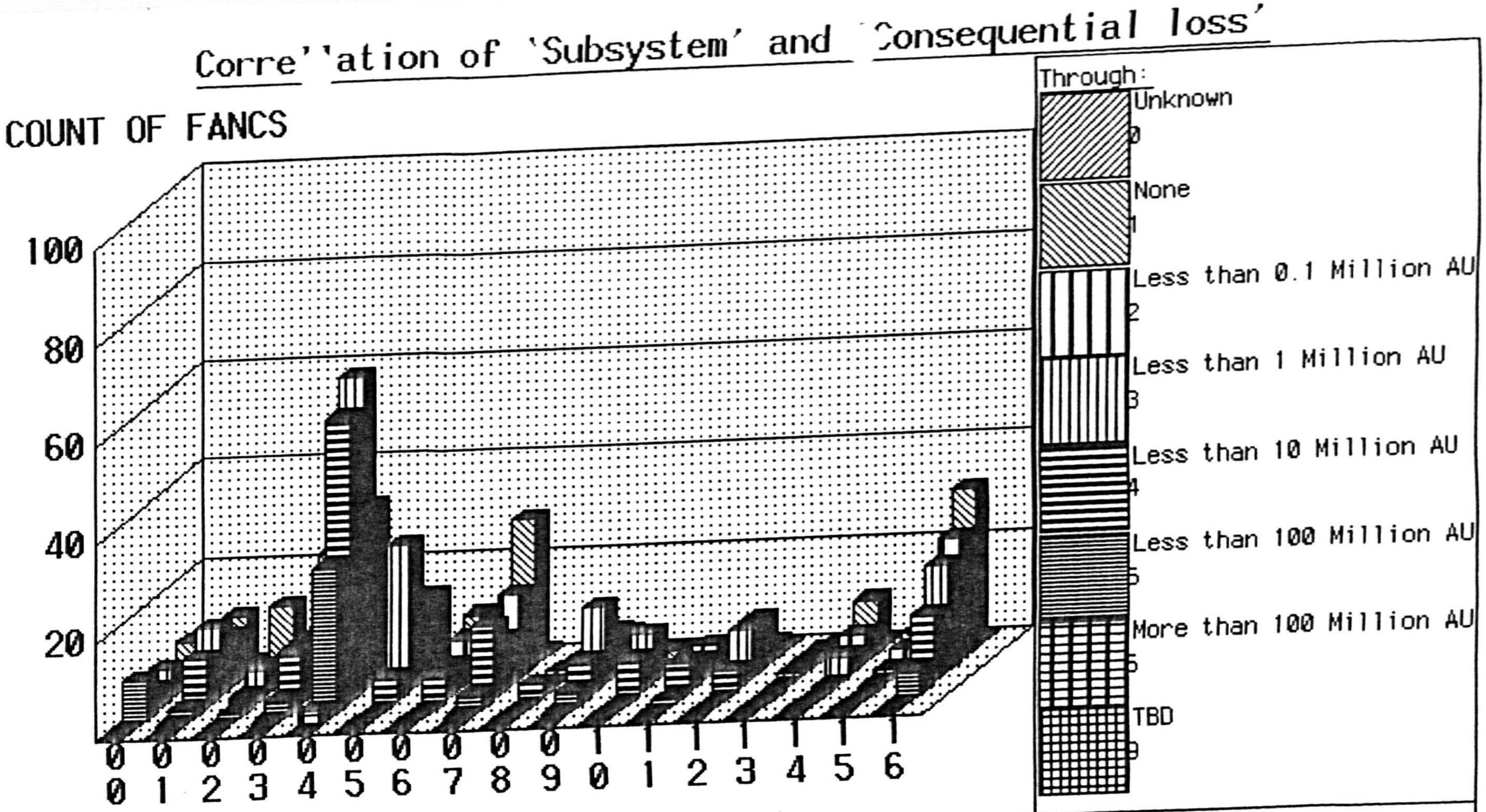
Rendezvous and Docking
13
Env. Control / Life Support
14
Crew Flight Control Operations
15
Ground Segment
16
Across:
0 Unknown
1 None
2 Less than 0.1 Million AU
3 Less than 1 Million AU
4 Less than 10 Million AU
5 Less than 100 Million AU
6 More than 100 Million AU
9 TBD
[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer



Across:

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[ESC] to leave graph, [F1] to Print Screen (Laser Jet Compatible) [F2] Print to PostScript Printer

ANNEX 8

Daily Record Analysis Details of Four Projects.
(Available on request from the author)

ANNEX 8

Daily Record Analysis Details of Four Projects.
(Available on request from the author)

ANNEX 9

DEFINITIONS

The following definitions are given to provide a specific interpretation of these often rather generally used words in the understanding of the model. Where a reference is provided the definition is taken from the literature; otherwise they have been defined for this research.

An **ATTRACTOR** is the trajectory towards which all other trajectories try to converge.(125).

CHAOS is persistent instability; it is a dynamic phenomenum.(123).

In pragmatic terms, critical support items are those aspects of the project that are essential in order that the main objectives are achieved; hence some degradation could occur but not to the fundamental objectives. This, once again(see ref.106), stresses the need to prioritise the aims of a project i.e. NOT to state that they are equally important and therefore "everything" must be successfully achieved "all" the time.

Thus, those risk indicators that apply to critical support items would be of paramount concern to the intervener.

DYNAMIC INSTABILITY is defined as the average of a measure of the rate of growth of small deviations(Kovalevskaya-Liapunov,152)

The term **ELEMENT** is defined as "a datum or value necessary to be taken into consideration in making a calculation or coming to a conclusion; as an example the elements of an orbit, in astronomy, are the quantities whose determination defines the path of a planet or celestial body, and enables us to compute the place of such a body at any past or future epoch."(206).

FLOWS are defined as any activity which requires the expenditure of resources; the latter covers money, manpower, time and procurement.

INTERVENTION is defined as the temporary application of INFLUENCE or CONTROL to a project by a third party, for example a manager(s) other than the project manager who is normally responsible for the day-to-day management of the project. (Annex 2 contains an explanation of the intervention concept by using a traffic control example.).

A **LOOP** is described and defined as follows:

" a loop relates to the resource flow(manpower and time) estimated as being necessary to "successfully" complete the following **phases**,

- selection(trade-off),

- design,
- manufacture,
- qualification,
- test,
- acceptance,
- assembly into the space vehicle,
- testing at system level,
- operation

of **a system, or part thereof**.
The above constitutes a "loop" in the following manner. For each of the above phases specific resource flows have been estimated; these flows are checked at certain points and the values thus obtained compared with the estimated value at that time; this feedback completes the loop. Clearly the resource flow estimates are rather meaningless if the successful outcome of the "phase" is undefinable i.e an open loop(see below); feedback becomes irrelevant.

NEGATIVE ENTROPY is the result of an adjustment to the system that results in a reduction of the prevailing entropy.

The second law of thermodynamics can be extended to open systems that exchange energy and matter with their surroundings e.g. a project. The two entropy components involved are 1), the transfer of entropy across the boundaries of the open system, and 2), the total entropy produced within the overall system. According to the second law the rate of generation of entropy inside the system is always positive; and only irreversible processes contribute to the production of this increasing entropy. Most quantities in the physical world can increase or decrease with time, but entropy must always increase with time. The entropy can however decrease locally during a given interval, but only at the expense of a larger increase of entropy in the environment so that it results in a nett increase in the global entropy; the mechanism of negative entropy is thus valid. Entropy is "times arrow", in the words of Eddington. It gives the direction in which time flows but it does not provide the rate at which time is increasing, so it cannot be used as a clock. Sometimes entropy increases more rapidly, and sometimes more slowly; only rarely does it remain constant. The second law does not provide the speed of degradation(180).

An **OPEN LOOP SYSTEM** is defined as:

- a system in which the meaning or outcome of any of its elements either,

  1) cannot be completely defined, or,

  2) cannot be directly linked with a previously experienced "similar" item which had a successful result.

In more detail an activity is defined as being **open loop** if the answers to the questions 1 through 8 are either "no" or "partially"; and "yes" or "partially" to question 9:

question 1: has the activity been done before by the contractors who are scheduled to do it?

question 2: is all the data needed to complete the activity available when needed; or is the outcome of the activity predictable?

question 3: is all the knowledge needed to complete the activity available when needed; or is the outcome of the activity predictable?

question 4: are all the interfaces defined when needed? (this includes interfaces between phases; see section 6.4).

question 5: are all inputs, including other bits of HW and/or SW, available when needed.

question 6: are perceptual and behavioural aspects addressed?

question 7: have the negative entropy injections, in order to maintain orderliness with increasing complexity, been identified, defined and planned?

question 8: is the activity reversable*.

question 9: do any of the answers to questions 2, 3, 5 and 6 depend on the outcome of an open loop activity?

* For the purpose of this thesis a hardware activity, for example, is classified as irreversible because it is normally not possible to "uncut" or "unmachine" a piece of material.

An **OPEN SYSTEM** is where the stability is in dynamic equilibrium; in which continuous change occurs yet relatively uniform conditions prevail, like the conditions in a pool beneath a waterfall.(102). See also the application of "negative entropy" in open systems above. An open system has the property of being able to exchange information, matter and energy across the boundary with its environment.

PROJECT SUPPORTS are used here in the manner of supports to a building or superstructure. When prefaced with the word "critical" it refers to those supporting items that are absolutely essential in order to carry, and balance, the overall load. In other words the ediface(project) would collapse, or weaken beyond certain limits of acceptability(risk or confidence), if one of the critical support items failed. It has already been stated that companies are, in fact, Open systems. It is in the context of the "stability of the dynamic equilibrium of the open system" that the critical support items are so important. This applies particularly in transitioning from linear to, and through, non-linear regimes.

RISK is defined as being a function of the perceived probability of the occurrence of a hazard(s), the perceived severity of the consequence(s) of that hazard, and the associated uncertainties.

RISK INDICATORS: can be static or dynamic. A static risk indicator is based purely on static or "snapshot" data; it provides a single picture of the flow status of the project at a particular time. An example of a static risk indicator is a PERT or CPN chart.

A dynamic risk indicator contains information concerning the increase or decrease of the flow rate(s) within the project. An example of a dynamic risk indicator would be a plot of the rate at which manpower is being used versus the rate by which a test is being successfully completed.

STRATEGIC CHANGE is defined in a bipolar manner; to be used in conjunction with the definition of strategy, given below:

1) primarily, as an actual, or potential, departure of the project operations from those delineated in the project strategic plan;

2) secondarily, when it appears that the strategic plan has not adequately accommodated the environmental effects such that there is a significant likelihood that the project will not meet the stated objectives

STRATEGIC PLANNING is defined as a journey that probes the need for change; it relates to the socio-political nature of the organisation, to perception , and to upper level management interpreting unanticipated environmental events.

STRATEGY is defined as the means of coping with both the external and internal changes; the path charted for the organisation being linked to the organisational goals and objectives which are to be achieved.

TOPOLOGY is defined as a sort of geometry that deals with continuities and connections among varying quantities(Poincare;152)

TURBULENCE is defined as the increase, or decrease, of dynamic instability from, or towards, steady state conditions.

TRAJECTORIES embrace aspects which:

- change as the project advances in time,
- represent the dynamic nature of the project,

  and

- can indicate an actual or potential strategic change or increase or decrease in risk.

ANNEX 10

ABBREVIATIONS

The following abbreviations have been used in this thesis.

- A5m: Ariane 5 common bulkhead(a launch vehicle fuel tank bulkhead);
- ABM: Apogee Boost Motor;
- Aer: Aerothermodynamics;
- AI: Artificial Intelligence;
- Ant: Antenna;
- AOCS: Attitude and Orbit Control;
- Bap: Bearing and Power Transfer Assembly;
- Bcl: Battery thin wall Cells;
- BDR: Baseline Design Review;
- C/D: Phase C/D(assembly, integration and test phase);
- CDR: Critical Design Review;
- CEO: Chief Executive Officer;
- CEU: Central Electronics Unit;
- CPN: Critical Path Network;
- C-W: Caution and Warning;
- Des: Design;
- DG: Director General;
- DGa: Dual Gate Amplifier;
- e.g.: for example;
- EPC: Electronic Power Conditioner;
- E & R: Escape and Rescue;
- ESA: European Space Agency;
- ESD: Electro Static Discharge;
- ESS: Electrical Sub-System;
- FMECA: Failure Mode and Criticality Analysis;
- FMW: Fixed Momentum Wheel;

- Hex: Hexfet;
- i.e.: that is;
- ITT: Invitation To Tender;
- PA: Product assurance;
- PERT: Probabilistic Evaluation of Resources and Time;
- PRR; Project Requirements Review;
- QER: Quarterly Executive Report;
- manP: Manpower;
- Mar: Manpower and Resources;
- Mat: Materials;
- MIC: Microwave Integrated Circuit;
- Mis: Mission;
- OBDH: On Board Data handling sub system;
- O-M: Organisation and Management;
- Pla: Planning;
- PP: Parts Procurement;
- Pro.Sup: Project Support;
- PSS: Propulsion Sub- System;
- Rad: Radiation;
- R: Resources;
- RFQ: Request For Quotation;
- RI: Risk Indicator;
- Rqt: Requirement;
- Saf: Safety
- Sched: Schedule;
- SFr: Sfernice Resistor;
- TEB: Technical Evaluation Board;
- The: Thermal;

- Tht: Tayco Heater;
- TT & C: Telemetry and Telecommand;
- TWT: Travelling Wave Tube;
- Uni: Unitrode Diode;
- Var: Varactor Diode;
- VSM: Variable System Model;
- WD: a "WATCH DOG" DG Committee.