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**NASA CONTRACTOR  
REPORT**

**NASA CR-61381**

**METHODOLOGY FOR THE SYSTEMS  
ENGINEERING PROCESS  
Volume II: Technical Parameters**

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**March 1972**

**Final Report**

**CASE FILE  
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**Prepared for**

**NASA-GEORGE C. MARSHALL SPACE FLIGHT CENTER  
Marshall Space Flight Center, Alabama 35812**

|  |  |  |   |                            |   |
|--|--|--|---|----------------------------|---|
| 1. REPORT NO.<br>NASA CR-61381   |  | 2. GOVERNMENT ACCESSION NO.                          |   | 3. RECIPIENT'S CATALOG NO. |   |
| 4. TITLE AND SUBTITLE<br>METHODOLOGY FOR THE SYSTEMS ENGINEERING PROCESS<br>Volume II: Technical Parameters  |  |  | 5. REPORT DATE<br>March 1972  |                            | 6. PERFORMING ORGANIZATION CODE                                   |
|  |  |  | 8. PERFORMING ORGANIZATION REPORT #<br>MCR-71-352                                   |                            | 10. WORK UNIT NO.   |
| 7. AUTHOR(S)<br>James H. Nelson  |  |  | 11. CONTRACT OR GRANT NO.<br>NAS 8-27567  |                            | 13. TYPE OF REPORT & PERIOD COVERED<br>Contractor Report<br>Final |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Martin Marietta Corporation<br>P.O. Box 179<br>Denver, Colorado 80201   |  |  | 14. SPONSORING AGENCY CODE  |                            |   |
| 12. SPONSORING AGENCY NAME AND ADDRESS<br>National Aeronautics and Space Administration<br>Washington, D. C. 20546   |  |  | 15. SUPPLEMENTARY NOTES   |                            |   |
| 16. ABSTRACT<br><br><p>This study describes a scheme based on starting the logic networks from the development and mission factors that are of primary concern in an aerospace system. This approach required identifying the primary states (design, design verification, premission, mission, postmission), identifying the attributes within each state (performance capability, survival, evaluation, operation, etc), and then developing the generic relationships of variables for each branch. To illustrate this concept, we used a system that involved a launch vehicle and payload for an earth-orbit mission. Examination showed that this example was sufficient to illustrate the concept; a more complicated mission would follow the same basic approach, but would have more extensive sets of generic trees and more correlation points between branches.</p> <p>This study showed that in each system state (production, test, and use), a logic could be developed to order and classify the parameters involved in the translation from general requirements to specific requirements for system elements.</p> |  |  |   |                            |   |
| 17. KEY WORDS  |  |  | 18. DISTRIBUTION STATEMENT<br>Unclassified-unlimited<br><br><i>George R. Shower</i> |                            |   |
| 19. SECURITY CLASSIF. (of this report)<br>Unclassified   |  | 20. SECURITY CLASSIF. (of this page)<br>Unclassified |   | 21. NO. OF PAGES<br>45     | 22. PRICE<br>\$3.00   |

FOREWORD

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This report is submitted in accordance with the requirements of Contract NAS8-27567. Martin Marietta Corporation submits this report in three volumes as follows:

Volume I--System Functional Activities (NASA CR-61380)

Volume II--Technical Parameters (NASA CR-61381)

Volume III--Operational Availability (NASA CR-61382)

CONTENTS

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|  | <u>Page</u> |
|--|-------------|
| I. PURPOSE . . . . .   | 1           |
| II. DEFINITIONS . . . . .  | 2           |
| III. TECHNICAL PARAMETERS . . . . .  | 3           |
| A. General Considerations . . . . .  | 3           |
| B. Aerospace System Definition/Design Technical<br>Parameters . . . . .    | 6           |
| C. Summary . . . . .   | 11          |
| IV. TECHNICAL PARAMETER DESCRIPTION . . . . .                              | 12          |
| A. Interrelation of Parameters . . . . .                                   | 12          |
| B. Example of a Technical Parameter Hierarchical<br>Relationship . . . . . | 16          |
| C. Summary . . . . .   | 25          |

Figure

---

|    |  |    |
|----|--|----|
| 1  | Straight-Line Parametric Curves . . . . .  | 3  |
| 2  | Fundamental Design Process . . . . .   | 6  |
| 3  | Example of Program Phases and State Relationships . . . . .                            | 8  |
| 4  | Systems Definition Sequence . . . . .  | 9  |
| 5  | Example of System Element-System State Relationship . . . . .                          | 10 |
| 6  | Mission Systems Design Tree . . . . .  | 13 |
| 7  | Example of Weight and Reliability Model . . . . .                                      | 15 |
| 8  | Development of Technical Performance Parameter<br>Hierarchical Relationships . . . . . | 18 |
| 9  | System Element Synthesis/Design Solution . . . . .                                     | 19 |
| 10 | Mission State Technical Parameter Tree . . . . .                                       | 29 |
| 11 | Launch State Technical Parameter Tree . . . . .  | 31 |
| 12 | Verification State Technical Parameter Tree . . . . .                                  | 33 |
| 13 | Assembly State Technical Parameter Tree . . . . .                                      | 35 |
| 14 | Storage State Technical Parameter Tree . . . . .                                       | 37 |
| 15 | Production State Technical Parameter Tree . . . . .                                    | 39 |

Table

---

|   |  |   |
|---|--|---|
| 1 | Classification of Parameters . . . . . | 8 |
|---|--|---|

## SUMMARY

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Developing interrelationships between technical parameters is one approach for describing a complex system in a logic network display. One main advantage of this method is that it gives visibility to the primary parameters of concern in controlling the development of a complex system.

This study describes a scheme based on starting the logic networks from the development and mission factors that are of primary concern in an aerospace system. This approach required identifying the primary states (design, design verification, premission, mission, postmission), identifying the attributes within each state (performance capability, survival, evaluation, operation, etc), and then developing the generic relationships of variables for each branch. To illustrate this concept, we used a system that involved a launch vehicle and payload for an earth-orbit mission. Examination showed that this example was sufficient to illustrate the concept; a more complicated mission would follow the same basic approach, but would have more extensive sets of generic trees and more correlation points between branches.

This study showed that in each system state (production, test, and use), a logic could be developed to order and classify the parameters involved in the translation from general requirements to specific requirements for system elements.

The technique of graphical description of technical parameter relationships was found to have limitations due to the high degree of correlation that exists between parameters of a complex system. The technical parameter trees developed for the reference system show some of these limitations. A more sophisticated method of determining and showing parameter relationships needs to be developed.

I. PURPOSE

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The purpose of this task is to identify the technical parameters that exist during, that are developed by, and that influence the definition/design phase.

II. DEFINITIONS

---

|                      |   |
|----------------------|---|
| Variable             | A quantity to which an unlimited number of values can be assigned in an investigation   |
| Constant             | A quantity whose value is fixed in any investigation  |
| Arbitrary Constant   | A constant that represents one particular quantity or number in a given investigation or problem but that may represent another quantity or numerical value in another investigation or problem   |
| Function             | A variable quantity whose value depends on and varies with that of another quantity or quantities; i.e., when two variables are so related that the value of the first variable is determined when the value of the second variable is given, then the first variable is said to be a function of the second, or $Y = f(x)$ |
| Independent Variable | The second variable (in the equation $Y = f(x)$ ) of a function to which values may be assigned at pleasure within limits, depending on the particular problem  |
| Dependent Variable   | The first variable of a function whose value is determined when the value of the independent variable is given  |
| Technical Parameter  | An arbitrary constant whose value determines the specific form of a system or system element but not its general form   |

|                          |  |
|--------------------------|--|
| Technical Solution       | The dependent variable in the process of solving a technical problem consisting of independent variables and arbitrary constants   |
| Technical Parameter Tree | A logic network that describes a generic relationship between technical parameters   |
| Mission State            | A part of a mission identifiable by a homogeneous set of requirements and factors that sets that part apart from other parts of the mission; i.e., the production state has little to do with the launch state; the transportation state has nothing in common with the orbit state; and so on |

### III. TECHNICAL PARAMETERS

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#### A. GENERAL CONSIDERATIONS

As indicated by the definition, a technical parameter is a factor in the general solution of a technical problem. It is an arbitrary constant that determines the specific form of the independent variable in the problem.

In a mathematical example, the equation

$$y = (x) a$$

is the equation of a straight line where  $y$  is the dependent variable,  $x$  is the independent variable, and "a" is a parameter that determines the slope of the line. The parameter "a" determines the specific form of the line but is not a factor in determining the general form of the line; i.e., a straight line (see Fig. 1).

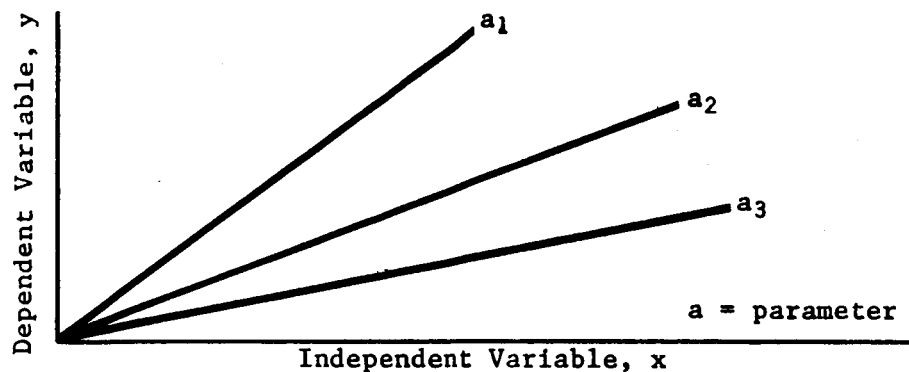


Figure 1 - Straight-Line Parametric Curves

In a system definition the same analytical relationship exists; however, the problem is more complex due to the multiplicity of parameters involved.

Relating the simple straight-line equation to definition/design phase applications, we have

$$Y = f (X) P$$

where



Y = technical solution;

X = concept for technical solution;

P = parameter(s) of concept.

For mission solutions

$$Y_m = f(X_m) P_{m_1}, P_{m_2}, P_{m_3}, \dots, P_{m_x}$$

where

$Y_m$  = mission concept solution;

$X_m$  = mission concept;

$P_m$  = parameters of mission concepts.

For system solutions

$$Y_s = f(X_s) P_{s_1}, P_{s_2}, P_{s_3}, \dots, P_{s_x}$$

where

$Y_s$  = system solution;

$X_s$  = system concept;

$P_s$  = parameters of system concepts.

For subsystem solutions

$$Y_{ss} = f(X_{ss}) P_{ss}$$

where

$Y_{ss}$  = subsystem solution;

$X_{ss}$  = subsystem concept;

$P_{ss}$  = parameters of subsystem;

and so on to the individual parts or the circuit-design level.

It must be understood that a solution at any point in the definition/design evaluation is a function of all the various subparts that make up the total. For example, the solution of a particular system must be made up of all the subsystems involved in the system  $Y_x = f(Y_{ss_1}, Y_{ss_2}, Y_{ss_3}, \dots, Y_{ss_x})$ . Consequently, the inter-relationship of the parameters of  $Y_{ss_1}, Y_{ss_2}, Y_{ss_3}, \dots, Y_{ss_x}$  must be defined and controlled so that the solution of any one subsystem does not preclude the solution of another.

The integration of parameters across the various subsystems and the integration of subsystems in a system solution are major roles of the systems engineering organization. These involve defining general requirements and interface requirements, indentifying the parameters, and trade study analyses. Note that the topic of parameter integration is not covered in this report.

B. AEROSPACE SYSTEM DEFINITION/DESIGN TECHNICAL PARAMETERS

The technical parameters that exist during, that are developed by, and that influence a system definition design are those involved in the analysis and synthesis of all elements that constitute the system. To describe these technical parameters, fundamental mission and development functions and requirements must be determined and translated into concepts and performance/design requirements. Figure 2 shows the fundamental process involved in developing these requirements from the point of determining mission objectives to the selection of system elements that meet the performance and design requirements. It follows, then, that the technical parameters are those of the mission, the system concepts, the system element concepts, and the performance/design requirements of the concepts. The steps shown in Figure 2 describe a set of transformations in which the requirements for the mission are expanded from a general and qualitative objective to a definitive set of element descriptions and requirements.

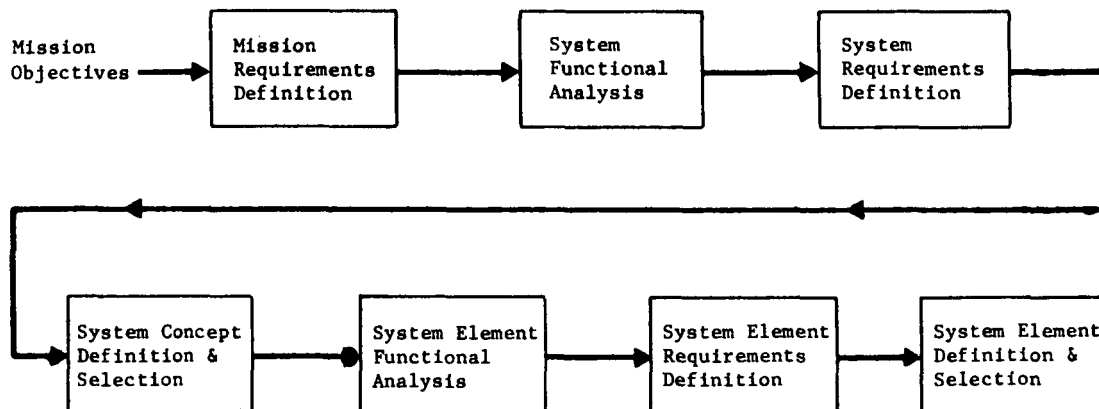


Figure 2 Fundamental Design Process

The first step in this process is the definition of particular mission requirements. This action is the result of a mission study that defines specific capability, availability/dependability, and survivability requirements for system development. These types of requirements are specified for each program phase that makes up the system's life cycle. The parameters of each of the phases are the specific states of that phase. This is consistent with the definition of a parameter--an arbitrary constant that determines the specific nature of an item but not its general nature.

Figure 3 shows specific states of a system and the relationship of the program phases to the specific state of each of the phases. Figure 3 also implies (correctly) that parameters may be of various levels; i.e., the parameters of the program objective are the program phases, the parameters of the program phases are the specific states of that phase, and so on. The requirements specified for each state are uniquely dependent on the specific mission. In general, the mission requirements identify:

- 1) what must be achieved;
- 2) mission success probability;
- 3) requirements for ensuring that men and/or equipment survive the mission;
- 4) where, when, and how the mission is to be performed.

All parameters for each state can be grouped under three general classifications: capability, dependability/availability, and survivability. These classifications apply to all states, and in the subsequent systems analysis are used as the basis for defining system parameters. Table 1 shows an example of parameter classification.

The system parameters definition is the result of a series of operational and systems analyses aimed at describing the functions and requirements that must be implemented by the system elements. This transformation examines the mission states, identifies the principal functions that must be performed, determines the general parameters to be applied, and defines these general parameters in terms of specific values in specific parameters. Figure 4 shows the evolution of parameters from the determination of program objectives to the solution of specific parameters in the form of specific designs.

Each mission state is then examined to determine the specific requirements that must drive the definition of the system.

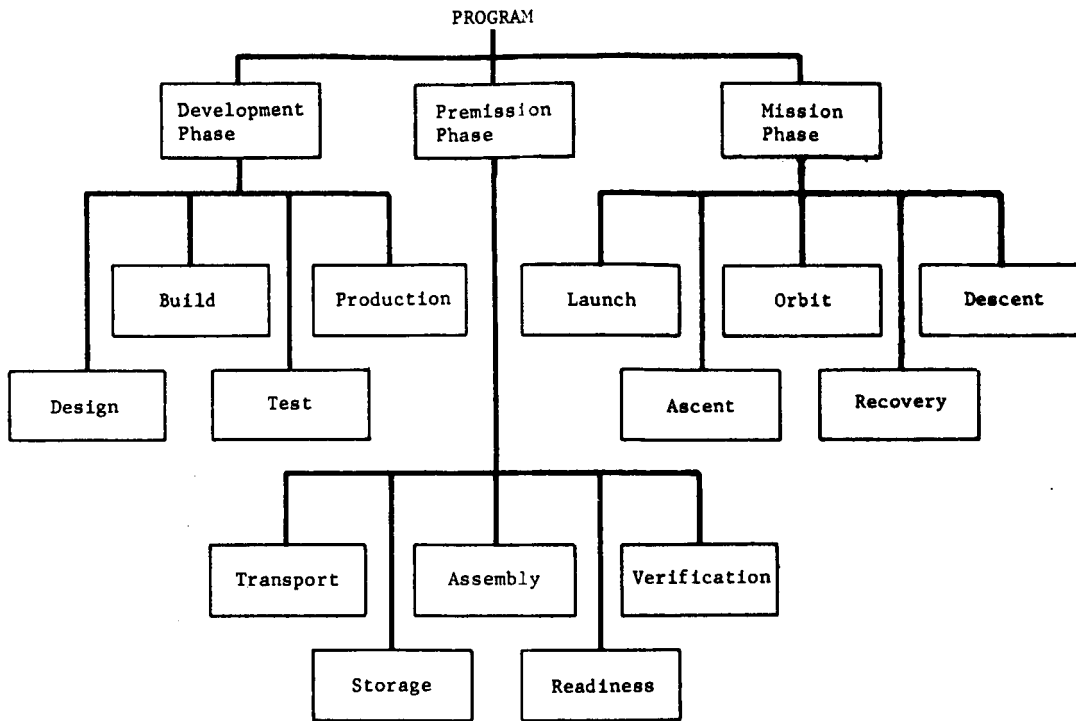


Figure 3 Example of Program Phases and State Relationships

Table I Classification of Parameters

| Capability   | Dependability/Availability  | Survivability   |
|--|---|---|
| Place a 20,000-lb payload into a 235-n-mi circular earth orbit at a 35° inclination      | Provide a 0.999 probability of making a successful launch within 32 hr                    | Provide means for three men to live and work in space for 56 days |
| Soft-land a _____ lb instrument payload on the surface of Mars                           | Provide a 0.98 probability of successfully launching within a prescribed launch window    | Provide a 5-yr storage capability for a launch vehicle system     |
| Provide a capability to rescue three astronauts from a manned, earth-orbiting spacecraft | Provide a 10-yr useful life for an orbiting payload                                       | Provide means for survival during reentry                         |
| Provide the capability to launch six payloads a year for 3 yr                            | Provide a 1-yr launch-readiness capability with a 0.95 probability of a successful launch | Provide means for complying with range safety requirements        |

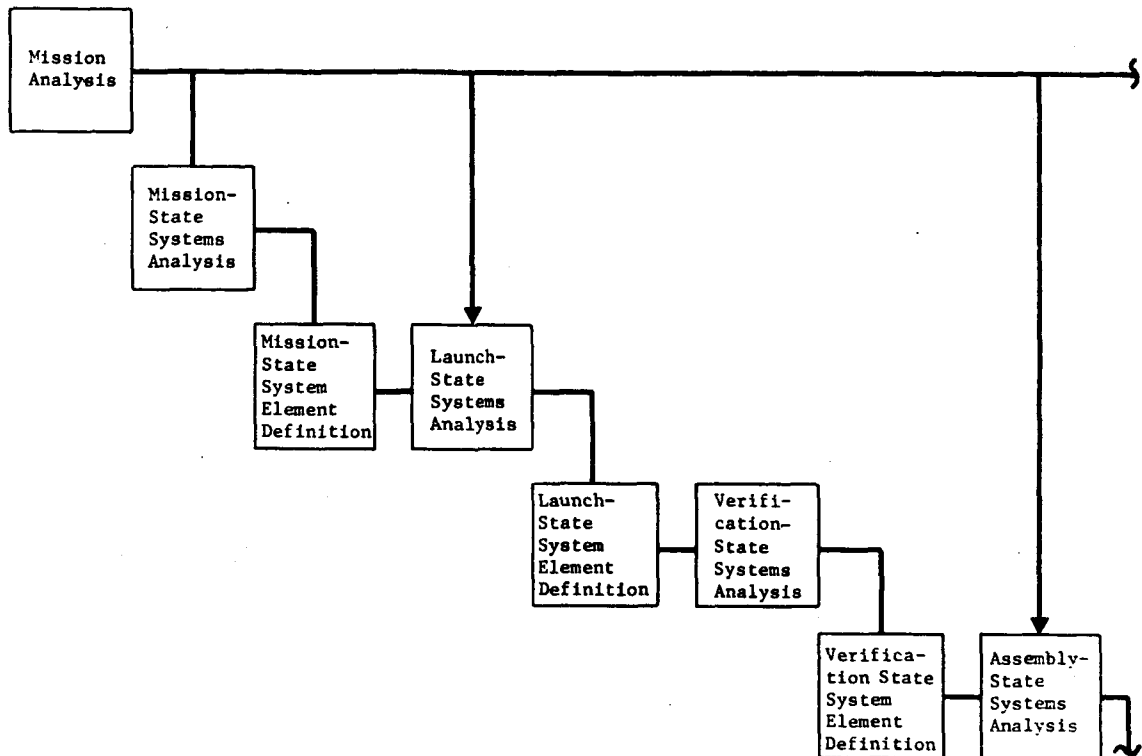


Figure 4 Systems Definition Sequence

The process, it will be noted, is sequential and the flow of activities is from the object mission back to the production state. This means that the definition of mission system elements must precede the systems analysis of launch, verification, assembly, etc. This logical sequence overlaps considerably in practice since these states are not mutually exclusive. The requirements of launch and verification, for example, do affect the object mission system.

The last two steps in the system process involve defining solutions to the system requirements. These solutions are the descriptions of system element concepts and performance and design requirements that, if met, would collectively achieve the mission objectives. The solutions are system elements consisting of airborne equipment, GSE, facilities, personnel, and procedures. For a complex system, this set of elements is extensive. The broad nature of solutions is indicated in Figure 5.

Note that for each of the system elements indicated, and for each system element, there is a specific set of parameters and a particular solution (concept). Although the parameters of each state are unique, they can be classified as shown in Figure 5. Once the system elements that are required for a typical mission have been identified, it can be seen that the parameters of each of

|                       | Production | Transportation | Storage | Assembly | Verification | Launch | Mission (Ascent) |
|-----------------------|------------|----------------|---------|----------|--------------|--------|------------------|
| Equipment             |            |                |         |          |              |        |                  |
| Airborne              |            |                |         |          |              |        | X                |
| Storage               |            |                |         |          |              |        | X                |
| Propellant            |            |                |         |          |              |        | X                |
| Guidance & Control    |            |                |         |          |              |        | X                |
| Electrical            |            |                |         |          |              |        | X                |
| Communications        |            |                |         |          |              |        | X                |
| Environmental Control |            |                |         |          |              |        | X                |
| GSE                   |            |                |         |          |              |        |                  |
| Checkout              |            |                |         |          | X            |        |                  |
| Operations            |            |                |         |          |              |        | X                |
| Handling              | X          | X              | X       | X        | X            | X      | X                |
| Safety                |            |                |         | X        | X            | X      | X                |
| Maintenance           |            |                |         | X        | X            | X      | X                |
| Facilities            |            |                |         |          |              |        |                  |
| Launch                |            |                |         |          |              | X      |                  |
| Mission Control       |            |                |         |          |              |        | X                |
| Storage               |            |                | X       |          |              |        |                  |
| Assembly              |            |                |         | X        |              |        |                  |
| Production            | X          |                |         |          |              |        |                  |
| Personnel             |            |                |         |          |              |        |                  |
| Launch                |            |                |         |          |              | X      |                  |
| Mission Operations    |            |                |         |          |              |        | X                |
| Maintenance           |            |                | X       | X        | X            | X      |                  |
| Assembly              |            |                |         | X        |              |        |                  |
| Crew                  |            |                |         | X        |              | X      | X                |
| Training              |            |                |         |          |              |        |                  |
| Production            | X          | X              |         |          |              |        |                  |
| Transportation        |            |                |         |          |              |        |                  |
| Test                  |            |                |         |          | X            |        |                  |
| Procedures            |            |                |         |          |              |        |                  |
| Checkout              |            |                |         |          | X            |        |                  |
| Launch                |            |                |         |          |              | X      |                  |
| Mission Operations    |            |                | X       |          |              |        | X                |
| Storage               |            |                | X       |          |              |        |                  |
| Logistics/Maintenance |            |                |         | X        | X            | X      |                  |
| Assembly              |            |                |         | X        |              |        |                  |
| Safety                | X          | X              | X       | X        | X            | X      | X                |

Figure 5 Example of System Element-System State Relationship

these elements comes from the states. For example, the parameters of a typical airborne equipment element (guidance and control) come from the mission state, but the parameters of a typical personnel element (maintenance) come from the storage state, the assembly state, the verification state, and the launch state.

In general, the parameters of any system element come from any state in which the element must perform its function. The system elements are those elements that are necessary and sufficient to describe what must be produced. When modified by parameters, the system elements provide the content of specifications.

#### C. SUMMARY

In summary, the technical parameters that constitute those present in the definition/design phases are:

- 1) specific states for the mission, premission, and development phases;
- 2) requirements for each specific state;
- 3) performance/design requirements for system elements.

The relationship of these parameters will be described in the following chapter.



#### IV. TECHNICAL PARAMETER DESCRIPTION

##### A. INTERRELATION OF PARAMETERS

In the previous chapter, the complex relationship of system parameters was described. The process of system definition and design involves many separate but interrelated analysis and synthesis activities that collectively result in the description of the system elements. Therefore, the systems engineering of a complex system requires that means exist for describing the logical relationship of activities in order to provide visibility for control and to determine that all results are complete and integrated.

There are many ways of describing the logic relationships of the elements of a system; e.g., analysis models, specification trees, and part networks. All describe some aspect of the interrelationships that exist during a system development.

For example, Figure 6 is a model of the system elements, subsystems, and equipment that make up a complete system. This model shows the assembly relationship of elements, their type, and the major categories of elements. As in any generic relationship description, it has value as a control mechanism. It is a check to determine that all elements are conceived, a means of assessing the impact of changes, and a guide to the allocation of roles and responsibilities. This example is a model of solutions.

Another type of model that provides a more detailed view of a system is a tree of technical parameters. Technical parameter trees describe the generic relationship between a set of parameters and a solution. Such relationships are contained in the analysis and synthesis of every system element and every subsystem.

One of the simplest forms is where the parameters all have the same dimension:

$$W = f(W_1 + W_2 + W_3 + W_4 + \dots + W_n).$$

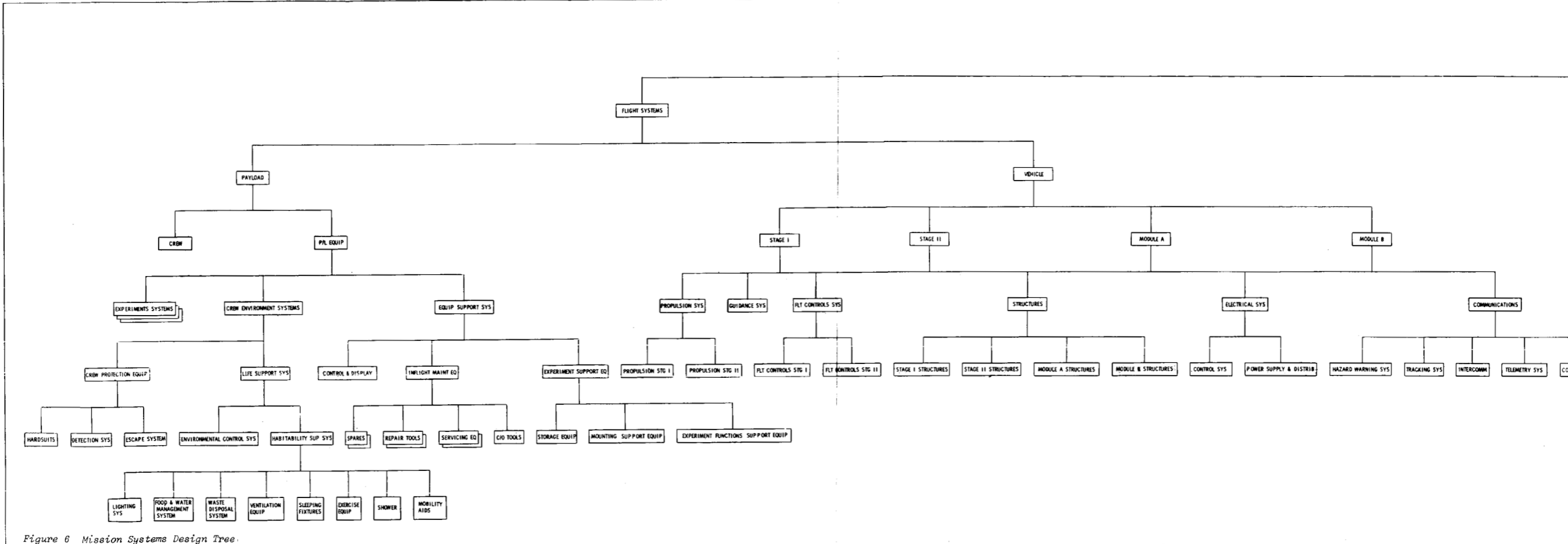
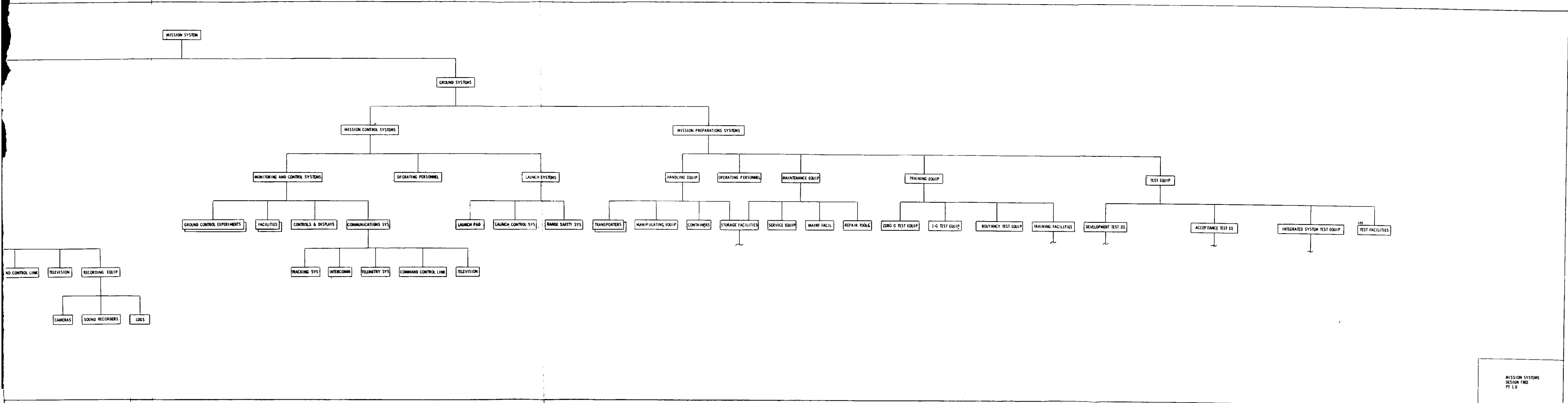


Figure 6 Mission Systems Design Tree

Part 1



Part 2

This is the case for a launch vehicle weight model and reliability allocation model, as shown in Figure 7. The complexity of a system often causes the relationship of parameters to be more complicated. This relationship can be described as follows:

$$\begin{aligned} \text{Mission System Requirements} &= f(\text{Mission Requirement}) \\ &(\text{Performance Requirement}) \end{aligned} \quad [\text{Eq 1}]$$

$$\begin{aligned} \text{Design Solution} &= f(\text{System Element Requirement}) \\ &(\text{Performance Capability}) \end{aligned} \quad [\text{Eq 2}]$$

for a vehicle system performing a specific mission. The parameters of the system requirements determine the specific solution in both equations; i.e., are the parameters of the system synthesis.

W = WEIGHT

R = RELIABILITY

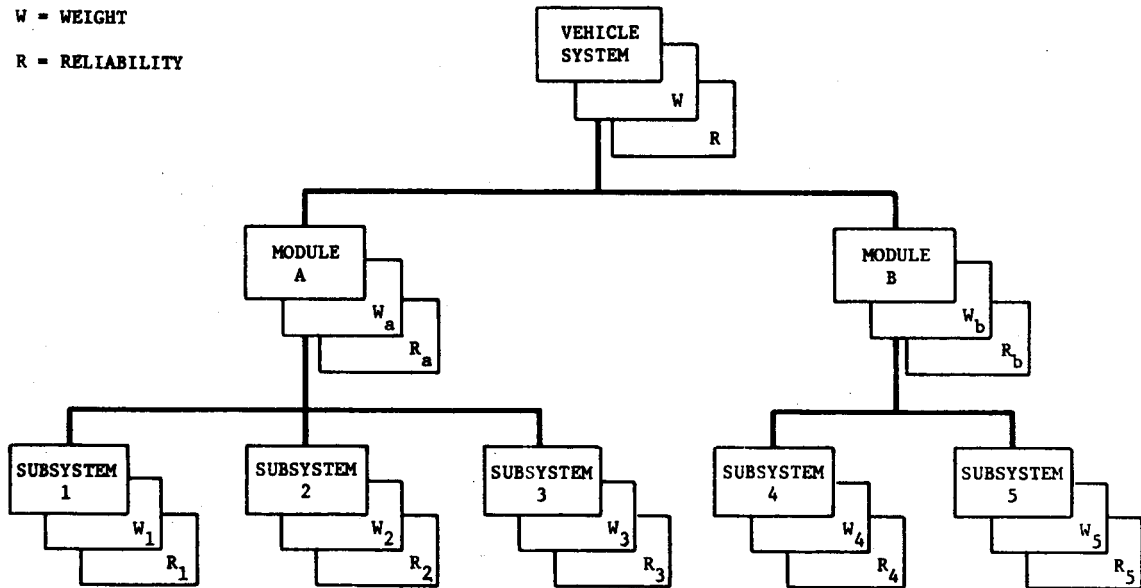


Figure 7 Example of Weight and Reliability Model

In other than the mission phase--that is, in the premission or development phases--the problem differs in that the design solutions are a function both of system requirements for the development state and of the design solution of the mission state. This complexity is explained in the following equations for system verification:

$$\begin{aligned} \text{System Verification Requirements} &= f(\text{Mission Success Requirements, Vehicle Systems, Performance/Design Requirements}) \end{aligned} \quad [\text{Eq 3}]$$

Verification System Element = f (System Verification Requirements,  
Vehicle Systems, Performance/Design Requirements) [Eq 4]

We see from this analysis [Eq 4] that the performance and design solutions (checkout, alignment and calibration GSE, facilities, personnel, and procedures) for elements of the verification system are functions both of the system verification requirements and of the unique performance and design characteristics of the mission-system elements. This same pattern holds true for other premission and development states: the design solutions are a function of the parameters in each state. The system requirements of each state, together with a generalized set of system-element performance and design requirements, provide the basis for describing the parameter relationships in a design solution.

The following section presents an illustrative example of an approach to describing the system technical parameters. Note that the method of presenting parameters *does not* constitute a development tool in the sense of providing a scheme for conducting a system engineering process. Rather, it is a way of graphically representing relationships that can be used for assessing the results of a system development.

#### B. EXAMPLE OF A TECHNICAL PARAMETER HIERARCHICAL RELATIONSHIP

The systems analysis performed during the system definition phase of an engineering activity will usually result in the determination of an initial set of technical parameters. Basically, the selection of technical parameters consists of analyzing customer requirements, establishing interrelationships between the various performance requirements, and defining a system configuration to meet these requirements. This activity usually comprises performance analyses, developing conceptual designs, and developing mathematical models to allocate the system requirements to the proposed system technical parameters. These allocation models are then used to establish performance requirements for the system technical parameters in order to establish the performance margins to be held in reserve to meet unforeseen future contingencies.

In addition, system effectiveness models are developed to establish the interrelationships and relative sensitivities of the primary system technical performance parameters. These models provide the basis for determining which parameters contribute significantly (on the subsystem and component level) in obtaining the data needed to predict performance or effectiveness at the system level.

The technical performance parameters selected at the system level usually consist of the system primary performance requirements, requirements associated with contract incentives, and requirements associated with areas of high technical risk. The technical performance parameters selected at the subsystem and component levels consist of those necessary to predict performance at the next highest level of assembly.

The following example illustrates the method of establishing such technical parameter hierarchical relationships. In a typical development program for a space launch vehicle, the primary system technical performance requirements would initially be selected because of their criticality with respect to mission success. These would be requirements specifying the payload capability, probability of mission success, injection accuracy, and probability of launch on time. Subsequently, during the design definition phase, each one of the primary technical performance requirements would be analyzed, performance allocation and prediction models would be developed, and a system configuration would be established. Figure 8 depicts an extremely simplified model of the payload capability requirement to illustrate the development of technical performance parameter hierarchical relationships at the subsystem and component levels.

In this example, a two-stage vehicle configuration had been selected as a result of a prior systems analysis investigation. The payload capability model that had been developed required hardware performance data inputs in terms of thrust, specific impulse, initial stage weight, and propellant outage. Therefore, exact values of these parameters would be specified for each stage and would be monitored throughout the system development to permit a performance evaluation of the overall system. The individual stage parameters would then be further allocated to the subsystems and components as shown in Figure 8 to permit a subsequent performance evaluation of the individual stages.

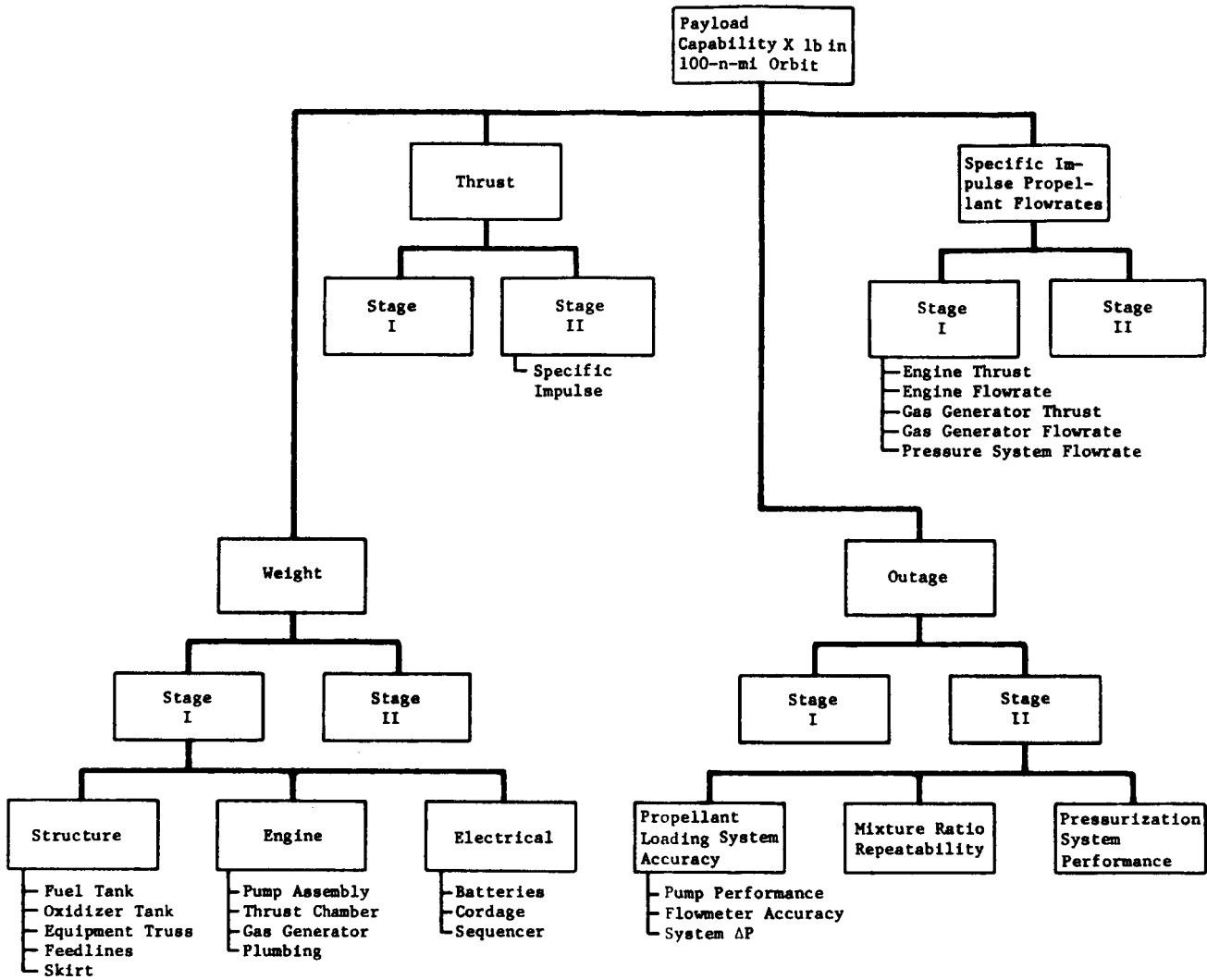


Figure 8 Development of Technical Performance Parameter Hierarchical Relationships (Simplified Two-Stage Example)

The above analysis reveals that technical parameters for complex systems can be displayed in an orderly fashion in each phase of the program for each major system element (payload, vehicle, support, etc). In addition, the parameters for each state could then be identified in terms of input requirements and system element parameters. In this respect, system parameters cannot be divorced from the system element synthesis in any part of the design cycle (concept, definition, and design phases). This condition results from the iterative nature of the design process. Figure 9 illustrates this condition with a generic breakdown into capability parameters, dependability/availability parameters, and survivability parameters. In the following section this concept is applied to a total launch vehicle system to illustrate in detail the role of technical parameter relationships for each mission state; i.e., launch, verification, assembly, storage, and production.

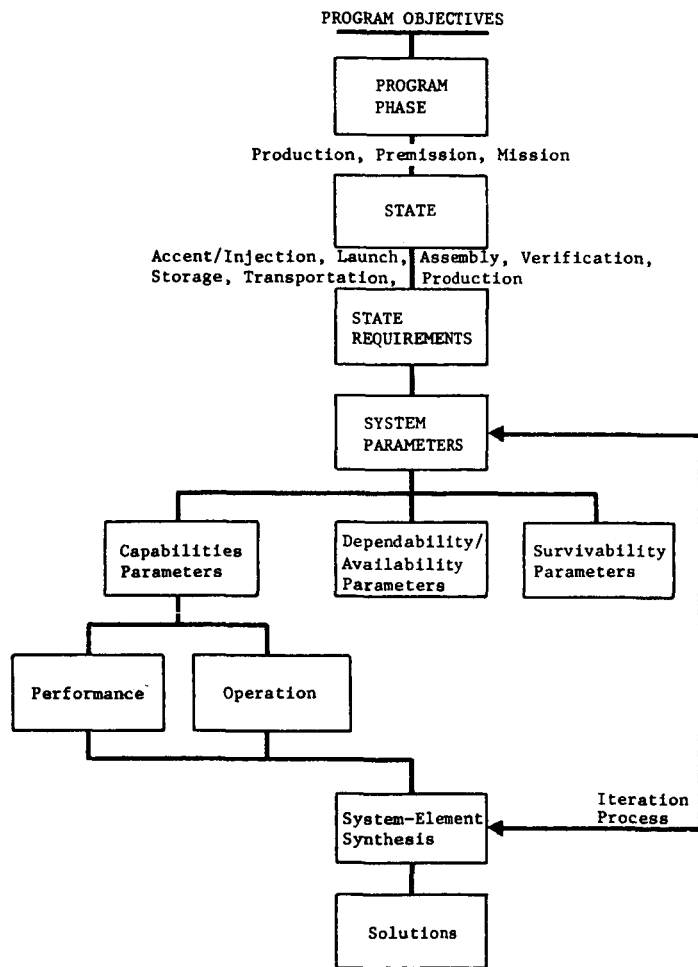


Figure 9 System Element Synthesis/Design Solution



1. Mission State Parameters

The mission state parameters are those involved in translating primary mission objectives into mission requirements, system requirements, and solutions that provide the performance capability, survivability, dependability, and mission operation and control. The reference mission objective used in this illustrative example to identify the technical parameters of this state is the injection of a payload into a prescribed orbit. Examples of mission parameters resulting from a mission analysis are:

- 1) Payload,
  - a) Interfaces (electrical, mechanical, and environmental),
  - b) Physical characteristics (mass properties, stiffness, configuration, load limitation);
- 2) Orbit requirements,
  - a) Type,
  - b) Altitude,
  - c) Inclination,
  - d) Accuracy;
- 3) Launch point;
- 4) Mission duration;
- 5) Natural environment,
  - a) Planetary physics (gravity gradient, atmospheric density gradient, ground wind model, wind aloft model),
  - b) Space environment (meteoroid incident probability, solar radiation).

These parameters result from a systems analysis investigation that defines an initial system configuration, which in turn, must be satisfied by system element designs. This systems analysis *is not* an uncorrelated activity. It is integral with the selection of solutions (subsystem concepts and their performance capabilities) in terms of an iterative relationship between many parameters. This, together with the existing interdependencies, provides a composite network for identifying technical parameters.

*Reference System Parameters* - In Figure 10 (Appendix), the parameters for the mission state of the reference system are identified. The primary threads of capability, dependability/availability, and survivability serve to classify the mission attributes and system requirements and to identify the system element solutions that result from each set of analysis and synthesis activities. The basic elements contributing to each design solution are indicated for each system and subsystem level. For example, the parameters necessary to specify the guidance and control functions are broken down into the computational aspect (flight path) as well as the subsequent implementation of these computations (steering and vector control). Finally, the hardware/software, systems design concepts, and procedures are also identified for each parameter or set of parameters.

## 2. Launch State Parameters

The launch state parameters result from mission requirements applicable to the launch operation and from the associated mission system requirements for preparation and execution of the launch activity. The mission objectives for launch are expressed as mission success probabilities, launch rates, launch location, and reaction times. These are the parameters that determine concepts for conducting launch operations and for selecting system elements needed to perform the launch for the reference system. The mission requirements are:

- 1) A specified launch location;
- 2) A probability of launch on time.

The mission system of a launch vehicle is therefore defined in terms of:

- 1) Configuration;
- 2) Subsystem performance requirements;
- 3) Subsystem operation description;
- 4) Subsystem launch preparation requirements;
- 5) Subsystem checkout requirements;
- 6) Subsystem handling requirements.

The systems analysis performed has as its objective the development of a launch operation concept that meets the mission requirements and that can be satisfied by launch system element solutions (concepts and performance/design requirements) in the form of facilities, equipment, skilled personnel, and procedures. The types of parameters for the launch state are similar in aerospace systems, but depend on the specific mission requirements.

*Reference System Parameters* - The technical parameters for the reference systems are illustrated in Figure 11 (Appendix). The classification by type of parameter provides the means of showing the mission system characteristics that have a direct bearing on the launch system synthesis, and shows the main single threads that lead to a specific launch system solution. At the conceptual design level these parameters provide an integrated approach for determining design specification. For example, the capability loop ties together the launch state final assembly, verification, and operations activities, which affect the vehicle ground support systems, event sequences, timer, etc. The various parameters contributing to a design solution can now be identified and integrated into a design configuration.

### 3. Verification State Parameters

The verification state involves the assessment and evaluation of the systems elements that make up the operational mission system. The systems include facilities, equipment, personnel, and procedures for:

- |                  |                     |
|------------------|---------------------|
| 1) Assembly;     | 4) Launch;          |
| 2) Logistics;    | 5) Mission control; |
| 3) Verification; | 6) Vehicle systems. |

The apparent anomaly of verifying verification equipment actually involves evaluating ground support equipment (GSE) in its installed and integrated state.

The verification activity arises directly from the mission objective and requirement for high mission success probability. The verification action ensures that the system elements, in their operational test condition, function correctly, both individually and as a total integrated system. This verification of all activities except the mission state is a one-time evaluation prior to its operational usage. The verification of the total system is an integral part of each mission.

The verification solution of any system element is shown symbolically in the following functional relationship.

Verification Solution = f (System Element, Functional Requirements, Interfaces, Test Requirements, Operating Procedures, Success Criteria).

*Reference System Parameters* - In Figure 12 (Appendix), the parameters for a launch vehicle verification plan are identified. Those shown are the system-level parameters. Note that the particular solution for each element constitutes the detail design solution. The parameters shown are those that would make up an integrated system verification plan, along with the control documentation procedure. It is important to note that anomalies in the verification process may affect the final design synthesis, possibly to the extent that the plan may have to undergo several iterations to account for multiple contingencies, such as missing a launch window because of bad weather or an equipment malfunction.

4. Assembly State Parameters

The assembly state includes the functional activities of assembling the mission system in preparation for performing the actual mission operation. The technical parameters of this state are a function of the configuration and handling requirements of the mission system. As one of the system development considerations, the system assembly results in the definition of a set of facilities, equipment, procedures, and personnel. The overall system/mission requirements that govern the nature of the assembly system elements are:

- 1) Launch rate;
- 2) Assembly/launch location;
- 3) Mission success probability;
- 4) Program duration.

The first of these directly affects the capability of the assembly complex. The location, mission success probability, and program duration affect the ability of the assembly systems to provide the desired safety and dependability of the total mission system. These factors are examined as part of the system/mission analysis, and a concept is selected that satisfies the mission requirements. In the definition/design phase, this concept is defined in terms of a specific configuration, and performance and design requirements. In the following section, the technical parameters involved in this synthesis action are identified for a launch vehicle system.

*Reference System Parameters* - Figure 13 (Appendix) identifies the technical parameters used in the definition of assembly-system elements. As shown, the configuration, handling, and protection requirements are the principal system requirements that determine the specific conceptual performance/design requirements of the assembly system elements. The mission requirements (launch rates) determine the size and number of assembly cells, shifts, handling equipment, etc, of the complex. Together, these elements define the total configuration.

5. Storage State Parameters

The storage state encompasses the activity of maintaining mission system elements in a state of passive readiness until needed. In the definition/design of a system where a storage mode is a part of the program plan, the mission and system analyses are conducted to identify the storage system elements and to identify their effect on the total mission system. The mission parameters that affect the storage state definition are storage location, storage duration, and mission success requirements, the latter being expressed in terms of the reliability of the system at the end of the storage mode.

The mission system parameters involved in the definition of storage system elements are primarily the system configuration and its handling, maintenance, and environmental requirements. The characteristics of the system of interest are the criticality of parts reliability as a function of time, and what must be provided in the form of maintenance and protection.

*Reference System Parameters* - Figure 14 (Appendix) identifies the system technical parameters of interest in defining storage system elements. This diagram illustrates the general mission system factors for all parts of a mission system. In a complex system, the storage-state systems analysis involves making a detailed examination of all subsystems and identifying the unique preventive-maintenance requirements of each element.

6. Production State Parameters

The production state involves the functional activities of manufacturing hardware from design drawings, performing the necessary tests during the manufacturing process, performing the functional tests on the completed hardware, and ensuring that the completed hardware is ready for shipment to its storage or assembly location. The mission system parameters involved in the production state are primarily those that involve schedules, quality control, and ability to meet acceptance tests. Any of these areas can affect mission initiation and success.

*Reference System Technical Parameters* - The parameters of the production state are identified in Figure 15 (Appendix). As can be seen, the list of parameters and the types of parameters are extensive. For this very reason, production-state parameters should be identified early in the development program. The parameters that are identified are performance parameters expressed in terms of schedules, objectives, and capacity of the production process and operation; survivability parameters expressed in terms of hazards and environmental control; and dependability parameters expressed in terms of mean time between failures (MTBFS) and quality control.

### C. SUMMARY

In this analysis and identification of technical parameters of the definition/design phase, we have shown that the technical parameters can be classified according to three basic types: mission, system, system element.

We have further shown that the parameters are logically broken down by mission state and classification (capability, dependability/availability, survivability). This development of a parameter hierarchical relationship reveals single threads in each state, which result from driving or influencing mission requirements to resulting design solutions. This exercise, conducted using a launch vehicle as a reference model, indicates that the approach could potentially be useful to provide downstream visibility to the critical and significant relationships in the development of a large and complex system.

Such a procedure would be useful for traceability and tracking purposes. This method of display is particularly important in that it highlights the interrelationships between the analysis and synthesis of various elements of the system configuration. For example, the mission system (launch vehicle) affects the selection, sizing, and specification of requirements for ground system elements for mission control, launch verification, etc.

This type of analyses suggests that the further development of such a methodology for systems engineering management purposes would provide a useful tool, and that it presents capabilities and advantages that complement already existing functional analysis procedures.



**APPENDIX**





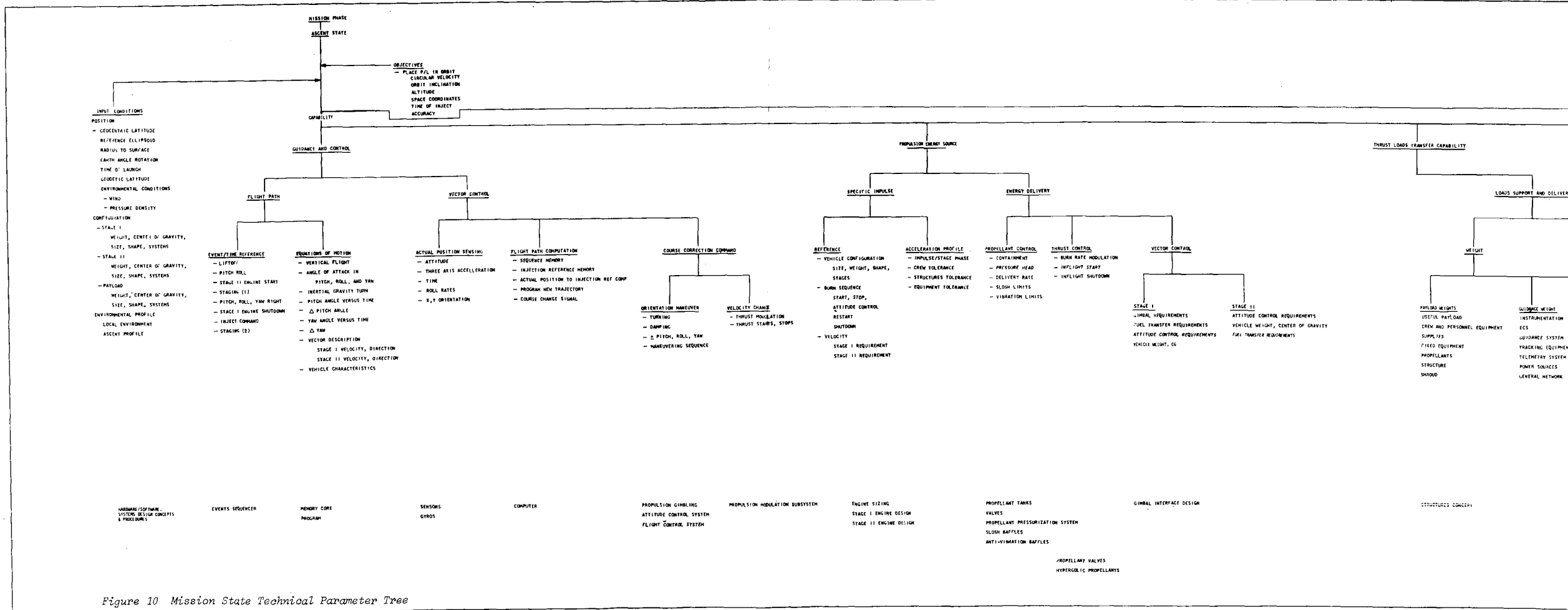
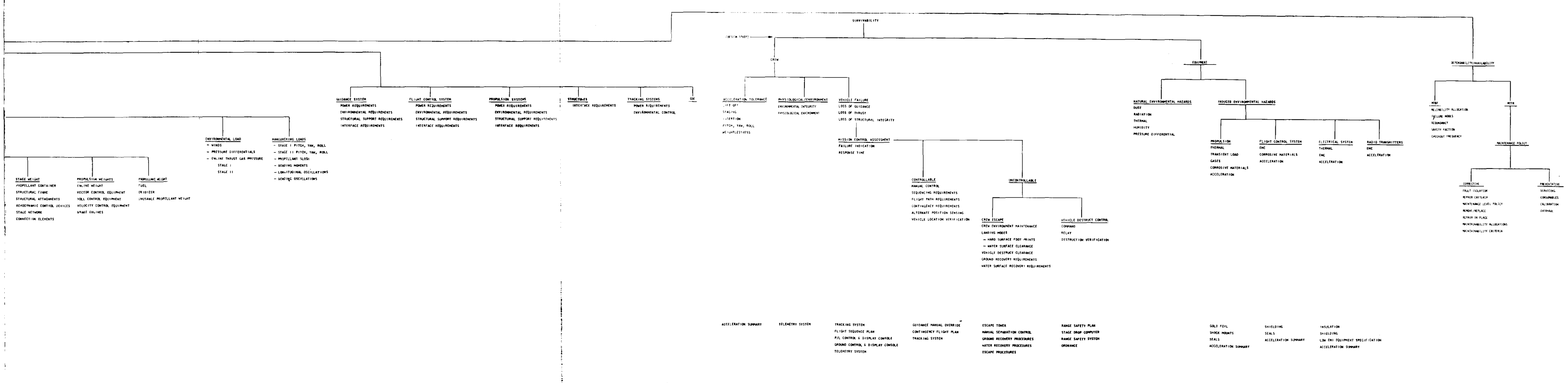


Figure 10 Mission State Technical Parameter Tree

Part 1



Foliant 2

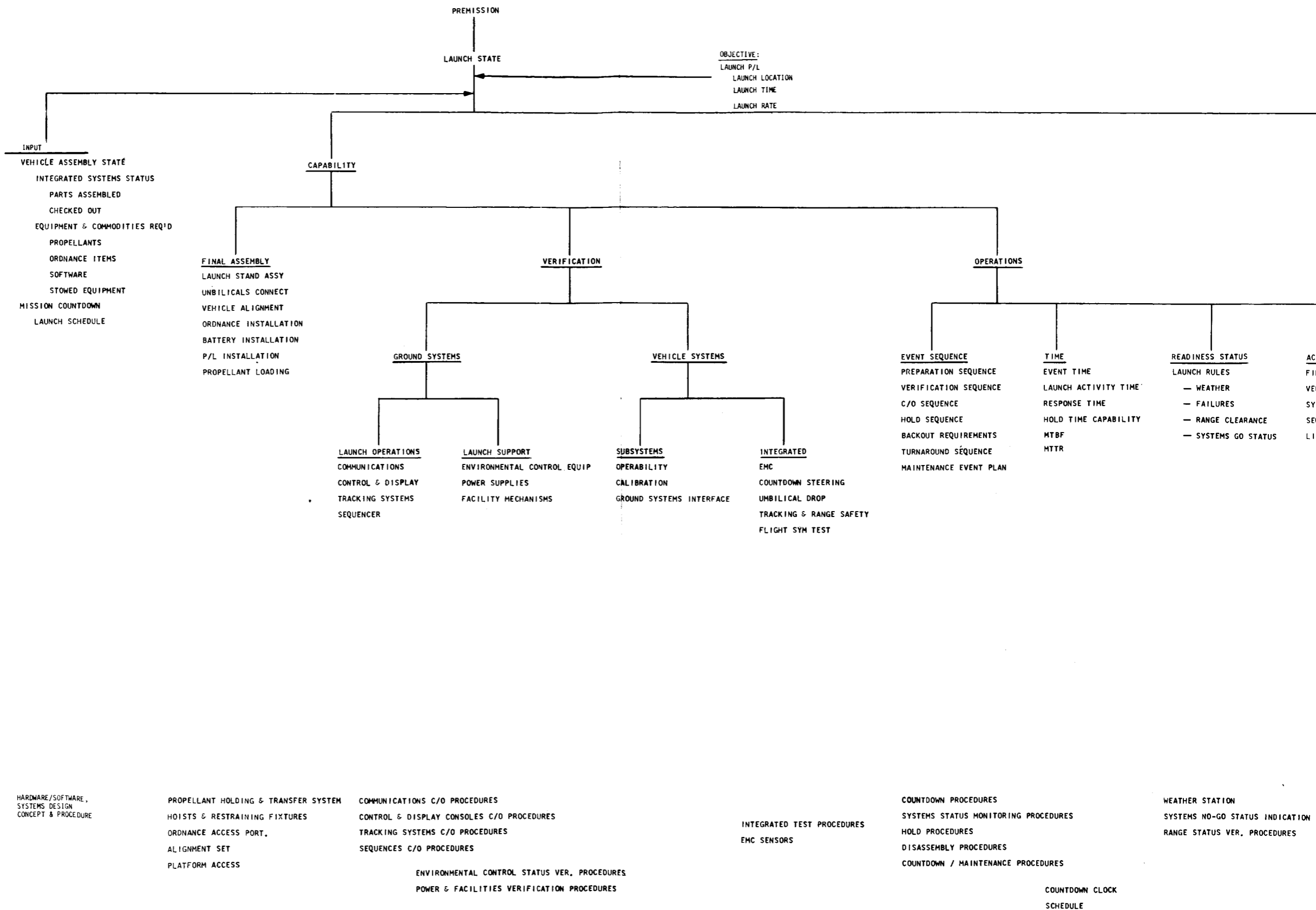
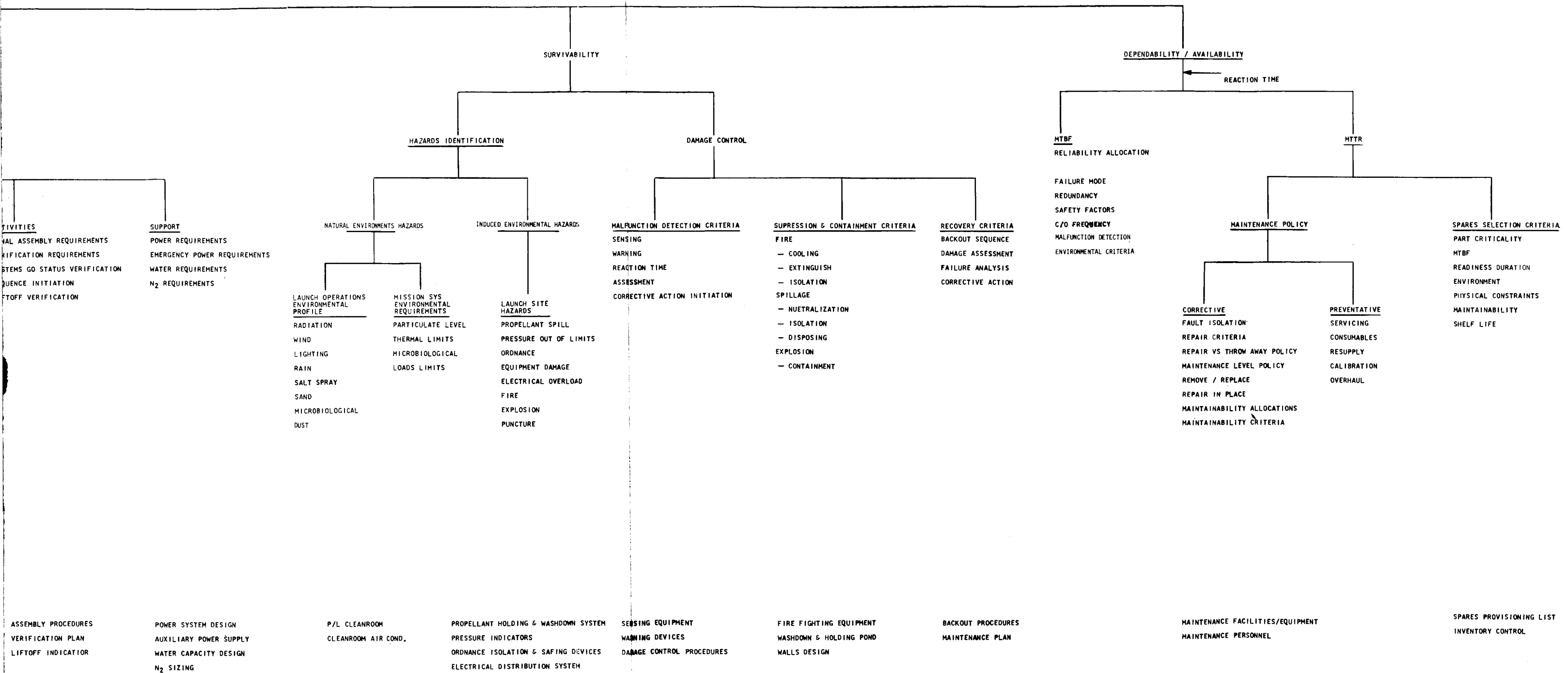


Figure 11 Launch State Technical Parameter Tree

*Followout 1*



Foldout 2

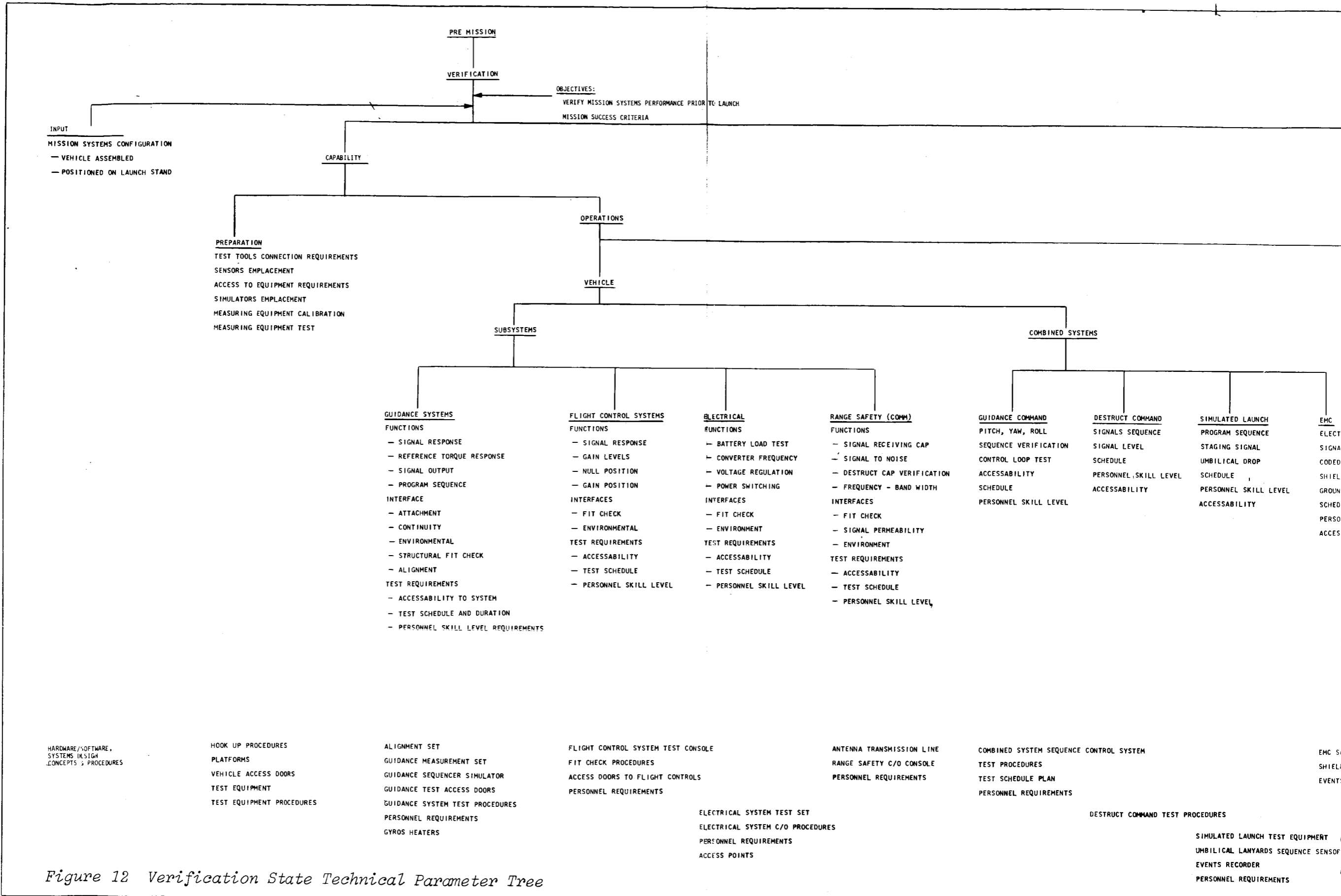
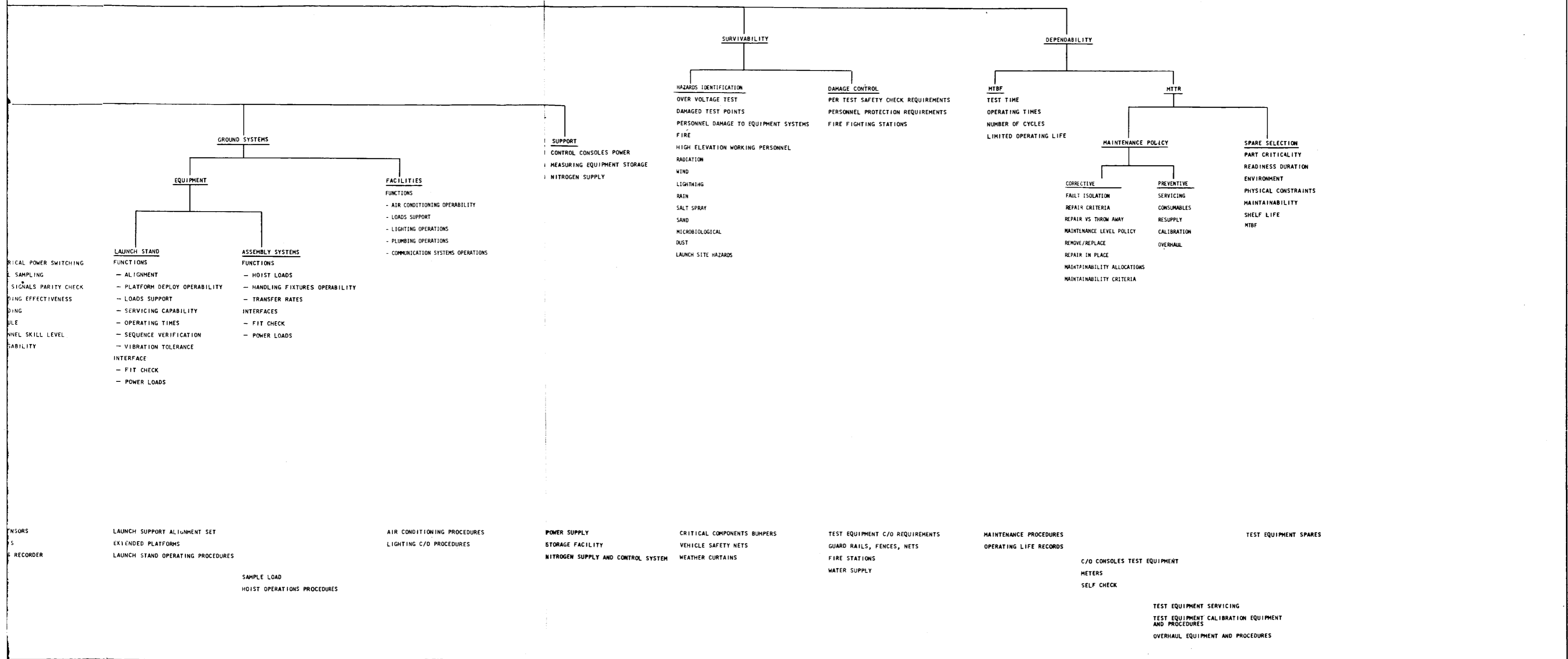


Figure 12 Verification State Technical Parameter Tree

Fold-out 1



Fold out - 2

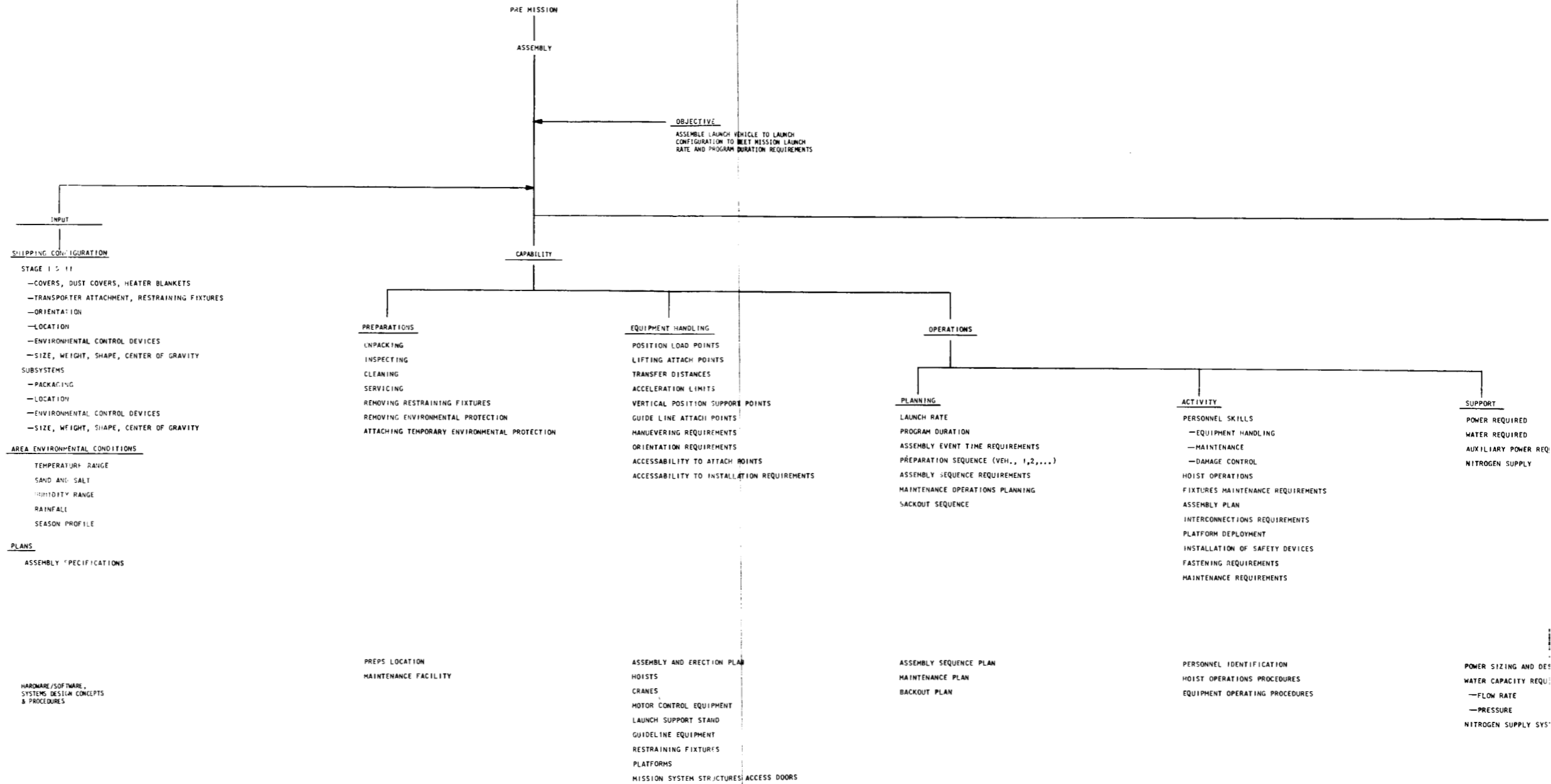


Figure 13 Assembly State Technical Parameter Tree

*fold out 1*



SURVIVABILITY

HAZARDS IDENTIFICATION

- LOSS OF ENVIRONMENTAL CONTROL
- COLLISION
  - EQUIPMENT HANDLING EQUIPMENT
  - EQUIPMENT DROP
  - STRUCTURES
- FIRE
  - EXPLOSION
  - HANDLING EQUIPMENT OVERLOAD
  - CORROSIVE FLUIDS SPILLS
  - MISALIGNMENT DEFORMATION
  - HIGH PLATFORMS
  - ELECTRICAL POWER EQUIPMENT
  - TOXIC ATMOSPHERE
  - WIND PROTECTION
  - RAIN PROTECTION

DAMAGE CONTROL

- FIRE FIGHTING REQUIREMENTS
- CONTAINMENT OF HAZARDOUS MATERIALS
- OVERLOAD REQUIREMENTS
- EQUIPMENT DROP PROTECTION REQUIREMENTS
- WALKWAY PROTECTION
- CONTAMINATION CONTROL REQUIREMENTS
- EQUIPMENT DAMAGE NOTIFICATION
- INDICATION REQUIREMENTS
- REACTION TIME REQUIREMENTS
- REPORT REQUIREMENTS

- FIRE FIGHTING STATIONS & PROCEDURES
- ISOLATION FACILITIES
  - DRAINS
  - WALLS
  - TANKS
- WASH DOWN FACILITIES
- WARNING DEVICES
- RAILINGS
- PERSONNEL WASHDOWN FACILITIES
- FIRST AID CENTERS

- FOUL WEATHER CURTAINS
- LIGHTING SIZING AND DESIGN
- ENVIRONMENTAL CONTROL DEVICES FOR MISSION SYSTEMS

DEPENDABILITY/AVAILABILITY

SYSTEMS EQUIPMENT

MAINTENANCE

- SERVICE REQUIREMENTS
- PERIODIC TEST REQUIREMENTS
- UNSCHEDULED MAINTENANCE REQUIREMENTS
  - INDICATION
  - ISOLATION
  - REPAIR IN PLACE
- REPARABLE / IRREPARABLE ASSESSMENT
- MTTR

- MAINTENANCE PROCEDURES

RECYCLE

- BACKOUT REQUIREMENTS
- REMOVE/REPLACE REQUIREMENTS
- SPARES
- MTBF
- SHELF LIFE
- TIME CYCLE RECORD

- BACKOUT PLAN
- NUMBER OF SPARES

ASSEMBLY EQUIPMENT

MTBF

- RELIABILITY ALLOCATION
- FAILURE MODE
- REDUNDANCY
- SAFETY FACTORS
- MALFUNCTION DETECTION
- ENVIRONMENTAL CRITERIA

- MAINTENANCE PLAN

MTTR

MAINTENANCE POLICY

CORRECTIVE

- FAULT ISOLATION
- REPAIR CRITERIA
- MAINTENANCE LEVEL POLICY
- REMOVE/REPLACE
- REPAIR IN PLACE
- MAINTAINABILITY ALLOCATION
- MAINTAINABILITY CRITERIA
- UNSCHEDULED MAINTENANCE PROCEDURES

PREVENTIVE

- SERVICING
- CALIBRATION
- OVERHAUL
- SCHEDULES
- CONSUMABLES

SPARES SELECTION CRITERIA

- MTBF
- READINESS DURATION
- ENVIRONMENT
- PHYSICAL CONSTRAINTS
- MAINTAINABILITY
- SHELF LIFE
- PART CRITICALITY

- SPARES IDENTIFICATION

*fold-out 2*

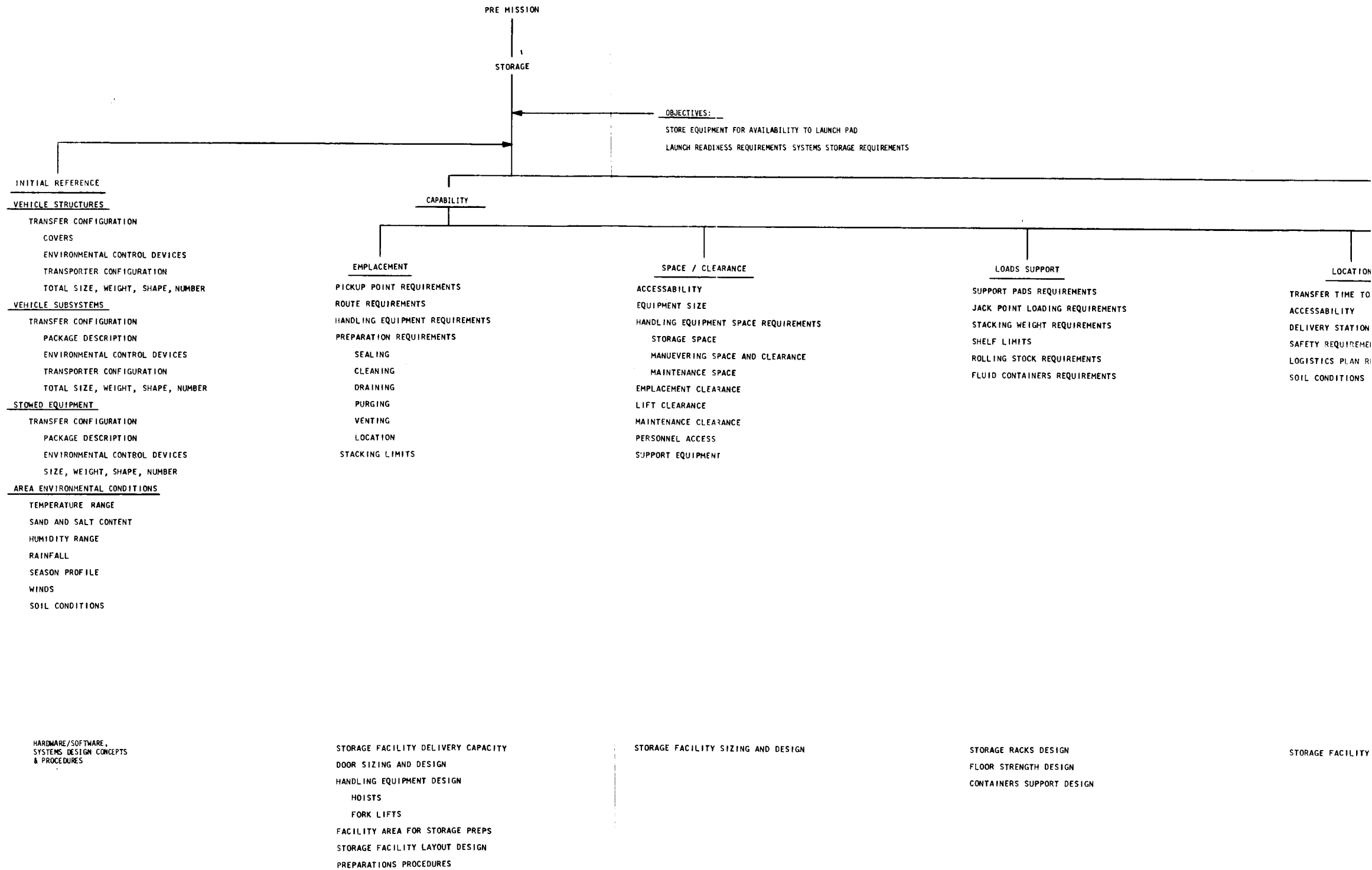
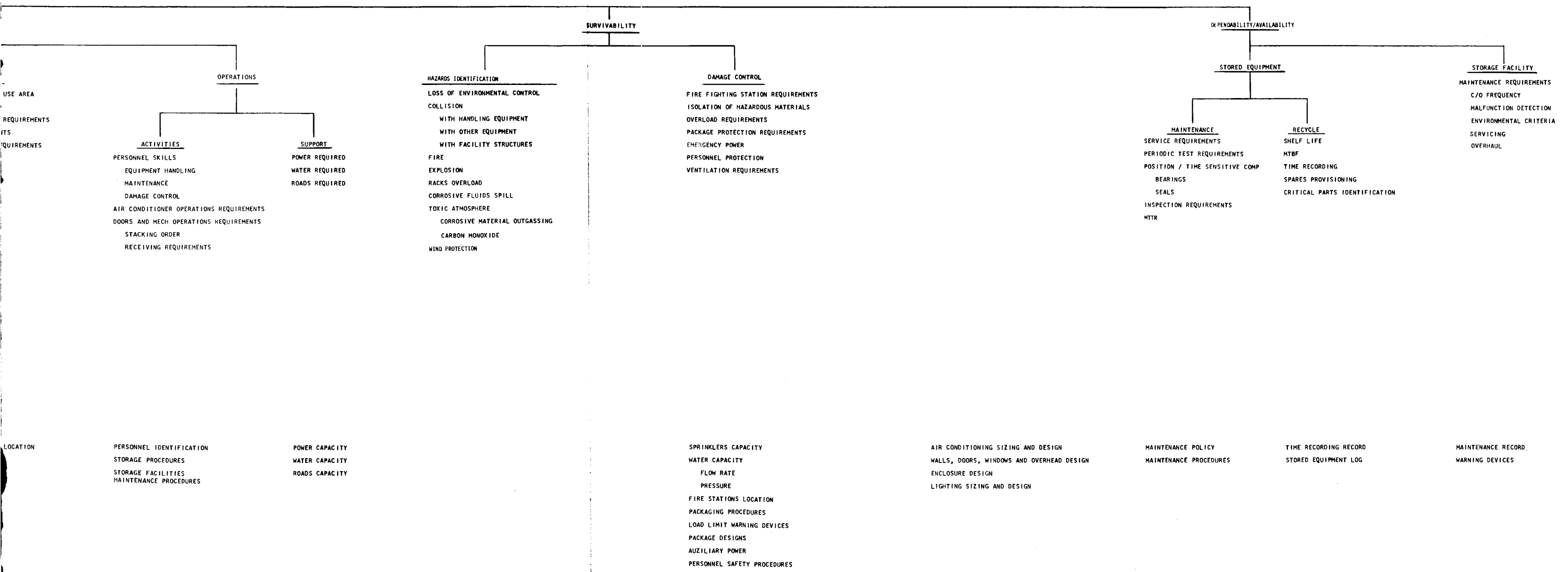


Figure 14 Storage State Technical Parameter Tree

*Fold-out 1*



*Fold-out 2*

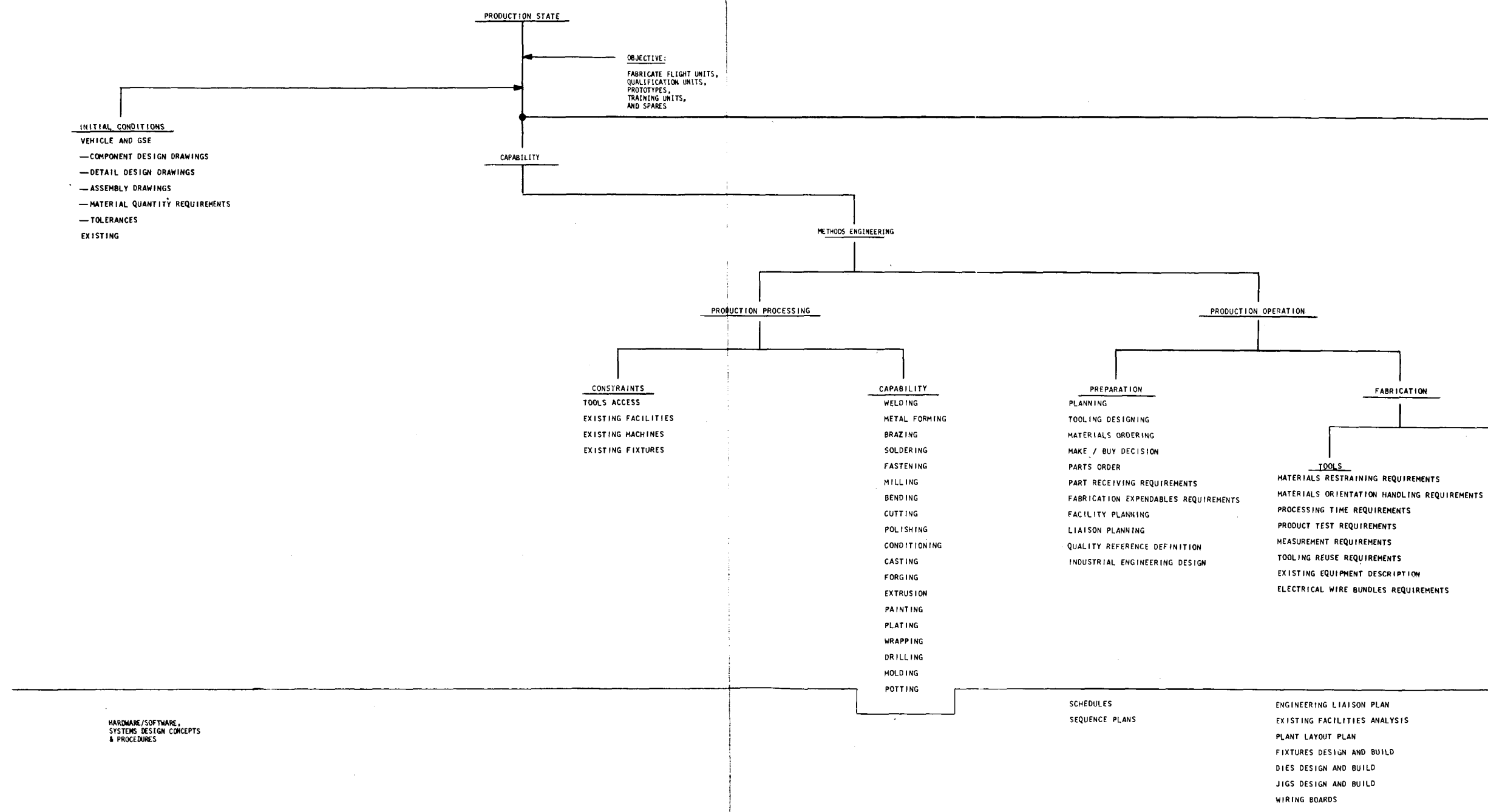
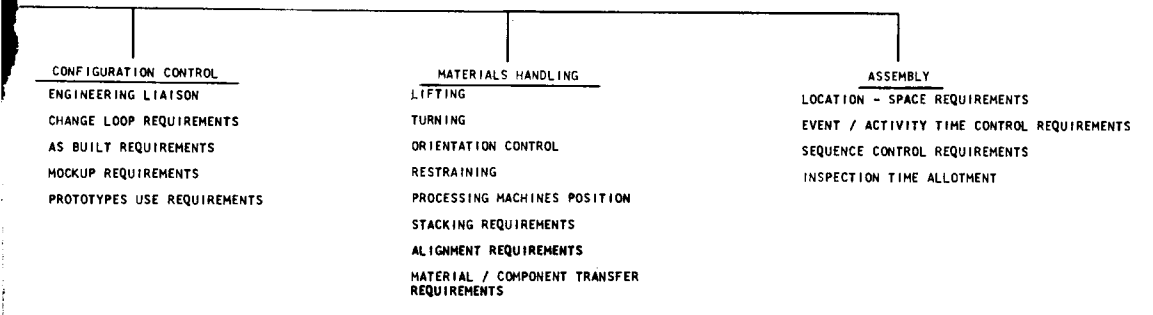


Figure 15 Production State Technical Parameter Tree

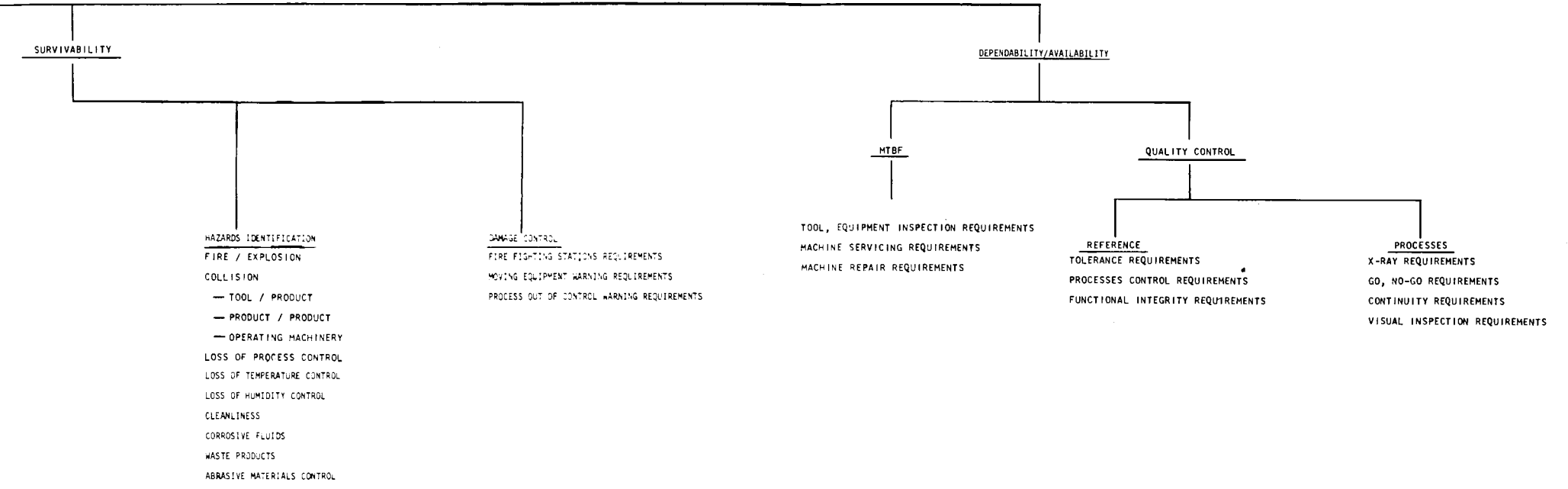
Fold-out - 1



PRODUCTION PLAN

HANDLING REQUIREMENTS  
PROCESS PROCEDURES

SEQUENCE PLAN  
FACILITIES SIZING, DESIGN AND BUILD  
TIME LINES  
PROCESS PROCEDURES



FACILITIES DESIGN

FIRE EXTINGUISHERS PLACEMENT PLAN  
SAFETY RAILS, FENCES  
PROCESS ISOLATION  
MOVING EQUIPMENT WARNING DEVICES  
FACILITY DESIGN

MAINTENANCE ANALYSIS  
PROCEDURES

INSPECTION SEQUENCE PLAN  
MEASUREMENT DEVICES DESIGN  
MEASUREMENT PROCEDURES

Fold-out 2