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## ENGINEERING MANAGEMENT OF LARGE SCALE SYSTEMS

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### Introduction

The organization of high technology and engineering problem solving, has given rise to an emerging concept. Reasoning principles for integrating traditional engineering problem solving with systems theory, management sciences, behavioral decision theory, and planning and design approaches can be incorporated into a methodological approach to solving problems with a long range perspective.

Long range planning has a great potential to improve productivity by using a systematic and organized approach. Thus, efficiency and cost effectiveness are the driving forces in promoting the organization of engineering problems.

This paper broadly covers aspects of systems engineering that provide an understanding of management of large scale systems. Due to the focus and application of research, other significant factors (e.g. human behavior, decision making, etc.) were not emphasized but were considered.

### Systems Engineering Concepts

#### A. Definition and Objective of Systems Engineering

A system is a combination of parts or elements to form a unitary whole. Systems engineering is a management of technology. This is accomplished by the following activities: (1) Transforming an operational need into a description of systems performance parameters and a systems configuration through the use of a process of definition, synthesis, analysis, design, test, and evaluation; (2) Integrating related technical parameters and ensuring compatibility of all physical, functional, and program interfaces in a manner that optimizes the total system definition and design; and (3) Integrating reliability, maintainability, safety, survivability, human, and other such factors into the total engineering effort to meet cost, schedule, and technical performance objectives.

A uniform systems engineering process is required to manage projects because:

1. The science and technology required to design and produce a completely integrated and coherent system exceeds any one person's capability to master;
2. There is a need for a communication vehicle for specialists with dissimilar technical knowledge, skills, and interests to contribute to an integrated system design and development process; and
3. Systems engineering, to be effective, must provide the process for making many technical and management decisions progressively as the need occurs in system design and development.

## **B. System Life Cycle**

A life cycle is used to develop a system. It begins with the initial identification of a need and extends through planning, research, design, production or construction, evaluation, consumer use, field support, and an ultimate product phase out (illustrated in figure 1).

## **Challenges of Large Scale Systems**

### **A. Large product organization**

Large scale systems require combined inputs of specialists representing a wide variety of engineering disciplines. These engineers must be able to communicate with one another as well as be conversant with such interface areas as purchasing, accounting, personnel management, and to some extent legal requirements. Technological and economic feasibility are no longer the main determinants for the engineer.

Large scale systems usually require fluctuating the manpower loading, and depending on the functions to be performed on the project, applying a phase-by-phase development process implementation.

Subcontracting is a major factor associated with large projects. The development of large scale systems can involve extensive contracting and subcontracting.

### **B. Technological growth and change**

Technological growth occurs continuously and is stimulated by an attempt to respond to some unmet current need and/or to perform on-going activities in a more effective and efficient manner. In addition, these changes are being stimulated by social changes, political objectives and ecological factors.

**Figure 1**  
 A life cycle is used to integrate various support mechanisms that ultimately bring a system into existence.

THE SYSTEM LIFE CYCLE	CONSUMER	Identification of Need	"Wants or desires" for systems (because of obvious deficiencies/problems or made evident through basic research results).
		System Planning Function	Marketing analysis; feasibility study; advanced system planning (system selection, specifications and plans, acquisition plan research/design/production, evaluation plan, system use and logistic support plan); planning review; proposal.
		System Research Function	Basic research; applied research ("need" oriented); research methods; results of research; evolution from basic research to system design and development.
	PRODUCER	System Design Function	Design requirements; conceptual design; preliminary system design; detailed design; design support; engineering model/prototype development; transition from design to production.
		Production and/or Construction Function	Production and/or construction requirements; industrial engineering and operations analysis (plant engineering, manufacturing engineering, methods engineering, production control); quality control; production operations.
		System Evaluation Function	Evaluation requirements; categories of test and evaluation; test preparation phase (planning, resource requirements, etc); formal test and evaluation; data collection, analysis, reporting, and corrective action; retesting.
	CONSUMER	System Use and Logistic Support Function	System distribution and operational use; elements of logistics and life cycle maintenance support; system evaluation; modifications, product phase-out; material disposal, reclamation, and/or recycling.

## **Systems Engineering Management**

Systems engineering management (SEM) provides the necessary overview functions to ensure that all required engineering disciplines and related specialties are properly integrated (Figure 2). These functions include planning, organizing and staffing, monitoring, and controlling which are used to design, develop and produce a system that will meet the stated need in an effective manner. The result is a system that has the proper mix of resource hardware, software, facilities, personnel, and data. The underlying objective is to produce a system at the right location, at the right time, with a minimum expenditure of resources.

### **A. Planning**

Planning is a process for developing and formulating a course of action to be taken in the future. The systems engineering management plan includes the appropriate planning information for the project as an entity. All projects should include a single top level document of this type to provide successful project guidance.

### **B. Organizing and Staffing**

The first step in organizing the project is to determine the governing activities. Grouping these identified activities in terms of a functional oriented structure of some type (e.g. unit, group, department, or division) establishes organization. Staffing the structure with appropriate personnel skills to perform the designated activities in a coordinated manner is the next step.

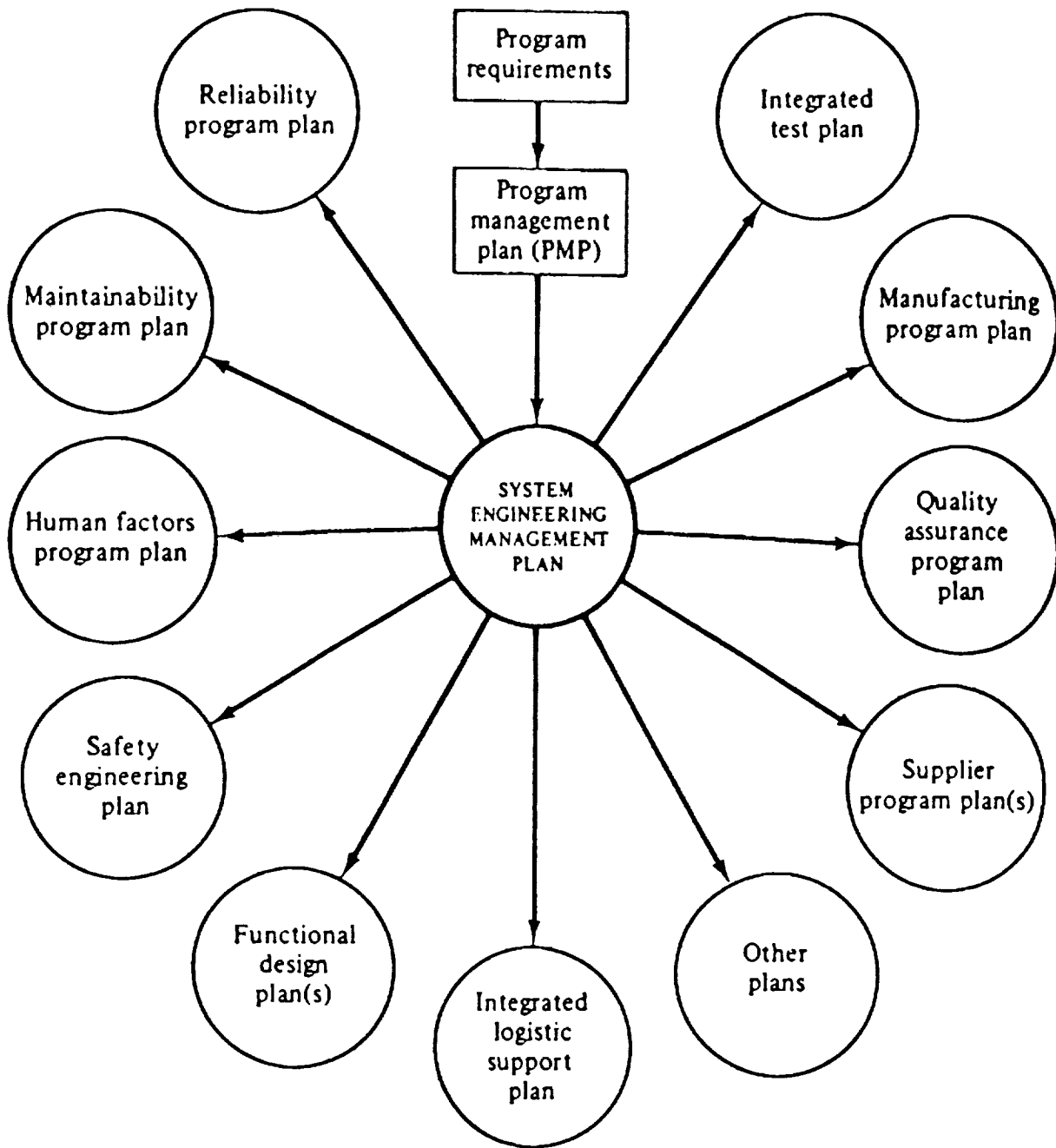
### **C. Monitoring**

Figure 3 is a basic milestone chart that gives the status of the project at a glance. It includes scheduled, actual and anticipated completion dates. This allows for careful scrutiny of the project status.

### **D. Directing and Controlling**

Directing program implementation consists of day-to-day managerial functions and the identification of responsibilities to ensure that project objective(s) are met. Project control is the sustaining of on-going management activity that will guide, monitor, and evaluate project accomplishment by the stated objective(s).

*Systems Engineering Management*



**Figure 2.**  
**Program Plan Relationships**  
This figure depicts the relationship between the PMP and governing activity, all of which need systems engineering management for preparation.

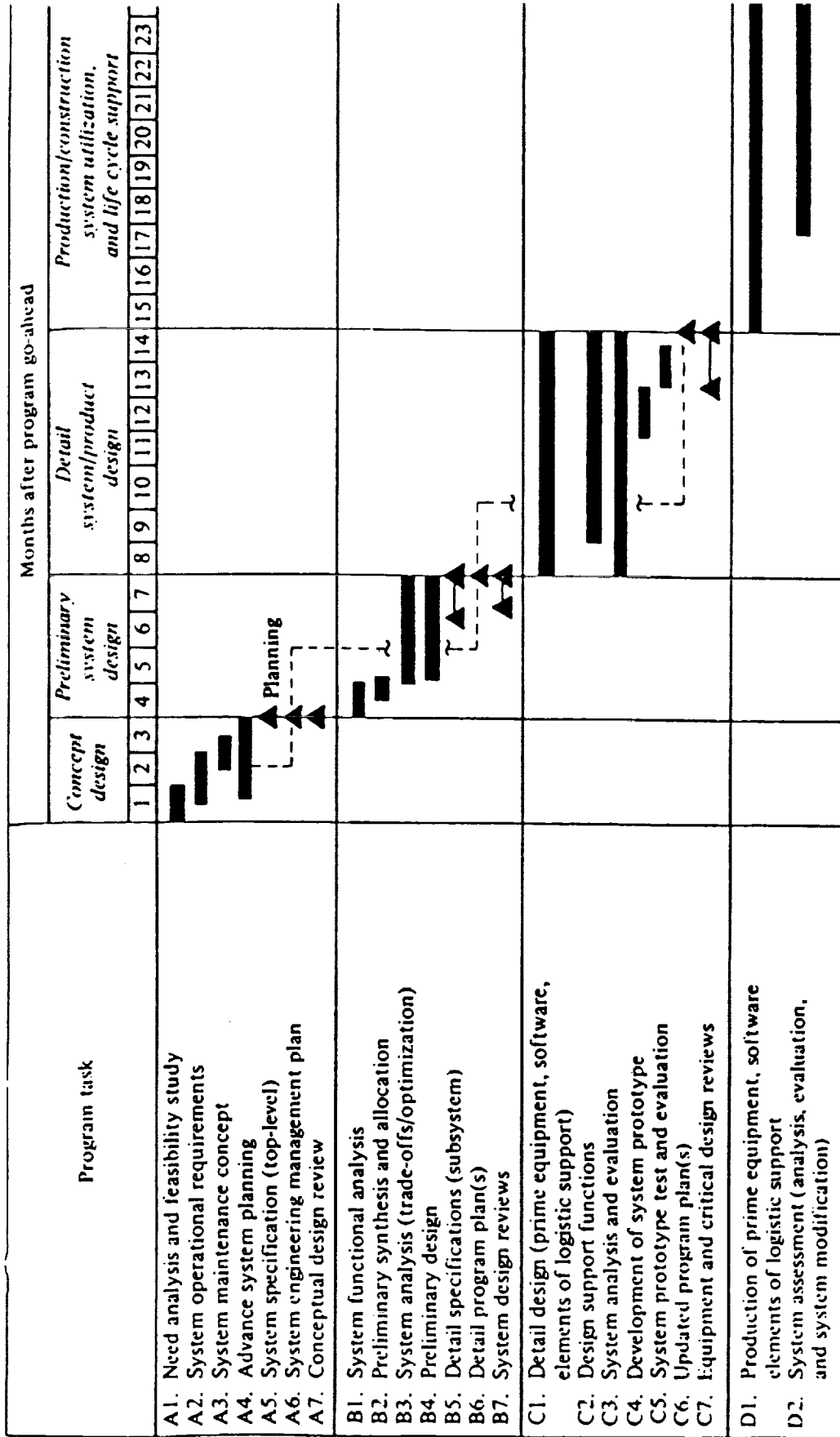


Figure 3.  
Basic Milestone Chart

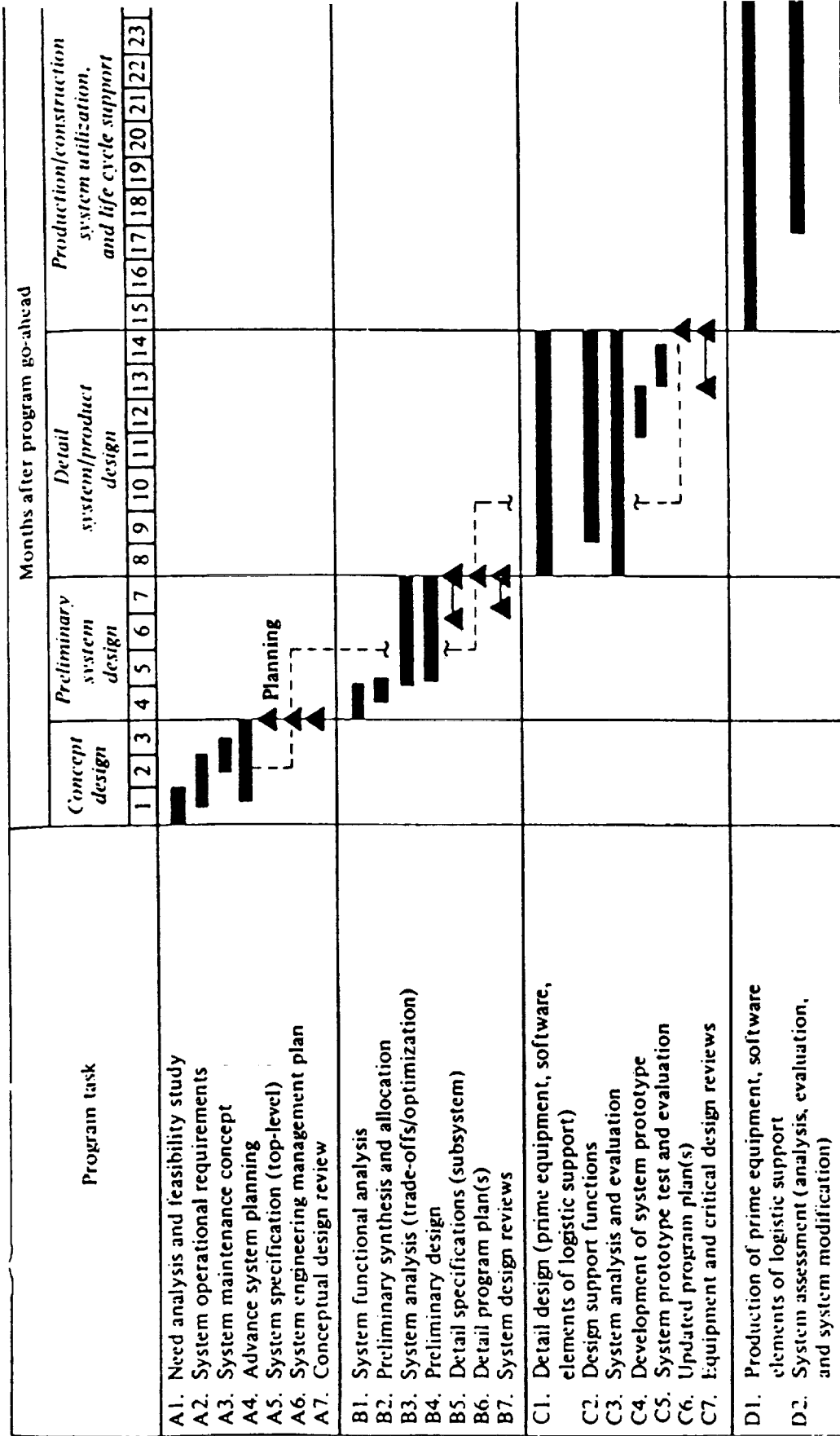
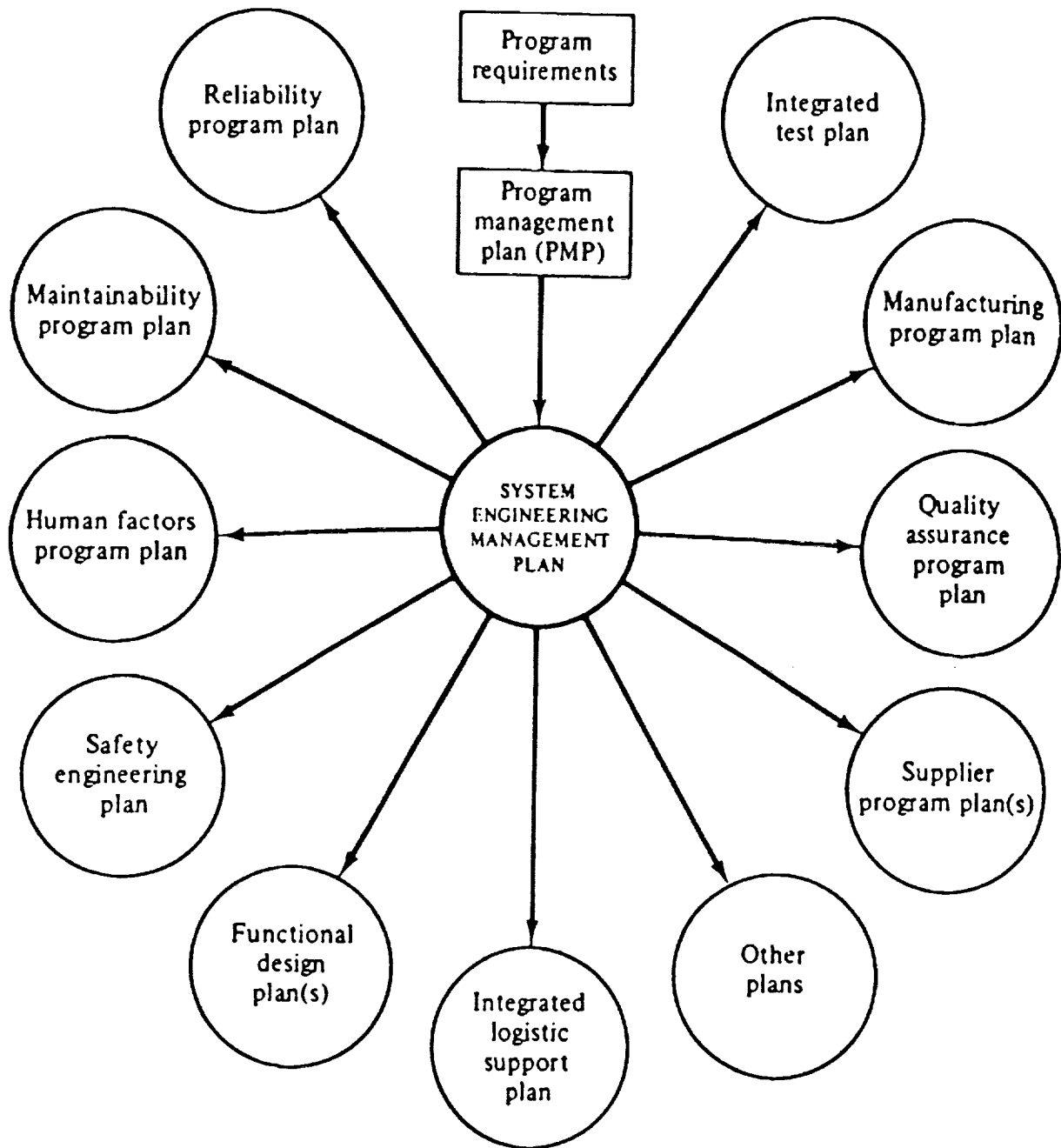


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## Summary

Considering the following questions when implementing systems engineering practices will ensure a well managed system of any magnitude.

1. Have systems engineering tasks been identified?
2. Have the responsibilities for systems engineering functions been established?
3. Has a systems management plan been developed?
4. Have detailed program plans been developed for reliability and maintainability?
5. Has a corrective action procedure been established to handle proposed system changes?
6. Have conceptual system equipment and critical design reviews been scheduled?

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**AN EVALUATION OF THE INTERFACIAL BOND PROPERTIES  
BETWEEN CARBON PHENOLIC AND GLASS PHENOLIC COMPOSITES\***

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**ABSTRACT**

The effects of moisture and surface finish on the mechanical and physical properties of the interfacial bond between the carbon/phenolic (C/P) and glass/phenolic (G/P) composite materials are presented in this paper.

Four flat panel laminates were fabricated using the C/P and G/P materials. Of the four laminates, one panel was fabricated in which the C/P and G/P materials were cured simultaneously. It was identified as the cocure. The remaining laminates were processed with an initial simultaneous cure of the three C/P billets. Two surface finishes, one on each half, were applied to the top surface. Prior to the application and cure of the G/P material to the machined surface of the three C/P panels, each was subjected to the specific environmental conditioning. Types of conditioning included: (a) nominal fabrication environment, (b) a prescribed drying cycle, and (c) a total immersion in water at 160°F.

Physical property tests were performed on specimens removed from the C/P materials of each laminate for determination of the specific gravity, residual volatiles and resin content. Comparison of results with shuttle solid rocket motor (SRM) nozzle material specifications verified that the materials used in fabricating the laminates met acceptance criteria and were representative of SRM nozzle materials.

Mechanical property tests were performed at room temperature on specimens removed from the G/P, the C/P and the interface between the two materials for each laminate. The double-notched shear strength test was used to determine the ultimate interlaminar shear strength. Results indicate no appreciable difference in the C/P material of the four laminates with the exception of the cocure laminate, where a 20 percent reduction in the strength was observed. The most significant effect occurred in the bondline specimens. The failure mode was shifted from the C/P material to the interface and the ultimate strength was significantly reduced in the wet material. No appreciable variation was noted between the surface finishes in the wet laminate.

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