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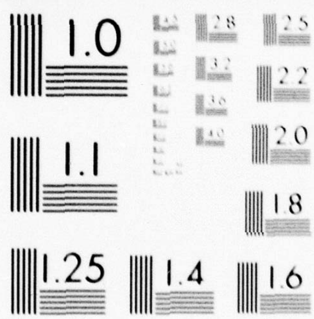


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**UNITED STATES AIR FORCE**

**AIR UNIVERSITY**

# AIR FORCE INSTITUTE OF TECHNOLOGY

**Wright-Patterson Air Force Base, Ohio**

# A CONCEPTUAL STUDY OF THE USAF AIRCRAFT ENGINE ACQUISITION AND SUPPORT MANAGEMENT SYSTEM

Ronald E. Fisher, GS-11, USAF
Alex Sanchez, GS-12, USAF

LSSR 14-78B

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The acquisition and logistics support of USAF propulsion engines has been studied extensively. The Procurement Management Review (PMR), completed in 1976, is the latest and most comprehensive review of this subject. The PMR recommended the creation of an Air Staff organization which would serve as a focal point for and provide overall policy direction on propulsion engines. This research set out to determine if such a proposed organization would resolve some of the fundamental problems found within the engine acquisition and support management system. A management cybernetic model was used to study the engine 'system' and to answer the research question. The authors concluded that the proposed organization would be inconsistent with the requirements of the model, and therefore, would not resolve the engine system's fundamental problems. This research found that the principal problem of the engine system was the fractionalization of its management organization resulting from a deficient management information system.

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# A CONCEPTUAL STUDY OF THE USAF AIRCRAFT ENGINE ACQUISITION AND SUPPORT MANAGEMENT SYSTEM

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

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has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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# CHAPTER I

## INTRODUCTION

The U.S. Air Force has the largest number and the greatest diversity of aircraft engines of any organization in the noncommunist world. The Air Force engine inventory represents 38,000 jet propulsion units valued in excess of $10 billion (1975 dollars). This inventory includes turbojets, turboprops, turboshafts, and turbofans. Over $500 million per year is expended on engine logistics support (29:1).

The importance and magnitude of the U.S. Air Force investment in engines requires an effective and efficient management system. The Logistics Management Institute (LMI) in a June 1972 study, "Methods of Acquiring and Maintaining Aircraft Engines," stated:

> Engine programs have run into difficulties; many of them have, in the end, proven far more costly than their original life cycle cost estimates. Engine maintenance problems have contributed to the reduction of the availability of the weapon system. Delayed engine developments have postponed the introduction of new aircraft. Requirements, as defined prior to and during development, have often been inaccurate and incomplete, necessitating complex budgetary adjustments, procurements, reallocation of personnel, and reassignment of other resources [19:2-3].

The management of Air Force jet engines is exercised through a complex organization headed by Headquarters

U.S. Air Force through the Systems Command, Logistics Command, the Major Commands and the Air National Guard. Figure 1 illustrates the organizational structure within the Air Force for jet engine management (17:123).

Headquarters USAF provides policy guidance for the management of jet engines and initiates basic Air Force planning documents. Additionally, it monitors the jet engine management program and allocates funds to the various commands on the basis of appropriations received and priorities established.

The Air Force Systems Command (AFSC) and its prime engineering division, the Aeronautical Systems Division (ASD), are responsible for the design, development, and acquisition of new and modified jet engines. ASD provides the design engineering and procurement functions for all Air Force gas turbine engines. Specifically, the development effort on engines is conducted by the Deputy for Propulsion, ASD/YZ.

The Air Force Logistics Command (AFLC) provides logistics support and services for Air Force organizations, systems, and commands. Headquarters AFLC establishes the overall policies and procedures for the logistics support and services for jet engines at the two Air Logistics Centers (ALC) assigned to Jet Engine Maintenance--San Antonio ALC and Oklahoma City ALC.

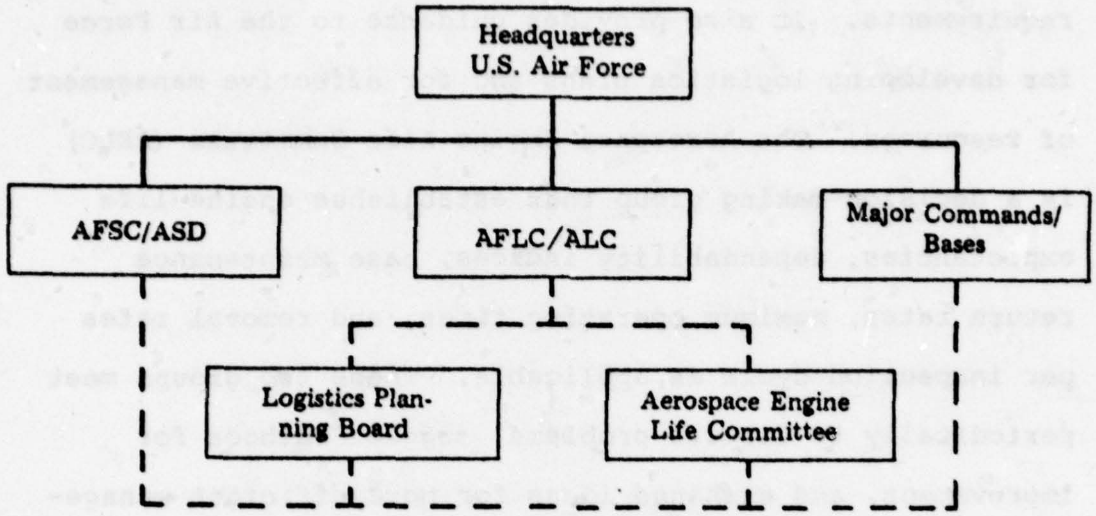


Fig. 1. Basic Air Force Structure for Engine Management [17:123]

The major commands (Air Training Command, Air Defense Command, Military Airlift Command, etc.) are the users of the jet engines. The commands are responsible for the day-to-day operation and maintenance of the engines. Reporting of engine status and maintenance actions is the responsibility of the various operating bases of the major commands.

Superimposed on the normal line organizations for engine management are two other groups--the Air Force Engine Logistics Planning Board and the Aerospace Engine Life Committee. These groups were established by Air Force Manual 400-1, Selective Management of Propulsion Units (31; 32; 33). The Air Force Logistics Planning Board acts in an advisory capacity on matters relating to spare engine requirements. It also provides guidance to the Air Force for developing logistics plans and for effective management of resources. The Aerospace Engine Life Committee (AELC) is a decision-making group that establishes engine-life expectancies, dependability indices, base maintenance return rates, maximum operating times, and removal rates per inspection cycle as applicable. These two groups meet periodically to discuss problems, suggest methods for improvement, and exchange ideas for more efficient management of the Air Force engine program.

This fractionalized system of managing the acquisition and support of jet engines within the Air Force has been frequently criticized. The following remarks were extracted from recent studies:

> The GAO found no evidence that the practice traditionally followed by the military services to develop and acquire engines is the best or more cost-effective method [26:2].
>
> There is much misunderstanding surrounding the process for acquiring and supporting jet engines. . . . As a result, symptoms of engine problems rather than root causes are frequently addressed by management [29:278].
>
> Air Force logistics support requirements for engines are not well defined, or consistently defined [28:29].
>
> The Air Force is monitoring rather than managing its engine acquisition process. The area is over-studied and under-solutionized. Duplication of effort exists. . . . Different management criteria are used by Air Force organizations which results in management focusing its attention on the problem of the day and giving a suboptimized management decision [29:280].

As a result of numerous and continuing problems, the acquisition and support management of jet engines has been studied extensively. The latest effort, the Procurement Management Review (PMR), which was concluded in 1976, had as one of its primary tasks the location and review of the studies, papers, and reports on engine acquisition and logistics support (29:I-1). The PMR study was able to locate and analyze seven major engine studies within the federal agencies from 1970 through 1974; eleven RAND Corporation studies from 1965 through 1975; and twenty-three on-going engine studies as of 1 December 1975. A listing of these studies is included in the appendix.

The PMR was initiated by direction of the Deputy Chief of Staff (DCS), Systems and Logistics, Headquarters USAF. This ten-month study had as its primary purpose "a comprehensive review of the policies, procedures and practices used by the Air Force in acquiring and supporting aircraft gas turbine engines [29:7]."

The results of this study were summarized into twelve major conclusions.

1. <u>Management Decision Making Process</u>. Air Force decisions on engine matters are primarily aimed at achieving a real-time or near-term solution. The lack of a common criterion for determining the "goodness" of an engine, coupled with the lack of complete and accurate life cycle cost data, results in suboptimized decisions not based on total system costs.

2. <u>Organization</u>. The Air Force organization for engine management is fractionalized. Its stature is

not commensurate with the importance of this subsystem. Many Air Force engine problems today are management related problems.

3. Technology. Today, technology is oriented toward improving engine performance; however, there is a discernible effort to consider engine reliability, maintainability and durability in early technology programs. Management attention and resources must continue to focus on performance technology if the United States is to retain its world technology leadership. At the same time increased attention and resources must also be devoted to maintenance technology to reduce future operating and support costs.

4. Procurement. Air Force engine procurement strategy is constrained by high technological and financial risks and a limited number of contractors. Numerous procurement strategies have been used over time with mixed results. Until the Air Force actually demonstrates via funding and contractual requirements, a real desire to achieve greater reliability, maintainability, durability and life cycle cost visibility, logistics economy will be slow in coming.

5. Development Process. The engine development process is evolving and improving. The process suffers from time and funding constraints. State-of-the-art engine development programs invariably experience hardware failures and major setbacks. Engine development usually requires about twice the time needed for airframe development. If developed concurrently with the airframe, fully developed production engines will not be available to meet the system delivery schedule. It appears that all levels in the Government do not fully understand and/or accept these facts concerning the engine development process.

6. Testing. Engine testing is being tailored to more accurately reflect mission requirements. However, the full potential of analytical, ground, air, and operational engine testing has not been exploited.

7. Maintenance. A firm, realistic engine maintenance concept is not developed early enough in the process. The modular maintenance and on-condition maintenance concepts have been oversimplified and are not completely understood. At present, these concepts are not, and cannot be, implemented in the Air Force as conceived. In general, maintenance is driven by

operational readiness and not life cycle considerations and its efficiency suffers as a consequence.

8. Logistic Support. Logistic support for engines is driven by production and operational readiness rather than overall or long range cost considerations. Support is impaired by time and funding constraints.

9. Component Improvement Program. The purpose and operation of the Component Improvement Program are not fully understood at all levels within the Government and Industry. The Component Improvement Program, or a similar effort, is necessary for timely engine development/maturing and operational support; however, Government management of the effort should be strengthened.

10. Contractor Performance. Engine contractors' performance has been a reflection of Government management emphasis. Air Force contracts contain precisely defined performance and schedule parameters, and contractors have performed well in these areas. In the less emphasized areas of reliability, maintainability and durability, their performance has not been exceptional, especially when time and money constraints have restricted development efforts.

11. Commercial-Military. There are basic differences between the commercial and military in engine development and procurement, inventory size, mission, route structure and stability, flying hour program, and maintenance practices and workforce. These must be recognized and taken into account when assessing engine management policies and practices. Commercial engine activities are more cost oriented and the airlines give more continuing high level attention to efficient engine management.

12. Cost Considerations. The entire engine management process is hampered by inadequate cost data. Current or near-term costs outweigh life cycle costs in most management decisions [29:2-3].

The PMR assessment of the current process of acquiring and maintaining jet engines was that ". . . the same troublesome conditions . . ." described in the Logistics Management Institute report (19) were ". . . as descriptive of the current environment as it was of the situation in June 1972 [29:8]."

The PMR made several recommendations to improve the process of acquiring and supporting jet engines. The principal recommendation which this research effort addressed was:

> An Air Staff organization with corporate responsibility and accountability for propulsion be established. It would have the overall Air Force fiscal and policy making responsibility for propulsion. The organization would be the focal point for all Air Force related propulsion activities. It would serve as a centralized source of policy, direction, and visibility for overall propulsion system requirements, acquisition, and logistics support. . . . The Air Staff organization should be of sufficient stature and have the necessary authority to carry out these responsibilities [29:3].

## Problem Statement

The existing complex and fractionalized engine acquisition and support management structure does not provide adequate management and information control.

## Analysis of Complex Systems

The PMR and the other previous studies indicate that the process of acquiring and managing engines is conducted within an extremely complex system. It involves: (1) development of new engines or modifications of existing designs to meet new performance specifications, (2) integration of engine with weapon system development within critical time frames, (3) continuing logistics support over the entire life of an engine on a world-wide basis,

(4) monitoring and controlling equipment and systems which are constantly entering or leaving the inventory, and (5) reacting to changing operational requirements and a plethora of other variables all of which are constantly interacting within a changing environment. This research effort will focus on the management of complex organizations and, in particular, the USAF acquisition and support management of jet engines.

Steinbruner identified the attributes of a complex system as: (1) power to make decisions is dispersed over many units and/or individuals, (2) uncertainty exists because of an imperfect correspondence between information and its environment, and (3) tradeoffs occur when decisions are made which achieve greater returns in one area at the expense of optimality in other areas because of conflicting values or goals (24:16).

The understanding of complex systems was addressed by Ludwig Von Bertalanffy who is credited with being the founder of what is now called General Systems Theory (GST). He wrote that a

> . . . system can be defined as a complex of elements standing in interaction. There are general principles holding for systems, irrespective of the nature of the component elements and of the relations of forces between them [11:199].

Systems thinking is a step in the development of man's approach to the study of complex phenomena which attempts to place components in the proper perspective to one another, to study their mutual interactions and the effect of those interactions on the whole, as well as on the way the whole affects and is affected by its environment (23:26-27).

Systems thinking differs from the more conventional analytic method in that it emphasizes the synthesis of components and their mutual interactions (a macro view). The analytic approach is principally a micro view which: (1) is preoccupied with the external or physical portion of the universe; (2) emphasizes the division and subsequent composition of phenomena; (3) quantifies causal relations; and finally, (4) establishes precision as the ultimate ideal of every researcher (23:7).

In contrast to these analytic principles, systems thinking is based on: (1) organicism, the philosophy of putting the organism at the center of the conceptual scheme; (2) holism, viewing phenomena as organisms that exhibit order, openness, self-regulation, and goal directiveness, focusing on the whole rather than on the parts; (3) modeling,

> . . . instead of breaking the whole into arbitrary parts, one attempts to map his conception of the real phenomena onto the real phenomena. This is done by abstracting from the real phenomena those characteristics that are relevant and by disregarding those features of the real phenomena that are not needed for the explanation or prediction of the system's behavior [23:8];

(4) understanding, realizing that life in an organism is an on-going process and that one gains knowledge of the

whole, and further that what is observed is not reality itself but rather the observer's conception of reality (23:8).

The movement of thinking away from the analytic and towards the systems approach is more than a mere shift in emphasis. "Systems thinking is a more meaningful way of looking at and approaching the study of complex phenonema [23:8]."

The application of the systems approach (paradigm) to management can be conceived as consisting of the following three steps: conceptualization, analysis and measurement, and computerization. Conceptualization is the process of understanding and organizing the interrelationships among the components of an organization into a logical network to reveal the direction of the organization. The conceptual framework is then converted into a quantitative network (model) whereby the logical relationships are given values. The original abstraction has now been transformed into an econometric model. The final step in the application of the systems approach to management is experimentation with the model over time which is referred to as simulation (23:253-260).

The systems approach has evolved into two major branches, General Systems Theory (GST) and Cybernetics. While the goals of GST and Cybernetics are similar, an understanding of complex organisms and organizations, they do differ in methodology.

GST has its roots in the organismic conception of biology and draws heavily upon mathematics, physiology, and economics. The principle areas of study concern the phenomena of growth and evolution. GST holds that

> . . . the pattern of growth and its intermediate and final stages follow the same process, whether the growth is of a single organism, or a group of organisms, or of society itself.

GST tries to identify similarities in organisms or organizations with the hope of constructing a model for explaining and predicting growth phenomena in general (23:9-12).

Cybernetics is the science of control and communication and draws heavily from engineering (especially from servo-mechanics and feedback), computer sciences, mathematics, telecommunications and physiology. Whereas GST looks at growth and evolution, cybernetics is concerned with "general principles and laws by which one can study the phenomena of control and communications whether in the living or the nonliving system [23:20]."

Ashby, in <u>An Introduction to Cybernetics</u>, believed that cybernetics offers two scientific virtues: (1) a single vocabulary of concepts suitable for representing diverse systems; and (2) a method for scientific treatment of any system whose "complexity is outstanding and too important to be ignored [6:43]."

## Management Cybernetics

Figure 2 traces the evolution of systems science into its major branches, GST and Cybernetics. Furthermore, it illustrates some of the applications of systems science to the solution of managerial problems. One specific application is management cybernetics which has as a goal the application of the fundamentals of cybernetics to the domain of management control (23:503). Studies, in particular the Procurement Management Review, of the engine acquisition and support process have described the system as fractionalized, complex, and lacking in centralized control. Therefore, management cybernetics, which focuses on communication and control, is an appropriate approach to the analysis of the jet engine acquisition and management process.

A management cybernetic model is described in Stafford Beer's Brain of the Firm. The model is used not only as an analogy, but more importantly to disclose the key structure of the system under study. Beer believed any viable system could be used as a model, but chose to use the human body because it "is perhaps the richest and most flexible viable system of all [7:99]."

Beer's generalized management cybernetic model is composed of five major subsystems; the lowest three are

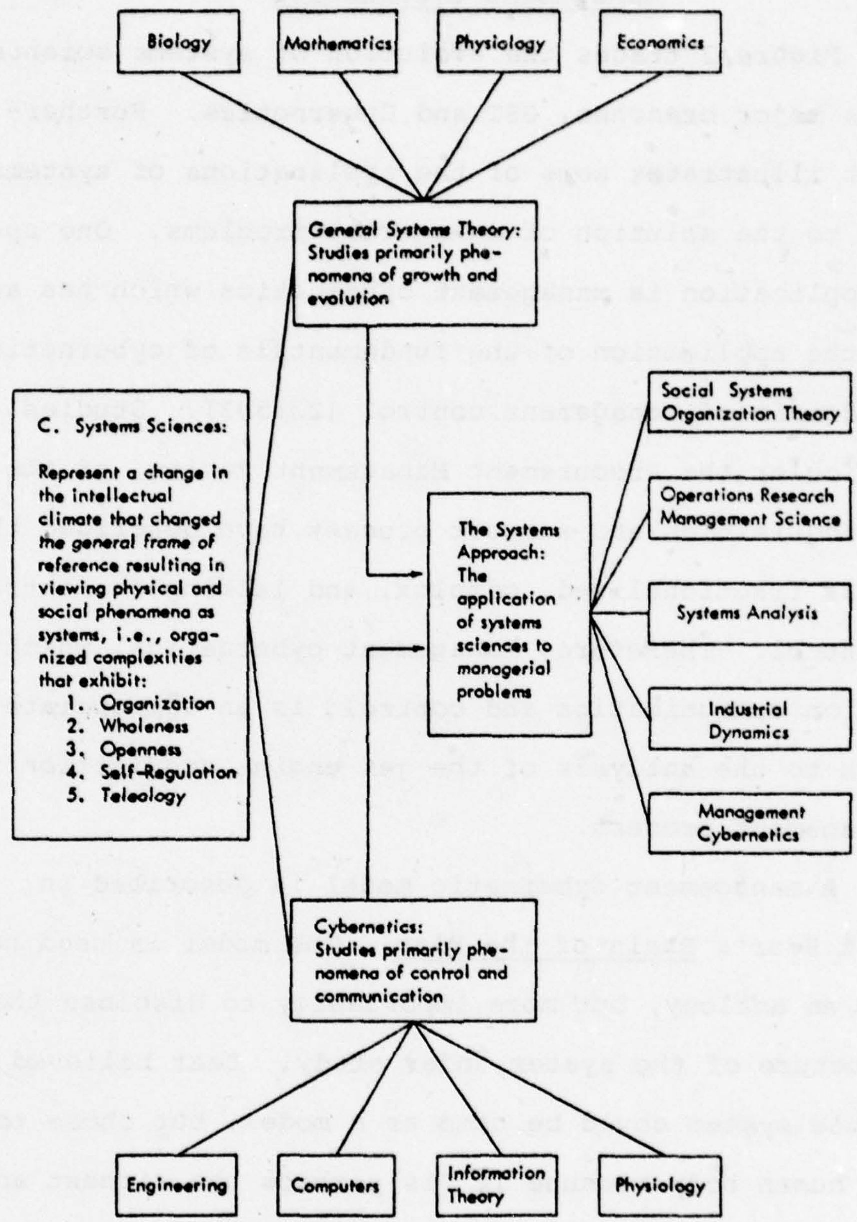


Fig. 2. An Overview of Systems Science [23:11].

concerned with the regulation of internal stability while the top two maintain dynamic equilibrium with the external world and are capable of system arousal and adaptation (7:100). An illustration of Beer's model is provided in Figure 3.

In the example of Figure 3, System 1 is composed of four operating units and each unit is responsible for producing an output or achieving some other purpose. These operating units filter information from the environment and amplify communication back to the environment. A similar information loop exists between the operating units and management. Figure 4 illustrates these relations. As an example, an Air Force operating unit could be an organizational maintenance squadron with management residing in the squadron commander's office and AFM 66-1 being the management system.

System 2 is primarily an interface between Systems 1 and 3. It provides necessary information to System 3 and coordinates activities in all System 1 operations to prevent uncontrolled oscillations between operating units.

System 3 monitors System 2 and is capable of modifying System 1 structure. An example of a structural modification might be changes required as a result of deficiencies reported by higher headquarters inspections. System 3 is the highest level of self-regulation of internal stability; that is, it governs the stability of the internal

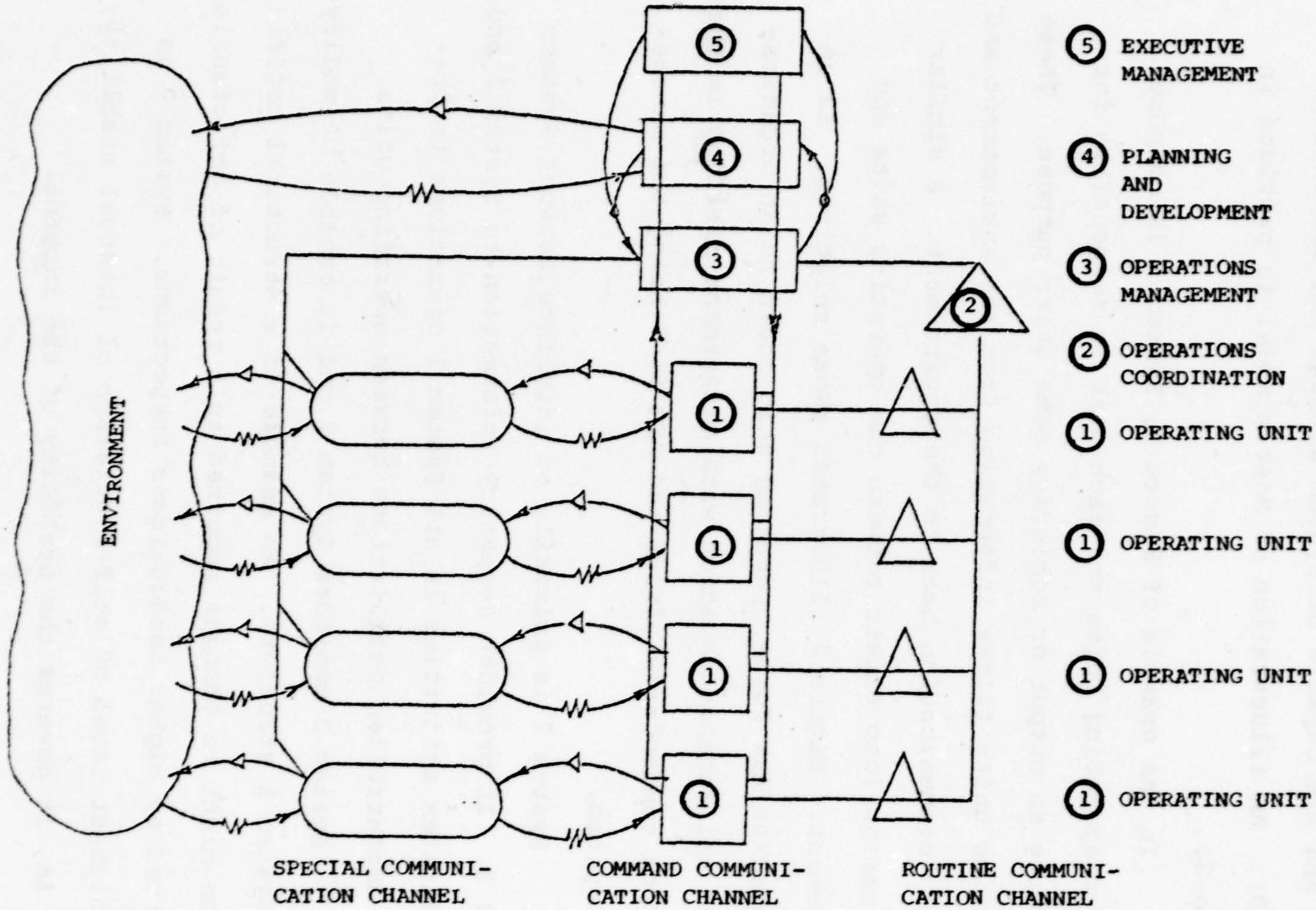


Fig. 3. A Generalized Management Cybernetic Model [14:12]

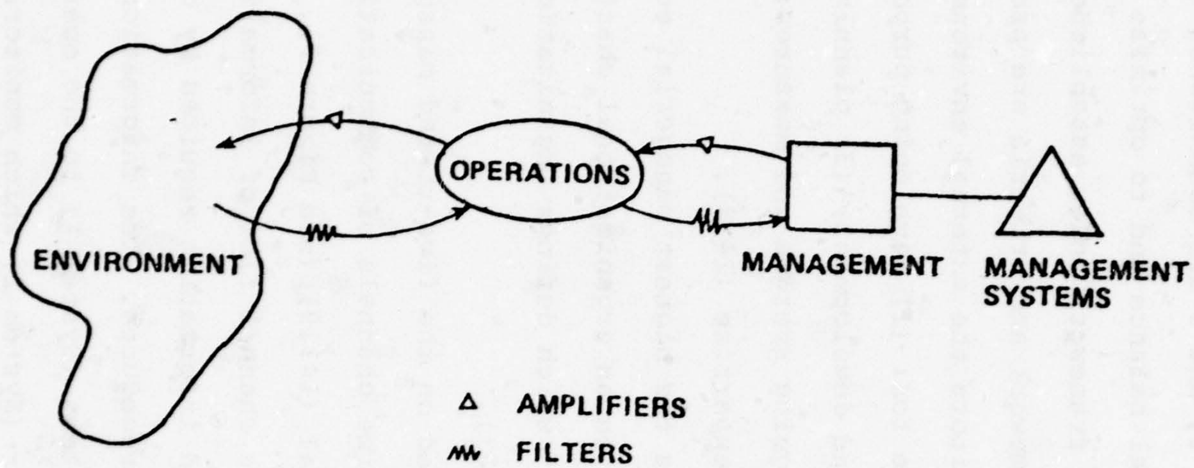


Fig. 4. System 1 Schematic [14:7]

environment of the organization. Additionally, it transmits higher level policy and special instructions to the operating units.

Systems 1, 2, and 3 are established to maintain a homeostatic internal balance and to optimize performance within an accepted framework under established criteria (7:230). That framework and criteria are provided by System 4 which monitors the external environment. System 4 is also responsible for: (1) developing purpose; (2) conducting research and development; (3) planning and managing projects; (4) designing systems and measures; and (5) providing functional expertise (14:8).

System 5 is the highest managerial echelon of the firm as it is seen on an organizational chart. It is the "brain of the firm" which defines organizational purpose and structure (7:253).

Superimposed on the five-tiered management cybernetic model are three channels of communication: routine, command, and special (14:19) (see Figure 3).

The routine channel flow of information includes all of the data and information required by company management systems and procedures. The information flows through the management systems (System 1) to the operations coordinating center (System 2) which monitors the information and serves as an input filter on the path to the operations management center (System 3).

The command channel carries upward information which informs higher management whether or not an operating unit is functioning within the desired levels. This channel bypasses System 2 which is concerned only with routine information. Traveling downward are changes in structure required for the achievement of organizational purpose.

The special communications channel carries all non-routine information needed for special purposes or problems. Typically, special communications are audit reports, technical seminars, and consultant reviews.

## Research Questions and Objectives

The jet engine acquisition and logistics support process within the USAF has been studied extensively. As previously indicated, one study concluded that the process has been ". . . over-studied and under-solutionized. . . [29:280]." Nevertheless problems of information and control continue to exist within the system.

A recommendation was made that an office be established at the Air Staff level to provide fiscal and policy guidance and have corporate responsibility and accountability for propulsion (29:3).

### Research Questions

1. Would the establishment of corporate level management resolve fundamental problems identified within the existing system?

2. If such an organization is to be established, what should be its scope and responsibilities?

## Research Objectives

1. Determine the purpose of the engine acquisition and support management system.

2. Describe and understand the existing system.

3. Describe and understand the management cybernetic model.

4. Map the existing system onto the management cybernetic model.

5. Identify deficiencies within the existing system using the model as a diagnostic tool.

6. Make recommendations regarding the organizational structure of the engine acquisition and support management system in accordance with the principles of the management cybernetic model.

## Scope and Methodology

### Scope of the Research

This study is limited to the first and most important stage of the systems science paradigm--that of conceptualization. Conceptualization is

> . . . understanding and organizing the interactions among the elements making up the phenomenon under scrutiny into a logical network of relationships in such a way as to reveal the direction of the underlying structure [23:249].

However, to appreciate and evaluate the structure of an organization it is necessary to define its purpose. "Structure combines the elements of the total system in a way that will achieve purpose [14:3]."

Conceptualization permits an understanding of the entire system. Once the structure and purpose of a system have been defined, an understanding of a specific problem within the system is made easier.

> It cannot be overemphasized that the use of systems science to solve managerial problems . . . proceeds from understanding to prescribing and not the other way around [23:247].

Managerial problems call for solutions which affect future events. These events are unpredictable and the manager must necessarily make inferences from incomplete information. His inferences will be more realistic if he understands the complete picture (23:246-247).

Chapter I, an introduction to this research, briefly described the existing engine acquisition and support management system and its management structure. There followed a discussion of recent studies and criticisms of the existing system. The concept of complexity was introduced and the systems science paradigm was used to explore complexity in organizations. The management cybernetic model was introduced as a specific application of the systems science approach.

Chapter II is devoted to the first two research objectives which are to determine the purpose and describe the existing jet engine acquisition and support management system. Chapter III presents a detailed discussion of the management cybernetic model. The existing engine acquisition and support management system is then mapped onto the model in Chapter IV. Chapter V concludes the research by identifying the deficiencies of the existing system and making recommendations regarding the organizational structure of the engine acquisition and support management system based on the management cybernetic model.

Although the scope of this research is limited to conceptualization, which is only the first step of a complete systems science analysis, it is, nevertheless, the most important. Hopefully, this study will provide the necessary background to allow a complete analysis at some future opportunity.

Methodology of the Research

The first objective of this research was to determine the purpose of the engine acquisition and support management system. Christopher stated that Systems 5 and 4 of the management cybernetic model, the highest levels of management, are responsible for defining and developing the purpose of an organization (14:8).

The investigation of the engine acquisition and support management system has revealed that within this system the principal operating agencies are the Deputy for Propulsion (ASD/YZ), representing the acquisition function, and the Directorate of Propulsion Systems (AFLC/LOP), representing the support function. Therefore, personal interviews were conducted with the Directors of these agencies to establish the purpose of the engine acquisition and support management system.

Specific questions asked of the Deputy for Propulsion (ASD/YZ) were as follows:

1. ASD/YZ is responsible for the acquisition of engines, while AFLC is responsible for their support. Do you perceive these functions as part of one system comprising both acquisition and support?

2. What would you perceive to be the purpose of an engine system which includes the functions of both acquisition and support?

3. What do you perceive as the purpose of your organization (ASD/YZ)?

Specific questions asked of the Director of Propulsion Systems (AFLC/LOP) were as follows:

1. ASD/YZ is responsible for the acquisition of engines, while AFLC is responsible for their support. Do you perceive these functions as part of one system comprising both acquisition and support?

2. What would you perceive to be the purpose of an engine system which includes the functions of both acquisition and support?

3. What do you perceive as the purpose of your organization (AFLC/LOP)?

The answers to the above questions will establish the apparent purpose of the engine acquisition and support management system, which is the first objective of this research effort.

To achieve the second objective of this study, a description of the existing system, the primary source of information was the Procurement Management Review (PMR) study concluded in 1976. The PMR had as its primary purpose "A comprehensive review of the policies, procedures, and practices used by the Air Force in acquiring and supporting aircraft gas turbine engines [29:7]." The PMR, consequently, has an exhaustive description of the acquisition and support management system as of 1976. This study extracted from the PMR that information necessary to allow a current description of the system.

However, since the conclusion of the PMR, there have been changes to the system. For example, a new organization has been created, the Air Force Acquisition Logistics Division (AFALD) within AFLC. Its primary purpose is to drive down the costs of owning and operating Air Force weapons systems. AFALD fills a void between the "designers"

(AFSC), the "users" (Air Force Operational Commands), and the "maintainers" (AFLC) (3:2).

Therefore, the PMR was supplemented with a discussion of the current system elements and their functional relationships. Interviews were conducted with the Directors of key agencies of the acquisition and support management system to determine the functional relationships between these organizations, how the system functions, where decisions are made, and how information flows. These key agencies are Director of Propulsion Logistics (AFALD/SDD), Deputy for Propulsion (ASD/YZ), and Director of Propulsion Systems (AFLC/LOP).

Specific questions asked of the Director of Propulsion Logistics (AFALD/SDD) were as follows:

1. How do you determine the logistics requirements that are to be considered by ASD on USAF propulsion engines?

2. What assurance is there that ASD will accept and act on these inputs?

3. How are differences in ASD acquisition requirements and AFLC support requirements reconciled?

4. Who has the final decision as to what logistics considerations will be included or considered in the acquisition phase of USAF propulsion engines?

5. What is the functional relationship between AFALD/SDD and AFLC/LOP?

Specific questions asked of the Deputy for Propulsion (ASD/YZ) were as follows:

1. How were logistics considerations incorporated into the acquisition process prior to AFALD?

2. How has the creation of AFALD changed this process?

3. How are conflicts or differences between ASD acquisition requirements and AFLC support requirements reconciled?

4. What measures of performance have been established for ASD/YZ and what control systems are in effect to assure that the required level of performance is obtained?

Specific questions asked of the Director of Propulsion Systems (AFLC/LOP) were as follows:

1. How do your logistics requirements reach ASD/YZ on new engine development and what assurances do you have that your inputs will be considered?

2. What measures of performance have been established for AFLC/LOP and what control systems are in effect to assure that the required level of performance is obtained?

3. What are your responsibilities to AFALD/SDD?

4. What do you perceive to be the responsibilities of AFALD/SDD to AFLC/LOP?

The third objective of this research, a detailed description of the management cybernetic model, was obtained through the reading of pertinent literature on management cybernetics, principally that of Stafford Beer. Some of the books reviewed were: Brain of the Firm (7), Designing Freedom (10), Decision and Control (9), Cybernetics and Management (8), and Management Systems (23). The model in Brain of the Firm is comprised of five subsystems and three information networks. Each of these subsystems and information networks is discussed in detail as to what it does, how it fits into the model, and what its functional relationship is with respect to the other subsystems.

With a thorough understanding of the management cybernetic model the fourth research objective, mapping of the existing system onto the model, was achieved by identifying and positioning on the cybernetic model the individual, group, committee, or system that performs each of the requisite functions of the engine system. The validity of the model was accepted based on the research of Stafford Beer and William F. Christopher.

Having mapped the existing system onto the management cybernetic model, the fifth and sixth research objectives, identifying deficiencies and making recommendations regarding the organizational structure, were accomplished. The deficiencies and recommendations presented are based on the authors' interpretations of how the existing engine acquisition and support management system compares to the management cybernetic model.

## CHAPTER II

## THE STRUCTURE OF THE USAF AIRCRAFT ENGINE ACQUISITION AND SUPPORT MANAGEMENT SYSTEM

Chapter I introduced the jet engine acquisition and support management system, hereafter called the engine system. This complex organization is directed by several Headquarters USAF offices. The offices serve as policy directors for: acquisition (Air Force Systems Command), support (Air Force Logistics Command), and operating commands (SAC, TAC, etc.) of jet engines. This chapter is devoted to a detailed description of this engine system. Because of the complexity of the total system, any attempt at a comprehensive review would be both excessively voluminous and, more importantly, repetitious of many excellent studies.[1] This description of the engine system focuses on the major system components and their functional relationships, as well as the endogenous and exogenous constraints.

### A Description of the Engine System

One of the recognized ways to understand any system is to model its behavior or operation. A descriptive model

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[1]A partial listing of both completed and on-going studies is contained in the appendix to this study.

is made up of system components, their functional relationships, and the constraints acting on the system. Present DOD policy requires that every new major weapon system be subjected to an orderly progression of key program decision milestones from its conceptual formulation to its final operational deployment and logistic support (37; 38). This "life cycle" of a weapon system is divided into five phases: (1) Conceptual, (2) Validation, (3) Full Scale Development, (4) Production/Deployment, and (5) Operational/Support (16:6).

Within each phase of any new weapon system, the constraints and functional relationships change as the various components become more or less involved in the system's development or support. The five phases of the weapon systems acquisition process have been used as a basis for developing a descriptive model of the engine system because any description of the system as operating solely within one phase could not generate an understanding of the system through its life cycle.[2]

<u>The Conceptual Phase</u>

<u>Overview</u>. The life cycle of a weapon system is initiated by an AF/DOD analysis of the need to fulfill a

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[2]The Procurement Management Review (29) has done an outstanding job in describing the then existing acquisition and support system for jet propulsion units and was used extensively for the following discussion.

required operational objective. The prime concern being the actual need for a new weapon system. To justify this acquisition either the new weapon system must do a job significantly better than the system in use, or a new defense need has been generated. Following justification and overall weapon systems performance requirements, an analysis is made to determine the engine characteristics necessary to meet these requirements.

Technology. Technology has been the prime means of achieving better system performance through improving the characteristics, as well as processes in forming and fabrication of materials. Considerations regarding materials have typically been thrust to weight and material durability. The Air Force Aero Propulsion Laboratory (AFAPL) monitors the effort in engine component advancement principally through two programs: The Advanced Turbine Engine Gas Generator (ATEGG) Program and the Aircraft Propulsion System Integration (APSI) Program.

While located at engine manufacturing plants, ATEGG is monitored by AFAPL. This continuing program allows engine contractors to concentrate their resources on a given section of an engine. This advanced technological program is procured under a cost plus fixed fee contract.

The APSI program is a joint venture of Aero Propulsion Laboratory and the Air Force Flight Dynamics Laboratory. The two labs try to achieve greater sophistication in matching engines to airframe. Continuous studies are made to explore the impact of airframe, engine, and installation changes on the overall system (29:47).

Required Operational Capability. In the conceptual phase, almost all of the program effort is directed toward the weapon system and its capabilities. The need for such systems is recorded by all Air Force Major Commands in a document titled Required Operational Capability (ROC). An ROC is formulated jointly by organizations responsible for Operations and Requirements at a Major Command Headquarters. The ROCs from all Major Command Headquarters are systematically reviewed and assigned priorities at HQ USAF. It then becomes the responsibility of the Deputy for Development Planning at ASD to design system concepts to satisfy those ROCs requiring new systems.

The ROC is used to

> . . . identify an operational need and to request need or improved capability for the operating forces. The capability sought is described in terms of operational objectives, operational environment, support and maintenance concepts, and concept of operations [30:2].

A Maintenance Concept appears in the appendix to the ROC and is the responsibility of the logistics and maintenance organizations at the Major Command Headquarters.

The importance of this ROC maintenance concept is to define the basic maintainability requirements of the using commands. The maintenance concepts, like the ROC, are system oriented. Parameters for reliability or performance are specified for each system (18:2-3).

It is important to note that engine manufacturers believe that maintenance reliability and durability of an engine are determined primarily in the conceptual phase and the early portion of the validation phase, when the basic engine design is established. This stresses the importance of the maintenance concept in the ROC.

> If the maintenance concept for the engine is not clearly specified in the ROC, it will be left to the technicians in AFSC, working in conjunction with engine manufacturers. Their interests may not coincide with those of the user or AFLC [29:39].

It is generally recognized that there are few improvements that can be made during the full scale development and later life cycle phases to drastically alter the reliability and maintainability levels that have been designed into an engine.

<u>Procurement</u>. Generally, no major procurement events related solely to engines occur during the conceptual phase. The Air Force at this time is concerned with the total system and is dealing mainly with the airframe manufacturers.

## The Validation Phase

Overview. During the conceptual phase, a series of iterations are performed in order to evaluate potential capabilities of a proposed system. These iterations continue until a decision is made that the proposed system either satisfies a need and has sufficient potential to justify formal system development, or it is not worth further effort.

The validation phase begins with the decision to explore further development of a new weapon system. The System Program Office (SPO) is normally established during the conceptual phase and provides the continuity needed for the transition into the validation phase.

The prime purpose of the validation phase is to select the system and contractors for the development effort. The range of strategies to accomplish this selection may vary from merely selecting a sole source development contractor, to a major competition including a full fly-off between competitors.

Technology. The demonstration of technology plays a major part in the validation phase. Risks associated with new technology and the potential benefits to be gained are evaluated.

Engine components incorporating new technology must be evaluated for performance potential during this phase.

The APSI/ATEGG programs initiated during the conceptual stages are normally two or more years old by the beginning of the validation phase. The government managers of these programs serve as expert advisors in the advanced technology area throughout the validation phase.

Role of Performance. Performance has traditionally been the paramount factor considered in the validation phase. Logistic characteristics of new engines such as maintainability, durability, and reliability might be considered, but performance characteristics are overriding. Efforts to include life cycle costing as part of the validation phase are now being implemented by including engine requirements such as reliability and durability. Nevertheless, performance and cost are the main factors considered during the validation phase, partially because they can be easily measured and verified (29:50-51).

AFSC/AFLC/Contractor Interface. AFLC representatives become more active in the validation phase of the system's life cycle and are included in the Source Selection Committee (SSC). However, the Air Force Systems Command (AFSC) is responsible for the actions of the SSC and provides most of the manpower.

The interface between engine and airframe contractors is very close during this phase. The contractors coordinate changes in airframe which impact on the engine.

Possible engine improvements to offset these changes or increase system performance are evaluated by the engine contractor.

Procurement. Major procurement strategy decisions are made during this phase. Program characteristics are refined and validated to achieve minimal risk. Engine development is the responsibility of the Deputy for Propulsion (ASD/YZ), with the overall responsibility for the entire weapon system residing within the System Program Office (SPO).

Throughout the validation phase, system characteristics, performance, cost, and schedule are validated and refined through extensive studies, analysis and/or prototype testing. The engine manufacturers submit data on available technology and their assessment of the risks involved. Based on analysis of the Air Force and manufacturers' data, general engine specifications or operating parameters are established. These specifications are put into a Request For Proposal (RFP) asking for a preliminary design, a hardware development, or a prototype engine. The competing contractors' designs and/or hardware are evaluated and the Source Selection Authority (SSA) then selects the competitor who will develop and produce the engine.

The engine contracting organization negotiates contracts, usually cost plus fixed fee (CPFF), with the competing contractors during the source selection process. These contracts are drawn up as though each of the competitors will win. Once negotiations are completed, the contracts are signed by the contractors and held by the government pending the outcome of the source selection. At this time, the selected contract is executed, while the rest are discarded.

The negotiation of these contracts prior to source selection takes advantage of the existing competitive situation and provides for additional concessions from the engine contractors. However, the consequences of this maneuvering could result in an engine that can't be produced at the quoted price or within the specified time, as well as lowering performance requirements to permit acceptance and delivery of the engine (15:3-6).

The full scale development phase normally begins with execution of the contract. These contracts provide for full scale development of the engine and usually contain options for production engines. The Full Scale Development (FSD) contracts are usually CPIF with Fixed Price Incentive (FPI) arrangements for the production options.

The Full Scale Development Phase

Overview. A ratification decision by the Secretary of Defense is required prior to commitment of resources to Full Scale Engineering Development of a new weapon system. Although the readiness of the weapon system to enter full scale development (FSD) and the operational need for the system were reaffirmed during the validation phase, DOD Directive 5000.26 prescribes additional determinations before the ratification decision is given. These other determinations include consideration of system trade-offs; quantity, resource, and scheduling realism; reduction of major uncertainties and risks to acceptable levels; cost-effectiveness of the proposed system; establishment of valid design to cost goals; identification of the approach for major subsystems; satisfactory testing and evaluation, as well as a sound future program; and the acquisition strategy, including contract type, is consistent with program characteristics and risk (36:5-6).

Trade-offs. The two areas where major trade-offs occur during this phase are engine vs: airframe and performance vs: support.

The development of the engine requires a longer lead time and more critical milestones than the airframe development. Nevertheless, it is the airframe schedule which is given high visibility and, therefore, appears to be the pacing schedule for the weapon system. What usually happens is engine development programs are tailored to meet time constraints of the airframe. This may result in the Air Force accepting an engine which has not been fully developed (29:77).

Performance and support trade-offs occur when a decision is made to attain specified engine performance, or to diminish this performance to accommodate higher rates of reliability and maintenance.

Test and Evaluation. The engine is required to pass specific tests during the FSD phase. Preliminary Flight Rating Test (PFRT) and Qualification Test (QT) are the major engine testing milestones.

The PFRT series, which determines the safety and acceptability of the engine for use in experimental flight testing, lasts from eighteen to thirty months. If the engine passes this series, it then must go through the QT series. The entire series of both tests normally require thirty-six to forty-eight months to complete. After passing both series, the engine is considered to be suitable for production and use.

Procurement. During the FSD phase, the engine and all support items are designed, fabricated, and tested to yield a preproduction engine that closely approximates the final production design. Procurement strategy is set before the engine program reaches this phase, thus a Cost Plus Incentive Fee type contract with specific provisions will most likely be used to procure engine development. The risks encountered during this phase make this type of contract acceptable to both the Air Force and the contractor (29:93).

Organization. The Full Scale Development Phase of the cycle is a time where more organizations become actively involved in the process. The SPO cadre rapidly increases its manning and AFLC increases activity by manning the Integrated Logistic Support (ILS) Office. Representatives from the ALCs, designated as System Manager and Item Managers for major subsystems, are assigned to the ILS Office. Additionally, representatives from the Major Commands which will receive the system are assigned to work with the SPO. These representatives monitor the system development progress and aid in future planning for the day when the system becomes operational.

Cost Considerations. The majority of the engine development costs up to QT are expended in the FSD phase. Various studies estimate that nearly 25 percent of the life cycle cost of an engine is expended in the development process up through QT. Other study efforts indicate that 95 percent of the total life cycle cost will be defined by the system decisions made by the end of the FSD phase. This being the case, the considerations given to engine costs in the conceptual, validation, and FSD phases vitally affect the total costs incurred by the Air Force (20:14-19).

## The Production/Deployment Phase

Overview. A production decision by the Secretary of Defense is required prior to commitment of resources to final production of a new weapon system. During the Full Scale Development phase the weapon system has proven its readiness for production, DOD Directive 5000.26 required factors are determined, and the production decision is made. Once these system decisions are made, the engine enters the production phase. In this phase, the engine, spare parts, and other ancillary equipment are produced for operational use.

Procurement. Although the actual purchase of the production engines, Aerospace Ground Equipment (AGE), test equipment, data and spare parts required to support the engine occurs in the Production/Deployment phase, their procurement occurred in the FSD phase through production options attached to the FSD contract. This is the initial production contract.

Additional follow-on contracts are negotiated prior to the exercise or expiration of the final production option on the FSD contract to maintain continuity. A follow-on contract provides a firm fixed price (FFP) during its initial year, with annual renegotiations for the remainder of the contract period. This arrangement is frequently cited as being unique to engine procurement (29:105).

The primary difference between engine and most airframe contracts is timing. Price is redetermined annually on the engine contract while system contracts are normally redetermined at the completion of the contract period, which may be in excess of five years. This results in a moderate price readjustment being made to an engine program annually and a major readjustment being made to a system contract at the end of the contract period.

Spare Engines. Headquarters AFLC has the responsibility of computing spare engine requirement quantities which are needed to fill base and depot supply pipelines. These requirements are forwarded to AFSC/ASD for funding. Approximately 30 percent of engine production is used to fill supply pipelines (29:109).

Trade-offs. Modern weapon systems are very complex, thus providing many alternatives for solutions to specific problems encountered in development, manufacture, and operation. These alterations usually result in trade-offs. The most frequent trade-offs are engine vs: airframe and performance vs: support.

Most major trade-offs between engine and airframe are made prior to the production phase. However, exposure to extremes of the operating environment may result in unexpected engine/airframe characteristics requiring further trade-off decisions. Typical problems resulting from exposure to the environment are: insufficient engine thrust, excessive airframe drag, system weight above design, or any combination of these factors.

The trade-off decision tends to be for the option involving the least time and cost: modify the system design causing the problem, or modify the engine to increase power to overcome design problems. System redesign normally occurs with minor deficiencies, whereas engine modification occurs when there are significant shortfalls in the system performance (29:128-130).

Unexpected problems in logistic support of engine components may require a decision to change or modify operating characteristics of the aircraft, or to redesign components showing lower than anticipated mean time between failure rates. A trade-off example would be the decision to lower power settings for takeoff and climb to altitude to compensate for higher failure rates within the engine plant. The issues revolve around the most acceptable balance between performance and maintenance cost.

Organization. The primary emphasis during this phase is the transfer of responsibility from AFSC to AFLC.

According to Air Force Regulation 800-4, this transfer is to be done at the earliest practical date during the production phase (35).

The system and item managers' responsibilities increase in preparing for receipt of the new weapon system to their command. With this increased activity, there is a reciprocal decline in SPO manning and activity.

The Operational/Support Phase

Overview. The operational/support phase overlaps the production/deployment phase. The formal breakpoint between the two phases occurs at the transfer of program management responsibility (PMRT). However, AFLC activities actually begin during the production/deployment phase in producing spare parts, collecting usage data, overhauling engines and correcting service problems. The operational/support phase extends throughout the life of the engine to its disposition.

Organization. During the operational/support phase the number of organizations providing maintenance support of aircraft engines reaches its peak. Since PMRT has not usually occurred until well into the phase, the SPO personnel continue to work on engineering and Component Improvement Programs (CIP). The Air Force Manual 400-1, "Logistics: Selective Management of Propulsion Units," Volume I, "Policy and Guidance," outlines AFLC's major areas of responsibility (31:3-1 to 3-4).

The Air Force Logistics Command (AFLC) is charged with the overall management of aircraft engines after PMRT. There are two Air Logistics Centers (ALC) performing all depot level maintenance, San Antonio ALC and Oklahoma City ALC. At Headquarters AFLC, Wright-Patterson AFB, Ohio, the Directorate of Propulsion Systems (AFLC/LOP) serves as the focal point for engine management by providing plans, policies, and procedures necessary to accomplish this overall management function.

Additionally, some of the Air Force engine management is done by committees attempting to straddle diverse functions to facilitate the responsibility transfer from Systems Command to Logistics Command, as well as transferring technological information on the not yet fully matured engine. Four of the more significant committees are the Engine Advisory Group (EAG), the Propulsion Review Board (PRB), the Aerospace Engine Life (AEL) Committee, and the Air Force Engine Logistics Planning Board (ELPB).

The Engine Advisory Group (EAG) is an ASD/Air Force Aero Propulsion Laboratory (AFAPL) team, whose purpose is to formulate, evaluate, integrate and coordinate the plans and programs necessary for the continuation of development and improvement efforts on propulsion units. While chaired by ASD, representatives from the supporting Air

Logistics Center, AFLC/LOP and the Arnold Engineering Development Center are also members (1:1-4).

The Propulsion Review Board (PRB), co-chaired by ASD and AFAPL, includes representatives from AFLC. Providing an assessment of the quality, quantity, and scheduling of development programs, this Board determines if an engine is ready to move to the next step in its development process (2).

The USAF Aerospace Engine Life (AEL) Committee establishes forecasting factors for the supportability of engines. It is chaired by the Director of Propulsion Management (AFLC/LOP) and meets semi-annually to derive dependability indices, base maintenance return rates and engine life expectancies (31:2-2).

The Air Force Engine Logistic Planning Board (ELPB) is similar in composition and chairmanship to the AEL. It meets, as necessary, at the discretion of the chairman

> . . . to establish policy and guidance on matters relating to management of engines and related equipment. . . . It provides logistics guidance to Air Force activities for use in developing logistics plans and in effectively managing Air Force resources [31: 2-1].

Spare Engines. AFLC determines spare engine requirements prior to and during the production phase. During the operational phase, it must support all installed and spare engines to insure that the using commands are capable of meeting their operational commitments.

Within the early operational phase, problems with durability and/or reliability of engines result in the greatest demand for spare engines. Typically, this high demand occurs during the first five to eight years of the operational phase. As the engine matures, the requirements for spare engines normally decrease (34:1-5).

*Replenishment*. Throughout the operational/support phase all spare parts required to support engines must be procured and on hand. The Air Logistic Centers are responsible for maintaining an adequate inventory of spare engine parts for the life of the engine.

*Maintenance*. A generalized engine maintenance concept is developed and prepared during the conceptual phase of the acquisition process. This concept later becomes the design guide in the development phase for the required maintenance characteristics. The maintenance concept is refined and evaluated through the FSD phase; as the engine enters production and operation, the maintenance concept is finalized.

Jet engine maintenance is conducted at three different levels; depot, intermediate, and organizational. Depot level maintenance is conducted at two Air Logistic Centers. Each ALC has the capability for complete engine overhaul which includes disassembly, inspection, repair, and full scale testing of the basic engine. Jet engine intermediate maintenance (JEIM) entails both scheduled and unscheduled maintenance activities performed within the base engine shop. Normally, when there is a limited number of installed engines or when the base facilities are constrained by the level of authorized disassembly, a consolidated JEIM shop is established to service these bases. This consolidated JEIM facility is called a "Queen Bee." Finally, organizational maintenance includes engine inspections and servicing, as well as the replacement of minor components and accessories.

The Component Improvement Program (CIP). The purpose of the CIP is to obtain engine improvements through contracted engineering support. The type work performed is directed principally toward developing repair procedures. Additionally, the CIP is used to eliminate safety of flight problems, resolve service-revealed deficiencies, maintain specification performance and reduce logistics support costs (5).

Cost Considerations. One of the conclusions reached by the PMR study group was that "the entire engine-management process is hampered by inadequate cost data. . . ." The study found the greatest deficiencies in cost data during the operational/support phase. The reason was found in the plethora of data collection systems resulting in piecemeal engine cost data, with no single data collection system capable of providing a total cost picture.

> Air Force engine cost data is inadequate for determining engine life cycle costs. It most certainly is inadequate as a tool for making day-to-day life cycle cost decisions [29:180].

Generally, Air Force management is performance and mission oriented; cost is not the prime consideration. Examples being: depot managers are evaluated on how well they meet engine production schedules; managers at the base level are concerned with generating the engines required to support scheduled aircraft sorties; and procurement managers are evaluated on the timeliness of the contract generating process. Therefore, engine management tends to be quite fragmented and the supporting data collection systems reflect this fragmented structure.

## Some Recent Changes to the System

Since the completion of the PMR in late 1975, two significant changes affecting the engine community have occurred. The first was the creation of the Deputy for Propulsion (ASD/YZ) and the second was the establishment of the Air Force Acquisition Logistics Division (AFALD) within AFLC.

With the creation of the Deputy for Propulsion, all procurement and production functions are now conducted within a single office. Previously, the major System

Program Offices (SPOs) were encouraged to procure their own engines as part of their primary responsibilities as a "Super-SPO"; an engine SPO was used to procure all other engines.

The new Deputy for Propulsion within ASD operates through Joint Engine Program Offices (JEPO), which reflect the current major engine acquisition programs. There are presently three such JEPOs; TF34, F100, and F107. These JEPOs are staffed (matrixed) by personnel from the ASD Directorates of Program Control, Procurement and Manufacturing, and Engineering and Testing, as well as from the AFALD Directorate of Propulsion Logistics.

Due to the increased costs of supporting new weapon systems, the Air Force Acquisition Logistics Division (AFALD) was established in July, 1976. This new organization was charged with the responsibility of "driving down the costs of owning and operating Air Force weapon systems [3:1]."

> AFALD was established to provide a greater degree of logistics unity to achieve the maximum reduction of major weapon systems life-cycle costs. The division improves the interchange of information between AFLC and Air Force Systems Command (AFSC), particularly the flow of feedback data from Air Force combat commands using the systems [27:1].

The Deputy for Acquisition Programs (AFALD/SD) is the focal point for major weapon system acquisition management. This office is responsible for integrating all logistic efforts of the AFALD into common goals and objectives in support of each SPO. The responsibility for propulsion logistics is carried out by the Deputy for Propulsion Logistics (AFALD/SDD). AFALD/SDD is co-located (matrixed) within the JEPOs of ASD/YZ and is recognized as ASD/YZL within the Propulsion SPO (4).

## Purpose of the System: Desired and Actual

Investigation of the system has revealed two distinct purposes; desired and actual. The desired purpose is to obtain the most advanced and best performing engines within the constraints of time, technology and lowest life cycle cost.

The actual purpose is to obtain the best performing engines within the constraints of time, technology and acquisition costs. Life cycle costing and other logistic considerations are factors in the decisions made during the development phase of the engine; nevertheless, performance is the overriding consideration.

> Experience has shown that the more advanced the technology used in an engine, the more likely that logistics problems will be encountered in the field. Although most designers recognize this basic fact of life, logistics considerations do not determine the choice of technology. The selection of engine technology is based almost exclusively upon two factors; the increased system performance that can be achieved, and the probability that the required technology can be successfully incorporated into the proposed engine, within the system's cost and time constraints [29:41].

# CHAPTER III

## THE MANAGEMENT CYBERNETIC MODEL

The Introduction, Chapter I, provided a brief description of the management cybernetic model. This chapter expands on that description and provides a more detailed explanation of the model. In addition, rationale for the development of the model is provided and appropriate examples of the model subsystems within Air Force organizations are presented.

It was stated earlier that one of the virtues of cybernetics is "that it offers a method for the scientific treatment of the system in which complexity is outstanding and too important to be ignored [6:43]." Stafford Beer refers to these systems as "unthinkable systems" in the sense that they are really too complex to fathom (7:67). The tremendous complexity in today's organizations, coupled with the accelerating rates of change, have reached the point where knowledge of

> . . . how to run companies, how to organize them, how to service them, how to do anything at all in government or business is just not known any longer. Both knowledge and experience seem to have run out [7:28].

Beer (7), Christopher (14), Steinbruner (24), and others believe that what is required today is clearly a new model of organizations or any complex system; the organizational charts which we have always used are no longer sufficient. Mathematical, analytical, and mental models are inadequate when applied to complex systems and, therefore, are unable to meet our needs. What is needed is a model of viable systems which can continuously adapt to the changing environment no matter what causes the change, unless it is a complete destruction of the system. It is against this background that Beer developed his management cybernetic model.

## The Model as a Replication of the Human Nervous System

Because of its exceedingly complex design, Beer chose the human nervous system to model complex organizations. The human body is confronted by both internal and external stimuli requiring varying levels of functional responses. The many conflicting demands on the body are resolved quickly and smoothly, allowing the organism to operate efficiently. This is possible because

> Most of the control is intrinsic in that "senior management," conscious cerebration itself, does not and in most senses cannot concern itself with the biochemical or electrical details [7:115].

When the body requires rest, it can be obtained, yet when violent action is urgently needed, the human body can respond immediately. As Beer wrote,

> . . . surely this is good management par excellence. . . . It ought to be successful, . . . it is

the fruit of several millions years of research and development [7:115].

As indicated earlier, the management cybernetic model is composed of five subsystems arranged in a hierarchy. Systems 4 and 5 can be thought of as the volitional control, while Systems 1, 2, and 3 form the autonomic control system. When one speaks of autonomy in the human body or an organization, autonomy refers to the branch or function which is responsible for its own regulation.

The autonomic function is essential for maintenance of a stable internal environment. In the human body, a change in the ambient temperature may so affect the body that the internal controls react automatically. Regardless of the cause of the change in the ambient temperature, the autonomic control responds to maintain a stable body temperature. The important point here is that the brain does not consciously intervene; the body reacts automatically.

Likewise, in an organization there should be an autonomic system which responds to environmental changes (within set limits) without interference from Systems 4 and 5. However, there will be times when Systems 4 and 5 must be called upon. A person will flee a burning building to survive. This is a System 5 function. Changes to the financial environment such as increased taxes may "force" an organization to relocate (flee); a System 5 function.

A management cybernetic model can be used to represent any viable system. Figure 5 presents a corporate organization which is described below.

System 1

In Figure 5 the circles represent operating divisions of the corporation. These divisions produce an output or perform some service. In an industrial organization, a division represents manufacturing, marketing, engineering, etc. In a military organization such as an Air Logistics Center, the divisions could represent the Directorates of Maintenance, Procurement, Materiel Management, etc. The Divisions, Divisional Directorates, and Divisional Regulatory Centers comprise System 1. Figure 6, Operating Division Diagram, illustrates a System 1 in isolation. The elements of the division diagram are: (1) operations (Operating Divisions), (2) management of the operations (Divisional Directorate), (3) management systems which organize information in consideration of the purpose of the operating division, and (4) the external environment (14:5).

The arrows in Figure 6 indicate information flow. Sensors at the end of each arrow sense and transduce the

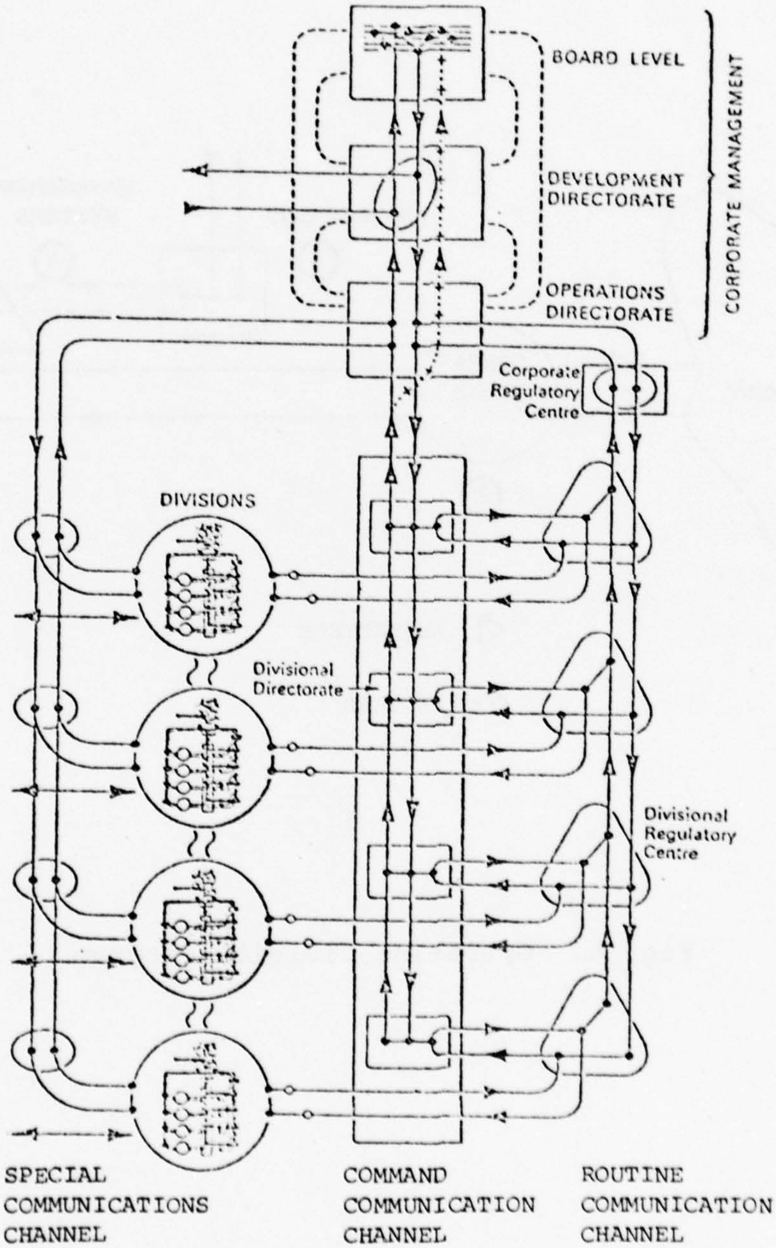


Fig. 5. A Management Cybernetic Model [7:199]

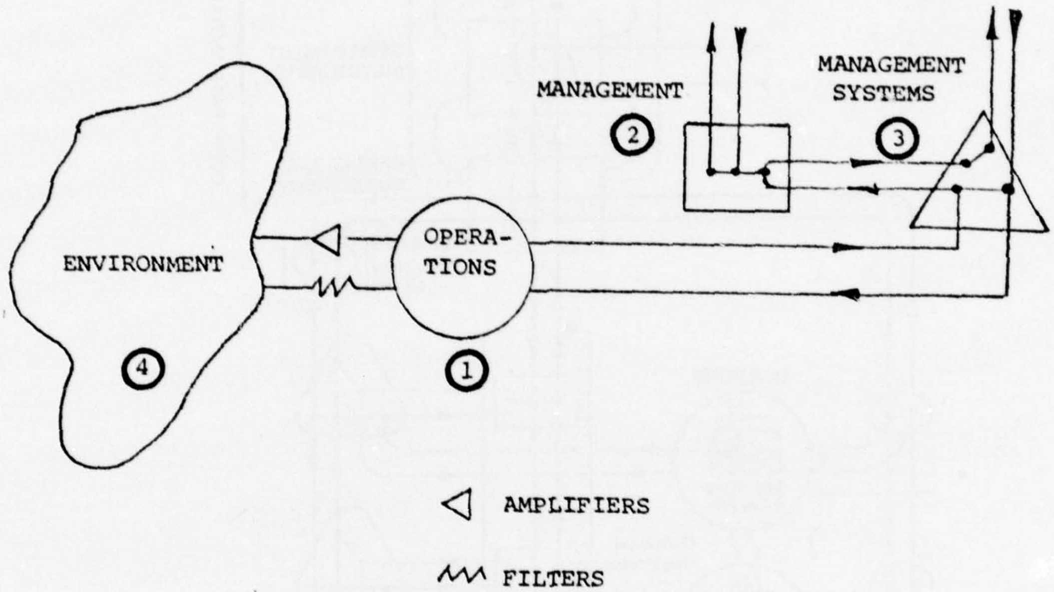


Fig. 6. Operating Division Diagram

data into meaningful information. For example, operations need not know everything that is out in the environment, *but it must know all that matters*. Likewise, management does not need to know all the data generated by operations, *but it must know what matters*. Obtaining information, as opposed to raw data, requires filtration as shown in Figure 6. Amplification allows effective communication of information from management to operations, and from operations to the environment.

The operating division (System 1) has several important characteristics. The division:

1. Comprises operations or functions and their management.

2. Relates to an external environment.

3. Has a purpose and a structure to achieve its purpose.

4. Is largely self-regulating.

5. Is controlled through information flow relating to its purpose.

6. Provides information through a system of measures (14:8).

The Cybernetic Management System (Figure 5) shows that operations are run by management via the divisional regulatory center (management systems). The division is essentially autonomous, however, there is one limitation to this autonomy; the division continues to be part of the overall corporation. This limitation poses three management constraints:

1. It must operate within the intentions (purpose) of the entire corporation.
2. It must submit itself to the coordinating framework of System 2.
3. It must submit to the autonomic control of System 3 and the volitional control of the Corporate Management (Systems 5 and 4).

All these constraints ensure the survival of the corporate body [7:201-205].

System 2

System 2 can be explained simply as a metasystem subsuming all of Systems 1. It is an elaborate interface between the Systems 1 and System 3. Its purpose is to provide the means of controlling oscillations between the divisions (7:220-224). As stated, the Systems 1 divisions are essentially autonomous; each having different goals and each competing for the corporation's limited resources. The smooth operation of the corporation depends to a large extent on effective interdivisional communications. This coordination is accomplished via System 2, the Corporate Regulatory Center.

Figure 5 can be used to illustrate how coordination is accomplished among the divisions. Assume a corporation is comprised of four operating divisions. Assume also that the output of Division A forms part of the input to Divisions B, C and D. Obviously, a production breakdown in Division A would have consequences for the other divisions.

The output data from Division A goes directly to System 2 and simultaneously to all the other divisions via the routine communication channel. The managers of Divisions B, C, and D can take immediate action to counteract the problem in accordance with their evaluation of its severity.

Another important function of System 2 is the transmittal of information to System 3 management. In this example, if the problem were perceived as severe enough to require informing higher level management, that information would be immediately passed on to System 3.

System 3

System 3, the Operations Directorate, the highest level of autonomic management, is designed to control the stability of the internal environment of the corporation. However, System 3 is also the lowest level of corporate management (see Figure 5).

Homeostatic Management. The self-regulatory sector of the corporate model is made up of Systems 1, 2, and 3. There are two disparate homeostatic systems within this autonomic sector: sympathetic and parasympathetic.

The routine information channel on the right-hand side of the management cybernetic model (Figure 5) is similar to the sympathetic nervous system in the human body. Its purpose is to handle routine information through the corporate regulatory center (7:136). On the left-hand side of the model is another information channel leading to System 3. Christopher referred to this as the special communications channel (14:9). It is similar to the para-sympathetic nervous system in the human body. Its purpose is to provide information needed for special purposes, or to deal with special problems or opportunities (14:20-21). System 3 uses these two channels to obtain a balanced mass response which provides a general homeostasis (7:144-145). The following example illustrates this behavior.

Consider a hypothetical corporation and assume that the Board of Directors (System 5) formulates a plan calling for a new all-out corporation effort. This plan is directed through Systems 4 and 3 and down the command axis to the operating divisions. As long as the required effort is within the capabilities of the operating divisions, System 2 merely fine tunes the coordination required between the divisions, while System 3 monitors the process. The information output of the divisions is processed through the routine communications channel (the sympathetic system) to System 3. Suppose, however, the effort required to implement the plan is such that it strains the operating divisions. System 2 tries to balance the demands from the operating divisions but oscillations occur. Division A tries to adjust to Division B's breakdown, but Division C cannot keep from being affected and further exacerbates the oscillations. System 2 cannot intercept the information flowing between the divisions; it can only monitor them. The information about this dysfunctional behavior is now being transmitted to System 3 by the special communications channel (the parasympathetic system). It is now System 3's function to evaluate the information it is receiving from the right- and left-hand loops to produce an overall internal stability (7:169).

Corporate Management. System 3 also serves as the lowest level of corporate management. In this capacity it implements directions passed down the command axis from Systems 5 and 4.

## System 4

System 4, the Development Directorate (see Figure 5), lies in the vertical command axis between Systems 5 and 3. System 4 can be viewed as performing a staff function. Beer viewed System 4 as a linking mechanism or a switch between the volitional control of System 5 and the autonomic control of System 3 (7:173).

System 4 provides the framework and criteria used by the autonomic system in its attempt to maintain internal equilibrium and to optimize performance (7:233-241).

Christopher listed some of the functions of System 4 as:

1. Monitoring the external environment.
2. Developing purpose.
3. Conducting research and development.
4. Planning and managing projects.
5. Designing systems of measure.
6. Monitoring the organizational model.
7. Providing functional expertise [14:8].

The existence of a System 4 in many organizations may be difficult to visualize. Beer contends that the System 4 functions must be present if there is a viable system. ". . . there is always a System 4 even if it is not identified in quite the form specified here [7:233]."

System 5

System 5 is the highest managerial echelon of an organization; it is the Board of Directors, the "Brain of the Firm." The function of System 5 is to establish both the purpose of the organization and the structure necessary to carry out this purpose.

## Role Mobility Within the Model

The management cybernetic model contains five subsystems. It is important to recognize that some individuals can simultaneously function within several levels of the system. In the corporate example given, one individual could function as: an executive vice-president responsible for operations, a System 3 function; a member of the Board of Directors, a System 5 function; and head of a corporate project, a System 4 function. It is important that the role an individual assumes within the different systems be recognized at all times; if there is a blurring of roles, a distortion of the decision-making process can result in poor decisions (14:10).

## Communication Channels Within the Model

Information flow through the five subsystems enables the organization to make "good" decisions; that is, decisions that achieve the required purpose. Figure 5 shows the three communication channels that link the five systems.

### The Routine Communication Channel

The routine channel connects all Systems 1 to System 3 through the operations coordinating center. Problems that develop in any of the operating divisions are immediately known by all other divisions and necessary adjustments can then be made (14:19-20).

### The Command Communication Channel

The command channel carries upward, information which is not required for routine operations, and informs higher level management whether or not the divisions are operating within prescribed limits. If divisions are operating smoothly, all that travels upwards is information indicating "I'm OK." The command channel also handles information flowing downward to the operating divisions from higher level management. Such information must be in the form of directions, policy or structural changes which the corporate management feels is necessary to carry out the purpose of the organization (14:20).

## The Special Communication Channel

The special channel carries all nonroutine information needed for special purposes or problems. The need for this information to insure the homeostatic balancing of the autonomic control system was previously discussed. Typically, special communications are audit reports, technical seminars, and consultant reviews. In the Air Force, Inspector General reports would be an example of information processed through the special communications channel (14:20-21).

## Management Information Systems: Criteria for Performance

The dynamics of the entire system depend on the speed and accuracy of information flowing through the communication channels. Of particular importance is the flow of performance information emanating from the operating divisions. If the autonomic system is to provide the necessary control, it must have immediate information regarding the performance of the operating divisions.

The information system is crucial, for it contains information on which decisions are based and which drives the entire decision-making process of the system. Institutional instability occurs when the autonomic controls (System 3) either do not have the needed information to make decisions leading to stability, or the information is too late to be useful because new perturbations within the system have already occurred (10:1-17).

Effective management information systems will focus on the timely transmission of a few key performance measures. Christopher introduced a limited methodology for the development of measures of performance (13). He found that there are a few key performance areas such as market position, profitability, and productivity which provide objectives that guide the affairs of the organization.

> Measures of progress toward the achievement of these objectives provide the control for management to lead the total infinitely complex enterprise to the achievement of its purpose [13:2].

The simplification offered by the key performance objectives makes effective management possible by what cyberneticians call the attenuation of variety (10:18-34).

Beer also viewed the area of performance measures as crucial. He provided a system of performance measures utilizing indices, ratios or pure numbers. The creation of these measures required the defining of three levels of capacity.

1. Actuality--What can be accomplished with existing resources, under existing constraints.

2. Capability--What can be accomplished with existing resources, under existing constraints if efficiency were 100%.

3. Potentiality--What ought to be accomplished by developing resources and removing constraints, while operating within the bounds of known feasibility [7:207].

These three levels of capacity were then used to form two ratios:

1. Productivity--The ratio of actuality and capability.

2. Latency--The ratio of capability and potentiality [7:208].

Performance, a pure number, is the product of latency and productivity or the ratio of actuality and potentiality. Beer confessed that

> . . . although the absolute values of the productivity and latency indices provide only approximate assessments, movements of these indices over time provide the information that we really need [7:210-212].

The computer processing of these indices, as measures of the performance of the operating divisions, can be easily accomplished. Furthermore, there is no possibility of misinterpretation of such performance measures. A few indices of performance is all that management would need to guide most of the affairs of the organization.

## Recursion Within the Model

An important characteristic of the cybernetic model is its recursiveness. Recursion implies a system within a system. "If a viable system contains a viable system, then the organizational structure must be recursive [7:287]."

This recursion allows each operating division to be considered as an entire system having five subsystems and three communication channels. In Figure 5, the entire model is reproduced in each of the circles representing the operating divisions. Divisional management, which is System 1 in the corporate model, would now represent System 5 in the divisional model. This recursive feature can be extended upwards or downwards in any organization. "It is this recursive characteristic which makes this model representative of any organization [7:200]."

# CHAPTER IV

## THE ENGINE SYSTEM: A MANAGEMENT CYBERNETIC MODEL

The purpose of this chapter is to map the existing engine system onto a management cybernetic model. This mapping process entails identifying and positioning on the model the individual, group, committee or system that performs each of the requisite functions of the cybernetic model. The following chapter will then use this model as a diagnostic instrument for identifying organizational or structural problem areas within the engine system.

As introduced in the previous chapter, the management cybernetic model is composed of five levels or systems. These five systems are recursive; that is, a system within a system. The concept of recursion is illustrated in Figure 7, a Recursive Model. At the upper-right is an organization called "Air Force," which is representative of the USAF at the highest level of recursion. Within the organization, the Secretary of the Air Force would represent System 5 while System 1, the operating divisions, would be represented by the Major Air Force Commands. At one level of recursion below the Air Force organization would be the major commands. System 5 would now be the Commanders of these major commands and System 1 would be

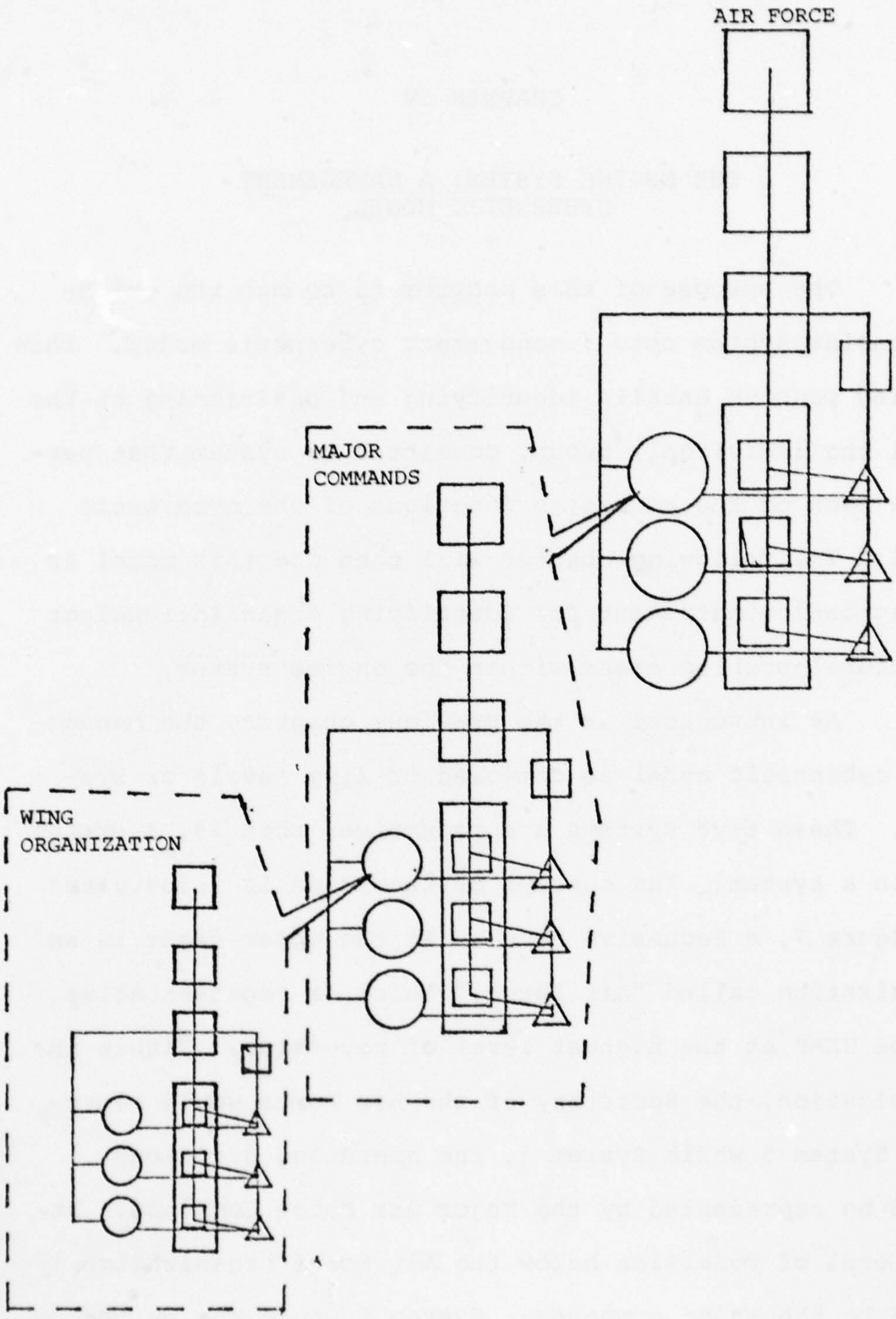


Fig. 7. Recursive Model

the flying organizations or wings. The model could be extended down another level so that the Wing Commander would now be a System 5 and the Deputy Commanders for Operations and Maintenance would be part of the System 1.

For the purpose of this research, the engine system is divided into three sectors: acquisition, support and acquisition logistics. These three sectors have been investigated through the appropriate number of recursions needed to present a general overview of how the United States Air Force buys and manages its jet engines.

## The Acquisition Sector

### Acquisition Level 1

The acquisition sector of the engine system requires four levels of recursion to achieve a generalized understanding. At the lowest level, Figure 8, the Joint Engine Program Offices (JEPO) function as the System 1 operating divisions. Three of the existing JEPOs are the TF34, F100 and F107.

The System 2 activities are principally directed at providing System 3 with information. There appears to be little need for one operating division to know how the others are performing, thus each JEPO tends to act with a great deal of autonomy. The information network is composed of briefings, meetings and periodic reports.

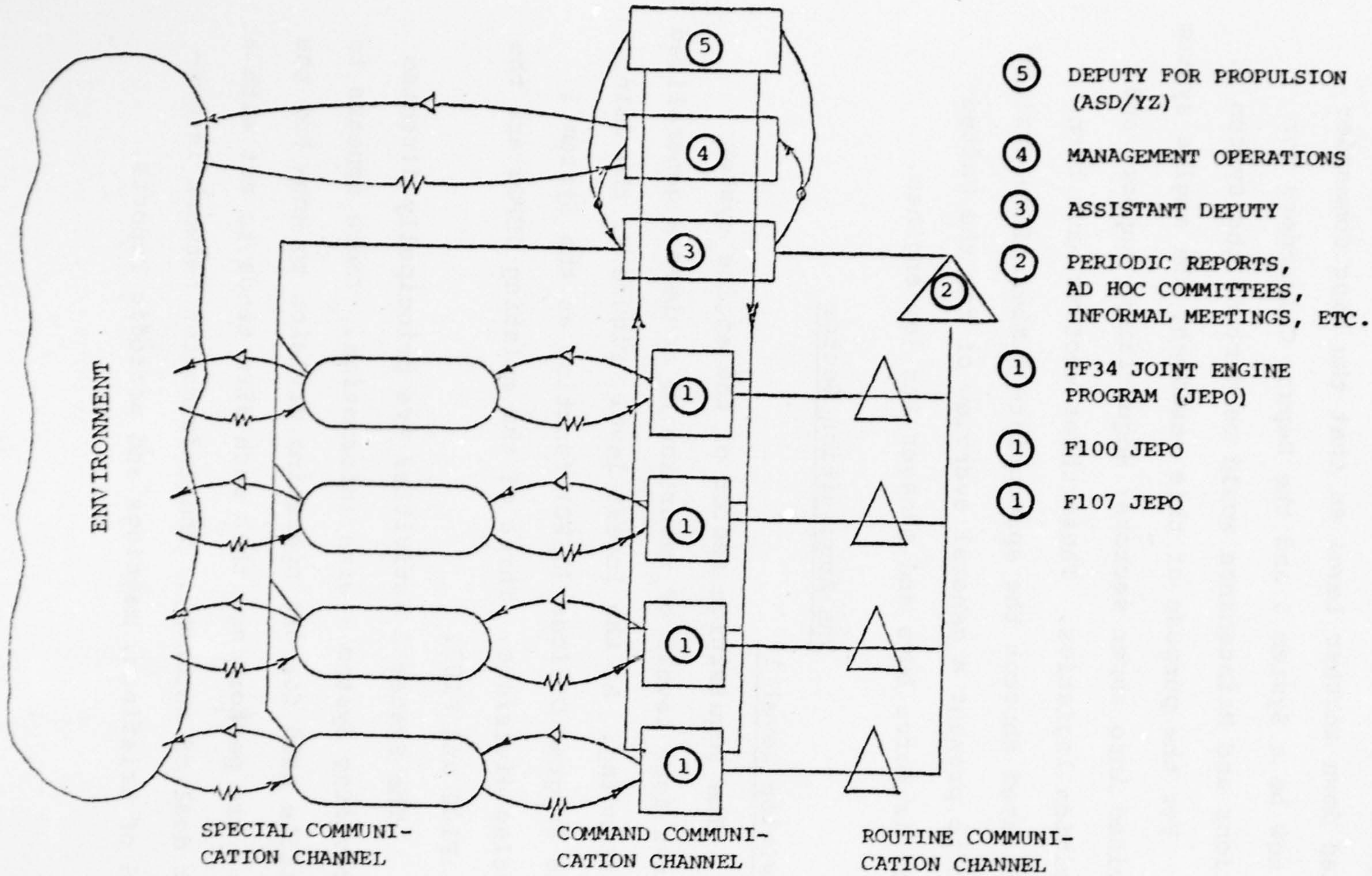


Fig. 8. Acquisition Level 1

The control of the engine offices is the jurisdiction of the Assistant Deputy for Propulsion, who functions as a System 4, as well as a System 3. The System 5 functions are performed by the Deputy for Propulsion (ASD/YZ).

Figure 8, Acquisition Level 1, illustrates this level of recursion. While the illustration connotes clearly defined systems within the organization, this investigation found that in this particular level of recursion and in many others, the functions of top level management (Systems 5, 4, and 3) appear to be composed of an almost continuous interaction between the Director, his deputy and the staff.

Acquisition Level 2

The next higher level (see Figure 9), shows the Deputy for Propulsion (ASD/YZ) functioning as a System 1 operating division. Other operating divisions would be the major System Program Offices; F-15, F-16, and A-10.

At this level of recursion, there is considerable interaction between the SPOs and the Deputy for Propulsion. Under the present concept of engine procurement, ASD/YZ is the focal point for all propulsion development and procurement. There must be constant communication between ASD/YZ and the SPOs to assess the trade-offs required between airframe and engine modifications.

System 2 consists mainly of formal reports between the SPOs and ASD/YZ, as well as staff meetings, ad hoc

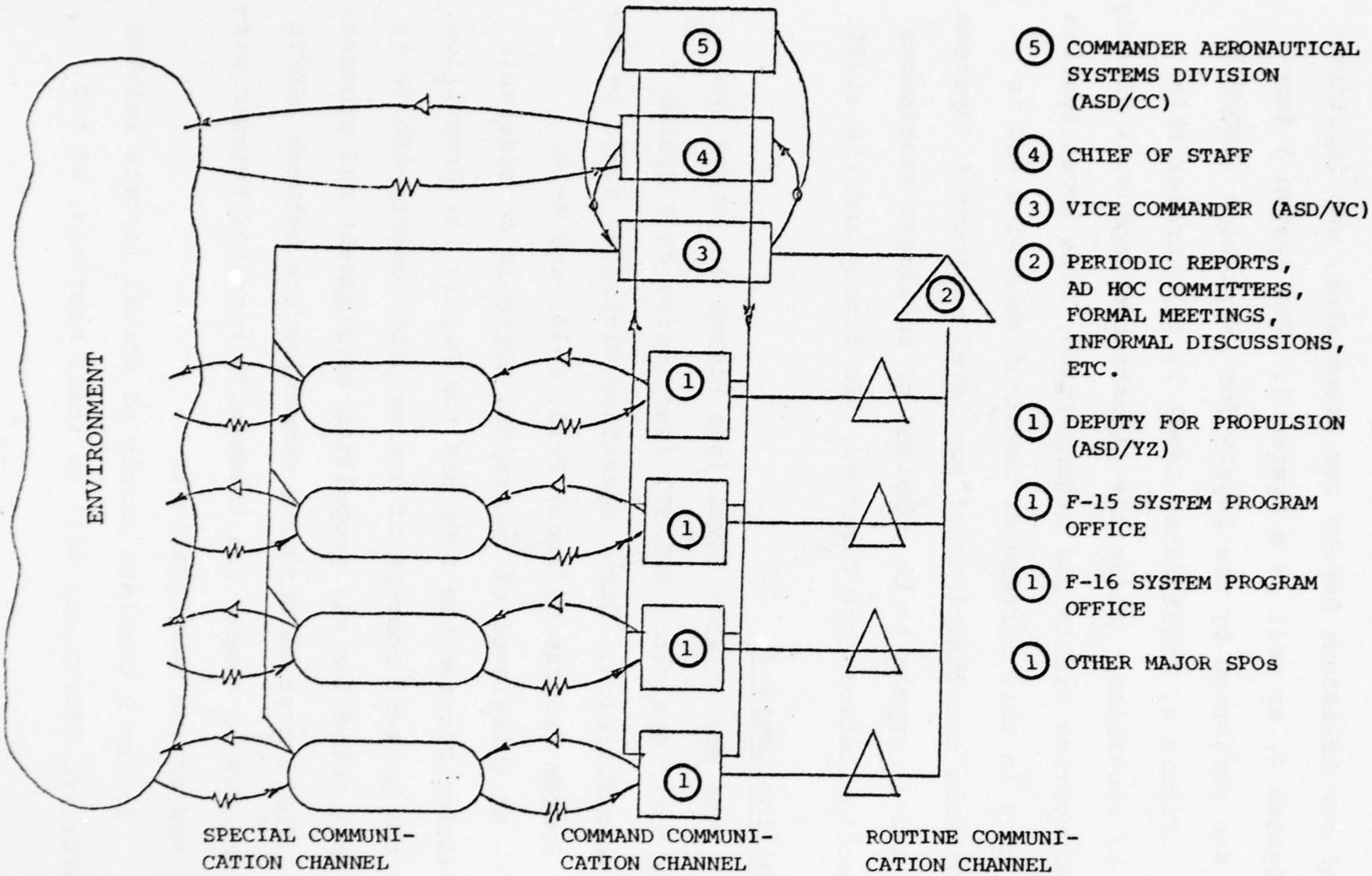


Fig. 9. Acquisition Level 2

and formal committees, and informal discussions. There is, however, no definitized reporting system at this level.

Systems 3 and 4 functions are performed under the direction of the Vice Commander, ASD and the ASD staff. The Commander of ASD (ASD/CC) performs the System 5 functions.

Acquisition Level 3

The third level of recursion is shown in Figure 10. ASD, the Electronics Systems Division (ESD), and the Space and Missiles Systems Organization (SAMSO), constitute the System 1 operating divisions. The Aeronautical Systems Division functions autonomously, communicating minimal information regarding divisional operations to Air Force Systems Command. In fact, at the AFSC level there are only two people who deal with propulsion matters exclusively (12). However, there are definite communication channels between the SPO and the supporting ASD and ESD functions.

System 3 functions, at this level of recursion, are performed by the Chief of Staff, AFSC, in conjunction with the Deputy Chiefs of the various functional areas. System 4 functions, such as planning, directing, and conducting special projects, are handled by the Chief of Staff, Air Force Systems Command (AFSC/CS) and the staff agencies.

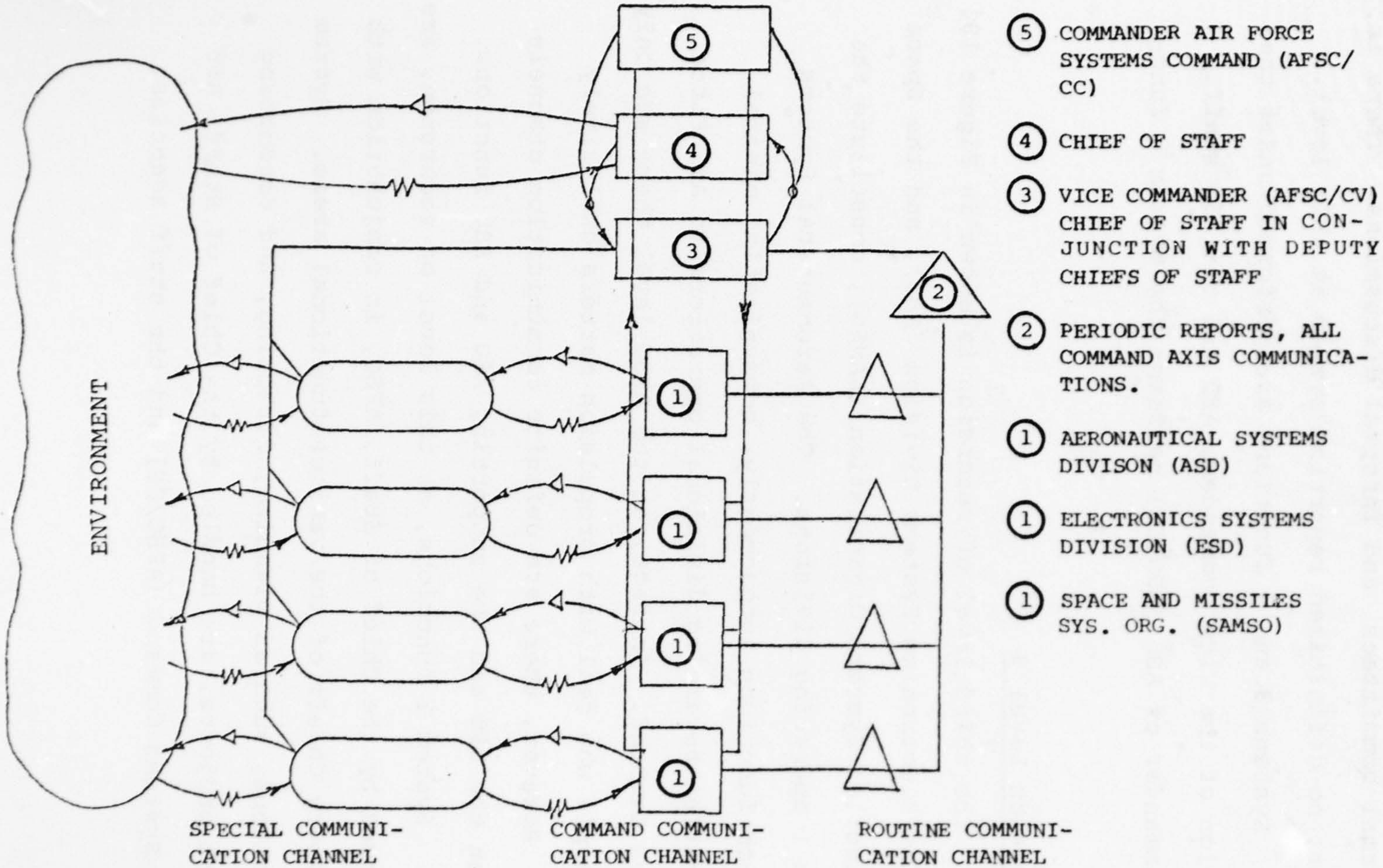


Fig. 10. Acquisition Level 3

System 5, top level management, resides with the Commander, AFSC (AFSC/CC).

## Acquisition Level 4

The final level of recursion, Figure 11, entitled Acquisition, Support, and Acquisition Logistics Level 4, includes AFLC, AFSC, and the operating commands functioning as System 1 operating divisions. System 3 functions, at this level of management, are the responsibility of the USAF Chief of Staff in conjunction with the various functional Deputy Chiefs of Staff.

While System 4 functions are the responsibility of the Special Staff, as in the lower levels of recursion, some of the System 3 Deputy Chiefs of Staff also perform System 4 functions.

Performing the functions of the top level of management, System 5, at this level of recursion, is the Secretary and Under Secretary of the Air Force.

The System 2 functions and the curious positioning of the Air Force Acquisition Logistics Division, within this highest level of recursion, have been postponed until AFALD and the acquisition logistics sector are discussed.

# The Support Sector

## Support Level 1

The support sector of the engine system also consists of four levels of recursion. The lowest level,

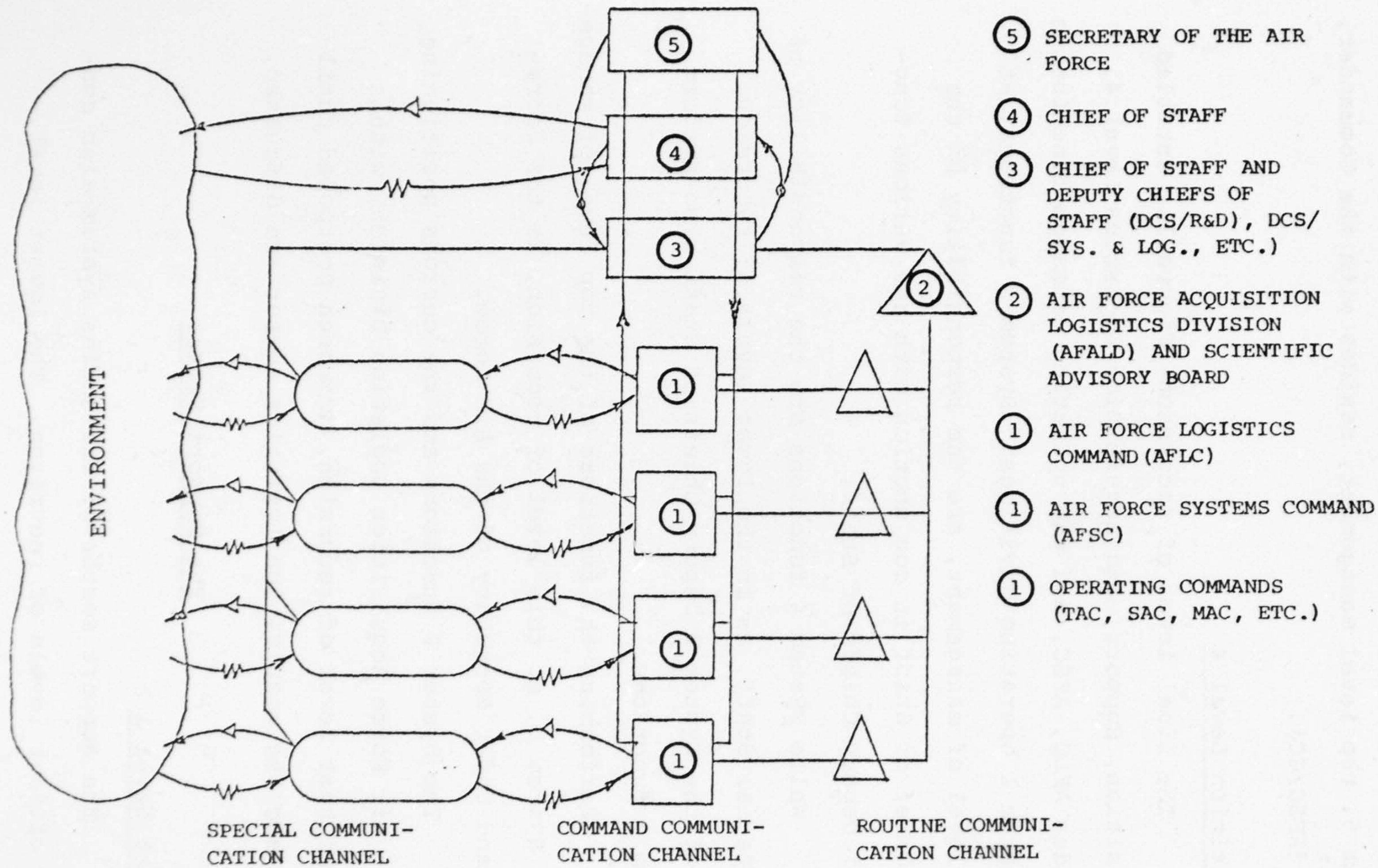


Fig. 11. Acquisition, Support and Acquisition Logistics Level 4

Figure 12, represented in the model presented is headed by the Directorate of Material Management (DMM), within a particular Air Logistics Center.

At this level of recursion, the operating division (System 1) involved with engine management is the Propulsion Management Division (MMP). The System 2 functions take the form of periodic reports, staff meetings, ad hoc committees, and personnel meetings between the Deputy Director and the managers of the operating divisions.

System 3, the Deputy Director of Materiel Management, also performs some of the functions of System 4, such as developing purpose and monitoring the external environment. Other System 4 functions are performed by the operating divisions when dictated by the DMM; these include providing functional expertise, planning and managing specific projects, and designing systems of measure.

The Director of Materiel Management (DMM) functions as the System 5 at this level of recursion. Additionally, there is considerable interaction between the Director and his Deputy; the Deputy Director could function as a System 5.

Support Level 2

The next higher recursion level is shown in Figure 13. At this level, the model represents as the system, two of the Air Logistics Centers having propulsion engine

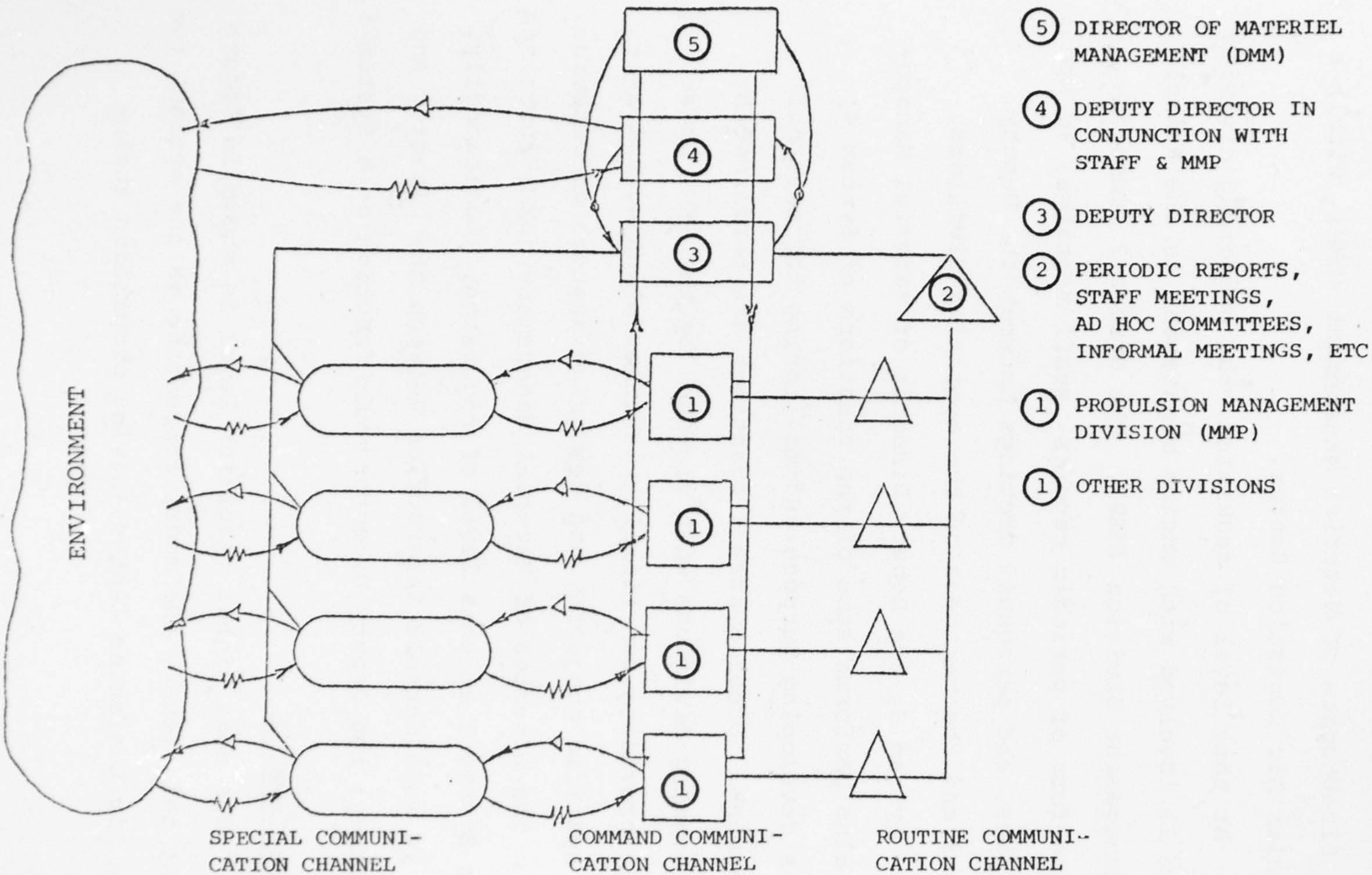


Fig. 12. Support Level 1

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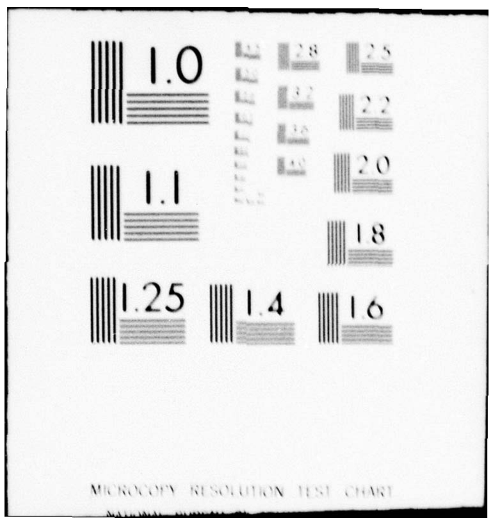
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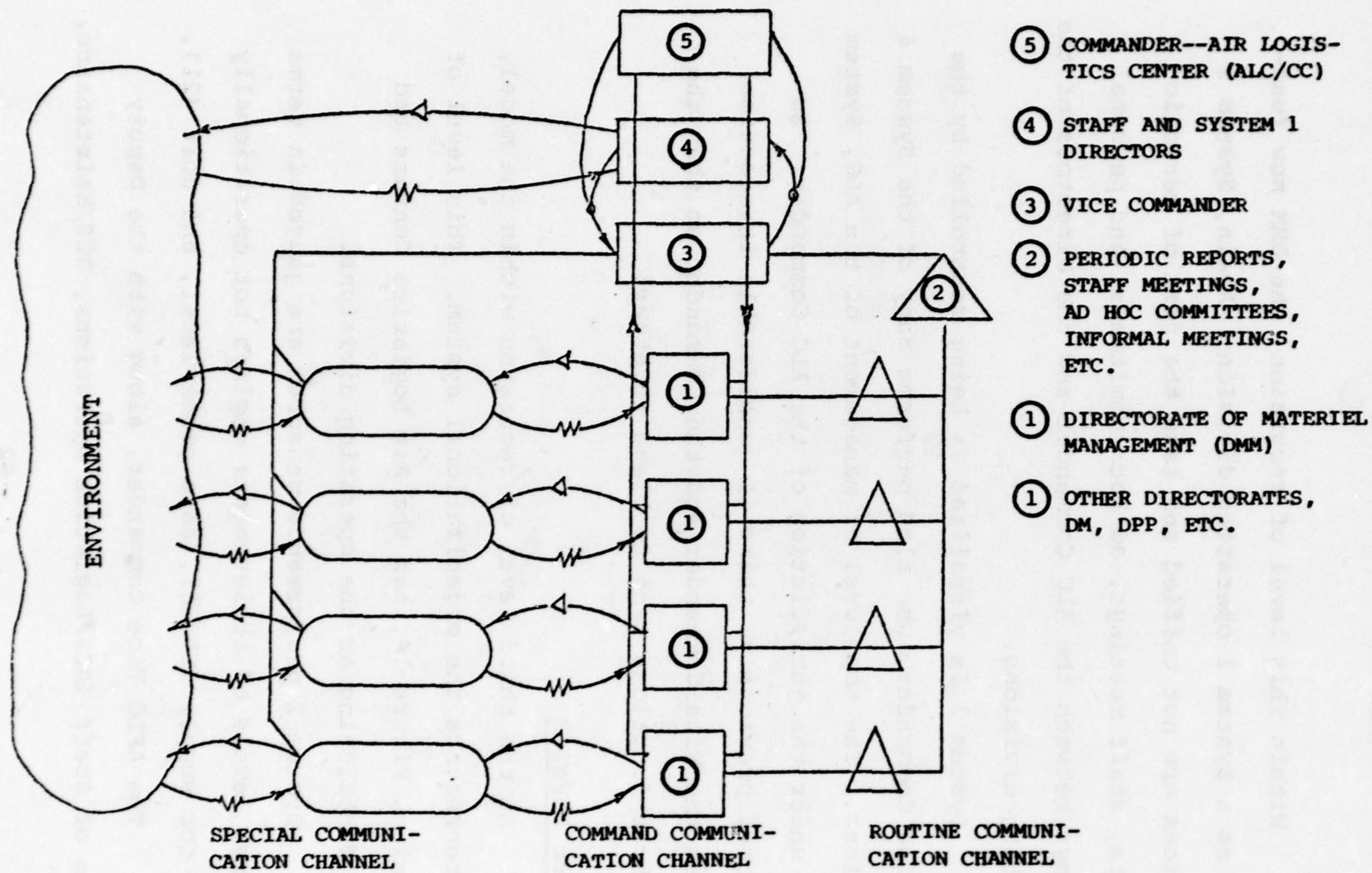


Fig. 13. Support Level 2

management responsibility, San Antonio ALC and Oklahoma City ALC.

Within this level of recursion, the DMM now functions as a System 1 operating division. Again, System 2 functions are not unified and take the form of periodic reports, staff meetings, ad hoc committees, and personal meetings between the ALC Commander and the Directors of the operating divisions.

System 3 is visualized as being controlled by the ALC Vice Commander, who also performs many of the System 4 functions. The top level of management of the ALC, System 5, is under the jurisdiction of the ALC Commander. As indicated previously, there is considerable interaction between the Vice Commander and the Commander so that the top three functions tend to blend together.

## Support Level 3

At the third level of recursion within the model, AFLC represents the organizational system. This level of recursion, Figure 14, has the Air Logistics Centers and AFALD functioning as the operating divisions.

System 2 performance measures are gauged in terms of three levels of achievement: engines not operationally ready for supply (ENORS), base stock level, and cost (21).

The AFLC Vice Commander, along with the Deputy Chiefs of Staff (DCS/Logistics Operations, DCS/Maintenance,

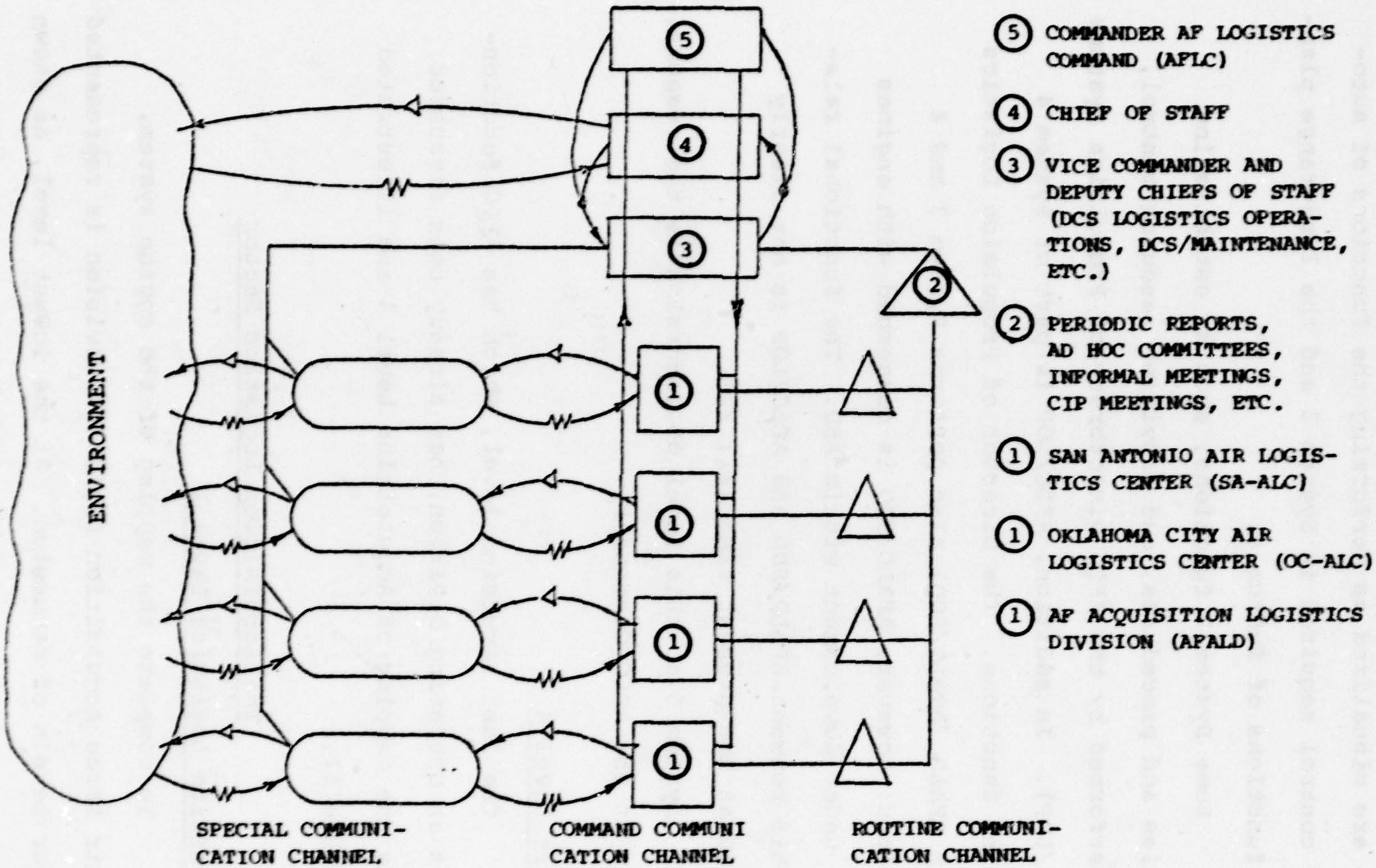


Fig. 14. Support and Acquisition Logistics Level 3

etc.) are visualized as performing the functions of autonomic control required in System 3 and the long-range planning functions of System 4.

Some System 3 functions, such as establishing policies and procedures, and providing resource control, are performed by the AFLC Directorate of Propulsion Systems (AFLC/LOP). In addition, AFLC/LOP is part of System 4 planning functions. The Director of Propulsion Logistics within AFALD (AFALD/SDD) also performs System 3 and 4 functions; however, AFALD/SDD is concerned with engines still under development within ASD. The functional relationship between AFALD/SDD and AFLC/LOP is not clearly defined at the present time (21; 22).

System 5 at this level of recursion is the responsibility of the AFLC Commander.

### Support Level 4

The last recursion level, which has AFLC functioning as an operating division, has already been discussed during the mapping of Acquisition Level 4 and illustrated in Figure 11.

## The Acquisition Logistics Sector

### Acquisition Logistics Level 1

To complete the mapping of the engine system, the Air Force Acquisition Logistics Division is represented by four levels of recursion. At the lowest level, as shown in Figure 15, the Directorate of Propulsion Logistics (AFALD/SDD), functions as a System 1 operating division.[1] Other operating divisions are the Directorate of System Programs (AFALD/SDM), and the Deputy Program Managers for Logistics (DPML), who are co-located within ASD, ESD and SAMSO.

The System 2 functions at this level are much the same as the other System 2 functions previously described. These functions take the form of periodic reports, staff meetings, and informal discussions. The System 3 and 4 functions are the responsibility of the Assistant Deputy for Acquisition Programs and his staff. The Deputy for Acquisition Programs (AFALD/SD) performs the top level management functions, System 5.

Acquisition Logistics Level 2

The highest level within AFALD is shown in Figure 16. At this level, AFALD/SD functions as one of the System 1 operating divisions. Among the other operating divisions are the Deputy for Acquisition Plans and Analysis (AFALD/XR) and the Deputy for Readiness Development (AFALD/AQ).

The System 2 structure is similar to the System 2 of the Acquisition Logistics Level 1. Corporate level management, Systems 3, 4, and 5 are presently being shared by

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[1] AFALD/SDD is co-located with ASD; within ASD its office symbol is ASD/YZL.

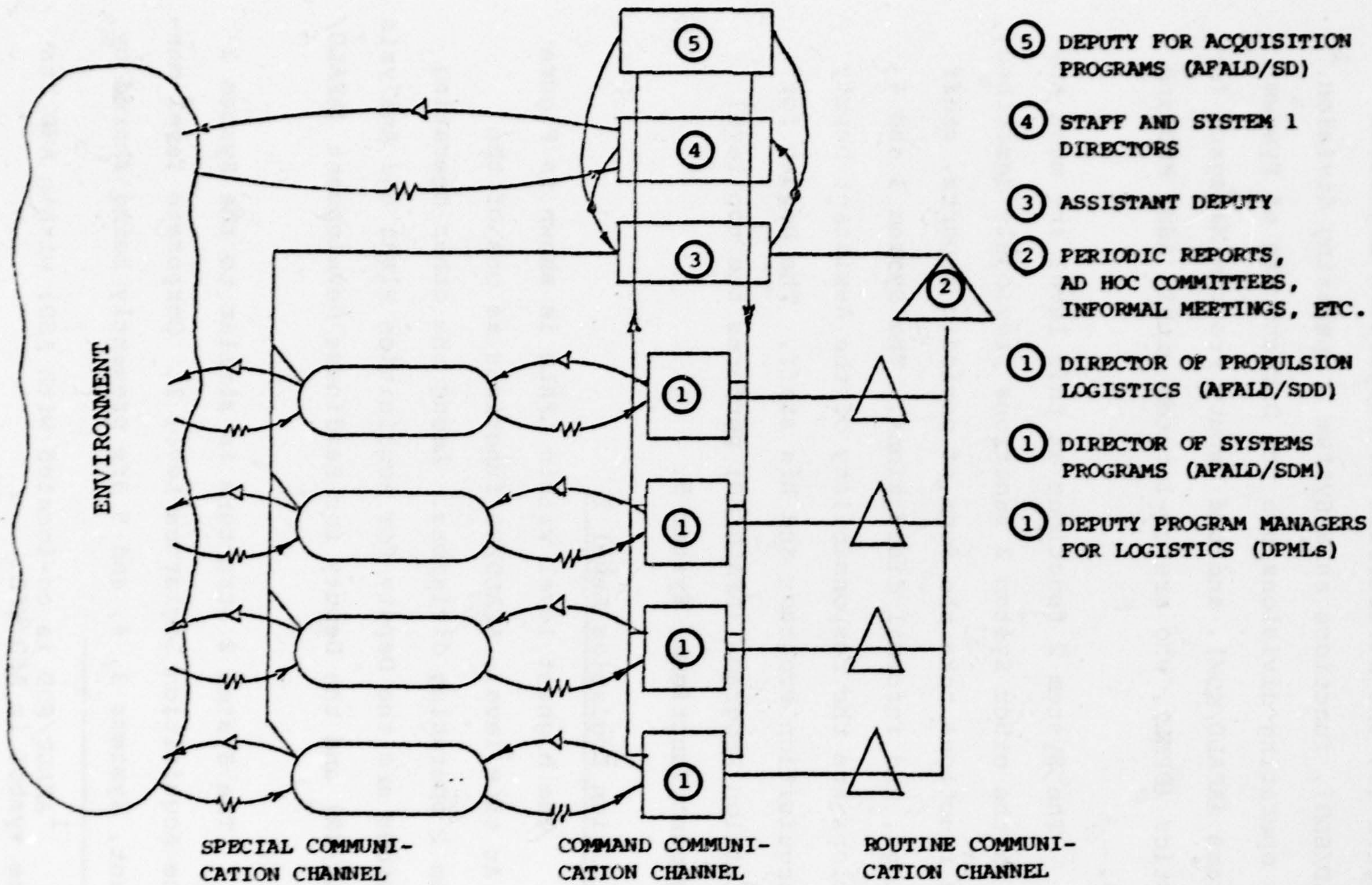


Fig. 15. Acquisition Logistics Level 1

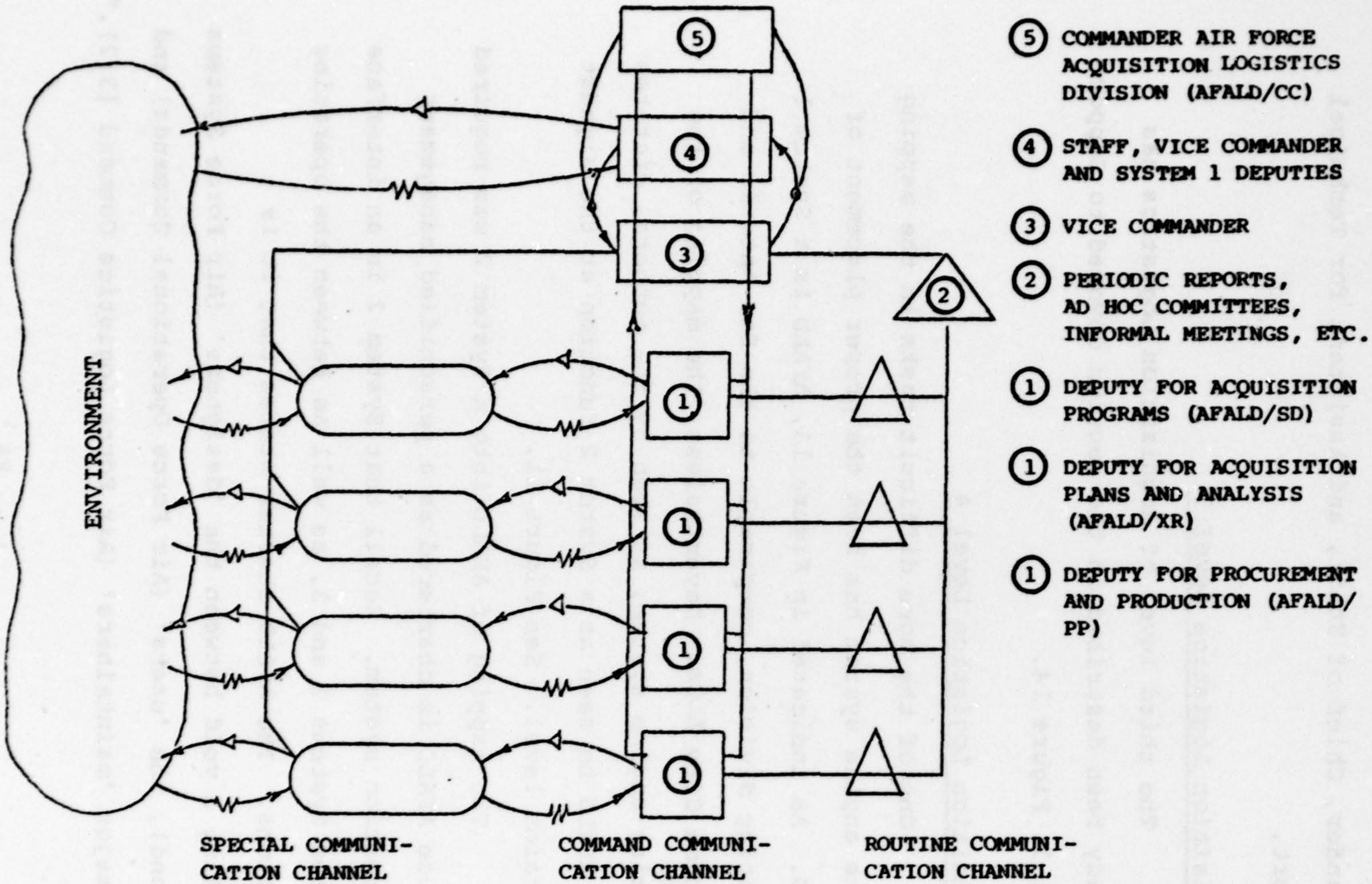


Fig. 16. Acquisition Logistics Level 2

the AFALD Commander, Vice Commander, Assistant to the Commander, Chief of Staff, and Assistant for Technical Support.

Acquisition Logistics Level 3

The third level of Acquisition Logistics has already been described in the section devoted to Support Level 3, Figure 14.

Acquisition Logistics Level 4

One of the more difficult tasks in the mapping of the engine system has been the proper placement of AFALD. As indicated in Figure 13, AFALD is a System 1 operating division, comparable to the San Antonio and Oklahoma City ALCs. Nevertheless, the mapping of the existing engine system, as seen by the authors, dictates that AFALD be seen as a System 2 function at the highest recursion level. See Figure 11.

The mapping of AFALD into a System 2 was required because AFALD is chartered as a personified management information system. Recall that System 2 is an interface between Systems 1 and 3, as well as between the operating divisions. The AFALD charter states that it is "Filling a void between the 'designers' (Air Force Systems Command), the 'users' (Air Force Operational Commands) and the major 'maintainers' (Air Force Logistics Command [3:2]."

This appears to be an excellent charter for a System 2 organization.

## The Engine System

The final step in mapping any system can be thought of as linking the particular sectors representing the various levels of recursion into one "macro-system." This system is illustrated in Figure 17, A Recursive Model of the Engine Acquisition and Support Management System.

## Summary

The preceding analysis represents the authors' mapping of the existing engine system onto a cybernetically designed management model. Isolation of specific functions, or what the model refers to as systems, was often difficult to achieve. Systems 3, 4, and 5, representing corporate level management, were neither well defined, nor clearly separated functions. Additionally, the authors found System 2 to be particularly undefined, especially within the higher recursion levels.

A final problem encountered in using the management cybernetic model, as opposed to a more orthodox organizational relationship model, was learning to overcome the tendency to fix one's attention on formal, instead of functional relationships.

The cybernetic model focuses on identifying those functions which are required of any viable organization,

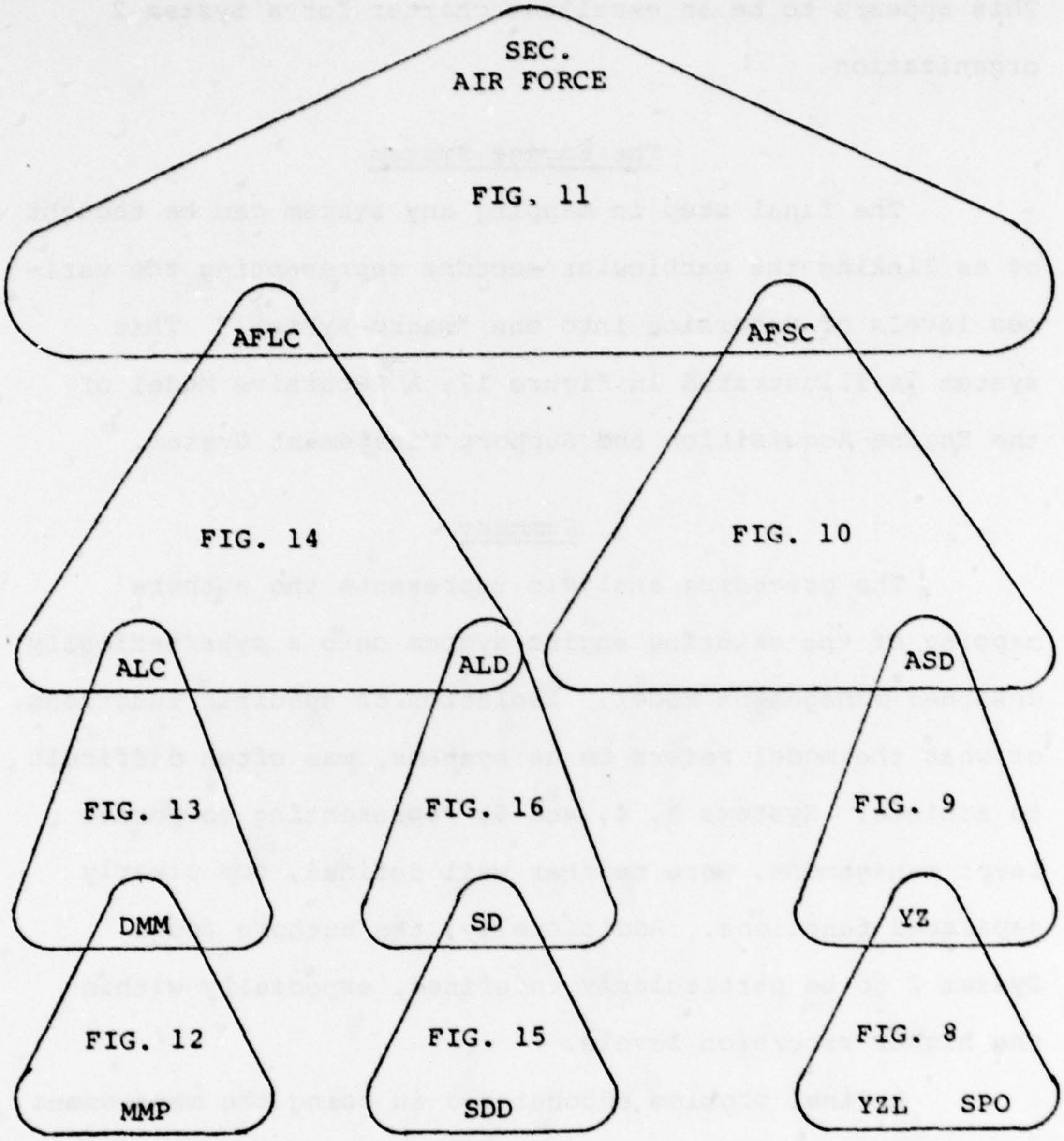


Fig. 17. A Recursive Model of the Engine Acquisition and Support Management System

whereas, a more conventional approach is primarily concerned with formal relationships within an organizational structure. AFALD is a good example of this difference. While the organizational charts show AFALD as an operating division of AFLC, AFALD is performing an interface function at the next higher recursion level. "Systems ought not to be considered in their appearances, but in their formal structures as information networks operating as sets of decision functions [8:24]."

# CHAPTER V

# CONCLUSIONS AND RECOMMENDATIONS

This final chapter is divided into three sections. The first section is devoted to an analysis of the engine system based on the mapping of the system in Chapter IV. In the second section, the results of the analysis are used to answer the research questions posed in the first chapter of this study. Finally, the last section presents recommendations on the restructuring of the engine system based on the principles of the management cybernetic model.

## An Analysis of the Engine System

The mapping of the engine system in Chapter IV revealed three major problem areas: (1) a fractionalized System 3 at the highest recursion levels, (2) an inadequate System 2 at all levels of recursion, and (3) an apparent inappropriate placement of the Air Force Acquisition Logistics Division within the Air Force organizational structure. Each of these problem areas is discussed separately.

### Fractionalized System 3 at the Highest Recursion Levels

The fractionalization of System 3 occurs at the highest recursion levels of the acquisition and support sectors (see Figure 10 and 14). It is, however, at the Headquarters USAF level of recursion that this fractionalization of System 3 is most critical. At this level the purpose of the engine system should be established and transmitted to the operating divisions, AFLC, AFSC, and the operating commands (see Figure 11). This purpose, established by Headquarters USAF, then becomes the basis on which the operating divisions structure their organizations. The organizational structures must be consistent and in support of this established purpose.

Figure 11 shows that the System 3 functions are being performed by the collective action of a consortium of Deputy Chiefs of Staff, each having an area of functional responsibility; i.e., Research and Development, Systems and Logistics, etc. These Deputy Chiefs of Staff have established their own routine and command communication channels with their corresponding functional areas at the lower recursion levels. This creates multiple communication channels and is, therefore, a violation of the management cybernetic model. The model dictates that System 3 be a single focal point for controlling the operating divisions.

The control of a large, complex organization such as the engine system is difficult. The problem is a general one of controlling the variety[1] generated by any large, complex system as described in Chapter I. This problem was addressed by Ashby in An Introduction to Cybernetics (6). His answer to the problem was the concept of "requisite variety" (6:207). Beer, who also addressed this problem of variety, believed that there is a variety equation which must be in balance. This equation requires that the variety of a system be balanced by the variety of its controller (10:18-34). This concept of balancing is the same as Ashby's requisite variety.

Imbalances are resolved in one of two ways. Either the system's variety is attenuated, or the controller's variety is amplified. The operating divisions are organized by functional or departmental areas, an attenuation process. Or, corporate level management creates functional management offices corresponding to the operating divisions, an amplification process. A common practice by organizations is to use a combination of attenuation and amplification (10:18-34).

The amplification process, of creating functional specialists within corporate level management, results in fractionalized control within System 3. Beer contended that the answer to the problem lies in the proper use of the computer, the only tool which can assist management in

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[1]Variety is the scientific term for complexity; the variety of a system is its number of distinguishable states (9:251).

providing requisite variety without fractionalization (10: 18-34). With the computer in the variety equation, the issue becomes a technical problem of developing an effective management information system, a System 2 function which is the next problem area discussed.

## An Inadequate System 2

The information system (System 2) is the key to controlling the dynamics of an entire organization. Information (for example, quantification of performance) is the basis for decisions, and, consequently, it drives the entire system (7:206).

The authors' research revealed that the management information system was the least adequate of all five systems required by the model. *In the engine system there is no System 2 as envisioned by the management cybernetic model at any recursion level.* The model requires that performance information be simultaneously available to the operating divisions and the System 3 controlling agency. Performance information in the engine system is in the form of periodic reports, staff meetings, written correspondence, informal meetings, etc. However, much of this information is out of date and subject to misinterpretation. In many cases there is little, if any, information flow between the operating divisions. The existing information systems clearly do not conform to the requirements of the model.

If the existing management information systems are inadequate, what then is required? Beer visualized an effective management information system as a computer network connecting the operating divisions and the controlling System 3 (7:159). Such a system can be readily developed with existing technology. The key to such a system is not to choke it with data, but to supply it with information.

> It is important to realize the distinction between data and information. Data are facts collected from observation or measurements. Information is the meaningful interpretation and correlation of data that allows one to make decisions [25:3].

Christopher in "Achievement Reporting--Controlling Performance Against Objectives" provided an excellent discussion on this subject. He stated,

> Control is the process of information flow that guides action to achieve purpose. . . . Control decisions are not so much imposed from higher management but more the result of information flow. . . . [13:14].

A System 2 management information system, as required by the cybernetic model, can be achieved by developing an appropriate computer software package. This software package would incorporate the concepts of performance indices (7:206-212) and achievement reporting (13:14-24).

## Inappropriate Placement of AFALD

As stated earlier, one of the most difficult tasks in mapping the engine system onto the cybernetic model was the correct placement of AFALD. AFALD's function is to fill a void between AFLC, AFSC and the operating commands; this is clearly a System 2 function within the highest recursion level. However, AFALD is a System 1 operating division within AFLC.

This disparity between the functional role of AFALD and its placement within the AFLC organizational structure has created conflict. As an example, the Directorate of Propulsion Systems (AFLC/LOP) views the Directorate of Propulsion Logistics (AFALD/SDD) as a System 1 operating division, similar to an Air Logistics Center, to which it dictates propulsion management policy. However, the functions of AFALD/SDD are not the same as a System 1, but rather that of a System 2. Furthermore, AFALD/SDD views itself as a policy-making office (a System 4 function) on new engines, similar to AFLC/LOP's role on engines which have gone through PMRT.

The observed conflicts can be resolved by the management cybernetic model. AFALD, since it is performing a System 2 function of the highest recursion level, should be an Air Staff organization. In this placement, AFALD would be performing an interface function between AFSC, AFLC, and the using commands in conformance with its charter as an arm of the Air Staff.

## Answers to Research Questions

The primary PMR recommendation, the establishment of an Air Staff organization accountable for propulsion engines, provided the basis for this research effort. Specifically, the research was aimed at answering the following questions:

1. Would the establishment of corporate level management resolve fundamental problems identified within the existing system?

2. If such an organization is to be established, what should be its scope and responsibilities?

The analysis in the previous section illustrated the deficiencies of the engine system. One of these deficiencies was the fractionalized System 3 at the highest level of recursion. The principal PMR recommendation was interpreted by the authors to mean the establishment of a separate Deputy Chief of Staff for Propulsion. However, a separate DCS/Propulsion would, in fact, add to the fractionalization which has already been identified as a major problem.

This recommendation, if implemented, would be another example of trying to provide requisite variety by amplification of control through the creation of functional specialists, a technique previously discussed and shown to be inefficient. The most efficient answer to the problem of providing requisite variety is an effective management information system.

Since the establishment of a separate DCS/Propulsion is not consistent with the requirements of the management cybernetic model, this research concludes that it would not resolve the fundamental problems of the engine system.

The second research question was predicated on a positive answer to the first question. The negative answer makes the second question moot.

## Recommendations

Based on the principles of the management cybernetic model, the following recommendations are presented:

1. The creation of a System 2 management information system as envisioned by the model. This will require research to:

    a. determine the aggregated measures of performance at the operating divisions within each recursion level.

    b. determine the computer software requirements to process the performance measures.

2. The establishment of AFALD as an Air Staff organization to enable it to carry out its charter of filling the void between the "designers" (AFSC), the "users" (operating commands), and the "maintainers" (AFLC).

3. The creation of a unified System 3, at the highest level of recursion, to be responsible for the control of the acquisition, support and operating functions. Figure 18, a Conceptual Model, illustrates an organizational structure incorporating a unified System 3.

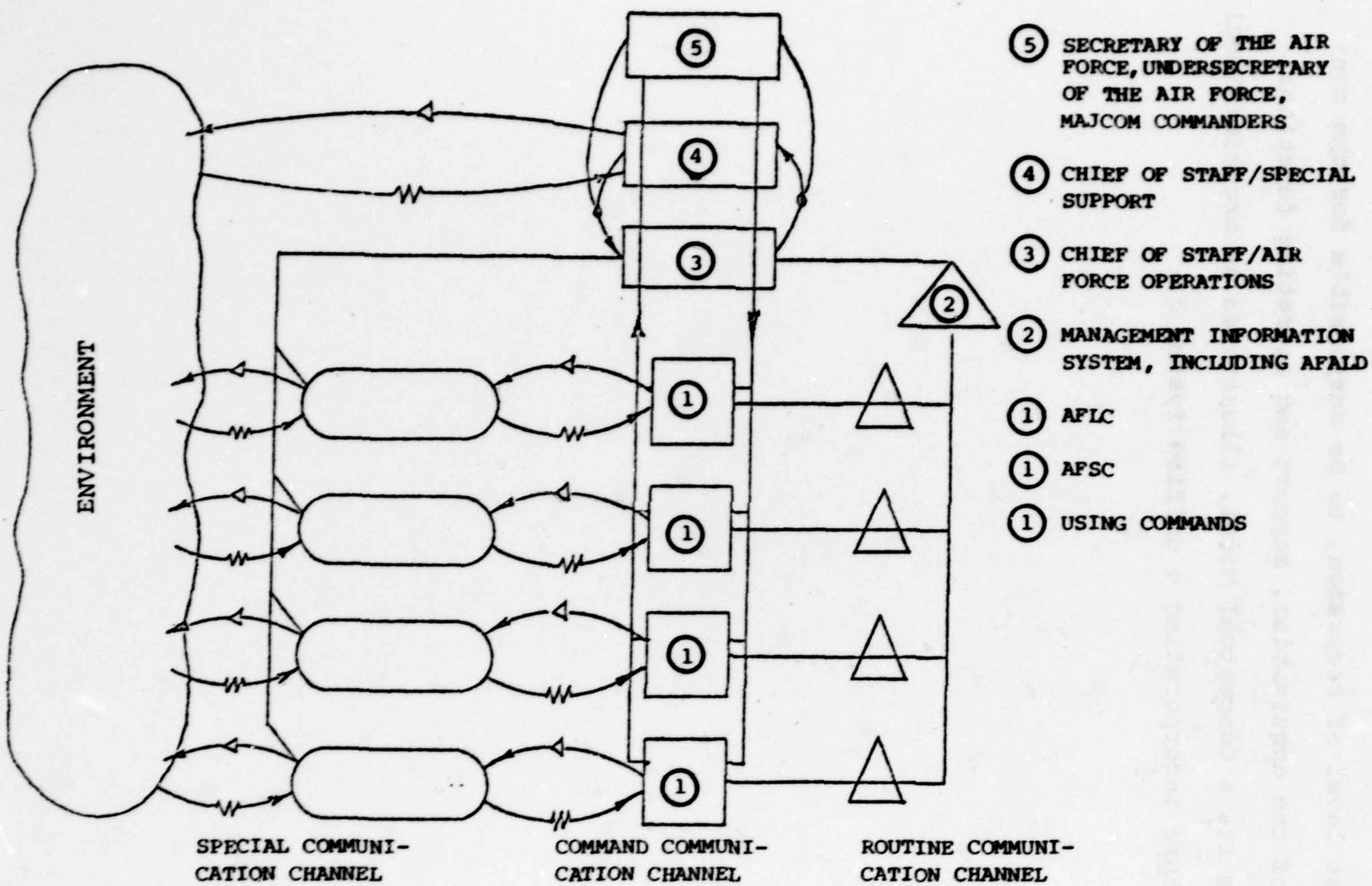


Fig. 18. A Conceptual Model

APPENDIX

JET ENGINE MANAGEMENT STUDIES

TABLE 1

MAJOR ENGINE STUDIES (29:I-1)

| | |
|---|---|
| Chandler-Snavely Report: | Management of Engineering Changes During Acquisition, January 1970 |
| ARINC: | A Study of the Aircraft Jet Engine Maintenance Program, May 1970 |
| JLC Panel: | A Study of the Aircraft Engine Acquisition Process, February 1971 |
| LMI Study: | Methods of Acquiring and Maintaining Aircraft Engines, June 1972 |
| GAO Report: | Problems in Managing the Development of Aircraft Engines, June 1973 |
| USAF SAB Report: | Ad Hoc Committee on Engine Development, August 1973 |
| NASA Report: | Economic Effects of Propulsion System Technology, July 1974 |

TABLE 2

RAND ENGINE STUDIES (29:I-2)

| |
|---|
| Policy Considerations in the Life-Cycle Process of Aircraft Turbine Engines: A Progress Briefing, November 1975 |
| Performance/Schedule/Cost Trade-Offs and Risk Analysis for the Acquisition of Aircraft Turbine Engines: Applications of R-1288-PR Methodology, June 1975 |
| Estimating LCC: A Case Study of A-7D, February 1975 |
| A Weapon-System Life-Cycle Overview: The A-7D Experience, October 1974 |
| Relating Technology to Acquisition Costs: Aircraft Turbine Engines, March 1974 |
| Technological Change Through Product Improvement in Aircraft Turbine Engines, May 1973 |
| Measuring Technological Change: Aircraft Turbine Engines, June 1972 |
| Estimating Aircraft Turbine Engine Costs, September 1970 |
| A Critique of Turbine Engine Development Policy, April 1970 |
| Aircraft Turbine Engines--Development and Procurement Cost, November 1965 |
| The Impact of the High Development Cost of Advanced Flight Propulsion Systems on Development Policy, October 1965 |

TABLE 3

ON-GOING ENGINE STUDIES (29:I3-4)

| Title | OPR | Initiator | Start | Scheduled Completion |
|---|---|---|---|---|
| PMR Aircraft Engine Acquisition and Support | AF/LGP | AF/LG | Apr 75 | Feb 76 |
| AF Aircraft Engine Acquisition | USAF IG | Hq USAF | Aug 75 | Feb 76 |
| Jet Engine Management | RAND | AF/RD | May 75 | Jun 77 |
| Engine Acquisition | AF/LGYY | AF/LG | Apr 75 | Open |
| Engine Health Monitoring System Evaluation | AFLC/MMP | Hq USAF | Jun 74 | Jun 77 |
| Spare Engine Requirements | AF/LGY AF/LGX | AF/CC | Jan 75 | Open |
| SAB Ad Hoc Committee Turbine Engines | AF/NB | AF/CC | Sep 75 | Jan 76 |
| SAB Ad Hoc Committee Gas Turbine Technology | AF/NB | SAF/RD | Nov 74 | Jan 76 |
| Comprehensive Engine Management System | AFLC/MMP | Hq USAF | Mar 75 | Open |

TABLE 3--Continued

| Title | OPR | Initiator | Start | Scheduled Completion |
|---|---|---|---|---|
| Systems & Resource Mgt Action Group System Support Panel | AF/SRMAG | AF/CC | Jul 75 | Jan 76 |
| Max TBO/Inspection Requirement Review | AFLC/MMO | AF/LGY | Oct 74 | Open |
| MSG-2 Review | AFLC/MMPC | AFLC/MMP | Apr 75 | Mar 76 |
| Air Pollution from AF Engine Test Facilities | AFLC/DEPR | AF/PREV | Apr 75 | Open |
| Power Management Reduced Thrust Takeoff | AF/XOO<br>AF/LGY | AF/CC | Sep 75 | Open |
| Contractor Warranty & Liability Study | ASD/RW | AFSC | Oct 75 | Dec 75 |

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