



PROBLEM SOLVING IN GOVERNMENT

PROJECT MANAGEMENT

by

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B.I.E., Georgia Institute of Technology

(1954)

SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

1966

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25 Grantland Road
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May 13, 1966

Professor William C. Greene
Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Dear Professor Greene:

In accordance with the requirements for graduation, I herewith submit a thesis entitled "Problem Solving in Government Project Management."

I wish to express my sincere appreciation to Dr. Arthur Rudolph, Saturn V Program Manager and Mr. Leland Belew, Engine Program Manager, of the National Aeronautics and Space Administration's George C. Marshall Space Flight Center, who enthusiastically endorsed the study; and to the project managers, and their associates, who gave generously and willingly of their valuable time to provide the information necessary for the completion of the field research. In addition to those who provided the basic information, I would like to express my appreciation and indebtedness to Professors Donald G. Marquis and Robert L. Kahn for their able assistance, patience, and detailed suggestions and criticisms.

Sincerely.

Elmer Loux Field, Jr.

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in

GOVERNMENT PROJECT MANAGEMENT

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Submitted to the Alfred P. Sloan School of Management on May 13, 1966, in partial fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

Project managers, who head small government project groups, are responsible for coordinating the technical and management efforts of government sponsored research and development under contract to industrial firms. To successfully discharge their duties, the managers must deal with many individuals -- both within the government and in contractor organizations. Since most of the project work is accomplished by individuals located in organizations which are not under their direct control, the managers attempt to persuade and motivate their "associates" to accomplish work tasks and solve problems within acceptable technical, cost, and schedule constraints.

The purpose of the thesis was to study the organizational and work relationships of the various groups which relate to the project manager in the process of solving project problems and, to determine the methods used and results obtained in resolving such problems.

Questionnaire and interview techniques were used to collect data from seven NASA launch vehicle and engine project groups. The projects selected were, for the most part, manned by different in-house and contractor groups. The projects were interdependent, however, because of interface requirements -- necessary for eventual integration of each project's hardware into a single composite launch vehicle system. The intent was to obtain data about specific problem situations from project managers and their associates who had helped solve the problems.

Variables relating to problem solving techniques are correlated with problem solution outcome and method of resolution parameters. Mean values of evaluated solution outcomes for several problem categories and organizational groups are compared and analyzed. This work was done in part at the M. I. T. Computation Center.

(Abstract Continued)

It was determined that technical problems generally result in more satisfactory outcomes than program problems; satisfactory solutions to problems result from use of mutual agreement resolution techniques; and, that projects with fewer in-house government personnel working on them have more satisfactory technical problem solution results than projects employing a higher number of government personnel.

Thesis Advisor: Donald G. Marquis

Title: Professor of Industrial Management

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CHAPTER I

I. INTRODUCTION

1. The Project Manager's Role

The project manager, whose responsibilities and problems are studied in this thesis, is an agent of the government. He is the head of one of many small project groups used by government agencies to coordinate the technical and management efforts of government sponsored research and development being conducted by industry. It is the project manager's responsibility to resolve all problems which may arise during the course of project development.

Together with his immediate subordinates, the project manager leads the government-contractor team through all phases of work from original planning, design and development on through to production and delivery of the finished hardware. He is responsible for preparing operating plans, schedules, approving allocation and commitment of funds, and formulating technical work requirements to be performed under prime contracts.¹

To successfully discharge his responsibilities, the project manager must deal with individuals representing a wide range of functional disciplines. He receives technical advice and requirements from the government research and development (R & D) laboratories; policy guidance from his supervisors and staff elements; and support in evaluating data and reaching decisions from his immediate subordinates and the resident project group located at the contractor installation. Members of all these groups,

1

Unpublished policy memorandum distributed internally to the organization studied.

including contractor personnel, are referred to individually as the project manager's project associates, and collectively as the project manager's associate groups.

A project manager is continually besieged with requests for changes to the project from his project associates. Occasionally the requests are at variance with the desires, policies or judgments of other associates and sometimes in conflict with the project manager's own best judgment. Situations of this nature represent conflict of some degree which must be resolved. Since it is the project manager's responsibility to solve all problems -- both technical and management -- which may arise during the course of a project, problem solving, through use of multiple input from his project associates, becomes his major function.

2. Purpose of the Study

A general study of the project management model will be presented in order to identify associate groups which provide technical and managerial input to the project manager. The manager's relationships with his project associates, including communication patterns, will be discussed, along with project performance pressures and questions which must be considered prior to making decisions.

The specific purpose of this thesis is to study certain problem situations which were encountered by project managers. An analysis will be made to determine what significant relationships develop between key factors such as class of problem (technical vs. program), associate group influence and the methods used and the outcomes or results obtained in resolving such problems.

The results of this research and analysis hopefully will provide a better insight into the problem solving process in a project management organizational model.

By analyzing problem types which seem to be the most difficult for the project manager to resolve, it is felt that more effective management tools or techniques may be developed to enhance better management of projects in the future.

CHAPTER II

II. STUDY OF THE PROJECT MANAGEMENT MODEL

In this chapter, the project manager's activities are examined in relation to his environment -- the project associate groups with whom he works. The atmosphere or essence of the relationships engendered by the project manager's association with these groups is defined and analyzed. With a background sketch of this type, the reader will visualize and better understand the source of inputs which influence projects -- and the factors which produce conflict or problem situations.

Project associates, both as individuals and as groups, attempt to influence a project usually by requesting changes in the status-quo. Associate groups within the government organization are analogous to Kahn's role sets²; and, in context with the government-contractor relationship, they are analogous to Evan's organizational sets³.

Associate groups are generally identified as entities within the formal organization -- with only a few exceptions. How these groups fit into the organization is explained in this chapter, but first, we will define the type of project organization studied in this thesis, and the functions and authority of a project manager.

1. Organizational Type

Government project management of industrial contracts can take many in-house organizational forms. It can vary from a completely autonomous project group, in which all personnel report on a direct line

²Kahn, Robert L., et al. Organizational Stress: Studies in Role Conflict and Ambiguity. (New York: John Wiley & Sons, Inc., 1964,) p. 13.

³Evan, William M. "Toward a Theory of Interorganizational Relations," Management Science, August 1965, pp. B217-230.

2

to the project manager -- all the way to a completely decentralized functional arrangement where almost all resources, men and money, are controlled by other groups or individuals. In the former, the project manager is the master of his project's destiny; and in the latter, he is a coordinator or expeditor. Somewhere between these two extremes lies the organization which was examined in this study.

Marquis and Straight proposed an organizational typology to distinguish between a project organization and a functional organization, and in addition, they introduced a hybrid of these two, called a matrix organization.⁴ The differences between these types are dependent upon who the personnel report to for work assignments and merit reviews, and where they are physically located. The matrix organization is one in which project personnel, who are physically located within other internal organizations (not the project manager's office), report to the project manager for work assignments, but, are located with, and are responsible to their "functional" home organization for merit review.

The project groups studied in this thesis are classified as the matrix type.

Earlier, Pace classified this same government agency organization as a matrix-overlay organization⁵ in a study of a project manager's influence on technical support groups.

⁴Marquis, Donald G. and David M. Straight, Jr., "Organizational Factors in Project Performance." Unpublished Working Paper at the Sloan School of Management, Massachusetts Institute of Technology, August, 1965, p. 15.

⁵Pace, Robert E., Jr., "A Study of a Project Manager's Influence on Technical Support Groups in a Project Overlay Organization." Unpublished Master's Thesis, Sloan School of Management, Massachusetts Institute of Technology, 1964, pp. 7-8.

2. The Project Manager's Functions and Authority

A dilemma which seems to be associated with the matrix organization (and one to which Pace referred⁶) is that the project manager has responsibility for the project, but does not have authority over the people who do the in-house government work. In effect, individuals from other organizations, who work on a project, are responsive to the project manager; but, at the same time, these individuals are responsible to their functional organization supervisors. Figure I graphically illustrates the authority and work assignment relationships which exist between project managers and their associate groups.

To help maintain control, managers are aided by small groups of subordinates. These small groups, including the project managers, are commonly referred to as the "project offices." Their most time-consuming job is processing and evaluating data which come from the in-house associate groups and from the industrial contractor. Using data processed in this manner, the project manager is forced to make decision choices primarily based on facts, analyses, and recommendations which come from groups over which he has no direct authority.

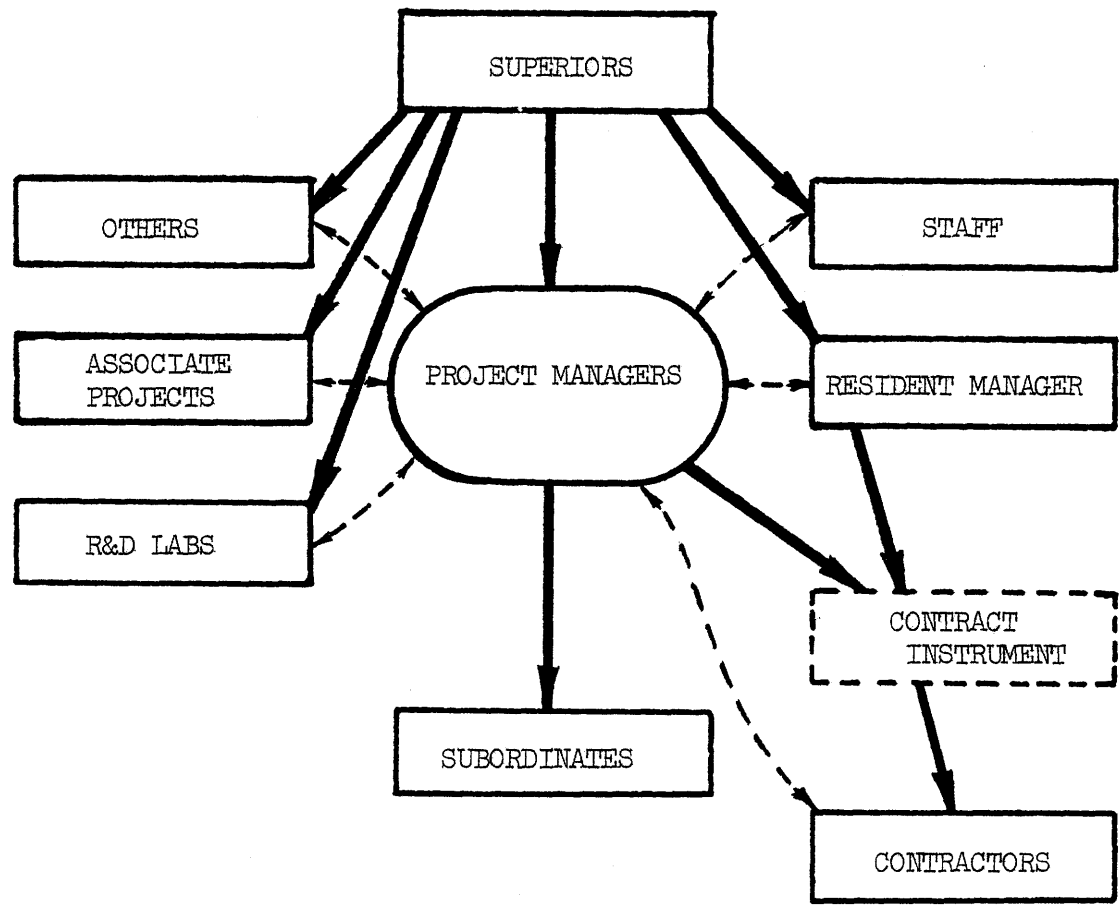
This analysis of a project manager's authority was stated, more succinctly, by Baumgartner who asserted that a project manager's degree of authority is never clearly delineated, and that the only real authority he has is what he can acquire by his own devices.⁷

⁶ibid.

⁷Baumgartner, John S. Project Management. (Homewood, Ill.: Richard D. Irwin, Inc. 1963), p. 75.

FIGURE 1

AUTHORITY AND WORK RELATIONSHIPS
BETWEEN PROJECT MANAGERS AND PROJECT ASSOCIATE GROUPS



—————> Direct Line of Authority (Responsible to the next higher group)

-----> Dotted Line of Project Work Assignments and Coordination. (Responsive to each other)

Note: A communications network actually exists between all groups.

The management manual of the organization studied defines the functions of a project office:

"...to define, direct, review and evaluate the composite government/industry performance throughout the phases of planning, coordination and contractor direction in the design, development, integration, production....and testing...." of project hardware items.⁸

It also states: "...Project Managers are authorized to take the actions necessary to accomplish these assigned functions...." This latter statement is fairly straightforward, however, an element of ambiguity enters the picture when one considers the large size of the projects, and the relatively small number of the project office subordinates available to evaluate the mass of data generated, coupled with the obvious necessity to motivate and persuade other groups to get the work done.

Several years ago, when these projects were first started, policy guidelines were very minimal. In lieu of a codified set of rules and regulations, project managers "did what had to be done" within the limits of common sense, prior experience, and the legal limitations of established procurement regulations. Today, it is observed, policy restrictions are still quite minimal thus allowing room for necessary maneuverability; however, project managers express a feeling that they are "boxed-in" by a steadily increasing number of forms and procedures. It is probable that the procedures and other government paraphernalia came into usage through necessity, dictated by a need for uniform information systems at higher management levels. On the other hand, some of the procedures, like configuration management, were instituted to aid the project manager to control engineering changes and documentation.

⁸ Unpublished policy memorandum distributed internally to the organization studied.

3. Associate Groups Within the Organization

Associate groups generally relate to the project manager in the manner described in the preceding section (see Figure 1). The purpose of this section is to define where the groups come from within the formal organization.

The organization studied is the largest field unit of a federal agency. Its formal organizational chart is broken down into three basic elements. Figure 2 schematically illustrates this breakdown, showing the basic elements of top management, staff and operations. Top management includes the center director, deputies and assistants. Staff includes, among others, legal, labor relations, and audit. Services is another staff function which takes care of purchasing, finance, and personnel. The operational level at the center, where the mission responsibility lies, is comprised of research and development operations and industrial operations organizations. Industrial operations is discussed first in the following paragraphs because that is where the project offices are located.

Industrial Operations

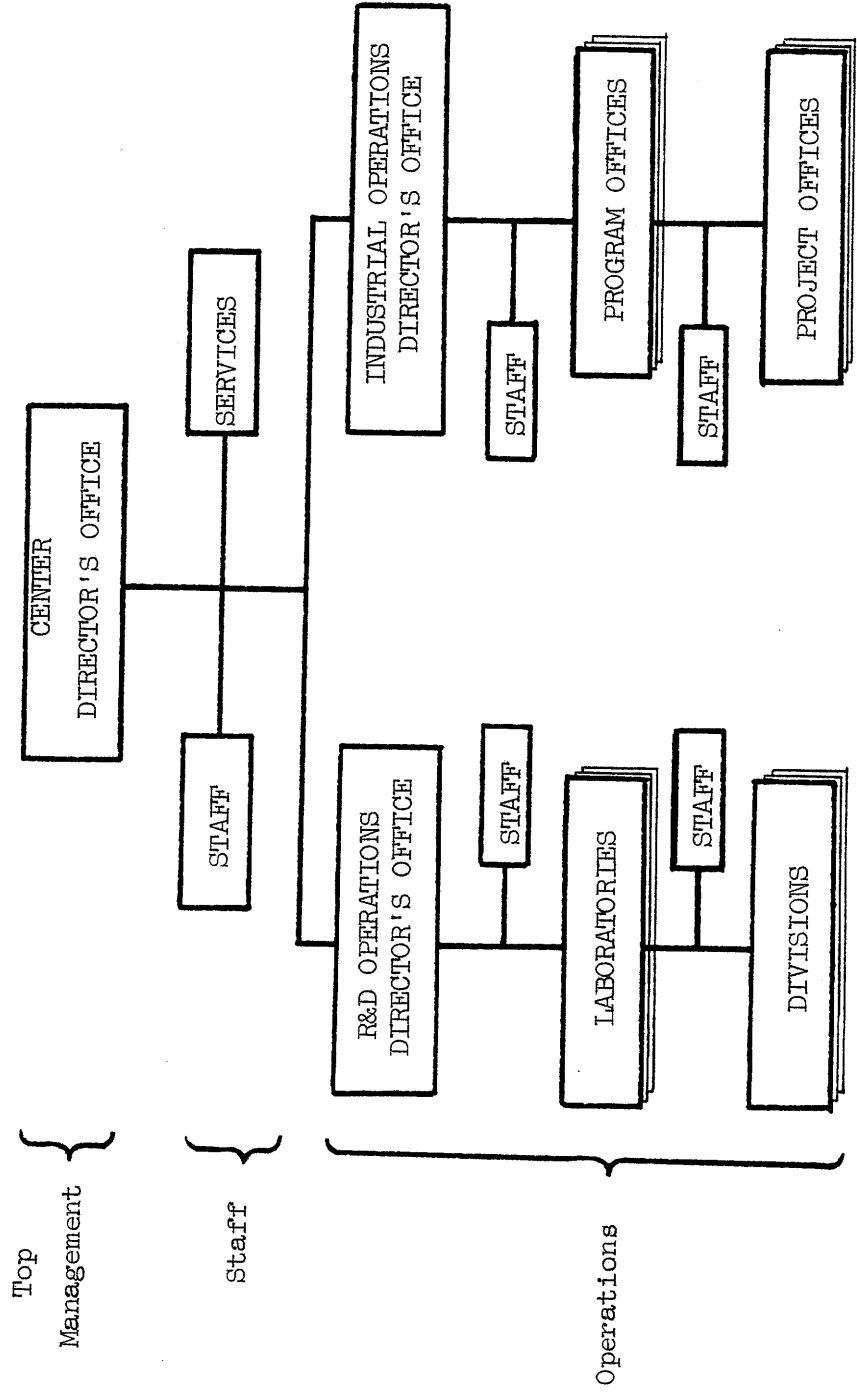
In general, design and production of project hardware by industry is directed by the industrial operations.

The industrial operations director, like the center director, has staff and operational elements directly under him.

If one considers the industrial operations director as top management of industrial operations, with a staff all his own, program offices represent the operational level within that organizational division. Furthermore, one can consider the program office in the same manner, where

FIGURE 2

FIELD CENTER ORGANIZATION



the program managers have staff elements with project offices as their operational level. Typical program office and project office organizations are shown in Figures 3 and 4, respectively.

Program managers, the industrial operations director and the center director are all classified as the project manager's superiors in the project associate groupings of this study. Also, most staff offices are considered as one project associate group -- whether they are located at the center, industrial operations, or program office levels.

A project manager has subordinates who perform essential functions. Those personnel working under his immediate control take care of the program control, engineering, development, manufacturing, and test and evaluation functions. Other personnel physically in his area on special assignments, in the "responsive to" the project manager sense, take care of contracting and facilities functions. All these groups, including those specially assigned, are considered as the project manager's subordinates -- another associate group designation for this study.

One feature of the project organization is the use of resident managers who are physically located at an industrial contractor's plant where the development task is actually being performed. Project managers assign a small number of their personnel to resident offices. A greater number of center personnel, such as laboratory engineers and contracting officer representatives, are assigned to the resident manager to contribute advice or services in the area of their functional speciality or profession. This entire group of center personnel located at the contractor's plant is considered as the project manager's resident associates in this study.

FIGURE 3
 TYPICAL PROGRAM OFFICE ORGANIZATION

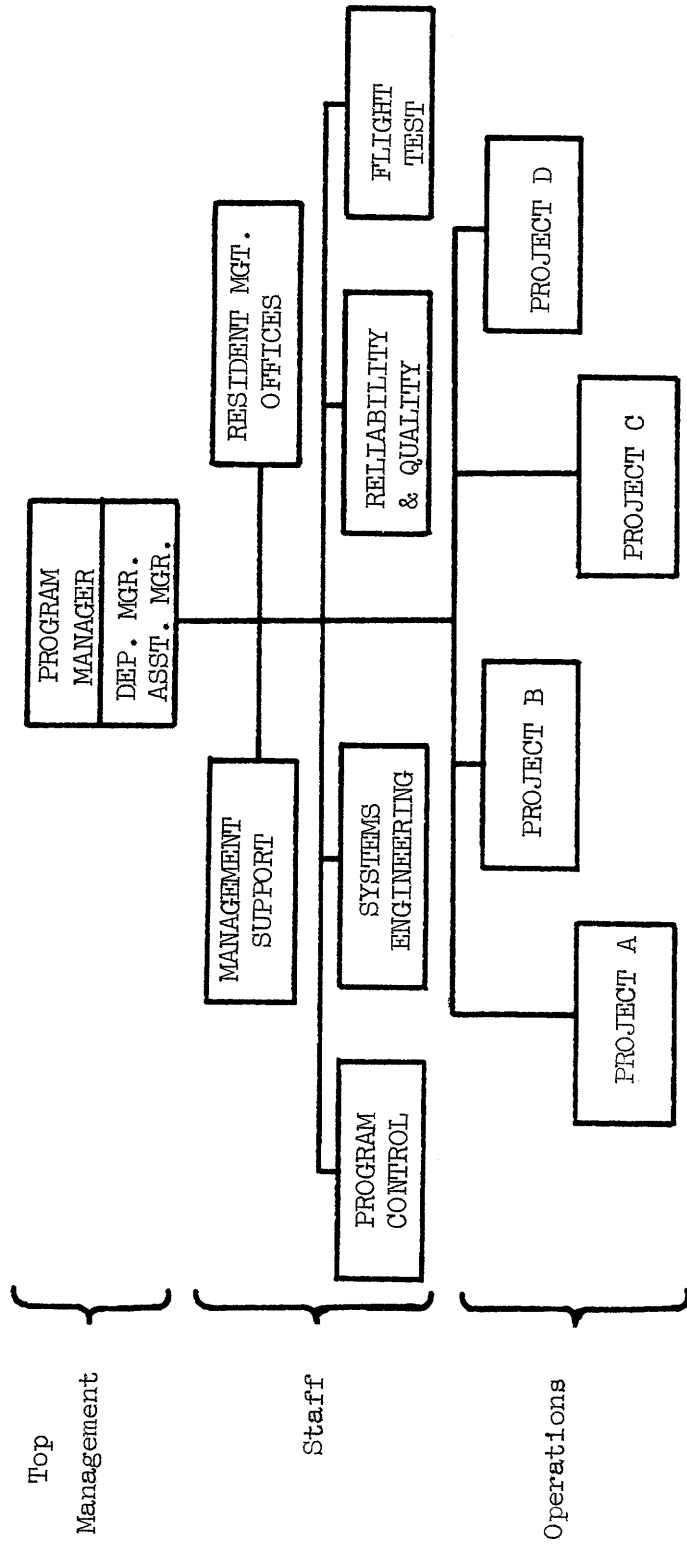
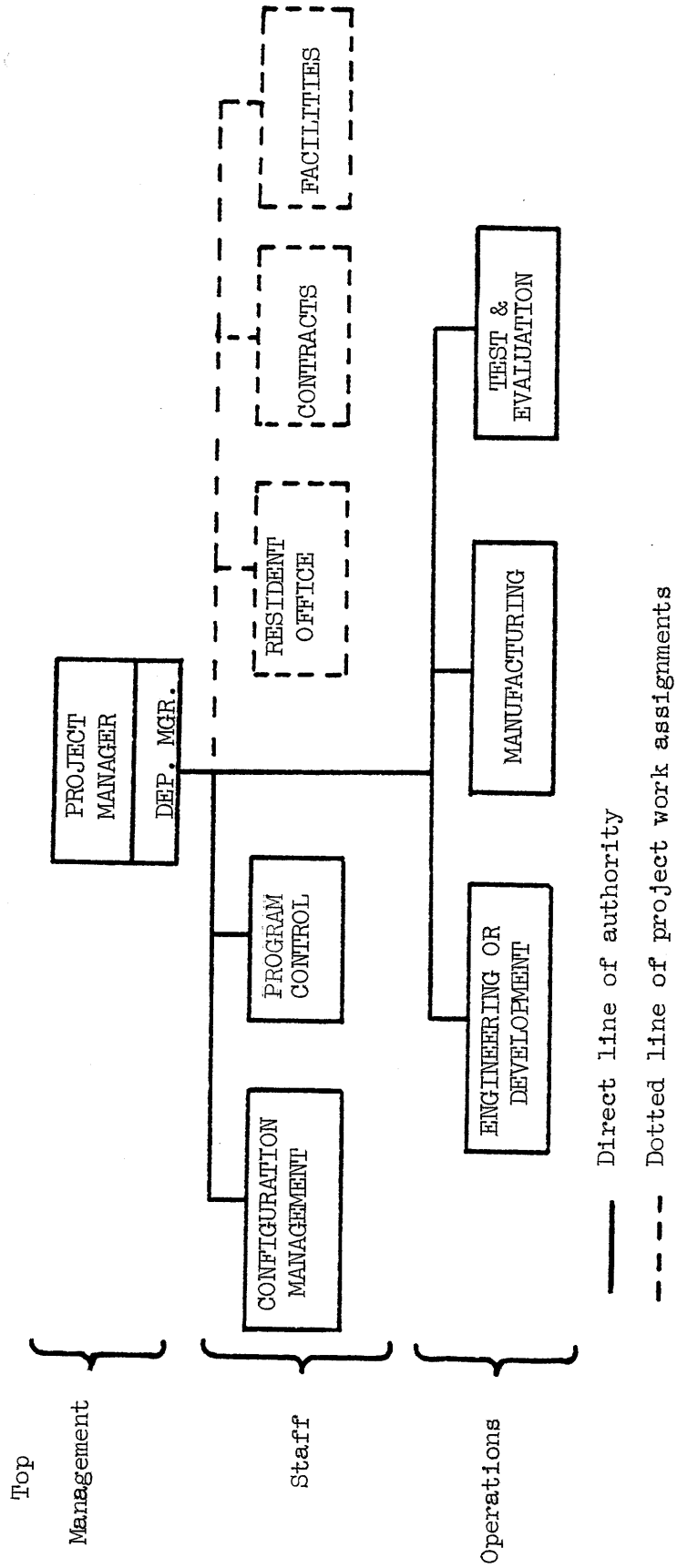


FIGURE 4

TYPICAL PROJECT OFFICE ORGANIZATION



Research and Development Operations

The in-house technical work on projects is conducted by the center's research and development operations (R&DO) organization shown in Figure 2. R&DO has fewer staff offices than industrial operations, but more operating elements, or laboratories, as they are called in R&DO. Each laboratory conducts research, and some do pilot manufacturing of experimental systems. Collectively, the laboratories have the capability to integrate all necessary systems into prototype flight hardware.

Because laboratory personnel are directly involved in applied research and development work, industrial operations has a unique resource to draw upon to technically monitor, and contribute to a contractor's development effort. To do this, most laboratories assign project engineers to coordinate the in-house technical review and analysis of industrial development work. Project engineers provide a single point of contact for liaison between the laboratories and the project offices. R&D laboratory engineers who exert an influence on a project are considered as a single project associate group.

Additional Groups

Each individual project which has a technical or program management interface with a "brother" project is designated as an associate project of the latter, and vice versa.

Government organizational segments remotely located from the center (not including resident offices) are called other associates. This group includes agency headquarters, other centers, and two off-site management teams which are organizational staff elements of industrial operations.

Finally, contractors are classified as a project associate group in this study. Although the industrial contractors do not fit within the government organizational structure, they represent the most significant associate group to project managers since they do the bulk of project development and production of hardware.

4. Associate Group Relationships and Communications

The purpose of this section is to describe the relationships and communication patterns which exist between the project manager and his associates.

A questionnaire was developed and mailed to seven project managers one month prior to ~~planned~~ personal interviews with the same individuals. A copy is attached as Appendix A. This questionnaire was designed to secure pertinent information about project size and to identify groups or individuals with whom a manager does business. It was also designed to stimulate the recipient's thinking about specific problem situations which could be examined in depth during the interviews.

Relationships With Subordinates

Within a project office a project manager generally works with four to six individuals. He spends more than two-thirds of his time on program or administrative problems when not faced with technical problems demanding immediate attention. Usually he consults with key employees who assist him in program control, contracting, manufacturing or engineering functions. His communications with the engineering and manufacturing specialists are not always concerned with the technical aspect of the project. Quite often they discuss procedural methods of processing data, evaluating proposals, and assignment of personnel to various work tasks.

Because they clearly comprehend the goals of the project, and are in a small group, subordinates have high esprit de corps-- much the same as the Marine Corps and Naval Demolition Teams. A factor which might further explain their high level of motivation is that they have a more complete picture of the whole project operation than any other group except, perhaps, for the contractor's project management team.

Relationships With Superiors

Communications with the program manager, his deputy, or others up the ladder, may occur three or more times a week. Monthly review sessions will find the project manager spending considerable time in meetings with his superiors. For the most part, this time is spent discussing project performance with the program manager and a few selected staff representatives. Weekly "staff" meetings are geared for general information dissemination and discussion of selected administration problems. Staff meeting time, therefore, is not productively spent on project matters, although the information received may have some effect on project operation.

Discussions between the project manager and his superiors are usually restricted to current problems which might affect the overall program. Such problems may be significant cost or schedule changes, or even a major test failure. As Boulding states, an organizational "hierarchy operates as an information filter upward...with each level only passing up to the next such information as it considers relevant."⁹

⁹Boulding, Kenneth E. Conflict and Defense (New York: Harper Brothers, 1962), p. 148.

After all, a superior does not need to know how many bolts and rivets were used by one of the projects last week! But he does need to know if a test failure will jeopardize the delivery schedule.

Relationships With Staff Elements

Project manager contacts with staff elements are more cyclical than continuous since they come every month -- prior to and during program reviews. The project manager's primary contact is with the program office program control staff, and, less frequently with program staff systems and test engineers.

Boulding describes the functions of staff in a manner with which project managers might facetiously agree:

"The main task of the staff is to collect and transmit information outside the line channels, which will give the executive in the upper ranks of the hierarchy some independent check on the general state of the organization. This is the function of accountants, statisticians, market research men, spies, intelligence officers, stool pigeons, secret police...and so on."¹⁰

Staff offices which have a reputation for helping project managers are viewed with considerably more favor than the latter part of this description implies -- as compared with those which don't! For instance; some staff offices tend to randomly load a project office with extra work beyond its capacity to adequately perform the basic task plus the new work.

A fairly continual exchange of information is normal between the project manager's subordinates and staff associates. Other than monthly sessions, the project manager usually becomes involved in communications with staff when changes in policies or procedures are encountered.

¹⁰ ibid.

For those interested in pursuing this matter further, an informative analysis of staff-line relationships, and suggested methods for improving them, is described by McGregor in The Human Side of Enterprise.¹¹

Relationships With R & D Laboratories

One of the more challenging relationships encountered by a project manager occurs when dealing with the R & D laboratory engineers. These contacts are fairly continuous -- not cyclical, as with staff elements. When severe technical problems are encountered, frequent meetings and phone calls consume considerable time.

Laboratory directors, or their deputies, are consulted only whenever a particularly sticky problem is faced. The majority of contacts, however, are with laboratory project engineers or specialists most closely associated with the technical problems.

Discussions with R&D laboratory personnel usually concern technical problem situations confronting the contractor. For instance: A problem at the contractor's plant is identified by laboratory engineers. They analyze it and a project engineer recommends a solution to the project manager. Possible ensuing discussions might take the following form:

- 1) The proposed solution does not fit within the limitations of project schedule or cost -- the project manager tries to persuade the engineers to approach the problem differently.
- 2) The proposed solution, or engineering opinion, may not be complete or explicit -- clarification or elaboration is required in order to transmit the information or give direction to the contractor.

¹¹ McGregor, Douglas. The Human Side of Enterprise. (New York: McGraw-Hill Book Co., Inc., 1960), pp. 145-175.

- 3) Or, the project manager may need to know more of the background which led to the problem in order to make a proper decision.

Relationships With Resident Groups

Because the resident project manager is located 2000 miles away (4 out of 7 projects), face-to-face contacts with the resident manager are infrequent. An average of one or two visits per month are exchanged between the project and resident managers, with the project manager traveling more often to the industrial site than the resident manager to the center. Duration of the trips may be from two to ten days. When both are at their own offices, a daily phone call maintains the communication link between the two.

The resident management office is located at the contractor's plant to provide on-site supervision and management of project operations. The resident manager has contract, technical, and other support personnel on his staff. With the excellent capability available and broad responsibility vested in this office, the project manager has a mechanism available for quick adaptation to changing events, whether the changes originate at the contractor's plant or at the center.

Relationships With Associate Projects

Associate projects, or "brother project" management offices, are physically located in the same building at the center. Unless two or more projects have a hardware interface or an explicit data exchange requirement, communication contacts during program review and staff meetings are sufficient. Hardware interfaces and schedule problem discussions

represent the majority of inter-project communications. The number of contacts per week varies, depending upon the time phasing of the projects. As delivery times approach, contacts become more frequent.

Relationships With "Other" Associate Groups

Communications between the project managers and other associate groups, i.e., government-owned test and launch sites, usually concern program topics such as scheduling and manpower requirements. Discussions with headquarters is usually limited to rare program problems like major contract changes or very serious technical problems which have an adverse effect on project cost or schedule.

Relationships With Contractors

Meetings between the project manager and contractor personnel occur more frequently than just the project manager's trips to the plant since the contractor maintains a liaison office near the center. Also, contractor personnel make frequent trips to the center for technical coordination and contract change negotiations. When the project manager is at the contractor's plant he may have many individual contacts with contractor technical and management personnel. Back home, at the center, his meetings and phone conversations with contractor representatives average about 4 per week. Almost all official correspondence is exchanged between the government and contractor project managers except for contractual instruments which require contracting officer's signatures.

The working relationship between the government project manager and the contractor's project manager is usually conducted in a cordial, problem-solving atmosphere.

The contractor/government political interface is probably the most difficult and challenging management problem which confronts government agencies and industry. The core of the problem is that factors which motivate contractor management are not the same as those of government management. The government agency's primary motivation is to perform scientific and technical missions -- on schedule and within estimated costs. The contractors' prime motives not only include accomplishment of those government objectives for which they have contracted, but also to sustain profits and profit making potential and to strengthen the corporation for future operations.

Communication Patterns

Working relationships are born and sustained by communications between the parties involved. Because of the obvious importance of communications in a matrix organization, information about a project manager's habits was gathered to better describe how often, and with whom, he does business. Data collected in the questionnaire yielded information, shown in Table 1, which indicates the number of times per week a project manager verbally communicates with individuals from each associate group. In addition, an estimate was made as to the classification of the nature of these communications -- whether they were technical or program. For definition purposes, technical communications pertain to design, engineering, manufacturing, or development test topics. Program communications pertain to funding, cost, schedule, administrative or management policy topics.

TABLE 1

PROJECT MANAGER'S COMMUNICATIONS
WITH ASSOCIATE GROUPS

<u>Communications With:</u>	<u>Number of Verbal Contacts per week</u>		<u>Estimated Percentage of Topic Classification</u>	
	<u>Mean</u>	<u>Range</u>	<u>Program</u>	<u>Technical</u>
SUPERIORS	5	3 - 10	80	20
STAFF	5	2 - 10	90	10
SUBORDINATES	40	20 - 60	70	30
RESIDENTS	5	3 - 10	60	40
R & D LABORATORIES	10	5 - 20	10	90
ASSOCIATE PROJECTS	2	1 - 4	60	40
OTHERS	0.5	0.2 - 2	90	10
CONTRACTORS	4	2 - 8	60	40

Note: Data listed above was secured from 7 project managers.

If one considers the number of possible contacts per week which might be experienced by a project manager, it must be concluded that he is a very busy individual. This raises questions related to the possibility that conflict might be induced by work overload. Such conflict might be manifested by time delays incurred in reaching final decisions for problem solutions.

5. Management Information Systems

Voluminous report requirements are imposed on the contractor and project manager. The purpose of these reports is to distribute project progress information to all levels of management. Deviations from individual project plans must be evaluated and explained, thus permitting staff elements to integrate the contents of individual project reports with the progress of associate projects, and take corrective program action when necessary.

Contractor reports are distributed to key personnel in most in-house associate groups. This permits multiple or redundant analysis by groups other than the project office and assures high visibility.

The project office reviews most data supplied by the contractor and in-house associate groups, and prepares monthly briefs for the program manager. These briefs explain deviations from approved plans and state what action has been taken to correct or to compensate for the deviations. When critical events or changes to the plans occur between monthly meetings, special reports are issued. This whole process is management by exception -- necessary because of the tremendous volume of data generated by each project.

The program manager reviews and analyzes all project briefs and, in turn, prepares a similar report for his superiors and associates.

6. Decision Considerations and Performance Pressures

The mechanics of decision-making for technical changes is not discussed in this study. Configuration management procedures adequately define that aspect of project management. Instead, I will attempt a broad description of how project managers view significant performance parameters as they relate to decision making. Questions raised by project managers are listed below to illustrate that there are some decision considerations that may not be too adaptable to computer-management of projects.

Decision Considerations

Answers to pertinent questions are evaluated prior to making decisions. These questions arise when weighing the potential effects of possible decision alternatives, and to validate the data or recommendations presented to the project manager. Typical questions a project manager usually asks himself and others, prior to making a decision, are listed below:

- Is a technical proposal sufficiently defined and justified to warrant approval?
- What bias do associate groups represent in their recommendations for action? How much can be accepted and how much rejected?
- Is a so-called "mandatory change" really mandatory, or is it "nice-to-have"?
- What alternatives are available? What is their relative worth?
- What is the probability that a preliminary cost estimate will escalate, because of a potentially inadequate technical definition?
- If a proposed change is not implemented now (before a better technical definition is available), what are the chances of a schedule slip if it were implemented 2 or 3 months from now?
- Can the contractor adequately perform an additional task, in view of his total present commitment?

- What are the risks of dropping a test program or design feature in order to conserve resources; and throwing all available effort into making a delivery on schedule?

These questions, and hundreds more, can be asked by project managers and their subordinates. The answers determine, to a large extent, what direction the decisions will take.

Performance Pressures

Three primary factors are considered when evaluating data leading to a decision for action -- cost, schedule, and technical performance. The relative importance of these factors, as viewed by government and industrial project managers, was recently evaluated by Marquis and Straight in a study involving 37 projects funded by 12 government agencies. They found that:

"Technical performance is by far the most important consideration, being ranked first by 63% of the company respondents, and 97% of government respondents. Meeting delivery schedules is a poor second with achievement of target costs third in importance. Almost all of the projects were under some form of cost-plus contract."¹²

To compensate for the apparent bias of government and industrial management teams to consider technical performance as most important, one federal agency recently issued guidelines to base incentive-fee contract provisions on a distribution which attempts to modify that tendency. The guideline incentive weights are approximately 40% schedule, 40% cost, and 20% technical performance. Whether this measure will help create a better balance between the three factors has yet to be determined from experience. One feature which future researchers should study is the effect of this guideline on actual technical performance -- a rather difficult variable to define and quantify on a comparable basis.¹³

¹²Marquis and Straight, op. cit., p. 6.

¹³ibid., p. 9.

It can readily be concluded from the foregoing that pressures are more intense at the higher levels of management to meet schedule and cost commitments, with less concern being paid to the hardware or technical goals. Conversely, in the lower levels of management, more value is placed on meeting the technical performance goals, with less value on cost and schedule commitments. Considering these forces at work, the project manager is something like the section of a plank near the fulcrum on a see-saw. The bending moment is very high at his position as he tries to support the goals of both extremes. Through persuasion, flexibility and technical judgment, the project manager and his subordinates must somehow achieve the best result. In research and development work, the best result is not always what either extreme initially wanted. Compromises are often made and objectives frequently altered in order to match better educated cost estimates with attainable schedule and technical performance goals.

Difficult Problem Rating

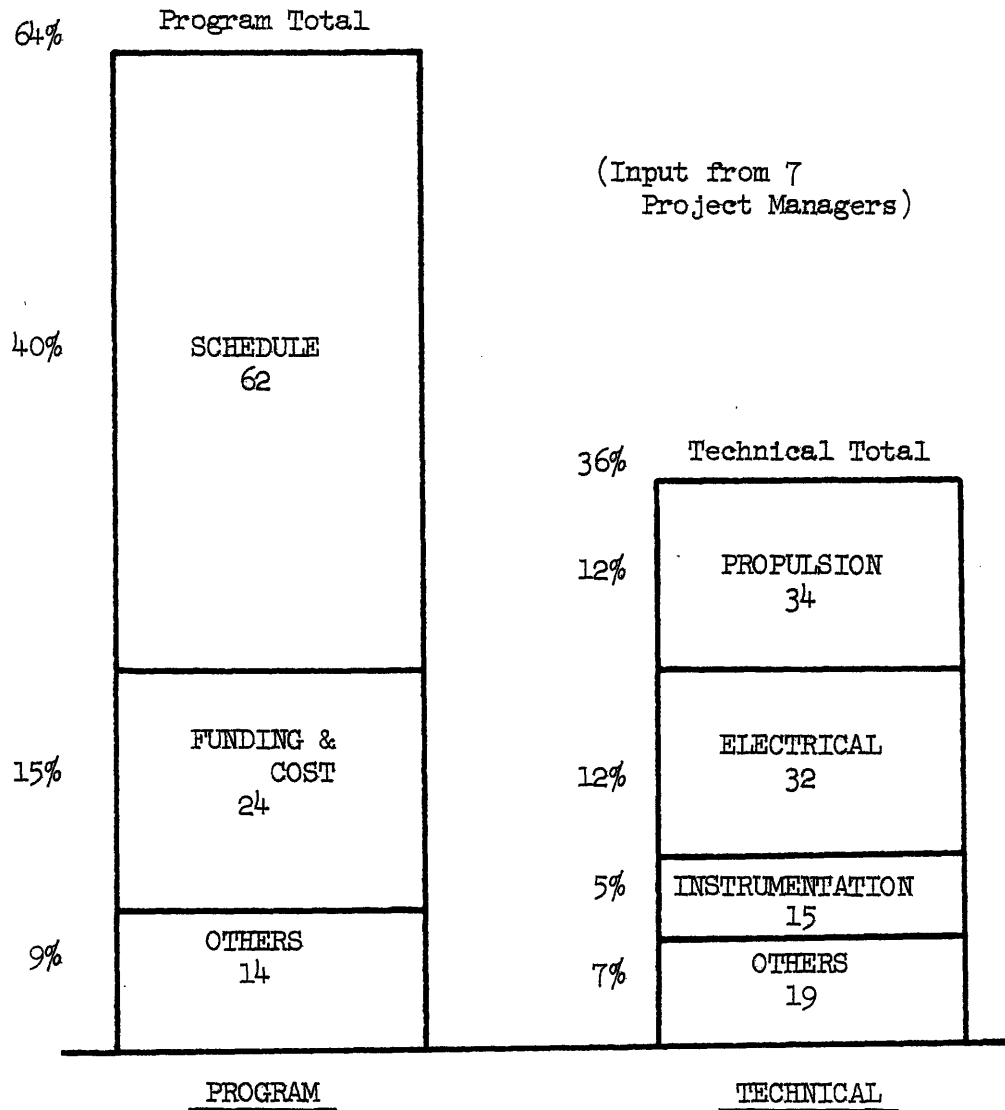
In the questionnaire the project managers were asked to state which types of problem decisions were the most difficult to make; and to list, by rank-order, the three most difficult they had faced. The rank-order listing was done for each of two classifications -- technical and program problems. They then reduced their list of six problems to a rank-order listing of the three toughest decisions. Responses were totaled by classification and categories and weight factors were then applied. A weight of three was applied to first-order problems; two to second-order problems; and, one to third-order problems. The results of the grading are illustrated in Figure 5. Program problems are shown to rank as more difficult to resolve than technical problems.

This ranking does not appear to correlate with the findings of Marquis who stated that 97% of the government respondents considered technical performance as the most important project consideration.¹⁴ Then, why did these project managers rate program problem decisions more difficult than technical decision problems? Some answers to this question might include: (1) The majority of technical problems are within the state-of-the-art, therefore relatively easy to resolve; (2) The whole project team is primarily trained to solve technical problems, rather than program problems; or, (3) Associate groups have relatively little interest in program problems, therefore little help is offered to project managers to resolve them. Possibly the answer is that project managers are judged by their peers and superiors on the basis of good technical performance, when, in fact, their primary job is to achieve a good balance of all parameters -- the technical, schedule and cost. A certain amount of conflict would be evident if a project manager's rewards were heavily weighted in one direction, such as technical performance, when at the same time he had an equal responsibility to achieve an acceptable level of schedule and cost performance.

How does the ranking of difficult decision problems fit into this framework? It is the author's opinion that the Figure 5 rankings represent project managers' feelings regarding their job responsibility pressure to perform. This pressure is probably weighted toward program problems in an effort to overcome associate group pressures which are biased toward technical performance. It should be also recognized, that

¹⁴ ibid., p. 6.

FIGURE 5
PROJECT MANAGER'S RATING
OF MOST DIFFICULT PROBLEMS



Note: Percentages shown outside the bars indicate the relative problem size as a percent of all difficult problems - Technical and Program

Numbers shown inside the bars indicate the relative problem size as a percent of the difficult problems within each classification - Technical or Program

at the time of the survey, all projects had either just started making first hardware deliveries or were almost ready to start. This may be a partial explanation for the heavy scoring of schedule problems. Perhaps if this study had been made during the earlier phases of development, technical problems would have scored higher than the program problems.

7. Summary

The project organization studied in this thesis is classified as a matrix type, in which personnel who work on the project receive their work assignments from the project manager, but are physically located in other organizations which control their merit performance ratings.

The project manager shares responsibility in all phases of project research, development, and production. His authority extends to whatever depths of project detail he can reasonably assume but he is limited in exercising any substantial degree of authoritative control because his relationships with the majority of personnel who work on the project are of a coordinative nature.

The project manager is supported in his job by individuals from project associate groups who specialize in various technical and management functions. These associate groups tend to influence the direction a project takes by making analyses and recommending changes to current project plans.

The project manager communicates with individuals from associate groups to validate and better understand recommendations for various problem situations so that proper decisions can be made for changing the project's course.

Project progress is evaluated on the basis of cost, schedule, and technical performance. Although project managers feel that program problems, such as cost and schedule, are the most difficult to resolve, they (and their associates) feel that technical considerations are the most important for acceptable overall project performance.

When a project manager is faced with the task of selecting one course of action from several alternatives, his choice is influenced by two factors. The first factor is the amount of pressure applied by his associates who try to influence his decisions; and the second is an internal performance pressure to effect an acceptable balance between cost, schedule, and technical performance. Conflict situations occur whenever a potential decision deviates too far from the ideal objectives of these two pressures.

CHAPTER III

III. PROBLEM SITUATION RESEARCH

1. Plan For The Research

The plan for this phase of the study was to collect data on problem situations from project managers and their associates, and to analyze the results.

Interviews with project managers were scheduled in advance. At the time of the interviews they were informed that their answers would subsequently be reduced to numbers in order to insure anonymity, and that the published thesis would contain no personal references. They were further informed that, for the purposes of correlating data, it would be necessary to assign a code number to their responses, but that the interviewer would be the only person having a key to the code. In secondary interviews, the managers' project associates were informed of the same ground rules. Due to time limitations and the quantity of data desired, however, it was found necessary to resort to the telephone in about twenty percent of these secondary interviews.

The above procedure for conducting interviews assisted in establishing an atmosphere of confidence and sincerity during the interviews which made the data much more reliable than they would otherwise have been. Several of the persons interviewed expressed an interest in the subject and a desire to read the completed thesis. They were assured of an opportunity to do so upon its completion.

2. Interdependency of Projects and Groups Studied

Seven active projects -- all under the cognizance of one NASA field center -- were studied. Three of the projects are rocket launch vehicle propulsive stages. One is a non-propulsive flight module used for guidance

and control of the assembled launch vehicle. Two are engine projects which supply hardware for the three propulsive stages. And, one supplies ground support equipment (GSE) for launch of an assembled vehicle. Each project provides hardware to be eventually assembled into one composite launch vehicle system.

Hardware Interfaces

Because independently produced hardware must ultimately be assembled and checked out as an integrated system, each project is mutually dependent upon the others for close coordination to insure precise compatibility of physical and functional interfaces. Although the original design criteria called for a minimum of dependent interfaces between separately produced hardware, a certain number were unavoidable. Interface management, therefore, is an important aspect of the coordination job.

New Technology

Three of the projects studied are mutually dependent because they each have the same "new technology" problem -- liquid hydrogen as a fuel. This was considered a major problem from the time the projects were initiated and it was mandatory that project groups share all newly acquired knowledge in the use of this fuel.

Government-Industry Teams

One project contractor had relatively little prior experience in large liquid rocket development, so a large segment of the government's experienced technical manpower force work side-by-side with his own men.

Another project development was started by the government long before a prime contractor was selected. Turnover of responsibility, in this case, was accomplished by having the contractor establish management and hardware assembly facilities close to the government field center.

Because four project contractors' engineering and assembly facilities were 2000 miles distant from the center, resident management offices were established to facilitate technical management liaison and prompt on-site decision making.

3. Selection of Problem Situations

Problem situations were jointly selected by the managers of the seven projects studied and the researcher. They covered a broad range of technical and program topics and were ones which the project managers considered of more than average difficulty and which they and their associates could remember in detail.

The time available for conducting the research limited the number of problem situations which could be studied, but an average of eight were selected for each of the seven projects. The number of problem situations and related interviews are shown in Table 2.

TABLE 2

NUMBER OF PROBLEM SITUATIONS AND INTERVIEWS

<u>Problem Classification</u>	<u>Number of Situations</u>	<u>Number of Interviews</u>
Technical	30	94
Program	<u>26</u>	<u>77</u>
Totals	56	171

The interview technique made use of a standard format which included specific questions which would allow follow-up. A copy of the form is attached as Appendix B. During the interviews, notes were taken on the forms for later reference. Immediately following an interview, the form was reviewed and additional comments were written to preserve the feeling of the answers. It was possible to capture the situation well enough that subjective numerical assignments could be made to many of the variables under study.

4. Analysis Of Data

The data secured from interviews are analyzed in this section. This work was done in part at the M. I. T. Computation Center.

Problem solution outcomes and the methods used to resolve the problems were correlated with a number of variables. Mean solution outcome values were also calculated for comparison and analysis of problem classifications, categories, associate groups, and project groups.

Correlation Analysis

The measure of solution outcomes. Problem situation values for several variables were correlated with the evaluated outcome of final solutions. The data used represent 53 of the 56 problem situations, each of which has at least two inputs from project associates. The data were secured from 168 separate interviews. Three problem situations were not used in the calculation of correlation coefficients because only project manager information about them was available, without separate information from their associates.

The correlation coefficient (r) measures the strength of linear association between two or more variables. It does not necessarily imply a cause-effect relationship. The correlation coefficient has a positive value if both of the parameters simultaneously increase, or a negative value if one parameter decreases while the other increases. The value of r is determined by the goodness of fit for a line-of-least-squares relative to the observed data.¹⁵

Table 3 lists the variables correlated with the respondent's evaluation of solution outcomes as viewed from the standpoint of all associate groups -- the whole project or program team. The outcome variable was evaluated by the respondents using subjective terms ranging from satisfactory to unsatisfactory. The correlation coefficients reported for solution outcomes with the variables are not a function of the number of people interviewed per problem ($r = .09$).

The strongest correlation is with mean personal satisfaction ($r = .82$). This high value may be slightly influenced by the sequence in which interview questions were asked, however, such a "halo-effect" is probably negligible since another variable (in Table 4) showed a coefficient almost as high. Sequence of questioning was not a factor in that case! The possibility remains, however, that an individual's judgment of solution outcome may be influenced by his personal satisfaction.

Another variable associated with satisfactory solution outcome is the extent to which an initial concept of a possible solution is eventually chosen as the final solution. ($r = .34$).

¹⁵Freund, John E. Modern Elementary Statistics. (New York: Prentice Hall, 1960). p. 328.

TABLE 3

VARIABLES CORRELATED WITH THE EVALUATION
OF SATISFACTORY SOLUTION OUTCOMES

	<u>r</u>	
Mean personal satisfaction with the final solution	.82	*
Solution comparability to an initial concept of a solution	.34	**
Difficulty felt by project managers	-.28	**
Delivery schedule delay	-.15	
Time delay to realize a final solution	-.11	
Cost change	-.01	
Number of project interfaces	.003	

* Significant at the .001 level

** Significant at the .05 level

Problems which are more difficult, as viewed by project managers, tend to result in less satisfactory solution outcomes ($r = - .28$).

Other parameters such as delivery schedule delay, time delay to realize a final solution, and cost change, are correlated negatively. One might agree with these correlation slopes, however, the positive correlation for project interfaces does not agree with a priori reasoning. Also, it was initially thought that the number of interfaces would have shown more association with solution outcome but-- the data showed practically zero correlation.

The general lack of correlation for these latter variables suggests that other factors, not adequately defined in this research, tend to reduce the effect of these variables on solution outcome -- perhaps the demand for high technical performance may be a factor.

The solution outcomes to project problems were also correlated with some aspects of the methods used to resolve problems. Table 4 lists the variables tested.

Mutual agreement methods of problem resolution proved to be strongly associated with satisfactory solution outcomes ($r = .71$). The cause-effect relationship is obvious -- mutual agreement methods lead to more satisfactory results. Looking at the other extreme, unilateral direction techniques lead to unsatisfactory outcomes.

Higher associate group freedom to influence the solution to problems is also associated with satisfactory solution outcomes ($r = .59$) and, when communication activity between associates is increased, satisfactory outcomes tend to result ($r = .24$).

Method of resolution correlations. Several variables were correlated with the methods used to resolve problems. The method variable was

TABLE 4

RELATION BETWEEN SOME ASPECTS OF THE
TECHNIQUES OF PROBLEM RESOLUTION AND
MEAN EVALUATED SATISFACTORY OUTCOMES

	<u>r</u>	
Mutual agreement methods of problem resolution	.71	*
Associate group freedom to influence the solution	.59	*
Communication activity	.24	**

* Significant at the .001 level

** Significant at the .05 level

evaluated by the respondents using subjective terms ranging from mutual agreement to unilateral direction. Table 5 lists the variables correlated with the respondents' evaluation of the methods used.

Higher associate group freedom to influence the solution to problems is strongly and significantly correlated with mutual agreement methods ($r = .59, p < .001$).

Mutual agreement methods tend to reduce the difficulty experienced by project managers when solving problems ($r = -.26$) and, such methods require an increase in communication activity on the part of the manager and his associates ($r = .24$).

Several variables which yielded low correlation coefficients are; time delay to realize a final solution, number of project interfaces, delivery schedule delay, and cost changes. The same variables which resulted in low correlations with respect to solution outcomes also have low values with respect to method of resolution. As with solution outcome, other factors may mitigate the effect of these variables on the method of resolution.

Analysis of Outcome Mean Data

Relative solution outcome mean values are examined and analyzed in this section when considering such parameters as technical and program classifications, problem categories, associate groups, and project groups. This analysis is performed for the purpose of determining the relationships that exist between sub-divisions of each parameter relative to the mean level of all problem solution outcomes taken collectively. All of the information (171 interviews) from the 56 problem situations was used to determine the mean values for each parameter.

TABLE 5

VARIABLES CORRELATED WITH
MUTUAL AGREEMENT METHODS OF RESOLUTION

Associate group freedom to influence solutions	.59 *
Difficulty felt by project managers	-.26 **
Communication activity	.24 **
Time delay to realize a final solution	-.16
Delivery schedule delay	-.054
Number of project interfaces	-.045
Cost change	-.039

* Significant at the .001 level

** Significant at the .05 level

The length of the bars shown in each figure represent the relative value of each parameter identified. Scale values are the same for all of the figures which follow. The direction of each bar indicates whether the solution outcomes were either satisfactory, + (to the left), or unsatisfactory, - (to the right) relative to the mean value of all problem solution outcome data. The number of interviews conducted (from which the mean values were derived) are listed with each parameter, thus providing a measure for weighing the validity of the data represented by the bar lengths.

Problem classifications and categories. Figure 6 illustrates the comparative differences in mean values between technical and program classification outcomes. As shown, technical solution outcomes were evaluated as more satisfactory and, program outcomes were evaluated as unsatisfactory, compared to the average for all problems.

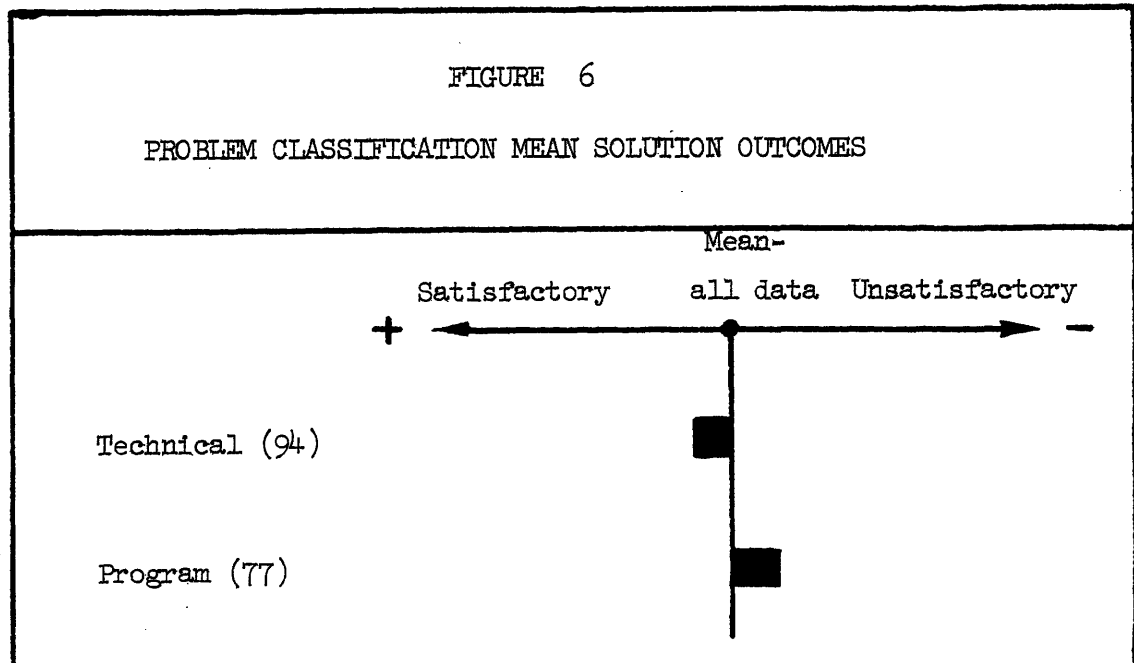


Figure 7 shows each classification -- technical and program -- broken down into categories which describe functions common to the aerospace industry. The technical mean values were fairly well distributed -- some category outcomes were evaluated as satisfactory and others as unsatisfactory. It may be significant that mechanical functions (structural, mechanical GSE, and propulsion) were evaluated as satisfactory, as compared to electrical functions (electrical, instrumentation, and electrical GSE) which were all evaluated as unsatisfactory relative to the mean outcome level for all problems. Most program problem category values were strongly concentrated on the unsatisfactory side of the ledger, except for one -- facility utilization.

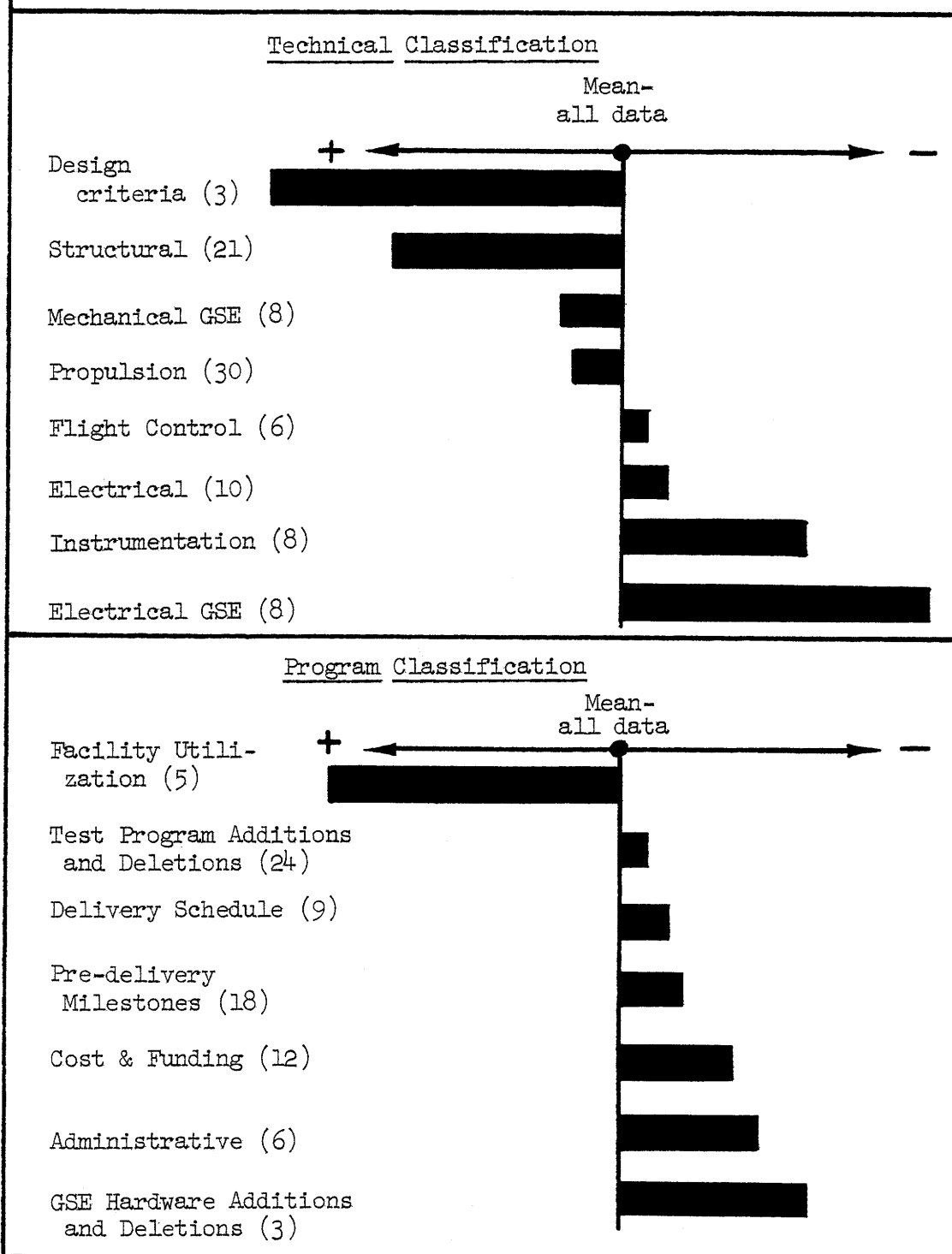
Why were technical outcomes evaluated more satisfactory than program problems? The answer lies partly in the relative degree of importance which associate groups place on high technical performance, and partly due to the method of problem resolution ($r = .71$). Possibly another reason is that project managers are better equipped from prior experience, and intellectually to solve technical problems effectively, as compared to program problems. There is no single pat answer, but it is fairly certain that associate group pressures are higher for technical performance considerations.

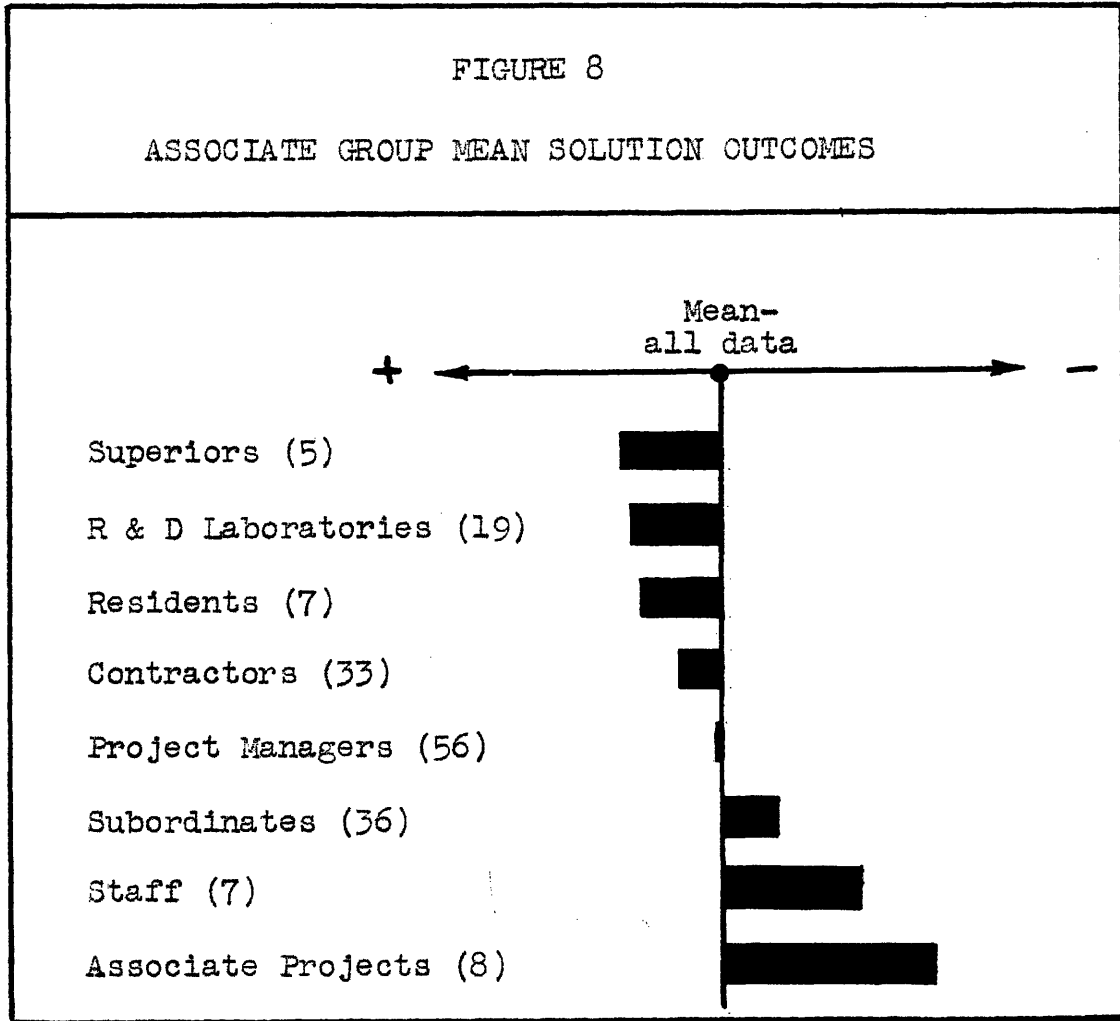
Associate groups. Figure 8 shows solution outcome mean values of associate group evaluations relative to the mean level of all problem outcome values, taken collectively.

Project managers evaluated solution outcomes approximately at the reference level for all problems. This may not be too surprising since project managers provided more input than any other single group, but, it

FIGURE 7

PROBLEM CATEGORY MEAN SOLUTION OUTCOMES





is interesting to attempt an evaluation of why associates groups "voted" as they did relative to the project manager's evaluation of outcome.

Those associate groups which viewed solution outcomes as relatively satisfactory include; superiors, R & D laboratories, residents, contractors, and project managers. Those which rated outcomes as relatively unsatisfactory were; subordinates, staff and associate projects.

Associate groups which evaluated solution outcomes as more satisfactory may view the overall results of the problem solving process more favorably because of political reasons which require that they be optimistic (i.e., superiors and contractors), or because the solution outcomes agreed with their efforts to influence the final solutions (i.e., R & D laboratories). In the case of the residents, they may either be influenced by the contractors' more optimistic evaluation because they are located at the contractors' sites or, they may be physically in a better position to realistically appraise solution outcomes.

Those groups which evaluated solution outcomes as less satisfactory may have been concerned with problems which are more difficult to effectively influence from their positions (i.e., subordinates and staff), or perhaps the competitive nature of inter-project coordination and compromise leads to unsatisfactory outcomes, as with associate projects.

It could be significant that supervisors evaluated outcome the highest of any associate group -- which might suggest a "seeing through rose colored glasses effect." But, since three other associate groups ranked not too far from the supervisors' mean outcome value, color optics should not be a factor.

The relatively low outcome appraisal expressed by subordinates may just mean that they either see solution outcomes in a different light than their bosses, or that the project managers did not communicate their slightly higher optimism to them.

Associate projects, or brother projects, felt that the problem solving process left them short since outcome was rated quite low. This would suggest that inter-project problems may be a critical factor.

Finally, the staff, which is supposed to apprise top management of the "true state of the organization"¹⁶, sees the solution of problems in a rather dim light as compared to most other associate groups. Their evaluation of solution outcomes may be analogous to the critic's appraisal of an actor's performance.

One further step was taken to analyze the associate group data. Figure 9 shows technical and program classifications separated. The technical half of the figure is solidly on the satisfactory side, except for associate project groups. Program outcomes were generally evaluated as unsatisfactory by all groups, except for the more optimistic superiors and contractors.

The comparative results, shown in Figure 9, suggest that most associate groups are highly motivated to achieve satisfactory solution outcomes to technical problems, to the apparent exclusion of satisfactory program problem solution outcomes.

Analysis of project groups. Figure 10 shows the evaluated solution outcome mean values for each project. The data are displayed relative to the mean level of all the data taken collectively.

Projects G and F solution outcomes were evaluated more satisfactory than the average, and Project C was evaluated exactly at the reference mean level of all problems. Four other projects (A, D, B, and E) were, in varying degrees, evaluated by the respondents as unsatisfactory relative to the mean level of all problem solution outcomes.

An attempt was made to determine if there were any significant differences in the solution outcomes when comparing projects more heavily

¹⁶ Boulding, loc. cit.

FIGURE 9

ASSOCIATE GROUP MEAN SOLUTION OUTCOMES
FOR PROBLEM CLASSIFICATIONS

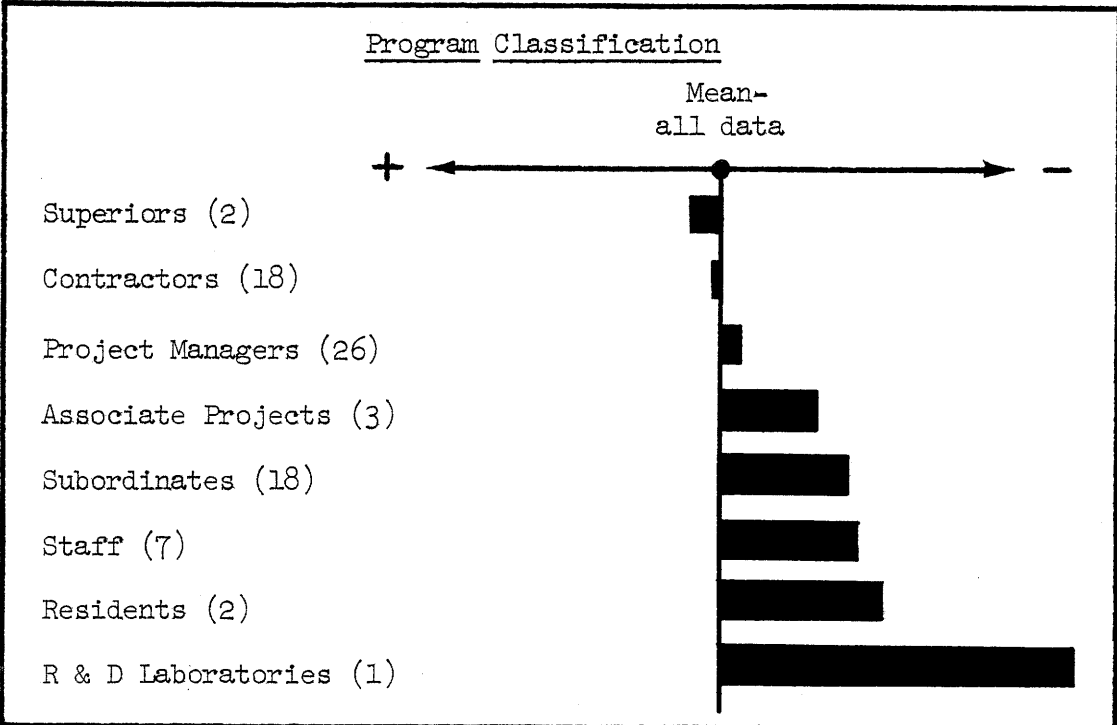
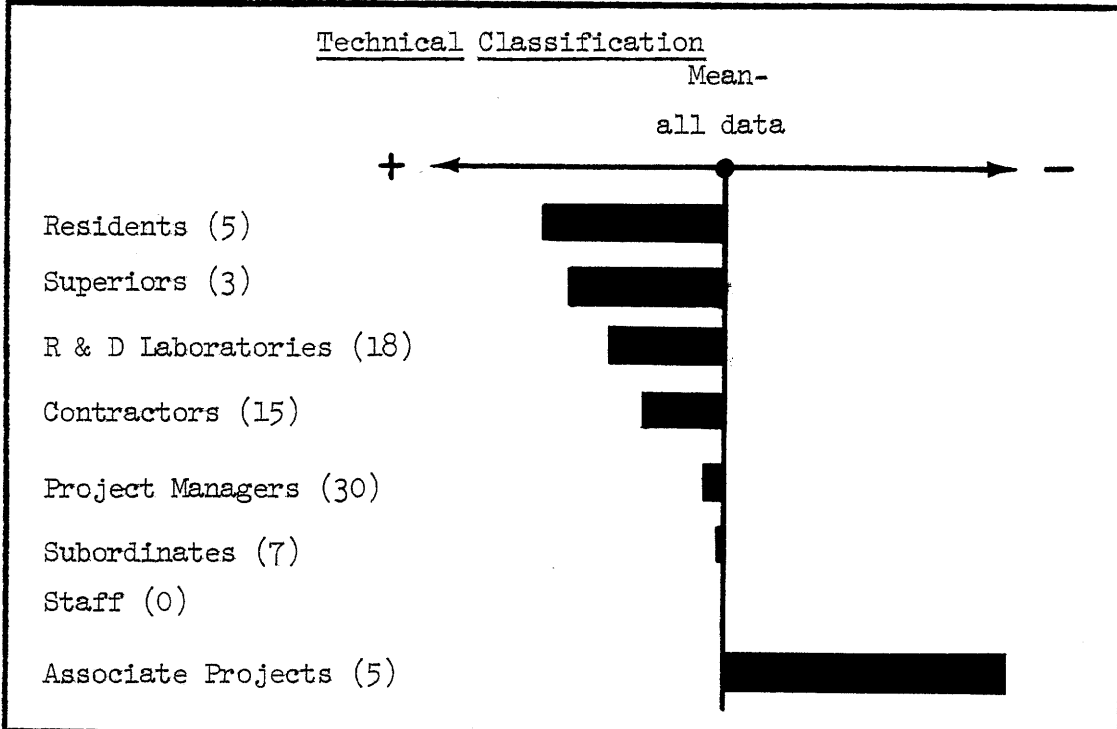
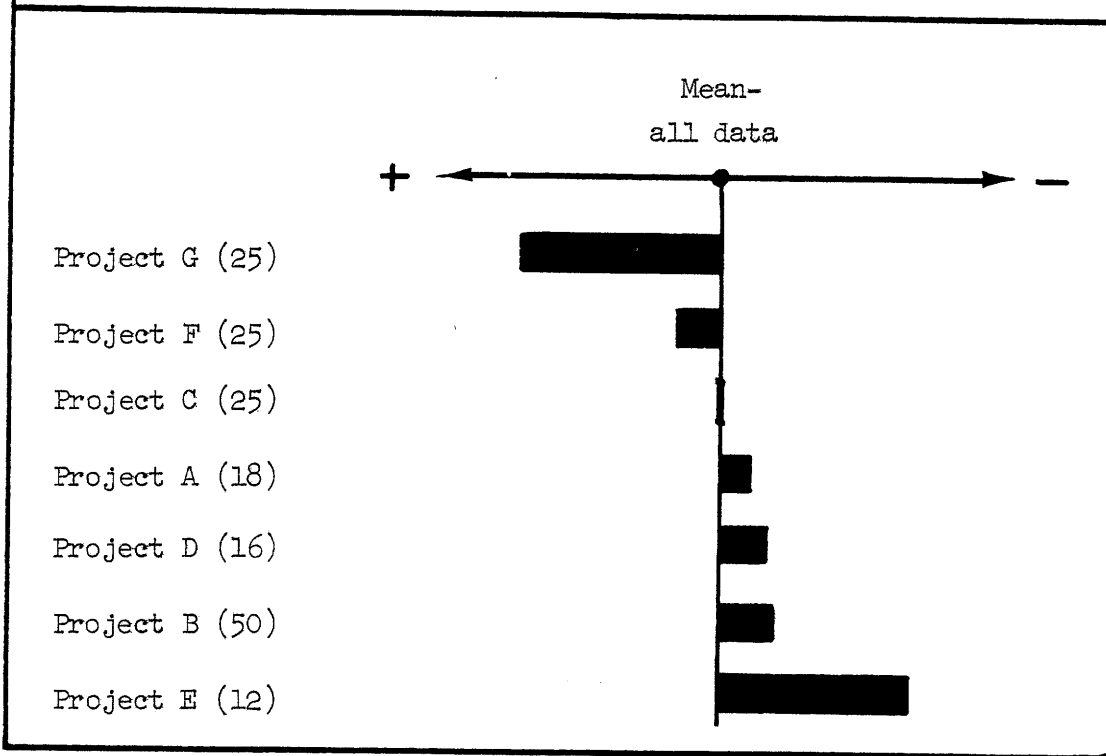


FIGURE 10
PROJECT GROUP MEAN SOLUTION OUTCOMES



monitored by center personnel than projects which have less in-house effort applied. To do this, the projects were separated into two groups. The criteria for separation was based on the number of civil service employees (direct headcount) charged to a project per million dollars of estimated project cost for the current fiscal year. Using this in-house headcount per cost (H/C) factor, values ranged from approximately 5.0 to 0.34. An arbitrary division value was selected at one man per million dollars cost (H/C = 1.0). Three projects fell on the lower side (H/C < 1.0), and four on the higher side (H/C > 1.0).

Figure 11 shows project mean solution outcome evaluations for these two H/C categories. On the average, projects with fewer in-house personnel working on them (H/C < 1.0) were evaluated by the respondents with solution outcomes rated more satisfactory than projects employing a higher number of personnel (H/C > 1.0).

This analysis was carried one step further. By breaking down each project's problems into technical and program classifications, the data were examined again to determine if any definite patterns would emerge. Figure 12 illustrates the mean outcome values for each project when considering the technical-program dichotomy. Differences in the H/C division of technical problems reveals a startling contrast. Outcome mean values moved substantially toward the satisfactory end of the scale for all projects where H/C < 1.0, while all projects with an H/C > 1.0 had their solution outcomes evaluated as quite unsatisfactory relative to the mean level of all problems.

FIGURE 11
PROJECT GROUP MEAN SOLUTION OUTCOMES
FOR HEADCOUNT PER COST DIVISION

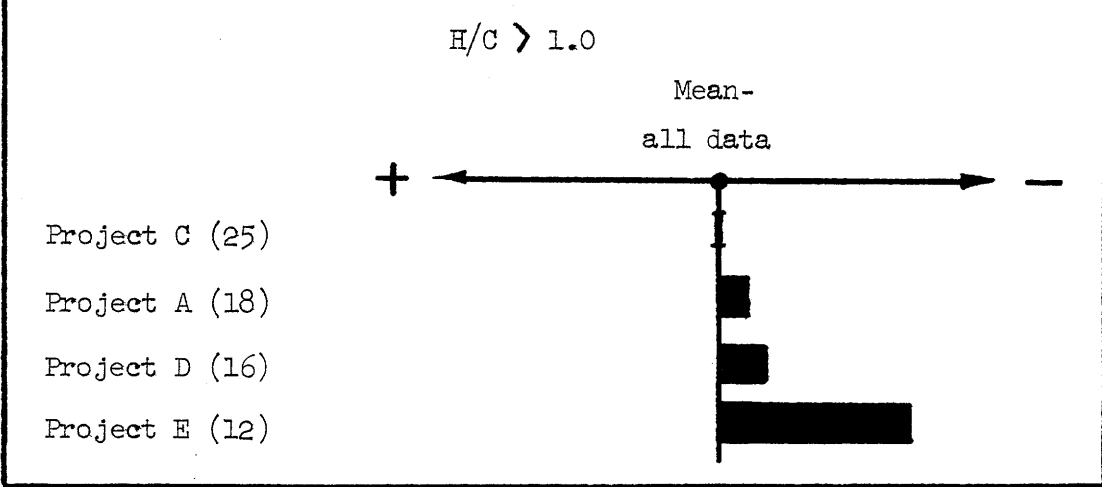
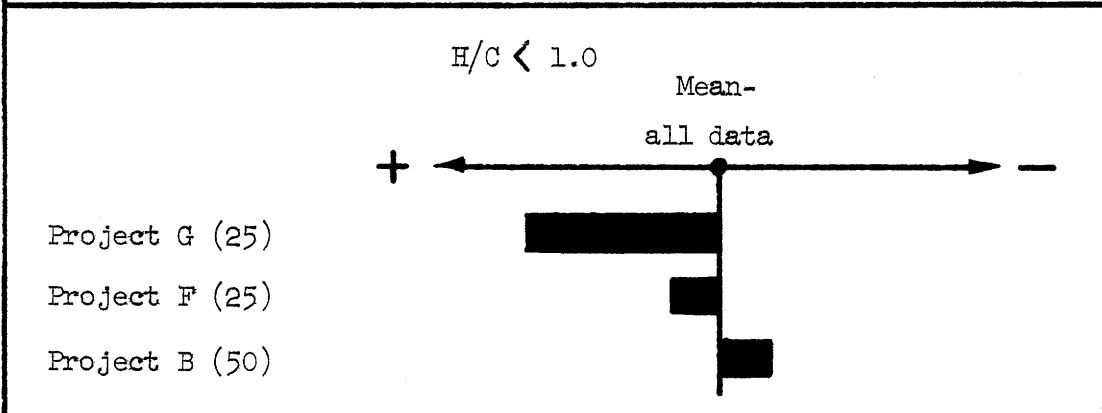
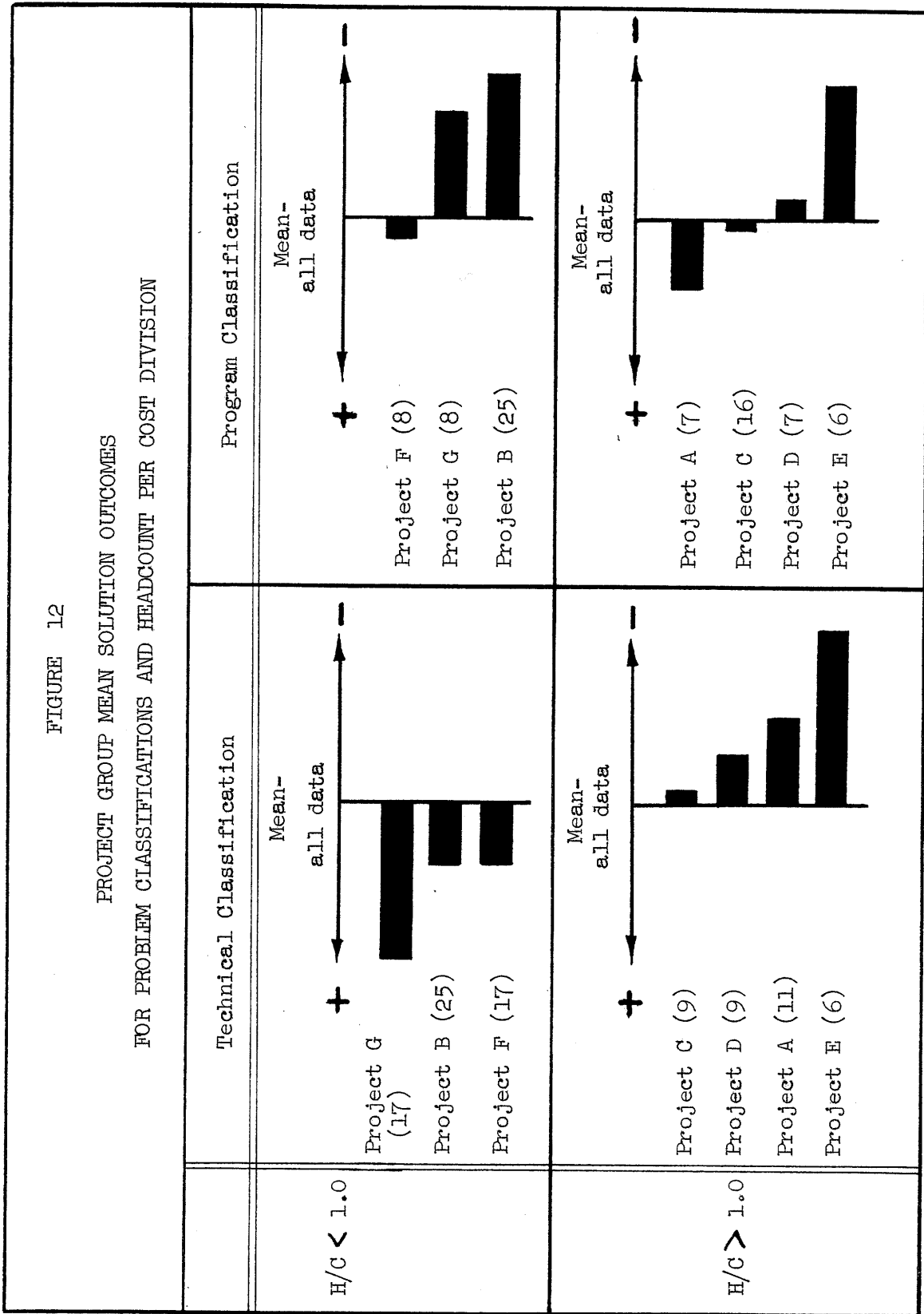


FIGURE 12

PROJECT GROUP MEAN SOLUTION OUTCOMES
FOR PROBLEM CLASSIFICATIONS AND HEADCOUNT PER COST DIVISION



Program problem solution outcomes, on the other hand, were somewhat improved for projects where $H/C > 1.0$, compared to projects with an $H/C < 1.0$ (although both H/C groups averaged on the unsatisfactory side of the ledger).

The comparative switch between technical and program outcome levels, for the two H/C groups shown in Figure 12, could become a significant consideration if these findings were used as criteria for choosing optimum in-house project manpower support levels.

What explanations are there for the differences in evaluation of technical solution outcomes between the two H/C ratio groups? One possible explanation is that in projects which have an $H/C > 1.0$, the contractor's design may be exposed to more critical scrutiny, consequently the frequency and intensity of designer's-choice arguments are higher -- thus causing the use of heavier government associate group pressures, and possible unilateral direction methods to overcome contractor resistance. Because the outcome correlation with method indicated strong association ($r = .71$), it could be concluded that unilateral direction yielded the unsatisfactory solution outcomes which were reported by those projects with higher H/C ratios. It therefore follows that since technical outcome satisfaction levels were rated relatively low, it is obvious that the respondents were not too happy with whatever technical directions were given.

Another possible way to look at the data shown in Figure 12 would be to consider that projects with an $H/C < 1.0$ rely quite heavily on the contractors to solve technical problems. As a result, government associate groups are confronted with a larger proportion of program problems. A low

degree of technical penetration into contractor affairs, may result in a lack of detail knowledge by in-house associates, of the technical problems as they really are. Program problem severity, therefore, might be caused by technical problems of which the government agency is not fully aware; hence, their inability to help solve the real problem at its source.

6. Summary

The principal objective of the thesis research was to examine how project problems were resolved and the solution outcomes which resulted.

Individual problem situations were used as a focal point for collecting data from project managers and their associates. The situations were jointly selected by the project managers and the researcher.

All of the projects included in this study were dependent upon each other in varying degrees -- either for reasons of hardware interfaces, new technology, or interdependent government-contractor team relationships.

Correlation analysis revealed that the most satisfactory problem solution outcomes resulted from use of mutual agreement methods of resolving them ($r = .71$). When solution outcomes are satisfactory, those associates who have an input also tend to be personally satisfied ($r = .82$).

Mutual agreement methods tend to reduce the difficulty felt by project managers in resolving problems. Such methods, however, require an increase in communication activity by all the parties concerned.

Associate group freedom to influence the solution to problems leads to satisfactory outcomes. It was also found that if an initial concept of a possible solution is eventually chosen as the final solution, the result tends to be a satisfactory outcome.

Analysis of the data suprisingly revealed that there was no significant correlation between solution outcome and; (1) schedule, (2) cost changes, (3) number of interfaces, and (4) time delays incurred prior to reaching a final solution decision. This suggests that other factors tend to reduce the effect of these parameters on solution outcome -- perhaps pressures for high technical performance is a factor.

Technical problems, in general, are resolved more satisfactorily than program problems. Mechanical problems tend to be solved more satisfactorily than electrical type problems and, funding problems are resolved less satisfactorily than schedule problems.

Project managers view the outcome of problem solutions close to the mean outcome level of all problems taken collectively. Superiors, R & D laboratories, and contractors view outcomes as more satisfactory. Subordinates, staff, and associate projects see solution outcomes as less satisfactory than the average.

It was also found, based on the data secured from interviews and other sources, that project groups with fewer in-house associates (on a headcount per annual project cost basis) experience more satisfactory solution outcomes to technical problems than do project groups with a higher headcount per cost ratio. The reverse was found for program problems since projects with more in-house associates tend to have their program solution outcomes turn out more satisfactorily than projects with fewer in-house associates on the job.

CHAPTER IV

IV. CONCLUSIONS AND SUGGESTIONS FOR FURTHER STUDY

Organizational Factors

A matrix organizational structure places the project manager in the role of a coordinator who gets project work accomplished by parceling task assignments out to groups over which he has no direct authority. Acting as a coordinator with limited authority, the manager must rely on communication techniques and other means to motivate and persuade the majority of his project associates to solve project problems.

The project manager's relatively weak position in a matrix organization encourages his project associates to influence a project's course in directions they deem most important.

Method of Resolution and Solution Outcome Associations

Satisfactory problem outcomes result from use of mutual agreement methods of resolving them. Conversely, when unilateral direction techniques are used, the resultant solutions tend to be unsatisfactory.

Mutual agreement methods help to reduce the difficulty felt by project managers in resolving problems. Such techniques, however, require an increase in communication activity by all parties concerned with the problems. Associate group freedom to influence the solution to problems also contributes to satisfactory solution outcomes, presumably because it is an element in attaining mutual agreement.

No significant correlations were found between either the method or outcome variables and program problem categories such as cost and schedule. Probably, associate group emphasis on high technical performance mitigates any potential correlation between program performance parameters and the method or outcome variables.

Problem Class Comparisons

Technical problems generally result in satisfactory solution outcomes. Program problems, however, result in comparatively less satisfactory solution outcomes. Mechanical type problems tend to be solved more satisfactorily than electrical type problems. Cost and funding problems are resolved less satisfactorily than schedule problems.

Associate Groups

Project managers evaluate problem solution outcomes approximately at the mean level for all solution outcomes, taken collectively. Superiors, R & D laboratories, contractors, and residents view the outcome of problem solutions to be relatively satisfactory -- as compared to project managers and the mean level for all problems -- while, subordinates, staff and associate projects tend to evaluate solution outcomes as relatively unsatisfactory.

Those associate groups which view outcomes as satisfactory may view the overall results of the problem solving process more favorably because of political reasons, or because the outcomes agree with their efforts to influence the problem solutions.

Those groups which evaluate outcomes as unsatisfactory may be concerned with problems which they can not effectively influence.

Project Groups

Projects which have fewer in-house government employees working on them experience considerably higher satisfactory solution outcomes to their technical problems than projects which have a greater number of persons employed. This finding is contrary to the a priori claims frequently expressed by proponents of the government arsenal concept.

The above result is reversed for program problem solution outcomes since projects with a higher number of in-house employees evaluate their program solution outcomes slightly less unsatisfactory than groups with fewer personnel. This suggests a swap or trade-off of outcome values between technical and program class problems for the various extremes of in-house participation.

It might also suggest that since projects with less in-house help rely heavily on contractors to solve their technical problems, the government associates are confronted with a larger proportion of program problems. A low degree of technical penetration into contractor affairs (fewer R & D laboratory associates) may result in a lack of detail knowledge of severe technical problems. Their more severe program problems, therefore, may be caused by technical problems of which the government agency is not fully aware; hence, their inability to solve the real problem at its source.

Suggestions for Further Study

R & D schedule and cost parameters are easily defined, quantified, and capable of comparative analysis for evaluation. Technical performance parameters are not as easily defined or capable of analysis. A study of technical performance characteristics would be useful to help improve industry-government measurement techniques.

A study of the sizes of in-house project groups using the headcount per annual project cost factor, as started in this thesis, should be continued and expanded by including many more projects from

several government agencies. Analysis of a more comprehensive accumulation of data might eventually result in beneficial changes to the present forms of government organizational structures, and their contractor relationships.

Different combinations of incentive-fee weighting factors for technical, cost, and schedule performance parameters are used in R & D contracting with the intent of placing specific emphasis on contractor performance in areas where effort is desired most. A study should be conducted, and repeated at frequent intervals, to determine the actual effect of various incentive-fee formulae on performance.

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APPENDIX A

APPENDIX A
QUESTIONNAIRE
FOR PROJECT MANAGERS AT
GEORGE C. MARSHALL SPACE FLIGHT CENTER

This questionnaire is part of a research study of R & D organizations being conducted at the Massachusetts Institute of Technology. The objective of the study is to identify situations in which conflicts (problems) exist, and to determine the various ways that project managers resolve these problems.

The attached questionnaire is designed to collect data which will provide only a broad-base definition of pertinent project parameters. It deals with problem areas only in a general sense. The information which you provide may be used for correlation with real problem situations. The precise problem situations will be jointly selected and discussed by you and the researcher. Your answers to all questions will be most helpful.

Your answers in this questionnaire and subsequent interviews will be kept strictly confidential. Only the one researcher and the Faculty Advisors will see the answers. After the study is completed the questionnaires will be destroyed. A summary of the study will be made available to you if you desire.

In analyzing the data it will be necessary to test for correlation between groups and projects; therefore, each group and each project have been assigned a code number. The use of a code number system was decided upon to preclude the identification of any individual. Absolute values of cost will be disguised by specifying range values.

Any comments you would like to make about the questionnaire or the forthcoming interviews are solicited.

Return the completed questionnaire to: E. L. Field
25 Grantland Rd.
Wellesley Hills,
Massachusetts

Thank you very much for your cooperation.


E. L. Field

SPECIAL INSTRUCTIONS

1. Read the entire questionnaire over quickly before you start filling it in.

2. For those projects which are developed for two program uses (such as S-IV-B, J-2, and the Instrument Unit), special treatment of quantities, estimated costs, funding requirements, and number of changes must be considered so that eventual analysis of the data will not be biased by having incomplete or partial information. Therefore, please segregate applicable amounts or quantities as provided for in the questionnaire.

If a common piece of equipment, change, or other factor is used for, or benefits both programs (Saturn V and Saturn I-B), be sure to list it only once under the appropriate program. It is important that estimated costs, quantities of hardware, personnel, etc., not be counted twice. You make the decision under which program you want the data recorded.

All other projects (S-I-C, S-II, F-1, and GSE) should place their answers under the Saturn V blank only.

3. Only rough order of magnitude answers are required. At least two significant numbers for each answer should be listed. Try to maintain an accuracy of plus or minus 15% for all quantities.

PART I. PROJECT DEFINITION

Name of Project _____

Name of Project Manager _____

Organizational Code _____ Phone No. _____

A. Project Description:

1. General statement of project scope:

2. Number of major R & D items to be produced for ground test and development purposes:

Sat V _____ Sat I-B _____

3. Number of major end items planned for flight operations:

Sat V _____ Sat I-B _____

4. Total number of equivalent GSE sets planned for development, acceptance test, and launch area use:

	<u>KSC</u>	<u>Other Locations</u>
Sat V		
Sat I-B		

5. Physical size of the Saturn V flight item -- excluding GSE:

Envelope dimensions	{	Length _____ ft.
		Diameter _____ ft.
Weight	{	Dry Weight _____ lbs.
		Loaded Wet Weight _____ lbs.

B. Project Facility Sites:

Name all the facility site locations where project functions are either performed by contractor or government personnel. List only those sites where more than 100 personnel are working on your project.

Location	Basic functions accomplished	Sat V* or I-B	No. Cont. Pers'nel	No. Gov't Pers'nel

* If site serves two programs, leave item blank. If the site serves only one program, mark either V or I-B.

C. Project Size:

	<u>Sat V</u>	<u>Sat I-B</u>
1. <u>Manpower:</u>		
a. Number of Huntsville project office employees.....	_____	_____
b. Number of resident project employees including all Center support personnel.....	_____	_____
c. Number of other Huntsville personnel supporting project - including R & D Operations.....	_____	_____
d. Number of contractor personnel at all facility locations -- direct labor headcount.....	_____	_____
e. Number of other contractors supporting project.....	_____	_____
f. Number of other personnel.....	_____	_____
2. <u>Funding:</u>		
a. Total FY-66 project budget.....	\$ _____	\$ _____
b. Latest estimated total project cost to program run-out -- including the 5 vehicle follow-on for Saturn V.....	\$ _____	\$ _____
c. Project FY-66 funding distribution:		
(1) Principal Contractors *.....	\$ _____	* \$ _____ *
(2) R & D Contract support.....	\$ _____	\$ _____
(3) Others: _____	\$ _____	\$ _____
d. Total project cost to date.....	\$ _____	\$ _____

* List all contractors who are working on your project who draw 10% or more of the current FY-66 budget.

Contractor	Function or service	Planned funding amount for FY-66	
		Sat V	Sat I-B

PART II. PROJECT MANAGER'S ASSOCIATES

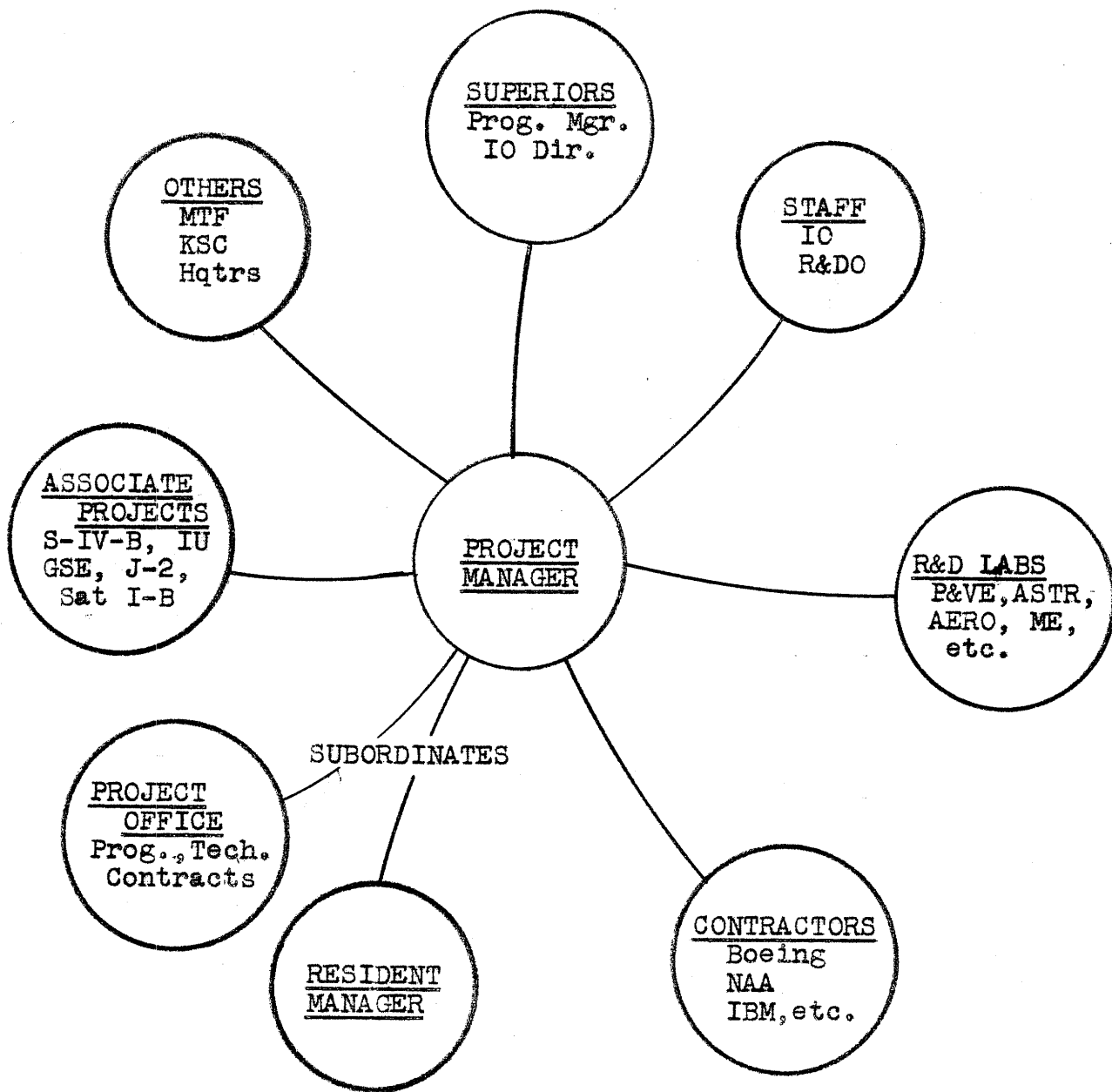
A. Associate Definition:

Figure 1, shown on page 7, generally illustrates a communications schematic linking a typical Marshall Space Flight Center manager with his work associates. The diagram shows only the link between the project manager and individual associate sets or groups. Naturally, communications are conducted between different members of each associate set, but these links are not shown here for the sake of simplicity and because this study is only concerned with your contact with those people and vice-versa.

B. Instructions:

1. Under the associate set classifications listed in the tables on pages 8 and 9, please list the names of the individuals with whom you communicate during the course of a typical month.
2. Beside the names, list organizational codes, the functional area of communication such as: Engineering; funding; manufacturing; scheduling; testing; etc.
3. List the estimated average number of hours per month you usually spend communicating with each person and the average number of individual communication contacts these hours represent. Communication time should include discussions, phone conversations, meetings in which you actively participate, and memo or letter composing time. If significant time is spent on different functions with one individual, please list the functions and times separately.
4. In order to keep the noise level reasonable, list no more than 2 or 3 individuals for each distinct organizational entity with whom you communicate -- for example -- the project engineer and working group chairman in the same lab or division.
5. The completed list should provide a fair representation of your principal project associates.

FIGURE 1. PROJECT MANAGER'S ASSOCIATES



LISTING OF PROJECT ASSOCIATES

Name of Associate	Orgn. Code	Communication Functional Area	Average	
			Hrs/ mo.	No. Contacts/ month
1. Superiors				
2. Staff				
3. R & D Labs				
4. Contractors				

PART III. PROJECT CHANGE ACTIVITY

- A. This portion of the questionnaire deals with changes issued against project contracts. We shall consider two basic categories of changes -- technical and program. For the purpose of this study, they are defined as follows:
1. Technical: Technical changes are defined as design changes which alter or better define the mechanical or electrical characteristics of the major end items (including stage and ground support equipment) with respect to a prior definition. This category includes engineering, manufacturing, tooling, and the basic development and production effort necessary to accomplish the change.
 2. Program: Program changes are defined as those which effect the project by changing: The quantity of end items; facility utilization; funding or cost; and, major program changes such as adding new test programs or deleting a portion of a previously planned test program.
- B. Based on the ground-rules listed above, please fill in the next page using your project records as the basis for answers. Interpolation may be required in some cases in order to segregate technical versus program cost values; however, use your best judgment by making considered estimates.
- C. Do either you or your contractor maintain a comprehensive list of all changes or proposed changes? Yes No If not, briefly state what type of records are kept on the reverse side of this page. If you have such a list, check the items listed below which indicate the level of detail available in the list.
- Name of change
 - Engineering change number (ECP, CRN, etc.)
 - Change order number
 - Who originated change (Contractor or Gov't)
 - Date of original inquiry (TD or ECR)
 - Date of Engineering change proposal (ECP)
 - Change order authorization date
 - Cost or price of change
 - Proposed or considered changes cancelled

1. Total Project Changes:

- a. Total number of technical and program changes issued against your contracts since the start of the project:

Saturn V _____ Saturn I-B _____

- b. Total cost increase attributable to all changes issued against the contracts (including any over-run costs):

Saturn V \$ _____ Saturn I-B \$ _____

- c. Original contract price (before changes):

Saturn V \$ _____ Saturn I-B \$ _____

2. Technical Changes:

- a. Total number of technical changes:

Saturn V _____ Saturn I-B _____

- b. Total cost increase from all technical changes:

Saturn V \$ _____ Saturn I-B \$ _____

3. Program Changes:

- a. Total number of program changes issued:

Saturn V _____ Saturn I-B _____

- b. Total cost increase from all program changes:

Saturn V \$ _____ Saturn I-B \$ _____

PART IV. DECISION PROBLEMS

What types of project decisions are the most difficult to make? To answer this question use the list of typical systems and program functions shown on the next two pages.

Instructions:

1. Check one blank in columns 1 through 4 for each system or function to indicate the level of difficulty you have experienced in making decisions pertaining to that item. If other titles are needed, list them. Those which are not applicable, leave blank.
2. In the column titled, "Rank Order of Difficulty", rate three (3) items which give you the most problems. Rank them in the relative order of difficulty experienced by you and your associates.
3. In the column titled, "Estimated Cost", list the approximate dollar value of cost attributable to each item. An accuracy of plus or minus 20 to 25% should be adequate. The total cost should be approximately equal to your answers to questions 2.b and 3.b of PART III (page 11).
4. After you have completed filling in your answers on the next two pages, come back to this page and rank order list your three toughest items out of the total of six (three technical and three program) which were answered in accordance with instruction number 2, above.

Rank order of three toughest items:

1. _____
2. _____
3. _____

PROGRAM DECISION PROBLEMS

Program Decision: Problem Areas	Difficulty				SAT V	SAT I-B	Estimated Cost
	1	2	3	4			
	Very Difficult	Moderately Difficult	Little Difficult	No Difficulty	Rank order of Difficulty -	Rate of Items	
Funding & Cost							
Delivery Schedule							
Pre-delivery milestones							
Facility Utilization							
Test program additions or deletions							
Stage hardware quantity additions or deletions							
GSE hardware quantity additions or deletions							

PART V. CHOICE OF PROBLEM SITUATIONS

- A. During January 1966, the researcher will come to Huntsville to discuss various conflict or problem situations which you have experienced during the last few years. Verbal input will be necessary in order to classify what the problems were and how they were resolved.
- B. The greater the number of situations of various types, the better will be the results of the study. Volume has its drawbacks; therefore, a simplified format for interview has been developed.
- C. It is intuitively felt that most of the project manager's problems concern project changes -- both the contractually authorized type and those that are not formally authorized in a contractual document. Both kinds represent some change in the existing plan prior to perception of the problem. Therefore, most potential problem situations probably will come from your change list.
- D. To start your thinking about the situations which might be studied, the following category types are suggested. Please list your first impressions of likely candidates by a general title and change order number (if any). At least two or three situations for each item are desired. Just jot down your ideas so that we can have a basis for quick selection in January. Your listings here will not be considered firm. You may come up with better ones between now and January.

1. Potential Technical Problems for Inclusion in Study:

a. Structural:

b. Electrical:

c. Instrumentation:

d. Propulsion:

e. Flight Control:

f. Mechanical GSE:

g. Electrical GSE:

h. Others:

2. Potential Program Problems for Inclusion in Study:

- a. Funding & Cost:
- b. Delivery Schedule:
- c. Pre-delivery Milestones:
- d. Facility Utilization:
- e. Test Program Additions or Deletions:
- f. Stage Hardware Quantity Additions or Deletions:
- g. GSE Hardware Quantity Additions or Deletions:
- h. Others:

APPENDIX B
Interview Form for Project Managers Only

PART I. PROJECT PROBLEM SITUATION DEFINITIONS

1. Name of project _____ Code _____
2. Problem title _____
3. Identification nomenclature:
 - Change order number _____
 - ECP or CRN number _____
 - Other _____
4. Brief description of the problem or change:

5. Classification and category: (Check one)

Technical

- Structural
- Electrical
- Instrumentation
- Propulsion
- Flight Control
- Mechanical GSE
- Electrical GSE
- Other _____

Program

- Funding or Cost
- Delivery schedule
- Pre-delivery milestones
- Facility utilization
- Test program additions
or deletions
- Stage hardware additions
or deletions
- GSE hardware additions
or deletions
- Other _____

6. Did this problem or change have any effect on other projects? Yes No If yes, check the projects effected.

- S-I-C
- S-II
- S-IV-B
- I. U.
- J-2
- F-1
- Launch GSE
- Other _____

7. Who originated the request for change or identified the problem at its inception? (Check one)

- Self (Project Manager)
- Superior
- Staff
- R & D Lab
- Contractor
- Project Office Subordinate
- Resident Office "
- Associate Project
- Other _____

Name of responsible individual: _____

Organizational code of person: _____

8. Which of your project associates had any input into the solution of this problem? List the names of the individuals in each associate group who had any input which you considered when arriving at the final decision. Use the form on the next page. Then circle the name of the individual who had the most significant or influential input.

8. Continued -- Input from associates:

<u>Associate Group</u>	<u>Names</u>	<u>Org. Code</u>
Superiors		
Staff		
R & D Labs		
Contractors		
Project Office Subordinates		
Resident Office Subordinates		
Associate Projects		
Others:		

9. Time required to resolve the problem:

- a. Approximate date of the first identification of the problem by any of the associates.
- b. Date of technical direction or letter requesting a proposal _____
- c. Date of contractor's engineering change proposal (ECP, CRN, or Budgetary Planning Estimate) _____
- d. Date of change order or other instrument which represented formal acknowledgement of a final decision or firm go-ahead; resolution of the problem; or firm denial of the proposed change. _____

10. Cost of change:

Was a definite increase or decrease in project cost associated with this problem or change? Yes No
 If yes, state an estimated amount and whether it was an increase or decrease.

SAT V \$ _____ Increase

SAT I-B \$ _____ Decrease

11. Schedule change:

- a. Was a schedule slip probable if the change had been authorized as originally conceived? Yes No
- b. If yes, did the final solution or method of resolving the change or problem accomplish the intent of the change without impacting the schedule? Yes No
- c. Were intermediate or non-contractual milestones changed? Yes No

Comments:

12. Rate the level of difficulty experienced by you in resolving this problem, or in making the final decision for change. (Check one)

- Very difficult
- Moderately difficult
- Little difficulty
- No difficulty

13. Additional comments applicable to this interview:

Interview Form for Project Managers and Associates

PART II. PROBLEM SITUATION PERCEPTION AND RESOLUTION

1. Name of project _____
2. Problem title _____
3. Problem identification:
 - Change order number _____
 - ECP or CRN number _____
 - Other _____
4. Brief description of the problem. What were the issues as you saw them?

5. Was the problem or change of a type which you might call chronic, continuing, or recurring as opposed to a unique problem which is generally settled or solved once and for all?

- Continuing type
- One-time type
- Other _____

Comments:

6. If this problem is of the continuing type, what is the approximate frequency of your involvement? How often do you communicate with someone else regarding it?

Comments:

7. In your opinion, what was the most significant factor which contributed to a delay (if any) in effecting a satisfactory solution to the problem?

- Inadequate technical definition
 Program considerations such as funding, scheduling, or contracting
 No appreciable delay experienced
 Other _____

Comments:

8. Do you feel that this problem could have been solved more satisfactorily if you personally had more time available to spend on it?

- More time
 Couldn't have been done better with more of my time
 I should have spent less time on it

Comments:

9. During the process of arriving at a final decision or solution to this problem, to what degree did you tend to increase your communications with others in an attempt to influence the decision outcome?

- Very active in communicating
 Moderately active
 Not very active
 Gave up trying to influence the final decision

Comments:

10. Was the nature of the final decision very close to the original concept of a possible solution, or was it different?

- Same concept
 Same with slight refinements
 Different but with some features of the original concept
 Substantially different solution

11. If you were to describe the method by which the solution was arrived at, which of the following categories best describes how the final solution was achieved?

- Mutual agreement by the parties concerned.
- One or more of the parties were persuaded to accept a compromise of minor factors, but their major objectives were achieved.
- Give and take, or negotiating occurred between the parties for the sake of reaching an agreement.
- Some parties disagreed on a proper solution. A directive from higher authority was ultimately accepted, thus settling the argument.

Comments:

12. If you were to rate the results or outcome of the final decision which resolved this problem or change, which of the following categories best describes the outcome? Frame your answer from the standpoint of all the parties who were effected - Contractor, R & D Labs, and the Project Office.

- Everybody is better off.
- Everybody got their main wants - the compromises were minor
- There were major trade-offs or compromises - Some people are better off and others are worse off.
- Everybody is worse off -- the decision didn't really solve the problem.

Comments:

13. What degree of freedom did you feel your project group had in influencing the solution to this problem?

- Completely free to take whatever action was felt necessary.
- Somewhat free but slightly influenced by other groups.
- Somewhat restricted because of the influence or pressure exerted by other groups.
- Completely restricted by policy or direction from others.

Comments:

(How influenced; what groups; what kind of policy?)

14. To what degree was the ultimate solution to this problem satisfactory to you personally?

- Completely satisfactory
- Significant factors were satisfactory but minor features were not.
- Significant factors were not satisfactory, but some minor features were.
- Entirely unsatisfactory.

Comments: