PROJECT MANAGEMENT IN THE APOLLO PROGRAM: AN INTERDISCIPLINARY STUDY

by

Eugene E. Drucker
William S. Pooler
David L. Wilemon
Bernard D. Wood

# SYRACUSE/NASA PROGRAM

NASA

National Aeronautics and Space Administration

Syracuse University

ACKNOWLEDGEMENTS

This report is built on a firm foundation of cooperation from hundreds of people in NASA, the Congress, and the Aerospace Industry. Most of these are listed in Appendix A, but it is possible that a few names have escaped our recollection. To all the people who took the time to talk to us and endure our frequent ignorance, we owe a huge debt of gratitude.

There are several individuals within NASA who we particularly wish to thank. Charles Bingman, formerly of the Office of Organization and Management, was instrumental in starting us down the path of discovery, and gaining entrée for us in various NASA organizations. His continued interest in our work and many stimulating discussions with us were among our most important resources. Richard Stephens of NASA's Office of University Affairs was also extremely patient and helpful in launching our investigation. At the Marshall Space Flight Center we are particularly indebted to Robert A. Smith II who constantly gave the team encouragement throughout the program. Mr. James Daniels who spent the better part of a year at Syracuse University also provided the team with many insights on the development of various NASA organization philosophies. We also greatly appreciated the assistance of Earl Young at the Manned Spacecraft Center in breaking ground for our initial interviews. Finally, we are indebted to Dr. Frank Hansing of the NASA University Affairs Office for his belief in the importance of NASA, working closely with various universities in the area of management research.

Several faculty members and graduate students formerly associated with the Project Management Group, although not participating in the actual writing of this report, have made important contributions to the research study. These were Professors George Frederickson, Richard Hopeman, Kin Tong, and Martin Barzelay; and students Henry Anna, Harry Lasher, Alphonse Sallett, John Cicero, Barry Kalmachter and Paul Nakai.

Special recognition must be accorded to Dr. John C. Honey of Syracuse University, who was not only instrumental in organizing the original program plan and obtaining a grant from NASA, but who also guided the large interdisciplinary group through its organizational birth pangs.

Mrs. Jean Golemo has been an invaluable aid to us by way of her efficient administrative assistance. It is not possible to enumerate the various secretaries who have toiled over lengthy transcriptions, but to Mrs. Joyce Koury, who has prepared the final manuscript with care and patience, we do owe a special vote of thanks.

CONTENTS

## SUMMARY

This report of the findings of an interdisciplinary group of research workers at Syracuse University deals with project management in NASA's Apollo program in four interrelated sections following the introductory chapter.

Chapter II examines the Apollo program in the context of the total NASA organization. Because of its importance, Apollo tended to be the dominant agency consideration for several years, and as a result, the continued existence of NASA as a large agency was threatened as that program began to phase out. The Apollo program was a unique undertaking. As such, organizational arrangements worked out during the course of the program's existence must be treated as suggestive of techniques that might apply in other organizational settings.

Within the Apollo program, the initial organization and its consequent changes proved to be influenced by various factors including the past history of the constituent parts of the effort, the national climate at the time the original decision to activate Apollo was made, the life-cycle nature of projects, the personalities and experience of people who were running the program, and the trade-offs effected which were particularly constrained by a tight schedule. Three significant organizational techniques that developed in Apollo are discussed. These are: the purposeful use of conflict to insure control by the top of the organization, the use of the change control panels to facilitate problem solving and coordination, and the use of matrix organizations coupled with a single authority nexus to insure continued functioning of the matrix.

Chapter III of this report deals with the nature of project management and the manner in which project managers functioned in the Apollo program.

There were a number of important managerial characteristics associated with Apollo project management methods. First, the form of project management used in Apollo was a problem-oriented approach. As such, its unique contribution to its larger "host" organization was to solve the complex organizational problems undertaken in accomplishing Apollo objectives. Second, the project management system used in Apollo was characterized by a multidisciplinary management approach because complex task resolution required the integrated efforts of many disciplinary specialists. In other words, in Apollo, project management provided the vehicle for the integration of organizational specialists with the complex problems undertaken. Third, the project management systems employed in Apollo were designed to provide the all-important responsibility point-of-commitment since one manager was ultimately charged with the success or failure of a task. Fourth, the project approach used employed a systems perspective in problem-solving. Not only did the project manager have to be aware of the internal workings of the project, he also had to be cognizant of the project's larger environmental context. Fifth, project management allowed flexibility and innovation in organizational design. This was often accomplished without a complete revamping of the entire structure of the NASA organization. This was evident in the major NASA centers whose functional organizations could be kept intact despite the size of the Apollo program.

Conflict was often a fundamental characteristic of Apollo project management. The value of the conflict produced depended upon how the

project team members perceived the conflict and how the project manager was able to manage the emergent conflict situations. Several examples are given in Chapter III of how conflict situations were handled by project participants in the Apollo program.

An examination of the influence styles by which project managers in Apollo were able to get compliance from interfaces focused on four primary sources of influence: reward power, punishment power, expert power, and referent power. It appeared that the most effective "management style" employed was one based on the project manager's expert and referent power. Moreover, the expert/referent style would seem to be less disruptive to the total organization.

Finally, four areas which produced problems for project managers in their day-to-day management activities were revealed. These were: managing human interrelationships in the project organization, maintaining a balance between technical and managerial project functions, coping with various types of project risks, and surviving institutional restraints and rigidities placed on the project organization.

The existence of a very extensive technical competence within NASA at the beginning of the Apollo program played a large role in shaping the management schemes used at the three major centers involved. Chapter IV of this report discusses the utilization of the in-house technical competence in the support of the Apollo program. Organizational diagrams for MSFC, MSC, and KSC are presented in such a way as to illustrate the relationships at each of the three centers between the Apollo program offices and the functional directorates.

A significant difference between MSFC and MSC is found in the location of sub-system managers in the Program Management side of the house at the former and within the functional directorates at the latter. This fostered resentments between the Research and Development Laboratories and the project managers at MSFC, though it did give the managers more direct control over details. The sub-system managers at MSC maintained better relationships with their technical bases and were exposed to less professional risk in assuming a management position, but project managers felt a lack of direct communication as a result.

Responsibility for Apollo was purposely diffused at MSFC so that center management was necessarily involved, whereas it was possible at MSC to ignore the center organization to the detriment of the program unless the ASPO manager specifically made an effort to involve the center. At KSC, Launch Operations had prime responsibility for launch and the Apollo offices served essentially as liason to the other two centers. The styles of operation of those two centers were reflected in their response to problems at KSC where MSC displayed a greater trust than did MSFC in its resident managers and contractors.

The problem of communication and control over changes in this tremendous program involving Headquarters and the three centers was very effectively met through the use of Change Control Boards and Configuration Control Panels at all management levels. These may represent the greatest contribution to complex project management made by NASA and the Apollo program.

It is doubtful whether any internal management scheme, no matter how well conceived or carefully executed, could have achieved the ambitious goals of the Apollo program without the tremendous personal dedication of essentially

every team member to the clearly defined goals of the program. It is also doubtful whether success could have been achieved if NASA had not maintained its own tremendous in-house technical capability. Nowhere else could a program manager depend on such support in dealing with contractors or in searching for the best in alternative proposals.

Chapter V of this report discusses the formal and informal relationships between Apollo managers and the contractors. The project managers dealt with their prime contractors formally through the project or contract officer and the resident NASA office. Informally, a great deal of communication took place between various pairs of people in NASA and in the contractor organizations. A compromise was necessary between the need for rapid communication and the more time consuming documentation for configuration and cost control. But this painstaking documentation is the only known method to insure control of a complex engineering system.

The MSFC type of project/contractor interface was somewhat more cumbersome, but more thorough, than that of MSC. The Huntsville projects, to the discomfort of the contractor, seemed to benefit more from in-house expertise partly because of the weaker authority of the project manager. Schedule pressures, however, justified the easier decision making of the MSC style. Resident offices played a very important facilitating role for both principals. The tendency of MSFC to by-pass the resident offices, however, limited the usefulness of these organizations. Contract negotiation through MSC was considered by contractors to be more direct and efficient than through MSFC where there was dual responsibility of contracts personnel to both institution and project.

Contractor program organizations changed constantly in terms of resource competition within the Company. The authority of the program naturally depended on its relative magnitude. Matrix management was really practiced by the contractors only at a particular stage in the program's history. For many reasons, the probability of a contractor effectively integrating the activities of other prime contractors is rather small. These functions were executed best by NASA itself.

The forced intimacy of a public agency with private corporations inevitably produced certain points of disagreement and irritation. There were valid grounds for some of the contractors' grievances pertaining to NASA procedures. Nevertheless, all concerned admitted (sometimes grudgingly) that these procedures have helped more than hindered the achievement of program objectives while fully protecting the public interest.

# CHAPTER I

## INTRODUCTION

As a part of a relatively modest NASA program at Syracuse University, an interdisciplinary team of faculty members and graduate students undertook a study of the characteristics of project management in the Apollo Program. The research was conceived partially in response to NASA's desire to make itself available as a learning laboratory in the area of large scale technological enterprise by a government agency. But it was also anticipated that an unbiased, objective investigation of project management practices by a group not affiliated with NASA or the federal government might result in some insights that very well could have evaded the eyes of those deeply imbedded in the NASA organization. The presumption that a University based research team could penetrate the NASA Manned Space Flight organization turned out to be quite correct. The team enjoyed from almost all NASA personnel contacted, an openness, a degree of cooperation, understanding, and confidence that exceeded the most optimistic hopes ever entertained by the team. For this ready exchange of ideas, the research team is deeply indebted to NASA, and to those of its prime Apollo contractors who were visited, and who responded in a similar way.

The complexity of the task originally defined required the team to constrain itself to the study of something less than the entire NASA operation, or even of the entire Apollo program. By virtue of the mutual interest of NASA and Syracuse University, the research team concentrated on the role of the project manager in the Apollo program. Since the term "project manager"

has many different interpretations in NASA and contractor usage, it should be noted that the type of project used as a model in the study is that exemplified by the LM, CSM, S-IC, S-II, and S-IVB efforts.

Since project management is not isolated from the larger organizational elements in NASA, nor from the prime contractors in industry, it was necessary to take cognizance of these considerations. Chapters II and V contain commentary on these facets of project management.

The make-up of the research team was guided by the requirements of the task, and an interest on the part of team members in interdisciplinary research. There have been some changes in the membership of the team, but the core of the team still consists of the following faculty members: Professor Eugene E. Drucker of Mechanical Engineering; Professor William S. Pooler of the Department of Sociology; Professor David L. Wilemon of the School of Management; and Professor Bernard D. Wood of Mechanical Engineering. As a by-product of the investigation, a good deal was learned about the interdisciplinary mode of research, and fed back into the operation. As a result the research group has become a close-knit, smoothly operating unit, contrary to the large number of groups which have attempted to function in an interdisciplinary mode but have succumbed to the many pitfalls which are known to exist.

The information on which this report is based was gathered by well over 200 intensive field interviews, almost always attended by more than one person from the team and usually from different disciplines. The interviews were usually tape recorded, transcribed, and submitted to interviewers for corrections. Above all, the interviews have remained

confidential, as guaranteed by the interviewers. NASA personnel at several levels at the three major field centers and headquarters were interviewed, as well as engineers and managers at the plants of five prime contractors, NASA resident people, Congressmen and Congressional committee staff members. A comprehensive list of interviewees appears as Appendix A.

During the course of the research, a three day conference was held with team members and various NASA interviewees in attendance. The purpose was to informally discuss and offer criticism of some of the preliminary hypotheses and conclusions. The remarks of the NASA representatives were extremely helpful in this regard, and many are to be found incorporated in this final report.

From the various sources, and additional documentation of many types, the research team formed a comprehensive picture of the various interactions of a project manager with the elements of his working environment. In a somewhat arbitrary manner, the presentation of this picture is arranged in four chapters. Although each was written by one team member, all chapters have undergone a detailed and critical examination by the other three team members.

In addition to contributions by the project manager group to the Semi-Annual Reports of the Syracuse/NASA Program, various papers, reports, theses, and articles have been written in conjunction with the research. These are listed in Appendix B.

# CHAPTER II

## NASA AND THE APOLLO PROGRAM: A MACRO-ORGANIZATIONAL VIEW

by

William S. Pooler

A. Introduction

B. Apollo as a National Goal

C. The Apollo Organization

D. A Comparison of Apollo Field Center Organizations

E. General Organizational Considerations

# CHAPTER II

## A. INTRODUCTION

The common theme underlying all of the work of the group has been the "project manager." Initial research quickly indicated that what he does can best be understood in the context of a series of overlapping organizational environments of increasingly larger scope within which his actions take place. It will be the purpose of this chapter of the report to describe and analyze the background and larger organizational factors which we have found to be related to the modes of project management adopted in the Apollo project. As well, some attention will be paid to the nature of the relationship between the form of project management and the environmental context. One unifying thread which ties together the points made in the discussion is the tentative idea that the organizational change processes exhibited by NASA and the Apollo program were a consequence of two salient dilemmas. First, NASA had to cope with a constantly shifting environment, changing through time from supportive to neutral to mildly hostile. Second, NASA also had to cope with the problem of combining a permanent bureau organization characterized by semi-autonomous technical research laboratories with a large, non-permanent program organization characterized by highly coordinated "contract monitoring" activities.

Before examining in greater detail the nature of these dilemmas and the resultant adaptive organizational forms, a few introductory remarks about the nature of modern organizations and an appropriate model one might

utilize to explain their pattern of development seems appropriate. Basically, all organizations have two problems to cope with if they are to survive. First, to do something, that is, goal-oriented activity to provide the raison d'etre for the organization; and second, to establish a context which facilitates the goal-oriented activity, that is, maintenance activity. It is necessary, of course, for these two sets of activities to be coordinated.

Typically in advanced societies, the form organization takes is one where increasingly the goal-oriented or task activities are more clearly separated from the maintenance or administrative activities. This is partly a consequence of the complex technology generated in urban-industrial societies. Complex tasks that require skill levels and patterns of coordinated activities which are highly variable in magnitude and duration can be conceived of and acted on in organized contexts. In a sense, organizational forms in advanced societies have been developing in such a manner as to lead to the creation of organizations within existing organizations.[1] Accompanying this pattern of development has been the attempt to exercise control by parallel forms of management to provide adequate direction and integration in the increasingly differentiated organizations.

A general assumption underlying most attempts to analyze large scale organization is that the character of the patterning of relationships is at least quasi-determinate. That is, given a set of conditions involving

---

[1]The Mission Control organization within the Apollo organization is an example of this.

among other things, the nature of the task activities, the state of the arts, the nature of the environment, the nature of the people involved, the past "history" of the organization, and current structure of the organization, one can predict the probable future states of the organization. This I repeat is an assumption, but it provides the basis for a strategy in attempting to discover the particular pattern of development of the organization under investigation and what is generalizable about that pattern, that is, what might apply to organizations in general. An implication of what has been said thus far is that one must proceed from the particular to the general, inductively, but at the same time one must continually build approximate models of what the general appears to be to give direction to one's investigation of the particular.

Matrix organizations have been developed in modern organizations which do not seem to fit the more traditional models of organization. In essence, the conception of a matrix organization is one where the work activities are organized around tasks or projects. These, in turn, cut across the existing functional-administrative activities in the organization. From the task or project perspective, the larger immediate organizational setting constitutes the maintenance-resource base. From the perspective of the organization, projects represent temporary sets of arrangements created to accomplish specific tasks. Often these arrangements are highly variable in scope, complexity, and duration.

The interdependence between the task or project and the larger organization is strong.[1] The project represents a way in which the organization is

---

[1]This discussion does not refer to the special case where the project and the organization are one and the same.

able to get something done. The larger organization is dependent on project success since the project constitutes the productive activity sector for the total organization. Thus, while authority is delegated to the project, it is not given complete autonomy. The larger organization provides the needed resources for the project, including the process of legitimizing the project, and thus the project is also dependent on the larger organization.

The conception of a large organization and one large project imbedded within it, is a special case of generic matrix organization. The general model supposes that there are numerous projects, with highly variable scope, in all different phases of maturation.

There are apparent tensions in the matrix form of organization. If one assumes that there is a finite and limited amount of organizational resources (men, money, skills, etc.) and organizational authority to be allocated, then obviously the projects are competitive. Clearly, the parent organization is superordinate to the project organizations. One of its major functions is to allocate the resources and authority in the organization to the projects, such that the demands of the projects are satisfied and the competitive tensions are minimized. As well, it is incumbent upon the parent organization not to allocate resources and authority in such a manner as to allow the projects to become superordinate to the parent organization. Projects are transitory entities, created for specific tasks. Their functioning must be controlled such that when they phase out, the parent organization is able to survive.

Specific to the Apollo program, this introductory discussion suggests that one should be able to locate a set of background factors which combined to produce the Apollo organization within NASA. Further, the changing configuration of background factors, the inherent strains in the resulting organization, the tensions produced by the large and dominant Apollo program organization, and the life-cycle character of the program, resulted in a series of organizational changes in NASA and the Apollo program organization. Both of these considerations are relevant for understanding the nature of the Apollo program organization and the varieties of project organization exhibited therein. As well, an examination of the NASA-Apollo complex from this perspective should provide insights into the general nature of project organizations.

## B. APOLLO AS A NATIONAL GOAL

The Apollo program represented a national goal. It publicly committed the United States, within 10 years, to safely land a man on the moon and return him to earth. This commitment had both favorable and unfavorable consequences for NASA.

The task assigned to NASA, while complex and requiring new technologies, was well defined, in a broad sense, which is a prime requisite for a successful project. The performance criterion specified landing a man on the moon and returning him safely to earth. The schedule criterion specified that the task be performed before the end of the decade, 1960-1970. The cost, while somewhat open-ended, was estimated to be between 20 and 40 billion dollars. The fact that the performance, schedule, and cost criteria were met is testimony to the exemplary nature of the organization and management scheme that was created for Apollo.

Yet another favorable consequence of the national commitment was the fact that the effort was relatively free from political considerations. This, in effect, meant that NASA was not defined as a supporter of, or a base of support for, either of the major political parties, and at least in the early years of the effort enjoyed bi-partisan support. Also, because the prestige of the United States, in terms of claiming technological superiority over the world community was being tested, great importance was attached to the effort. As a result, NASA had little trouble recruiting extremely competent personnel who were strongly committed to the manned space project, and who were able to view the totality of the program and

thus maintain perspective about their individual contributions. And finally, again particularly in the early stages of the program, financial resources were not constrained.

As noted, there were some unfavorable consequences of the national commitment as well. NASA was not equipped to manage such a large and complex undertaking. One result was that NASA had to undergo a process of quick growth primarily in those areas directly related to the Apollo program. Thus the agency was in effect subordinate to the project, and was severely handicapped in terms of legitimating itself as a long-term, enduring agency guided by a set of general goals. Related to this is the fact that NASA was viewed primarily as a sophisticated, technologically equipped organization which would primarily be the instrumental means by which the national goal would be achieved. That is, NASA, through time, became less often regarded as a general research and development agency concerned with aeronautics and astronautics. Rather Apollo and NASA were thought of as one and the same. Because of the funding mechanism, in fact, the Apollo program supported most of NASA's activities and as a result the cutbacks in budgets greatly affected not only the Apollo effort but the total capability of the Agency.

The specificity of the goal, particularly the time constraint of a decade and the commitment to public scrutiny of the project, proved to be troublesome. The problem was due to the necessity of "freezing-in" the total concept and the design of hardware as quickly as possible. Thus, the early research work revolved around design decisions involving the booster and spacecraft and these, in turn, were influenced by the mode chosen to launch men to the moon. By 1962-1963 lunar orbit had been decided

upon, the concept of the Saturn V cluster of engines had been selected and was in preliminary fabrication and test, and the spacecraft and lunar landing vehicle had been tentatively dimensioned and designed and initial fabrication work was commencing. Once these decisions were made there was ever decreasing latitude to change the design of any of the parts. The lead times were quite long, apprixiimately five years, and in the interim, new technological breakthroughs or advanced new features often had to be ignored. It has been noted, for example, that the Gemini spacecraft involved a much more sophisticated design than the Apollo spacecraft. Problems of integrating the major pieces of hardware with the men and the ground checkout and monitoring equipment, precluded fundamental changes in the basic design. Cost was not a large factor. Schedule, because of the time frame specified in the 1961 decision, was the prime consideration. Pure and simple, Apollo was originally conceived of as a space spectacular to gain back the previously held technological world leadership the U.S. enjoyed and other considerations such as scientific experimentation received low priority.

This severe time constraint is a key to understanding the organization and management of Apollo. First, the designs to achieve the objective were blocked out. Then the rest of the effort was devoted to building up, within NASA, an organization and management scheme which could manage the building and configuring of the hardware out-of-house, which could train men, and which could bring it all together so that the goal was achieved before the decade of the 70's. Through time the degrees of freedom, in terms of improving performance of each of the parts, were further constrained and management was more and more concerned with fitting all of the pieces together. As a

result, more men and resources were devoted to coordination and control, and new organizational structures were appended to the extant organization to insure safety and to meet the schedule.

The severe time constraint also contributed to the tendency of the Apollo program to dominate the host organization, NASA, which housed it. That is, there was a tendency for Apollo considerations to be paramount in NASA, and as a result it cannot be considered a typical project. While part of NASA, Manned Space Flight (really Apollo) formed a separate subunit of the overall organization. It was physically separated from the rest of NASA and yet still integrated, particularly in the sense that men and dollars flowed to NASA primarily through Apollo. As fervor for the "moon mission" dimmed, the binding of Manned Space Flight closer to the rest of NASA was attempted. This effort to make the manned program subordinate to the Agency was at least partly due to the fact that the continued survival of the Agency rested with the success of this large program.

## C. THE APOLLO ORGANIZATION

The Apollo organization consisted of a headquarters unit, three major operating field centers, a group of contractors, and ancillary personnel and resources as needed. Headquarters was given overall administrative and resource control over the total project, and final technical authority was also vested there. After some preliminary organizational attempts, responsibility was given to the head of the Office of Manned Space Flight who delegated the routine running of the organization to the Program Director for Apollo within the Office of Manned Space Flight.

By 1963 a general organizational pattern for stabilizing relationships between the field centers and headquarters had been worked out. The Headquarters Program Offices. OART, OSSA, OTDA, and OMSF were given both the responsibility for managing programs in their respective offices and the responsibility of controlling resources, primarily men and dollars, that the running of the programs necessitated. In effect the Program Office Directors then had institutional as well as program authority. To further strengthen their position, they were given the title Associate Administrator and expected to play the role of general manager for NASA in their respective program offices, and as well, manage the particular programs. For OMSF this meant that the Associate Administrator both headed up the Apollo program and was responsible for maintaining some balance between the Apollo program and the rest of NASA. As was noted above, the day to day running of the Apollo program was left to the Apollo Program Manager. Thus decisions made at the top of the Apollo organization could be backed up and coordinated with resources.

The three operating field centers primarily concerned with Apollo were tied into Headquarters in at least three different ways. First, the directors of the field centers were directly under the head of the Office of Manned Space Flight in terms of maintaining the field centers. Second, the Apollo Program Manager at Headquarters was linked to the Apollo program managers at each of the centers and used five functional offices: Test, Reliability and Quality Assurance, Systems Engineering, Program Control, and Flight Operations, to constantly monitor the progress of the program.[1] From the Office of Manned Space Flight then, institutional control flowed through the Center Directors to the rest of the center and program direction flowed through the Apollo organization at each of the centers.

The third link tended to tie both of these organizations together, both in terms of horizontal and vertical relationships. This link was the Management Council. It was made up of the head of the Office of Manned Space Flight, the three center directors, and their deputies. Once a month the Apollo program manager was charged with gathering his Apollo organization together and forging a presentation which would point out three aspects of the program to the Management Council; the match between schedule and progress, the nature of any problems that arose and what was needed to solve them, and the projected costs and resources necessary.

---

[1]The utilization of the functional offices by program people at the centers varied, and their effectiveness was also questionable.

With the Management Council mechanism all of the hierarchical levels of the Apollo organization were collapsed into two, the Council and the Program organization, and the three centers were brought together such that problems specific to centers and those that ranged across centers could be discussed and solutions arrived at. The head of the Office of Manned Space Flight, who both controlled institutional resources and had the ultimate Apollo program authority, by using the Management Council, was in a position to evaluate the "fit" between program and institutional activities. As well, he was made aware of any problems either specific to institution or program that arose as a consequence of lack of coordination between these two elements.

This organizational arrangement worked out for the Management Council, was instrumental for the success of the Apollo program and in effect provided the necessary authority to make the matrix concept work. That is, the person responsible for both dimensions of the matrix, the program activities and the institutional support, was in a position if necessary, to "force" cooperation between the dimensions of the matrix at any level. If one could generalize from this single instance, it might be hypothesized that matrix organizations, to function properly, must be structured such that a single authority nexus controls all of the dimensions which comprise the matrix and that feedback mechanisms must be established to insure that the proper information is available to that authority nexus. This is not to imply that cooperation must be "forced". As a rule, within the Apollo program there was a good deal of cooperation. But when things did not proceed smoothly there was a back-up device that insured that problems

could be alleviated and a smooth working organization achieved.

To go one step further, it also might be hypothesized that one of the dimensions of the matrix has to be given somewhat greater authority than the other dimensions. With Apollo, for example, the program people were given final authority in terms of the schedule, cost, and performance criteria. This was most clear at Huntsville and Houston where the respective program managers were given this authority. But, the system really worked because both of these program managers finally established very close working relationships with the head of each center. Thus, the head of each center, who formally had authority over both the technical and program sides of the house, could be brought in to settle disputes or help solve problems arising out of the matrix organizational set-up of each center. Interestingly, the Apollo program managers at the centers each had had long working relationships with the center directors. They also had had long working relationships with the people who were the technical experts at the centers. These latter factors appear to be quite important in accounting for the success that the Apollo program organization enjoyed, using the matrix organization technique.

One would suspect where an agency or a program office is involved in running many programs, the institutional agency-wide or program office-wide concerns would tend to dominate. Thus, size of program or project and its importance vis-à-vis the total organization are important variables to consider when decisions concerning the allocation of authority are made. It would still appear necessary to have a single authority point to bring about cooperation. But whether there should be equal allocation of

authority to both the functional and project dimensions, or whether grants of authority should vary with different sized projects and with different stages of the life cycle of the project is still pretty much an open question. Unfortunately, the uniqueness of Apollo does not provide much insight as to how these organizational problems can be solved in other organizations or at another time in NASA.

## D. A COMPARISON OF APOLLO FIELD CENTER ORGANIZATIONS

Each of the three operating centers of the Apollo program were organized differently. Huntsville was given the responsibility for building the booster assembly. Houston was given the responsibility for building the "manned" segments, the Spacecraft and the Lunar Module, for training the astronauts and for operating the mission. Kennedy was given launch responsibilities and associated final check-out and test for launch. Perhaps the first question might be; Why was the Apollo project broken out in just that configuration?

The scope of the Apollo program was vastly larger than any previous astronautical venture. Therefore, much that had to be designed and built was new. But there was the conscious attempt to keep and utilize what was already known and tested or at the very least what had an extremely high probability of working. Under these conditions it is reasonable to conclude that Huntsville, already part of NASA and functioning as the booster experts for the Agency, would be given responsibility for designing and building what came to be known as the Saturn V. It is even more predictable when it is recognized that the director of the Huntsville Center was one of the technical experts primarily relied on when the nature of the space effort and the needed booster capabilities were examined.

The decision to use Cape Kennedy, and build up a pad complex capable of launching the Apollo configuration was also quite understandable.[1] The selection of the director of that center also fits the general pattern,

---

[1] The site was already in use by NASA and skilled personnel were available.

for he had a great deal of launch experience and was thoroughly familiar with the requirements for a test and launch center to insure the successful firing of the Saturn V rocket. When the organization and management of Apollo at Cape Kennedy is compared to the other two centers, it appears to be quite unique. This is a function of the responsibilities it had and only insofar as necessary for the discussion of the organization of the Apollo program will its character be commented on. Geographically, Cape Kennedy was an obvious choice for the launching site of Apollo.

Houston is somewhat different from the other two centers in that it was especially created for Apollo. While the choice of the site is problematical in terms of the analysis being presented, the personnel who manned the Center are not. There has been a great deal of controversy and dialogue concerning the choice of Houston as a center site, but not about the responsibilities assigned to the Center, nor about the individuals selected for key positions within the Center organization. The men chosen to operate the Houston center were those in NASA who had the most experience planning and designing hardware for manned aircraft flight. Since before Apollo no one had manned spaceflight experience,[1] this seemed to be the logical group to be given this responsibility. Further, the group was given responsibility not only for the "manned" spacecraft hardware but also for the men and their flight as well. Thus, given the range of experience that existed, the Houston complex except for the site selection, also appears to represent a conservative decision in terms of responsibilities for a portion of the Apollo effort.

---

[1]This same group was also involved with the Mercury and Gemini programs.

Thus, to answer our first question, the original break-out of responsibilities to the three centers was understandable in the context of the past history of U. S. space efforts. It would have been possible to organize the effort in another way, with a lead center perhaps, or with only two centers--Huntsville and Cape Kennedy, for example. It is reasonable to argue that Cape Kennedy could have been expanded and housed the Houston center. Why this was not done is not clear.[1] But in any event, as a function of the high speed communication and transportation technology available in the 1960's, locating the center at Houston does not seem to have been a problem for the success of the program. In terms of the past history of space efforts, and in terms of manpower and experience available, it certainly seems reasonable to assume that the three operating centers of Apollo were given their responsibilities because of the original inputs to the decision to "go to the moon" by the various groups who eventually ran the three centers.

As with the 1961 Apollo decision, there are both favorable and unfavorable aspects associated with the use of three field centers and headquarters. All of the units were spatially separated and all, with the exception of headquarters, were concerned with tasks that could proceed in parallel and be integrated at a later time.

The fact that Huntsville and Houston were separated and that the division of labor was so clear impeded communication between the two centers. Thus, it was not unusual during most of the Apollo program,

---

[1]One reason given for not combining Kennedy and Houston activities was the lack of a "local" resource base to support such a massive organization.

for people at the middle and lower levels of the respective center organizations to have little or no idea about how the other center was organized and how work was proceeding. Interaction between the centers did occur through the Management Council, through the program organization, and through the change control panels. But these interactions were quite specific to a problem or some narrow coordination difficulty, and thus the expertise relevant to tasks beyond a particular center's responsibility, by that center's own personnel, was not utilized. Also, because of the lack of a generalized set of interaction techniques, the work at Houston and Huntsville did not exactly fit and many integration problems rose to the surface at Kennedy. Because of little communication between Houston and Huntsville, for example, Kennedy had particularly difficult configuration and test problems to resolve. Also, because of the separation of Huntsville and Houston, the spirit of cooperation and high degree of integration of the total organization working on this monumental undertaking was thwarted. It is fair to say that some animus existed between these two centers, and it was exacerbated by their separation both functionally and spatially.

The separation of the three centers and headquarters certainly contributed to all of the coordination problems which were continually troublesome for the program. The separation also was related to a general tendency to "projectize" tasks associated with Apollo. That is, at Headquarters, OMSF was spatially separated from the rest of NASA headquarters. At each of the centers, there was an effort to get the contractors to separate out from the rest of their work, the portion concerned with Apollo, and

to create an organization to run their piece of Apollo within, but clearly separate from the rest of their organizations.

While it is true that this tendency to "projectize" parts of the Apollo program had unfortunate consequences there were also benefits to be derived from this procedure. The breakdown and isolation of separable pieces focused responsibility for the different parts on highly visible units within industry and facilitated the monitoring of the contract. From the perspective of the contractors, it tended to enhance interaction between the center and the contractor. It also allowed more concerted effort to be focused on producing a reliable, high performance piece of hardware. This separation was also beneficial for the centers in that it gave a unity of task to the total center and tended to enhance relationships within each of the centers. This was particularly important because of the "built-in" conflict mechanism associated with the matrix organization that existed at each center.

The coordination problems at Kennedy were certainly aggravated by the separation of task and separation in space of the other two centers. For the group at Cape Kennedy to do its job properly, there should have been constant interaction between it and the other two centers. To design adequate configuration, test, and launch facilities, Kennedy should have had a view into the "innards of the bird" at Huntsville and have been apprised of all of the design and subsequent changes associated with the Spacecraft and Lunar Module. This was not the case as the two field centers developed a somewhat insular perspective due to their separation of function and their different spatial settings.

The organization of the Huntsville and Houston Centers were quite different. This was partly due to the insular perspective of each center, noted above, coupled with the tasks they had to perform, their past history, the existing state of the art, and to a degree the kinds of individuals involved in running the program and running the centers. One difference between the centers is captured by noting that Huntsville had a strong project organization and Houston a strong program organization. At Huntsville, the stages were relatively clean pieces of the Saturn V complex and hence even though there was a program manager, his coordinative function was simpler compared to Houston. The project or stage managers were mostly from the R&DO side of the Huntsville house and were well aware of the expertise that existed in the labs of R&DO and the "performance" commitment of the laboratory directors. Also, the stage managers were mostly highly technically qualified and as a consequence were in a position to decide issues involving a schedule-performance tradeoff. Each of the stages was such that they could be built relatively independently of each other, as was the case with the engines which were parts of the stages. Therefore, at Huntsville there was a series of projects, related but quasi-independent, managed by strong project or stage managers. Except for the S-II stage, the major tasks involved enlarging already existing boosters and for the first time manufacturing them out of house. To insure the meeting of schedule check points, the project or stage managers had the major problem of relating to the strong technical in-house expertise that existed in the labs at Huntsville, and the newly developed expertise that existed at the contractors. The resultant "troica" of schedule, performance, and cost decisions made

by the stage manager with cost emphasized by the contractors and performance by the R&DO people resulted in a strong project orientation. The program manager was a back-up for the stage managers, and since he had also been with the Huntsville group for a long period of time, he could help ameliorate problems that arose between the project manager and the labs over in-house or contractor issues. Further, the program manager had the confidence of the Center Director who took a strong hand in the running of the Apollo program at the Center, and as a result could get the assistance of the Center Director in helping maintain program and project perspective. There is little doubt that Huntsville R&DO people had a great deal of technical expertise, both in terms of design and planning and in terms of fabrication, and as a result tended to dominate the Center. Further, the past experience of the Huntsville people derived from the Arsenal concept of doing the complete job with the same people, in-house. Thus, it is a great credit to the selection process that it allowed quite strong project managers to be chosen, who for the most part had the skills necessary to allow program and project considerations to surface in such an environment.

Unlike Huntsville, Houston was characterized by a strong program organization. At Houston, there were not clearly separable pieces, except for the Spacecraft and the Lunar Module. In these two instances there were project managers similar to Huntsville but they were located in the Program Office. There were also functional directorates at Houston which had direct inputs into the Apollo program but in a manner far different from that which was obtained at Huntsville. Mission Control needed constant

interaction with the design and fabrication of the Spacecraft and Lunar Module, as did the astronaut directorate. The resulting man, communications, and hardware interactions, superimposed over hardware being designed and fabricated at the frontier of the state of the art both by in-house and contractor groups, necessitated a strong overall coordinative device. As a consequence, the program organization at Houston was the focal point where decisions were made and trade-offs achieved among safety, performance, and cost by the program manager, and cost, performance and safety by the contractors. At Houston, unlike Huntsville, the functional directorates did not dominate the organizations, basically because the technical experts had no base of experience in managing programs, the state of the art was to some degree unknown, and because of the man, communication, and hardware inputs all impacting and affecting the nature of the Spacecraft and Lunar Module configuration.

For Huntsville the major management problems involved setting up procedures to allow the project managers to manage the stages and thereby allow project considerations to dominate. At Houston, the major problem was building a program organization which could manage the great diversity extant at Houston and which could meaningfully involve the technical functional directorates located at the Center. The degree of success the program orientation had at Houston, to a measurable degree, is a function of a strong program manager who had a long history of association with the center personnel, and who was skilled enough to maintain program emphasis while encouraging center functional and contractor support. At Huntsville, the organizational success of the Apollo effort is to a measurable degree

a function strong project managers (stage managers) backed up by a technically and organizationally competent program manager and center management.

The success at each of the centers, with somewhat different project or program organizations is strong evidence for the nature of the task, the personnel available, the experiential base, and the prevailing knowledge or state of the art, all interacting to produce a viable form of organization and management. The form of the project or program organization was variable and stabilized only after a series of trials and errors. Perhaps this is necessary with research and development work of large scale and technological complexity. If so, it means that too much organizational and management planning is not appropriate for the development of successful projects and programs. It might be hypothesized that there must be a trial and error management and organization process analogous to the preliminary design and analysis phase of the actual research and development process which takes into account the uniqueness of the organizational setting, the task, the personnel, and other relevant factors.

## E. GENERAL ORGANIZATIONAL CONSIDERATIONS

Among the large number of organizational innovations introduced by NASA and the Apollo project, two stand out; the creative use of ambiguity and conflict, and the extensiveness and flexibility of the feedback networks from lower to higher levels of the organization.

1. Creative Use of Ambiguity and Conflict. The issue here involves the apparent purposeful use of conflict as a mechanism to insure control by the top of the NASA Apollo organization. The institutionalization of conflict is accomplished by either, or both, of two related techniques; partitioning responsibility in such a manner that it tends to exceed the degree and scope of authority associated with the responsibility, and delegating overlapping responsibility and/or authority such that some ambiguity exists as to how problems which arise are to be resolved. An example of the former would be where the project manager is given the responsibility for building some stage of the rocket and making sure it configures with the rest of the hardware. The scope of his delegated authority is less than his responsibility in his dealings with R&DO personnel and contractors. Thus, he is forced to rely on personalized techniques to accomplish his task rather than exercise delegated authority. Where issues cannot be resolved, they are brought to the attention of higher levels in the organization for resolution. Though highly simplified, this description of the interfaces between project manager, research and development (in-house) personnel, and contractor does make salient some important facts about NASA and the Apollo organization. It suggests that conflict can

be quite functional for an organization in insuring some modicum of control in highly decentralized, technologically complex organizations. It also suggests that structured conflict can be utilized to more personalize relationships in large organizations. Lastly, it suggests that this particular form of institutionalized control deals mainly with the productive aspects of organizations.

An example of institutional conflict in NASA is the creation of a variety of managers (project, functional, and institutional), all with some overlapping responsibilities and authority, essentially related to maintenance activities. Here the institutional, functional, and project managers tend to compete for scarce resources, men and money, and where conflicts arise, they are either settled by personalized interaction or by being brought to the attention of those at higher levels of the organization. The conflicts basically develop because there is no clear delinia-tion of responsibility and authority in terms of maintenance activities and as a result a good deal of ambiguity exists.

While the two methods of instituting conflict result in essentially the same things, control exercised by the top of the organization and more personalized relationships at lower levels of the organization, they are different in one very important respect. One form of conflict is oriented toward production activities and the other toward maintenance. It is interesting to note that of the two, the one that worked least well in NASA was the one instituted to deal with maintenance activities.

2. Extensive and Flexible Feedback Networks. A persistent issue facing all organizations is whether hierarchical or horizontal relationships

should predominate and the consequences that flow from that decision. NASA has worked out a mechanism that potentially has the capacity to overcome this dilemma, the creation of change control panels which were ostensibly used as a configuring device. In general terms, one can think of an organization as comprising a series of relatively insulated levels and within these levels, a series of relatively insulated sub-units. As problems arise that cannot be solved by the sub-units, the formal mechanism of a single level change control panel is initiated. Discussion of the problem among sub-units, at a single level either leads to the resolution of the problem or brings it into clearer focus and makes more evident the scope of the problem. If the scope is too large to be handled at any one level, members of the sub-units, now representing the variety of interests at a particular level, help initiate a change control panel at the next highest level where the potential to resolve larger scope problems exists. The exercise is repeated and either resolved or a next higher level panel is convened. In essence, the process is an emergent one growing out of the nature of the problem and its scope. While each particular problem resolution represents a substantive instance of the change control panel structure being utilized, the structure always remains as a viable problem solving mechanism. The numbers of levels involved varies from problem to problem, essentially determined by the scope of the problem, its importance, the amount of resources necessary to resolve it, the difficulty associated with its resolution, and proximity to launch time.

While this organizational innovation has only been outlined (see Chapter IV for details), it appears to be a wide ranging device to handle

feedback from lower to higher levels of organizations in a truly creative way. The assumption is that most occurrences are routine in organizations and can be handled at the sub-unit level. Where this is not so, the formal mechanism exists to actualize a decision-making apparatus that involves potentially all levels of an organization. This mechanism assumes that problem definition and resolution proceeds inductively from the smaller sub-units to higher and more far ranging levels of the organization, and that members of all necessary levels are importantly involved in the final problem resolution. There are some important issues that are related to this conception of the change control process as utilized by NASA and Apollo. For one, is the particular procedure only useful when you have a situation of geographically dispersed field centers and contractors and where you are dealing with quite complex and highly inter-related hardware assemblies? Here the issue is the generalizeability of the procedure. Another issue is whether this is mainly a feedback device for dealing with production activities or can it be modified to deal with a wide spectrum of problems associated with organizations? Another issue is the degree to which levels and sub-units within a level of an organization can be decentralized and the suitability of this device. Yet another issue has to do with the nature of the organization that is most appropriate for this kind of procedure. Is it only useful for R&D organizations dealing with advanced hardware construction or can it be utilized for all kinds of organizations? There are certainly other issues related to using this kind of technique, but the important point is that here is a novel feedback mechanism used with success by NASA, that should be explored for its general usefulness and application.

The Apollo management organization also contains other elements worth noting as they potentially have relevance for any complex, large-scale undertakings.

3. The creation and maintenance of a strong in-house technical and managerial base for the Apollo program functioned to provide NASA with the skills necessary to help design, manage, test, and successfully complete the hardware and software tasks. It can be hypothesized that to insure the successful completion of a large scale venture, an organization assigned such responsibility must have technical and managerial skills equal or surpassing those who assist the organization in the venture (see Chapter IV).

4. As part of its management responsibility, the Apollo program organization adopted procedures which resulted in detailed and extensive surveillance of contractor activities. The complexity of the undertaking, its importance, and NASA's overall program responsibility, were major factors in this development. Although there were difficulties related to contractor autonomy and as well, general coordination problems, this procedure appeared to be essential to the successful completion of the program (see Chapter V).

5. The "purposeful use of conflict" was utilized to overcome the problem of maintaining control among competing authorities, i.e., institutional position authority (field center head), technical authority (director of R&DO), and program authority. Conflicts occurred within centers, across centers, and involved headquarters and the contractors. The use of this conflict was successful because of the strong commitment to the success of the program.

a) Conflict was resolved by informal meetings, hardware reviews, change control boards, status reviews, etc.

b) Decisions which resolved the conflict were made known to the parties and rationales provided. Appeal procedures were available to the participants.

It can be hypothesized that one way of resolving the authority and responsibility dilemma in organizations, which is a function of positional authority versus technical skills, is the controlled use of conflict (see Chapter III).

6. Every effort was made to standardize the management and coordinative procedures in the Apollo program. Given the fact that this was a research and development program, an effort was made to standardize all relatively routine maintenance actions, evaluative activities, and repor ng procedures. The standardization represented an attempt to conserve resources for the "unknown" parts of the program. It can be hypothesized that research and development activity contains both novel and traditional aspects and that the traditional aspects should be standardized to optimize organizational response to the novel.

7. For the Apollo program, schedule was the foremost consideration and trade-offs were effected which de-emphasized cost and emphasized performance and safety, while maintaining strict adherence to schedule. It can be hypothesized that while schedule, performance and cost parameters are all management constraints, emphasizing any one of them is probably beneficial for the completion of a program and has important implications for the management of the program, as well.

8. In the Apollo organization, three general dimensions had to be coordinated; the technical or scientific, the overall internal organization, and the social, political, and economic environment. The Apollo program proceeded relatively smoothly when top NASA leadership consisted of three individuals; one who looked outward, one who acted as an internal general manager, and one who looked after the technical and scientific considerations. When this tri-partite division of labor was disbanded in 1965, the problems of NASA as an agency and in particular the Apollo program, were increased. It can be hypothesized that any technical organization, but particularly those organizations involved in R&D work, must constantly monitor all three dimensions and work out mechanisms to coordinate the various activities associated with each dimension.

9. The Apollo program utilized the technique of "projectizing" critical tasks or problems which arose in the course of the project. Closely allied to this procedure was the use of task forces. It can be hypothesized that the successful utilization of these temporary, situationally specific organizations was directly related to the degree they were perceived and utilized as temporary and high priority operating units.

10. As the Apollo program reached conclusion, there was a proliferation of control and reporting mechanisms resorted to by top management, to insure the coordination of the diverse parts of the program and to re-establish agency dominance over the program. For the most part these appended controls were indicative of the imbalance between program and host organization. Due to many different factors, Apollo dominated over agency concerns, and the continued survival of the agency at its existing

size was threatened with the termination of the program. It can be hypothesized that only when the total organization is created for a specific task, and therefore perceived as a temporary rather than an enduring organization, is it beneficial to allow program activities to become superordinate.

CHAPTER III

# THE ROLE OF PROJECT MANAGEMENT IN APOLLO

by

David L. Wilemon

A. Managerial Advantages of NASA's Project Management Systems ——

1. Problem Orientation
2. Multidisciplinary Emphasis
3. Responsibility Identification
4. Systems Perspective
5. Innovation in Organization Design
6. Communication Flexibility

B. Role of Conflict in Apollo Project Management

1. Introduction
2. Determinants of Conflict in Apollo Project Management
   a. Project Management/Technical Management Conflicts
   b. Conflict Within the R&DO Laboratories
   c. R&DO/Contractor Conflict
3. Some Problems Resulting from Conflict
4. Summary Hypotheses
5. Role of the Project Manager in Conflict Management

C. Interpersonal Dimensions in Project Management

D. Special Problems Faced by Project Managers

1. Managing Human Relationships
2. Balancing Technical and Managerial Project Functions
3. Coping With Risk in the Project Environment
4. Surviving Institutional Restraints
5. Summary Hypotheses on Special Problems Faced by Project Managers

E. Summary Remarks on Apollo Project Management Methods

## CHAPTER III

### A. MANAGERIAL ADVANTAGES OF NASA'S PROJECT MANAGEMENT SYSTEMS

Our investigation of the NASA project approaches uncovered a number of important advantages associated with the management of complex tasks. This section discusses what we consider to be some of the most outstanding characteristics of the Apollo project management system.

As we viewed the Apollo program, several basic variables became evident in explaining the rationale of why a project management approach was utilized and why project management was probably mandatory. The tasks undertaken in placing a man on the moon were exceedingly large, complex, costly, and required the effective coordination of thousands of individuals, millions of pieces of hardware, and thousands of private contractors and universities. As one observer cogently noted:

> In terms of numbers of dollars or of men, NASA has not been our largest national undertaking, but in terms of complexity, rate of growth, and technological sophistication it has been unique. Involved have been a government headquarters and widely dispersed set of laboratories and technological facilities; some 20,000 industrial contractors, sub-contractors, and suppliers; almost 400,000 non-governmental workers; and faculty members and students at 200 universities. Keeping all these parts--often working right at the edge of technological knowledge and capacity--finely tuned and in close harmony has been an organizational achievement of high order. 1

Since the task was considered too large to be undertaken by an all "in-house" NASA effort, a NASA/private contractor/university consortium was established as the primary "team." NASA assumed the role of technological

---

[1] Dael Wolfle, "The Administration of NASA," Science, November 15, 1968.

leader while the supporting private contractors and universities were delegated the responsibility to help design, fabricate, test, and deliver a significant portion of the program's necessary software and hardware. To assume the role of team leader, NASA relied on its strong in-house technical and managerial capabilities to initiate, direct, and monitor the work of contractors. As we have alluded to previously, without the high degree of in-house technical competence, NASA would not have been able to direct the development and manufacture of the necessary hardware undertaken internally, nor would it have been able to effectively monitor the tasks being undertaken by the thousands of contractors and sub-contractors. The entire development of the Apollo hardware was truly a "team effort" with NASA and its contractors working jointly on the various projects.

In addition to assuming the role of technical leader, NASA also had to assume the role of management leader in managing the cost, schedule, and performance objectives of the Apollo program.

1. Problem Orientation

The basic characteristic of project management is that a specific problem requires solving.[1] Often within Apollo problems were unique one-time undertakings where there was prior organizational experience. The problems to be solved in the Apollo program normally had three ancillary objectives--to solve the problem within stated performance objectives, cost objectives, and by a given schedule. Often these objectives determined how the problem or project would be managed, who would manage what sub-tasks, what trade-offs could be made, and how various simultaneous tasks

---

[1] See D. L. Wilemon, "Managing Product Development Systems: A Project Management Approach." Business & Economic Dimensions, May, 1970, pp. 14-19.

could be sequenced to "telescope" the task's development time.

The "problem" in Apollo was to safely land a man on the moon. This was the starting point for all the other activities which had to precede the actual accomplishment of the objective. The major "problem" was then analyzed to determine what other problem must be completed before that major objective could be accomplished. This procedure, in effect, segregated the major problem into thousands of distinct steps necessary to reach the ultimate goal of safely placing a man on the moon.

2. Multidisciplinary Emphasis

The nature and scope of complex problems frequently demand the inputs of several discipline-oriented specialists within and external to an organization for problem resolution. The problems encountered in Apollo often involve more than one basic discipline--thus expertise from other areas of expertise within the organization needed to be coordinated to effectively resolve problems. In essence, complex problems required the systematic integration of both technical and managerial expertise. For the most part the Apollo project organizations were designed to provide for the effective integration of the problem-solving capabilities of various discipline-oriented specialists. In Apollo the interdisciplinary efforts at problem-solving took two basic forms. The first case entailed discipline-oriented specialists on the immediate project team. If a problem developed these team members were expected to apply their expertise to the resolution of the problem. The second case occurred when problems arose where the necessary talent to resolve it were located in other parts of the NASA organization or external to it as was the case with supporting contractors.

3. Responsibility Identification

Project management approaches are designed to employ a deductive approach in breaking a project down into manageable segments. More specifically, a problem is broken down on a "systems" or "subsystems" basis. In Apollo, for example, the hardware necessary to accomplish its objectives were identified the S-1C, S-11, S-1VB, Command Module, Service Module, Lunar Module, Engines, and Ground Support Equipment, etc. Each of these were distinct projects because they possessed certain integrated characteristics. A manager was assigned as the principal manager (project manager) for each system with overall responsibility for cost, schedule, and performance objectives. Management responsibility was further assigned to each of the project's primary components or subsystems. For the S-1C vehicle, for example, subsystem managers reporting directly to the S-1C project manager were given responsibility for critical components. Subsystem managers, for example, were assigned to S-1C's mechanical structures, the propulsion system, the electrical systems, the instrumentation flight control systems, the environmental control systems, and the necessary ground support equipment. Because of the complexity of the task and the interface relationships, an organizational matrix was established to pin-point inter- and intra-organizational relationships. The development of these matrix-oriented responsibility relationships proved to be a significant innovation in managing the Apollo program.

The project/matrix organizati -al arrangement used in Apollo not only pin-pointed the project manager and his subsystem managers but also helped

delineate the technical supporting personnel found in NASA's various laboratories; the resident managers at the contractor's facilities, and contractor counterparts. These matrix relationships made clear who was responsible for what task and assisted in establishing a system of accountability throughout the NASA/Apollo organization.

4. Systems Perspective

Closely allied to the preceding discussion on the ability of project organizations to identify key responsibility areas, is that a project approach assists in giving top management an opportunity to view the "project" as an "action system." From an organizational perspective this allows management to survey the total performance of specific projects, project interrelationships, and the relationships of the projects to the institutional and functional areas of the organization. On large projects where considerable resources of the organization are being expended, this becomes crucial in terms of effective resource control and the minimization of conflicts over these resources. Frequently, for example, conflicts arise over priorities and resources among the various tasks any organization undertakes. If top management can maintain an overview capability of all the projects, by developing effective information management systems, they will then have a potentially valuable management tool to assist in allocating resources on a more rational basis.

5. Innovation in Organization Design

The development of project management methods have produced a number of innovations in the way organizations have traditionally functioned. Most organizations, for example, group their specialists under "functional" areas, such as, research and development, engineering, manufacturing, etc.

The specialists in each function report to a manager who has primary responsibility for maintaining their expertise and the quality of work performed by these specialists. However, as the tasks undertaken by large organizations became more complex in size and scope, the ability to coordinate these diverse groups of specialists became more difficult as in Apollo. Moreover, because highly technical projects required quick-acting, multi-disciplined inputs, they tended to require intensive coordination across organizational lines rather than vertically.

While there are many advantages inherent in the standard functionally-oriented organization structure, there are numerous disadvantages which affect an organization's ability to manage large, multidisciplined tasks. When an organization is organized primarily on a functional basis, the tasks of mobilizing diverse organizational resources among its various functional areas often becomes both cumbersome and difficult and raises such questions as follows:

1. Who determines what resources are needed, when they are needed, and how they will be employed?

2. Who has the authority and responsibility for mobilizing the needed resources across organizational lines?

3. Who should have the authority to mobilize the needed organizational resources?

4. What organizational mechanism, group, or manager will serve as the primary coordinator for the task?

5. How are priorities determined that arise between the needs of multidisciplined tasks and the needs of the functional organization?

Such questions point out the need of a management system which can operate within and through an organization's functional structure. The NASA project

management system assisted in delimiting many of these problem areas. In addition, functionally oriented organization structures often become "power centers" within an organization. The project management approach attempts to delimit these actual and potential power centers by focusing organizational strengths on tasks to be solved rather than on particular disciplines.[1]

6. Communication Flexibility

In the project organization a network of communication channels evolve—both formal and informal. The Apollo project management approach appeared to offer two principal advantages in terms of organizational communication. First, the project organization was established so that it would have a minimum of hierarchical restraints in communicating with top management. Moreover, since the project organizations often had a short chain-of-command, the communication efficiency among the Apollo project team members and project managers was enhanced. Directives from top management usually could be funneled directly to the project organization. Such a communication advantage offered speed, flexibility, minimal communications distortions, and more rapid decision-making capabilities.

In summary, the Apollo project management organizations were designed to operate both vertically and horizontally within the larger NASA "host" organization. The Apollo project organizations were then an over-lay organization on the NASA functional organization which allowed the project

---

[1] In the Apollo Program, for example, when critical problems developed, "task force teams" or "tiger teams" were frequently mobilized on very short notice to resolve the problem.

group to capitalize on the strengths of the functional organization while simultaneously overcoming many of the deficiencies inherent in NASA's functional organizations. This rather fluid approach to organizational design assisted in encouraging peer-to-peer communication, multidisciplinary integration of talent, and dynamic problem-solving capabilities.

## B. ROLE OF CONFLICT IN APOLLO PROJECT MANAGEMENT

### 1. Introduction

The objective of this section is to explore the role of conflict in Apollo project management, examine its determinants, and analyze both the positive and negative consequences of conflict. Conflict in the project environemnt is defined as the behavior of an individual, a group, or an organization which impedes or restricts (at least temporarily) another party from attaining its desired project goals. Even though conflict may impede the attainment of project goals, the consequences may be beneficial to the project if it produces new informational inputs which enhances the decision-making process. Conflict becomes dysfunctional if it results in poor decision making and a disintegration of the efforts of a project team.[1]

The significance of Marshall Space Flight Center's (MSFC) approach to project management is related to the complexity of the projects undertaken and the degree of coordination required to integrate NASA in-house expertise with the scores of supporting contractors. Early in the Apollo program a decision was made to utilize two parallel suborganizations to support the Apollo projects, i.e., Research and Development Operations (R&DO) and Industrial Operations (IO).[2] This decision made it possible to provide both

---

[1] This section is based on the paper, "Project Management: A View From Apollo," a paper presented at the Third Annual Seminar/Symposium of the Project Management Institute, Houston, Texas, October 15, 1971.

[2] Recently the names of these two directorates have been changed. Research and Development Operations is now Science and Engineering, while Industrial Operations is now called Program Management and two other directorates have been created as noted in Chapter IV.

specialized technical support and a managerial over-view for each project.

While the project groups in IO function on a programmatic basis, the R&DO organization operates on a "functional" basis and houses technical experts in virtually every engineering and scientific discipline relevant to space exploration. Personnel in the R&DO laboratories supported and assisted the various project groups in IO in planning projects, in recommending and implementing needed engineering changes, and in evaluating the technical and engineering capabilities of the supporting industrial contractors.

Having much broader responsibilities than the R&DO support personnel the project managers in IO were charged with the overall management of the business and technical dimensions of their projects. The project managers responsibilities thus encompassed the critical variables of project performance, schedule, and cost. Usually reporting to each project manager were several subsystem managers. These subsystem managers were delegated responsibility for the over-all management of a critical subsystem.

2. Determinants of Conflict in Apollo Project Management

Apollo project managers were required to cross both in-house organizational lines and transcend external corporate structures to elicit needed support for their projects. The necessity to coordinate diverse organizational units (R&DO, the contractors and IO) often fostered conflict situations in the Apollo project environment

a. Project Management/Technical Management Conflicts

Conflict frequently developed between the project management organization and the R&DO organization--the two in-house elements of the basic

project team.[1] Some of the conflicts had deep-seated historical roots while others resulted primarily from differences in professional viewpoints and motivations. Historically, some of the conflict between the project management groups and the R&DO groups can be traced to the initial implementation of the project management system within MSFC. A number of the key people in R&DO, for example, felt that they should direct the efforts of the supporting industrial contractors and that the implementation of a separate project management organization probably was not really needed. As a consequence, varying degrees of mistrust and conflict have occurred between the project management organization and elements of the R&DO laboratories. The conflict which ensued, especially early in the program, often resulted in power struggles which delayed decision-making. Contributing to the conflict was a lack of "organizational clout" by the project management organization.

One approach taken by MSFC's top administrators early in the program to bolster the strength of the project organization was to hire top talent from outside NASA to man key positions in the project organization. In some instances this practice involved hiring executives from private industry with proven track-records in managing complex tasks as well as military line officers with experience in missile development and management.[2]

---

[1] There are a number of conflict situations which occurred between the project management organization and the contractors which are not discussed here but which are fairly typical in "contractor management" situations. Disagreements, for example, arising over "the scope of a contract," "the value of a contract," and "intent of a contract" are rather common causes of conflict in contract management situations.

[2] This practice was even more prevalent at the Manned Spacecraft Center.

Although the R&DO group's responsibility was to provide technical direction for the projects, ambiguity sometimes developed over what was actually entailed in the term "technical direction." In essence, R&DO personnel could advise but did not have the authority to initiate project engineering changes outside the scope of the contract. In some instances, especially early in the program, attempts were made by some R&DO personnel to direct the contractors without first clearing their actions with the appropriate project management personnel. One project engineer in a contractor's organization perceived the existence of conflict between the R&DO groups and the project groups in this vein:

> The main conflict that occurs within NASA is between the technical side and the project side. They have conflicts over who the hell makes the decisions....

As the above quote implies, conflict sometimes existed between project management and R&DO over who had the "right" to issue directives to contractors. In effect, the lack of coordination between NASA's project groups and the R&DO organization would, on occasion, directly affect the operation of the contractor's efforts.[1]

In addition to the historical sources of conflict, conflict often was facilitated by the divergent motivations of personnel in the project management organizations and in R&DO. Personnel in R&DO, for example, often are highly motivated to achieve high quality and reliability ratings for the particular project or subsystem they support. Project specifications, for example, may call for a reliability factor of "R". Personnel in R&DO, however, may feel

---

[1]See Chapter V for further insights on this problem area.

a reliability rating of "R + $\Delta$" is better and that the necessary steps should be taken to change specs and achieve a higher reliability level. A project manager, on the other hand may feel that the project's specifications are adequate and that accepting a higher "R" rating is not worth the additional cost nor the impact on his schedule. One project manager explained how he perceived the motivations of his R&DO project team members this way:

> A lot of the individuals in R&DO give you a lot of static. They are and they should be purists. They want to do the best job they can and they argue with you long and loud.

A project engineer within the R&DO labs agreed, in principal, with the project manager's comment and stated:

> You can have a guy (in R&DO) that has nothing but technical responsibility. If he is only told that the system has to work right and woe be unto him if anything ever happens to it, he can afford to be absolutely stiff in his demands....

As both statements suggest, the basic motivation of the supporting R&DO personnel is to achieve the best possible technical solution to a problem. Unless a project manager is able to modify these motivations the success of his project may be endangered. Again, a project manager is motivated by performance but also by a more encompassing "set" of variables, such as, the successful completion of his total project on schedule within established budget parameters.

b. <u>Conflict Within the R&DO Laboratories</u>

The impression may have been given that the R&DO laboratories always presented a unified front in their dealings with the project management groups or with the prime industrial contractors. Often there was as much conflict within R&DO over the resolution of problems as between R&DO and

the project managers. Differences in viewpoints, professional orientations, and laboratory philosophy often engendered conflict within and among the laboratories. In cases where two or more labs within R&DO were involved in the resolution of a particular problem, conflict often would develop between the labs over which particular problem-solving approach to pursue.

Some of the conflicts which occurred within R&DO also were promoted by "jurisdictional" problems. A large number of multi-disciplinary problems occurred in Apollo requiring the input of several laboratories. When problems occurred which required a technical input from R&DO, conflict might develop over who should be primarily responsible for the total resolution of the problem--who should perform the "lead" in the problem's resolution.[1]

c. R&DO/Contractor Conflict

Conflict also occurred between R&DO and the supporting industrial contractors.[2] One project manager for a large, supporting contractor, for example, described a basic determinant of conflict between his organization and R&DO over problem resolution this way:

> I think R&DO is pretty successful at wanting to control the program...Everything that involves the configuration and technical aspects always has to be blessed by the labs. It's a headache but I can't say that it is bad--they're there to see that we do a technical job properly. So it becomes a thorn in your side primarily because there are so many R&DO personnel who look at each

---

[1]See the discussion on the concept of "lead" laboratories in Chapter IV.

[2]See Chapter V for the broader dimensions of conflict between R&DO/Contractor Conflicts.

> problem. You can always find a better way to build a mousetrap and many of the cases are just that....We have, however, uncovered many problems this way--so it's also been beneficial.

Conflict situations often developed over engineering changes which were perceived to produce only small marginal benefits in project performance. In addition, conflict situations appeared to be fostered when a number of people were involved in the technical decision-making process.

3. Some Problems Resulting From Conflict

If conflicts cannot be effectively resolved, a number of detrimental consequences can occur. First, the inability of a project manager to effectively manage conflict may cause the project decision-making processes to be lengthy and cumbersome. In Apollo, for example, when conflicts could not be resolved between the project organizations and the R&DO labs, each party had the option of appealing to higher management levels. Such a procedure if exercised excessively, would delay project decision-making processes.

Second, if conflict situations can not be adequately resolved it may lead to excessive documentation on the part of team members to protect themselves in case of "finger-pointing" which might result from project failure.[1]

Third, if project participants perceive that conflict situations are detrimental and distasteful they may take measures to avoid confrontations and meaningful dialogues with other project participants over issues that might place them in a conflict situation. A comment such as, "If they don't want us to help them why should we beat our heads against the wall," is often indicative of an attitude toward the avoidance of conflict. Project team members need to feel that their ideas are being judiciously evaluated and that

---

[1] This practice is sometimes referred to as maintaining "Pearl Harbor Files."

they have an opportunity to "win" on some of the key project decisions. If supporting project participants feel that they are not being heard and perceive that they are being repeatedly and unfairly over-ruled, they may simply "withdraw" from willing cooperative support.

Fourth, excessive conflicts among project participants may cause "coalitions" to be formed among some of the diverse groups supporting a project in order that their particular viewpoints will receive the maximum impact while minimizing the inputs of other groups. Such behavior may lead to "compromise situations" in order to get views expressed and thus lead to a sub-optimization in problem-solving. A number of project engineers in R&DO, for example, felt that the project management personnel and the contractor's personnel would often align themselves on key project issues and thus limit an open exchange of alternative problem-solving approaches. If real or perceived alignments occur among the principals of a project, they can make the participants spend their energies preparing for "battle" rather than engendering a mutually beneficial exchange of information and ideas.

4. Summary Hypotheses

By their fluid, interdependent nature project groups often promote conflict situations within organizations. A number of hypotheses are suggested from our study and prior researches that warrant further attention by any organization utilizing a project management mode. Each proposition suggests conditions and/or situations which may either increase or decrease conflict within the project management environment.

Hypothesis 1

The greater the diversity of disciplinary expertise among the participants of a project team the greater the potential for conflict to develop among the members of the team.

One of the key differentiating characteristics of Apollo was the high degree of technical expertise found within the contractors, the R&DO organization, and the project organization. Due to the level of this expertise a number of conflicting problem-solving approaches would often be suggested. Several managers in NASA and in the supporting industrial contractors suggested that the utilization of this high degree of technical expertise often varied greatly from the project management systems practiced within the Department of Defense. The existence of high degrees of diverse perceptions on a project team (as in the NASA context) was often related to the high degrees of expertise. And the more varied the perceptions and expertise the more likely conflict will develop among the project team members.[1]

Hypothesis 2

> The weaker the project manager's authority, reward, and punishment power over organizational units supporting his project, the greater the potential for conflict to develop.

It appears that the project manager's weak degrees of authority, reward, and punishment power over supporting project participants, R&DO, facilitated an environment conducive to conflict.[2] If a project manager has a high degree of reward power, those who support him may devote their efforts to the rewards they perceive he can give them rather than supplying the project manager with frank appraisals of a given situation. In a similar vein, if a project

---

[1] J. G. March and H. A. Simon, Organizations, New York: John Wiley and Sons, Inc., pp. 121-131, (1958).

[2] For a detailed discussion of the organizational consequences of using rewards and punishments on project team members, see G. R. Gemmill and D. L. Wilemon, "The Power Spectrum in Project Management," Sloan Management Review, Vol. 12, Fall 1970, pp. 15-25.

manager is capable of punishing those who support him, the support personnel may attempt to avoid the punishments they feel the project manager can administer by supplying him with the informational inputs they believe he wants from them.[1] If the Apollo project managers had possessed high degrees of reward and punishment power over the R&DO personnel, it is likely that the informational exchange between the two groups would have been less effective.

Hypothesis 3

> The less the specific objectives of a project (cost, schedule, and performance) are understood by project team members the more likely conflict will develop.

The more effectively a project manager is able to explicitly communicate the specific objectives of his project to those who support his project, the more likely dysfunctional conflict situations can be avoided. If, for example, the objectives of a project are ambiguous, conflicts may develop since project participants may be operating on the basis of different perceptions of the project's objectives and their own role in fulfilling them. In the early phases of a project's life cycle where project specifications may, by necessity, be ill-defined, there is often a greater likelihood that conflicts will develop than when specifications are more explicitly defined (as in the maturer life-cycle stages) and can thus be more specifically articulated to project team participants.

Hypothesis 4

> The greater the ambiguity of roles among the participants of a project team the more likely that conflict will develop.

---

[1] In contrast, we might expect to find a low degree of conflict among the participants of a project group where the project manager has a high degree of authority over participants.

When the roles of various project participants are ambiguous (which they may have to be at times) there is a greater opportunity for conflict to develop. Role ambiguity can cause frustrations among those supporting the project and raises the question of, who does what? When feasible, a key responsibility of any project manager is to clearly articulate the roles of the various project team participants. Top management also can play a key role in establishing clear definitions of the roles project participants perform--whether individuals or organizations. It should again be noted that ambiguity may develop over the goals of a project as well as over the means to achieve the goals. Most conflict in Apollo, however, occurred over the means to achieve project goals.

Hypothesis 5

> The greater the agreement on superordinate goals by project team participants the lower the potential conflict.

In Apollo, the presence of the superordinate goal, "a manned lunar landing," appeared to be a mediating factor which lowered the potential for detrimental intra-group conflict. The pervasiveness of this goal was constantly actualized by the highly visible program objectives of performance and schedule. If several diverse organizational groups support a project and there is a high degree of identification by each group toward a common superordinate goal, these groups will tend to lower their own goal identification and increase their identification with the goals of other participating groups in order to achieve the over-all objectives of a project. In other words, various groups jointly supporting a project must often make identification trade-offs with their own goals in order to achieve superordinate goals.

Thus, the effectiveness of a superordinate goal in mediating conflict is dependent upon the degree of identification with it.[1] One also can posit that the higher the degree of identification with a superordinate goal the lower the potential for conflict over the means to achieve a goal since alternative problem-solving approaches can be delineated more effectively.

In Apollo, not only was there the very dominant single goal of achieving a manned lunar landing, there also was a number of "situational crises" which developed that endangered the over-riding superordinate goal at various times during the program. If, for example, a serious problem emerged which could cause a potential crisis to develop, there would often be a concentrated focusing by all the involved parties (NASA and the contractors) in resolving the problem. When these "crisis situations" developed, the existence of a high degree of intra-group cohesion was evident. One project team member discussed how he felt about a serious structural vibration problem as follows: "On a 'show-stopper' we're all in the same bed together."

Hypothesis 6

> The more the members of a functional area perceive that the implementation of a project management system will adversely usurp their traditional organizational roles, the greater the potential for conflict.

If the functional units in an organization, such as R&DO, perceive that the implementation of project management methods will significantly affect their traditional roles and responsibilities, it is likely that

---

[1] M. Sheriff, "Superordinate Goals in the Reduction of Intergroup Conflict," American Journal of Sociology, No. 63, pp. 349-358.

conflict will develop between the functional units and the project organization. When a project management group usurps an important part of a functional area's traditional mission, it is likely that the functional units will resist the efforts of the project group to perform those functions in some way or another. One often finds this form of conflict, for example, occurring between the R&D departments and project management groups in the area of new product development in private industry.

5. Role of the Project Manager in Conflict Management

A key role of the project manager is to optimize the beneficial aspects of conflict.[1] This may mean lowering the intensity of a conflict situation while in other cases it may involve inducing conflict among the project participants. Conflict may be induced by promoting the flow of diverse informational inputs, by providing a facilitative environment for conflict, and by employing the emerging organizational development (O.D.) techniques. Creating a competitive atmosphere also is an important means of facilitating conflict.

When conflict situations arose in Apollo the project managers most often attempted to resolve the conflict at the project level rather than resorting to arbitration at higher NASA management levels. All of the project groups we studied had frequent meetings which dressed their task-oriented conflicts. These meetings tended to be straight forward and allowed the involved parties to "lay their cards on the table". By employing such direct confrontation methods the project managers frequently were able to dispose of problem situations before they became detrimental to the overall

---

[1] D. I. Cleland, "The Deliberate Conflict," Business Horizons, Vol. XI, No. I, pp, 78-80, (1968).

project.[1]

In terms of personal attributes helpful in resolving conflict, the project manager's technical and managerial expertise is critical. Not only can expertise assist project managers in gaining respect but it also can help them in the critical role of information gathering. The ability to collect, analyze, and disseminate information skillfully is mandatory in resolving task-oriented conflicts.

In addition to possessing adequate technical and managerial competence, the effective project manager must also provide an environment for conflict to occur. In this vein he must view conflict not as a problem to be on guard against and to avoid but rather as a source of ideas and information.[2] For the most part, the conflict which occurred in the management of Apollo projects appeared to be task-oriented rather than based on interpersonal problems among project team members. In terms of the general effects of each form of conflict, Evan suggests that conflict based on interpersonal dislikes tends to be negatively associated with performance while task-oriented conflict tends to be positively associated with project team performance.[3]

---

[1] For an informative account of various approaches which can be used in resolving conflict by managers performing integrative roles, such as, project managers, see P. R. Lawrence and J. W. Lorsch, "New Management Job: The Integrator. Harvard Business Review, November-December 1967, pp. 142-152.

[2] N. R. Maier and L. R. Hoffman, "Acceptance and Quality of Solutions as Related to Leader's Attitudes Toward Disagreement in Group Problem Solving," Journal of Applied Behavioral Science, pp. 373-386, (1965). Also E. P. Hollander and J. W. Julian, "Contemporary Trends in the Analysis of Leadership Processes," Psychological Bulletin, pp. 387-397, (1969).

[3] W. M. Evan, "Conflict and Performance in R&D Organizations," Industrial Management Review, Vol. 7, pp. 37-45, (1965).

In conclusion, conflict is a fundamental characteristic of Apollo project management. The value of the conflict produced depends upon the effectiveness of the project manager in promoting beneficial conflict while concomitantly minimizing its dysfunctional aspects. A good project manager needs a "sixth sense" to indicate when conflict is desirable, what kind of conflict will be useful, and how much conflict is optimal for a given situation. In the final analysis he has the sole responsibility for his project and how conflict will impact the success or failure of his project.

## C. INTERPERSONAL DIMENSIONS IN PROJECT MANAGEMENT

The objective of this section is to investigate some of the interpersonal relationships existing within the Apollo project groups. More specifically, this section discusses how project managers influence the technical specialists in the NASA organization over whom they have no direct authority, but on whom they are dependent for information and project support.[1] In other words, what "influence strategies" can a project manager use to accomplish the cost, schedule, and performance objectives of his project? In discussing the lack of authority over support personnel, one Apollo project manager noted the following:

> I think it makes it more difficult to get the job done when you have to rely on support people over whom you have no real authority.

To identify how P.M.'s get support for the projects without formal authority we examined some of the primary influence techniques employed by Apollo project managers.[2] These influence techniques are most apparent and most easily understood when we view the project manager's relationship with those in the research and development laboratories and those within the various functional areas of NASA.

We found that <u>expert power</u>, <u>reward and punishment power</u>, and <u>referent power</u> are the primary influence techniques employed by project managers. Expert power refers to the ability of the project manager to get his interfaces to do what he wants them to do because they attribute greater knowledge to him

---

[1] Portions of this section are adapted from G. R. Gemmill and D. L. Wilemon, op.cit., pp. 15-25. Also see: G. R. Gemmill and D. L. Wilemon, "The Power Spectrum in Project Management," Working Paper No. 26, Syracuse/NASA Program, Feb. 1970, and D. L. Wilemon and G. R. Gemmill, "Interpersonal Power in Project Management," Journal of Management Studies, October, 1970, pp. 315-328.

[2] See also, J. P. Cicero and D. L. Wilemon, "Project Authority--A Multidimensional View," IEEE Transactions on Engineering Management, Vol. 17, May, 1970, pp. 52-57.

or believe he is more "qualified" to evaluate the consequences of certain project actions than they are. Expert power can come from a project manager's managerial expertise or from his technical competence or both. In the area of managerial expertise the project manager may have abilities associated with the management of the project which enables him to build an influenc base over others. For example, the project manager is in a critical position that can allow him to have a systemic view of the total activities of the project. He knows what inputs and/or changes will affect the business side of the project. His management abilities are frequently demonstrated by his grasp of the complicated cost, schedule, and information systems attached to the project organization as well as his human relations skills.

In some cases it appeared that it was difficult for the project manager to exert influence based on technical expertise alone. However, this may be overcome if the project manager can view the project from a mixed technical/managerial perspective. It may also be overcome by his demonstrated abilities and track-record in making sound project decisions.

The ability to reward and punish directly or indirectly is another means by which project managers build an influence base. Although it appears that the project managers within the Apollo program cannot use reward power as freely as their counterparts in industry, in matters such as promotions and salary increases, they can reward project participants by:

1. Giving recognition--both formally and informally.
2. Providing organizational visibility.
3. Assigning stimulating work assignments.
4. Delegating responsibility.

Project managers can "punish" those who do not perform adequately by:

1. Isolating them from the primary action of the project.
2. Giving negative comments to the individual's superior.
3. By formal means, i.e., documenting the individual's lack of compliance.
4. Exposing mistakes of their interfaces to peer groups.

Referent power was another important source of interpersonal influence. It is based on the degree to which the project manager's interfaces 1)identify with and are committed to the objectives of the project; 2) identify with the organizational position of the project manager; and 3) identify and value their relationship with the project manager as an individual and as a manager. One project manager explained the alue of referent power this way:

> I think I have the confidence of my support people. I'm able to call them and get a very quick response without any question. I think it's mutual confidence...that I'm able to get them to respond. I can pick up the phone and call any fellow in the support group and tell them we've got a problem at the Cape and you've got to catch a plane. He doesn't work for me, he doesn't owe me anything but he'll do it....

It appeared that a project manager possesses a good basis for influencing his support people if they could identify with him, or could find a common basis for respecting him. As one manager stated, "There's a philosophy here that you aren't a good project manager unless you've come up through the bowels of engineering... Another project manager agreed with his observation and put it this way:

> I guess I'm sort of lucky in that I came up with the support people so they don't resent me. I have no trouble in getting along with them....It's been indicated that other managers who haven't come up through the ranks might have had more difficulty than I've had...

As indicated, friendship ties appeared to be an important source of influence for project managers. Those project managers who had the opportunity and time to develop relationships with those who supported them appeared to be better able to exercise referent power. To illustrate the importance of referent power another project manager when asked how he knew who to ask for advice when he needed support replied: "Strictly personal friends that I've cultivated over the years...and they may be anywhere within NASA."

What is the best "influence mix" then for a project manager to employ?

1. If a project manager has too much technical expertise, it may thwart the contributions of his supporting team members if he over uses it. Full commitment by the team members may be weakened because it destroys their intrinsic motivations in problem-solving if the project manager attempts to dominate in all problem-solving situations.

2. If he has too little technical expertise it slows down the decision-making process of the project. The project manager would frequently need to check on the advice he receives from his support people. In the process, he might lose control over his project.

3. If the project manager has too much referent power his support personnel may not want to tell him he's wrong since they may fear it would damage their relationship with him.

4. If the project manager has too much reward power, it may weaken the strengths inherent in NASA's skill centers. Good support people may want to gravitate to project work rather than build expertise in a functional work area. It may cause an unbalanced reward situation with the rest of the organization. Support personnel may be afraid to indulge in independent problem-solving if the project manager has too much reward and punishment power.

We conclude that the most effective style for project managers appears to be one based on expert and referent power rather than one based on the project manager's reward and punishment power or the use of his limited

degrees of authority. The expert/referent style seems best to promote independent, professionally oriented problem-solving. It is a model where the participants respond to "colleague authority" rather than formal authority.

## D. SPECIAL PROBLEMS FACED BY PROJECT MANAGERS

The high degree of intraorganizational interfacing and coordination required in project management and the complexity of the technology being dealt with produced a number of difficult problems for project managers. In this section we shall examine four specific problem areas which affect the role of the project manager. These four areas include: 1) managing human interrelationships in the project organization; 2) maintaining a balance between technical and managerial project functions; 3) coping with various types of risk in the project environment; and 4) surviving institutional restraints and rigidities.[1]

### 1. Managing Human Relationships

The Apollo project managers and his immediate team members required the support and services of diverse professionals within and external to the project organization. At MSFC, for example, project management personnel required the support of scientific and engineering specialists within the R&DO laboratories. As previously noted, these professionals may have entirely different motivations which often conflict with the objectives the project management group is attempting to achieve. For project personnel to effectively cope with these diverse motivations it often requires effective human relations skills--especially empathy. One project manager illustrated this point as follows:

> You have to understand who you are dealing with. An engineer in the laboratory may feel that he should settle for nothing less than zero leakage

---

[1] This section is largely adopted from: D. L. Wilemon and J. P. Cicero, "The Project Manager: Anomalies and Ambiguities," Academy of Management Journal, September, 1970, pp. 269-282.

> on a certain seal. He has a certain background, a certain psychological makeup that you have to understand, appreciate, and not violate. You can't tell a guy like that, go to hell, that he doesn't understand the problem. The guy can be a Ph.D. and can darn well know exactly what he's talking about. So you've got to find within your own means the mechanisms for communicating with him...and then again you've got to realize that he's communicating with us.

It appeared to us that the effective project manager is one who respects the motivations and viewpoints of his interfaces but is also able to get them to do what he wants them to do in terms of providing support.

2. Balancing Technical/Managerial Project Functions

In managing his project, the project manager must maintain a balance between the technical and managerial requirements of his task. When the project manager is directly confronted with a technical problem which may disrupt the designated objectives of his project, usually the project manager must make both a technical decision and a managerial decision before the problem can be resolved. For example, if research and development personnel inform the project manager that a critical component of the launch vehicle has only an "X" reliability factor, the project manager must weigh the technical decision of whether or not to accept the recommended reliability quotient against the overall management considerations of budget and schedule. Of course, when a problem occurs that has a high risk quotient, in terms of safety for example, the technical decision would outweigh the importance of the "management decision." As previously alluded to, a potential problem for the project manager lies in the possibility of overstressing either the technical or the management dimensions of his project.

The resolution of this problem appears to be in the project manager's understanding of his technical function and how he uses the project team to achieve performance requirements. While the management considerations, as evidenced by the MSFC/Apollo model, are clearly the responsibility of the project manager, he also has final responsibility for the technical performance of his project. He may either become deeply involved in the engineering problems or he may leave many of the details to other project team experts and maintain a more distant position.

Through analysis of interview data, the most successful strategy appears to be to display an understanding of and acute interest in the technical aspects of the problem while usually leaving its more detailed resolution to other technical specialists on the project team. A project team member emphasized this point as follows:

> All organizations suffer from having a man too interested in understanding everything. If that's the project manager's interest, I feel that he's misplaced. He can do a job, but it shouldn't be in management. He should be in a technical job... You sometimes can't reward a technical man...you put him in a management box and he makes things miserable. He's miserable and the people under him are miserable.

Again, the implication is that to maintain the technical balance, the project manager should be concerned with the technical details and yet remain somewhat apart from the more routine details.

While it is generally desirable for the project manager to leave many of the technical details to other team members, there are at least two mitigating conditions: 1) the perceived technical competence of the project manager; and 2) his ability to effectively use his project team.

An important determinant in maintaining the technical balance is the project manager's technical competence as perceived by those who support his project. The project manager coming up through the NASA organizational ranks often appeared to have more respect from support personnel than those coming from an unrelated field or coming from a position outside NASA. Thus, a project manager's perceived technical competence often appeared to be based on both his prior NASA experience and his abilities as a project manager.

As suggested, the project manager draws upon diverse organizational resources and his ability to effectively use the experts on his project team is critical for successful project performance. The effective management of a project team was described by one Apollo project manager as follows:

> A good project manager has to surround himself with experts. He doesn't need to be an expert engineer, an expert in finance, an expert in contracting, etc. He does, however, need a working knowledge of these things. For example, when an engineer starts talking to him about longitudinal oscillations, he has to know what the man is talking about. The prime thing that a project manager needs is the ability to listen and comprehend what his people are telling him.

A fundamental quality of many Apollo project managers is their ability to seek information from several diverse sources, evaluate that information, and make decisions based on all the alternatives. In terms of a project manager's ability to evaluate information, one manager stated: "...to me, this is what makes a real project manager."

3. <u>Coping With Risk in the Project Environment</u>

There are at least two catagories of risk that seem especially relevant to project managers: 1)project risk; and 2) professional risk. The first

form of risk, project risk, involves failure to do an adequate management job which may result in project failure either in terms of performance or in terms of critical budget or schedule objectives. Professional risk, on the other hand, centers around the possibility of professional obsolescence as the result of long-term tenure on a project which could result in the project manager losing his technical competence.

Project risk may be identified with the project manager's final responsibility for meeting and maintaining the performance, schedule, and budgetary objectives of the project. His success and the recognition of his ability as a manager, in part, depends upon his achievements in these areas. In effect, the project manager is the focal person in a highly visible management responsibility system. For example, in the Apollo program, the project managers in charge of launch vehicles and engines must frequently coordinate their operations with interfacing projects. In this sense, the project manager not only has responsibility for his own project, but shares in a real sense the responsibility for the other project managers' hardware.

Two rather different perceptions were found to exist among the Apollo project managers in terms of project risk. The disparity in conceptualizing project risk may be illustrated by the following two quotations:

> ° If my hardware didn't work and it failed in lift-off, it would be a catastrophic occurrence. I would completely expect to be replaced. Put it that way.
>
> ° If you don't want to accept the responsibility you don't have to, you just buck it up to the next manager and if he doesn't want to make the decision, he can go to the program manager.

In the first instance, the project manager perceives his responsibility as final and complete with the risk of project failure resting entirely on his shoulders. In the second case, the project manager is left with an option of whether or not to accept complete responsibility in critical areas. The first case is relatively unambiguous, however, the second leaves assumption of project risk up to the individual manager. Further research may provide a workable hypotheses for understanding under the conditions that determine the amount of risk a particular project manager is willing to assume. The purpose here is to point out that project managers perceive risk differently.

Apart from project risk, the project manager may also be confronted with a form of risk in terms of professional obsolescence. Advancement of the state of the art may bypass the project manager, for example, if he is unable to keep up with the rapidly changing practices in his engineering field. This is especially relevant in a rapidly changing program like Apollo where some of the major hardware projects have life cycles of eight to ten years. One project manager who had been in his position a number of years stated the implications of professional risk in the following manner: "I'm an obsolete engineer, I'm an untrained manager, and I'm too old to go back to school."

4. Surviving Institutional Restraints

Although project management is often defined in terms of its flexability, the antithesis of the traditional bureaucratic model of organization, many Apollo team members indicated that certain institutional parameters developed

over time which diminished the effectiveness of the project management concept. It was, for example, also suggested by some of the managers that the project management organization was not immune to "Parkinson's Law." As projects mature over their life cycles, various management systems and reporting mechanisms become attached to the project organization which produce rigidities and encumberances. For example, over the life of Apollo, various "staff offices" at the field center levels and at Headquarters placed rather stringent demands on the project organization in terms of data reporting systems, audits, and various types of project control requests. Many of these systems were not considered necessary by the project groups. One project manager explained how over a period of time, a project loses its flexibility this way:

> First you start out with a small organization and call it NASA. As you expand that organization you have more and more staff people at Headquarters and you have more people thinking up reasons why there's a need for a report. So, pretty soon you get hit with directives, some from Headquarters, some from every level. Many of these directives require comprehensive reporting; we've got a lot of people who think it would be real nice to have this report or that report, etc....

In order for the project managers to cope with increasing amounts of paperwork while maintaining peak efficiency in the management of their projects, they had to learn how to cope with the systems and data reporting requirements placed on them.

Aside from documenting the system, another variable which appeared to be a restraint on some of the project managers was the Civil Service rules, regulations, and requirements. Because of their rigidities, these requirements frequently became problems for the project manager in selecting

and molding a viable project team. For example, a project manager was not always able to choose his own men for his project no matter how qualified or how necessary they might be in terms of a particular task requirement. The man must first be "freed" from his present organizational position. One project manager alluded to the problem in this way:

> Nobody gets assigned to a job around here. You have to get permission from the people you work for. If it's just a lateral transfer, and say I really need a good strong project engineer, even if the center is in trouble and a man is around who isn't doing very much, if the person who is supervising his area feels strong about him and won't let him go, then you almost can't get him no matter how badly you need him...and that's kind of bad.

The problem of assigning manpower to build the most effective project team also appears in the reverse situation. If a team member's performance is below an acceptable level, the project manager may also have problems in "spinning-off"unneeded personnel. One project manager concerned about the effectiveness of some members of his team made this comment:

> I've got three people I could do completely without. But, if I asked for their release from this project, I would most likely have to give up my three best man, so, I just sit here and don't say anything.

The examples here only briefly touch the problems the Apollo project manager faces in surviving the system. If the project manager is evaluated in terms of how he meets his task responsibilities, any mechanism constraining optimum efficiency and flexibility is, in a real sense, a threat to the manager's capability of surviving the total project system.

5. Summary Hypotheses on Special Problems Faced by Project Managers

There are a number of summary hypotheses which can be derived from the preceding discussion which warrant further observation, discussion, and analysis. We believe each hypothesis is significant in helping understand some of the more important behavioral problems faced by project management personnel.

a. Managing Human Relationships

1. The degree to which engineering and scientific personnel associated with project teams are motivated to contribute to the objectives of the project varies with the project manager's ability to satisfy their professional goals within the context of the objectives of the project.

2. The greater the necessity of utilizing scientific and specialized engineering personnel in project problem-solving, the less effective the bureaucratic form of organization becomes and the more likely the tenents of bureaucracy will be violated.

3. The internal rewards in terms of motivation and ego-involvement for those who support the project manager are related in a positive sense to the project manager's ability to encourage autonomous problem-solving, when feasible, for them.

4. The greater the diversity of problem-solving situations available to project support personnel, the higher their motivation levels.

b. Balancing Technical and Managerial Project Functions

1. The greater the project manager's technical expertise, the more likely he will overly involve himself in the technical details of his project.

2. The greater the project manager's difficulty in delegating technical task responsibilities, the more likely it is that he will over involve himself in the technical details of his project (depending upon his expertise to do so).

3. The greater the project manager's interest in the technical details of his project, the more likely he will defend his role as a technical specialist.

c. Coping With Risk in the Project Environment

1. The project manager's anxiety over project risk varies in relation to his willingness to accept "final" responsibility for the success of his project.

2. The greater the length of stay in the project manager, the greater the tendency for project managers to remain in administrative or managerial positions during their careers since technical avenues for career advancement will be limited.

3. The degree of anxiety over professional obsolescence varies with the length of time the project manager spends in project management positions.

d. Surviving Institutional Restraints

1. The autonomy of a project manager decreases over the life of his project as institutional management and program management increases their desire for centralized project control.

2. The higher the degree of bureaucratization in terms of reporting systems, rules, and regulations, the more highly developed the informal communication channels of the project manager become and the more cumbersome the decision-making process.

## E. SUMMARY REMARKS ON APOLLO PROJECT MANAGEMENT METHODS

1. NASA's top management might have been more adept when establishing program management at the field center level. We feel that it took too long with the result of too much conflict for project management to be established at the major field center level.
2. Functional specialization, while facilitating in-house expertise, has promoted many organizational coordination problems within NASA. A parochial viewpoint by the labs at MSFC, for example, often hindered efficient intra-organizational coordination. In the future, more emphasis should be placed on disseminating a "total agency viewpoint."
3. Those who manage and select project managers and subsystem managers should place more effort on selecting those with proven depth in both technical and managerial experience.
4. NASA should establish a formal system for training project managers. We suggest perhaps the establishment of the position of "assistant project manager" would be helpful in training future project managers.
5. Headquarters should continually monitor its informational requirements which it requires from the field centers, the project organization, and the contractors. As projects mature there is a feeling that too much information is required of the project manager which probably has limited value to the recipient.
6. More training should be available to project managers in terms of interpersonal skills and Organizational Development (O.D.) techniques. Such training could facilitate their job of managing people and coordinating their projects.

7. A personnel system should be established which really allows for the flexible rotation of the younger subsystem managers and project engineers in and out of both management and technical positions. Such a system would greatly facilitate the training of the younger personnel and would help reduce the problem of technical obsolescence while increasing the appreciation and understanding of the "management" viewpoint.

8. NASA should not stifle in-house and inter-center rivalry. It is recommended that NASA assess the viability of establishing "Venture Teams" to promote innovative ideas as currently employed by many industrial corporations.[1]

9. NASA top management should examine whether the management structure at both field centers is excessive. For example, can PM and PD at MSFC be coordinated more effectively?

10. A concentrated effort should be made for the infusion and cross-fertilization of engineering and scientific personnel between NASA and the universities. Such a program could facilitate the infusion of fresh ideas and technologies to both NASA and the universities and potentially eliminate some of the problems fostered by the personnel policies forced on NASA.

11. A system should be investigated which provides a faster, more effective turnover of personnel in key project management positions while still allowing for the important variable of continuity--especially for projects that are of long-term duration.

---

[1] See D. L. Wilemon, "Program Innovation in a Complex Program," Syracuse/NASA Program, Working Paper 6223-WP-9, July, 1971.

CHAPTER IV

# UTILIZATION OF IN-HOUSE TECHNICAL COMPETENCE IN APOLLO PROJECTS

by

Bernard D. Wood

A. The Significance of In-House Technical Competence

B. Comparison of Centers

C. Center Organization and Apollo Program Support at MSFC

D. Center Organization and Apollo Program Support at MSC

E. Center Organization and Apollo Program Support at KSC

F. Change Boards in the Apollo Program

G. Conclusions

# CHAPTER IV

## A. THE SIGNIFICANCE OF IN-HOUSE TECHNICAL COMPETENCE

The Apollo program was eminently successful by any reasonable standards. One therefore looks for the factors that assured the achievement of the goals in the time specified and with the money available. It is our contention that the maintenance of a strong in-house engineering capability was one major enabling factor in NASA's success in the Apollo program. It is difficult to imagine the achievement of the goals without it. Any other government agency that manages programs in which actions necessarily depend on professional decisions should consider emulating NASA in this respect. Whether the professional field is related to the physical sciences (as in energy utilization) or the social sciences (as in public welfare), the parent agency must maintain its own professionally trained staff. This in-house capability cannot be rented. While there is a place for consultants from universities and other institutions, these can only supplement and cannot replace the agency's own competence.

Of course the size, technical complexity, and boldness of the Apollo program were all staggering. While these forced NASA to adopt management practices that were in many respects new, the lessons of Apollo management should not be dismissed as unique and inapplicable elsewhere. One very significant lesson is found in the skillful blending of outside contracting with in-house expertise. The effective management of the program, including the management of the in-house talent, assured the successes achieved.

The utilization of the private sector through prime and sub-contracts to accomplish the Apollo program is dealt with separately in Chapter V. It has been suggested that NASA could have contracted out either more or less of the responsibility, in the extreme making this either entirely an in-house effort or, on the other hand, entirely a contractor effort with little NASA input or supervision. It was more than a political or social expedient to have private industry in various parts of the country employ the bulk of the manpower particularly in the final design and the fabrication phases of the program. It allowed NASA to utilize the technical competence of industry without actually removing large numbers of scientists and engineers from the private sector, and it provided access to large manufacturing facilities without direct government ownership of and responsibility for the plants. For political and economic reasons, NASA could not have put on government service payrolls the number of people eventually involved in the whole Apollo program. Why then would NASA not have been wise to move towards the position of the Department of Defense, for instance, in giving to the contractor much more responsibility?

The technical complexity, the use of astronauts, and the involvement of national prestige in the manned space programs plus a growing in-house competence in which there was justified pride probably saved NASA from what, in our opinion, would have been a grave error: the assignment of too much unsupervised responsibility to contractors. Intensive supervision, though desirable, was not uniformly NASA's practice even within the Apollo program. There were instances of serious difficulties arising from the practice of some administrators at certain times to trust the

contractor in reliability and quality assurance as well as in design judgments. In this, MSC was more guilty than MSFC.

In general there was no cut-off point for the responsibility of NASA's technical experts. For some individual pieces of hardware and some software, NASA's laboratories and research and development offices coupled with its limited manufacturing capability performed the whole task from concept, through design, to manufacture and test. But this was unusual. In most instances, the original concept and at least some preliminary design were NASA's. This meant that people employed directly by NASA knew as well as anyone the objectives, the requirements, and the difficulties in the system or sub-system. When a contract was let for final design and fabrication, NASA had experts who could constructively criticize proposals as well as product. This was essential because ultimately NASA and not the contractor had to take the final responsibility for reliability and performance.

The existence of the professional competence within the agency was necessary but not sufficient to explain the success of the program. Improperly utilized, that group of dedicated enthusiastic engineers and scientists could have been disastrously frustrated. The question immediately arises then as to how this potential intellectual energy could best be harnessed. To answer that, we have carefully studied two of the major NASA centers responsible for Apollo. We have found two rather different management systems operating. From the point of view of this study, that is fortunate since project management in Apollo can fruitfully be approached through a comparison of the utilization of in-house scientist and engineers at the Marshall Space Flight Center (MSFC) and the Manned Spacecraft Center

(MSC). The fact that there were differences thwarts the tendency for men in any organization to accept the structure as perhaps the only way to operate.

## B. COMPARISON OF CENTERS

Both MSC and MSFC utilized some form of project management but with certain differences. Particularly noticeable differences were the location of sub-system managers and the assigned responsibilities of the Apollo program managers at the two centers. There are two important questions to be answered in this comparison: (1) Which system provided the better access to the research and development or other functional directorates for more effective utilization of the in-house technical capability in the program? (2) Which system provided the program and project managers with a better view of the achievements and weaknesses of the program as it progressed?

It is difficult to separate the consequences attributable to an organizational system from those attributable to the individuals involved. A center is a product of its history, the key men, and their capabilities, as discussed in Chapter II. It is also difficult to isolate effects on the program of the experience and competence of the various contractors and the state of the art for the tasks to be done. Nevertheless, as far as these can be separated, it is our view that: (1) the system at MSC (Houston) provided better penetration of the functional technical directorates with, incidentally, less resultant resentment and animosity at the working engineer level, and (2) the MSFC (Huntsville) organization provided better tracking of the program and its sub-components. The reasons and the effects will be discussed in this Chapter.

A careful study of MSC, MSFC, and KSC convinced us that ASPO at MSC, while being in a strong management position, depended heavily on the func-

tional directorates for the performance of real work. At MSFC, the management responsibility for the Apollo program was purposely diffused to involve the line organization of the Center more directly. At KSC, the APO was essentially a liaison office to bring MSFC, MSC, and Headquarters into decisions as necessary, while responsibility for the major task at that center was delegated to Launch Operations which was a functional directorate of the Center.

Although we had independently reached these conclusions, we found them substantiated by a recent NASA report in which management was only one consideration. A very concise statement of the management systems in the Apollo program is to be found in the Report of the Apollo 13 Review Board, submitted to the Administrator of NASA by the board's chairman on June 15, 1970. Appendix E of that long document is the "Report of Project Management Panel." NASA's adoption of the matrix approach to project management for the Apollo program is very succinctly presented. In explaining the responsibilities of Apollo managers at the three major centers, that report uses subtly different language for the three situations. To this reader, that language reflected the real differences found by our own investigations of the three centers, as summarized in the preceding paragraph.

The following three quotations are from that report. The emphasis is added by this writer:

MSC

> Responsibility for managing all aspects of the Apollo Program assigned to the Center is vested in the Manager of the Apollo Spacecraft Program Office (ASPO). . . . Virtually all of the Apollo tasks done in-house at MSC

> . . . are performed by the Center's line organizations (the functional Directorates) under the overall direction and coordination of the ASPO Manager.

MSFC

> Although the Saturn Program Office represents the Apollo Launch Vehicle Program Office for purposes of full-time management, the Director of Program Management has been designated the Apollo Launch Vehicle Program Manager. He manages and directs all aspects of the Apollo Program assigned to MSFC, drawing on technical support from the Science and Engineering Directorates.

KSC

> Overall responsibility for managing all aspects of the preparation, checkout, and launch of the Apollo space vehicles is assigned to the Manager of the Apollo Program Office (APO). All functional organizations at the Center participate in those activities under the overall direction of the APO manager. Direct responsibility for launch and checkout is delegated to the Director of Launch Operations.

In the management of the Apollo program, the responsibilities of the three Center Directors must not be overlooked. In assigning responsibility for the launch vehicle to MSFC, the spacecraft to MSC, and launch operations to KSC, the Associate Administrator for Manned Space Flight made the director of each center specifically responsible for Apollo Program functions at his own center. In actuality, however, the involvement of the Center Director and his staff was not the same at each Center and varied with time at the various Centers.

The implications of these organizational differences will be discussed further after a detailed look at the utilization of the in-house technical

resources at MSFC and MSC and a brief description of the operations at KSC.

Perhaps the most effective management tool developed in the Apollo program was the use of Change Boards. These operated at levels that exactly paralleled the management levels in the program. Their purpose was to deal with changes in hardware and software proposed or requested after design completion. In so doing, the Boards formed a formal channel of communication across each Center at various levels and across Centers. Because their structure was similar at the three Centers, Change Boards will be discussed in a separate section of this chapter.

## C. CENTER ORGANIZATION AND APOLLO PROGRAM SUPPORT AT THE MARSHALL SPACE FLIGHT CENTER (HUNTSVILLE)

This section and the two to follow deal with the organization of the Centers as they existed at the end of 1968. That date represents the end of the period of greatest NASA concentration on Apollo. Shortly thereafter, all the manned space flight centers experienced some reorganization, initiated at least in part by the necessity to provide flexibility for the introduction of other manned programs. It will, of course, be interesting to take note of the later changes, for instance those at MSFC in February, 1969. This will be done briefly at the end of this section.

The official organization of the Marshall Space Flight Center, as of October, 1968, is shown in Figure 1. It is important to note that the relationships dealt with here were found to remain essentially unchanged when "Industrial Operations" became "Program Management" and the "Research and Development Operations" directorate was reorganized into "Science and Engineering" and "Program Development" in 1969.

In Figure 1, only a few boxes have been filled in and they will be dealt with in particular. It is immediately obvious that below the level of the staff function offices of the Center, the whole organization was divided into only two directorates. What is not obvious from the chart is that most of the Center's budget flowed through the hands of the I.O. directorate, indeed through one program which was the Saturn V office. Also, most of the Center's personnel worked under the R&DO directorate. While four programs in I.O. are represented by the boxes, these were by

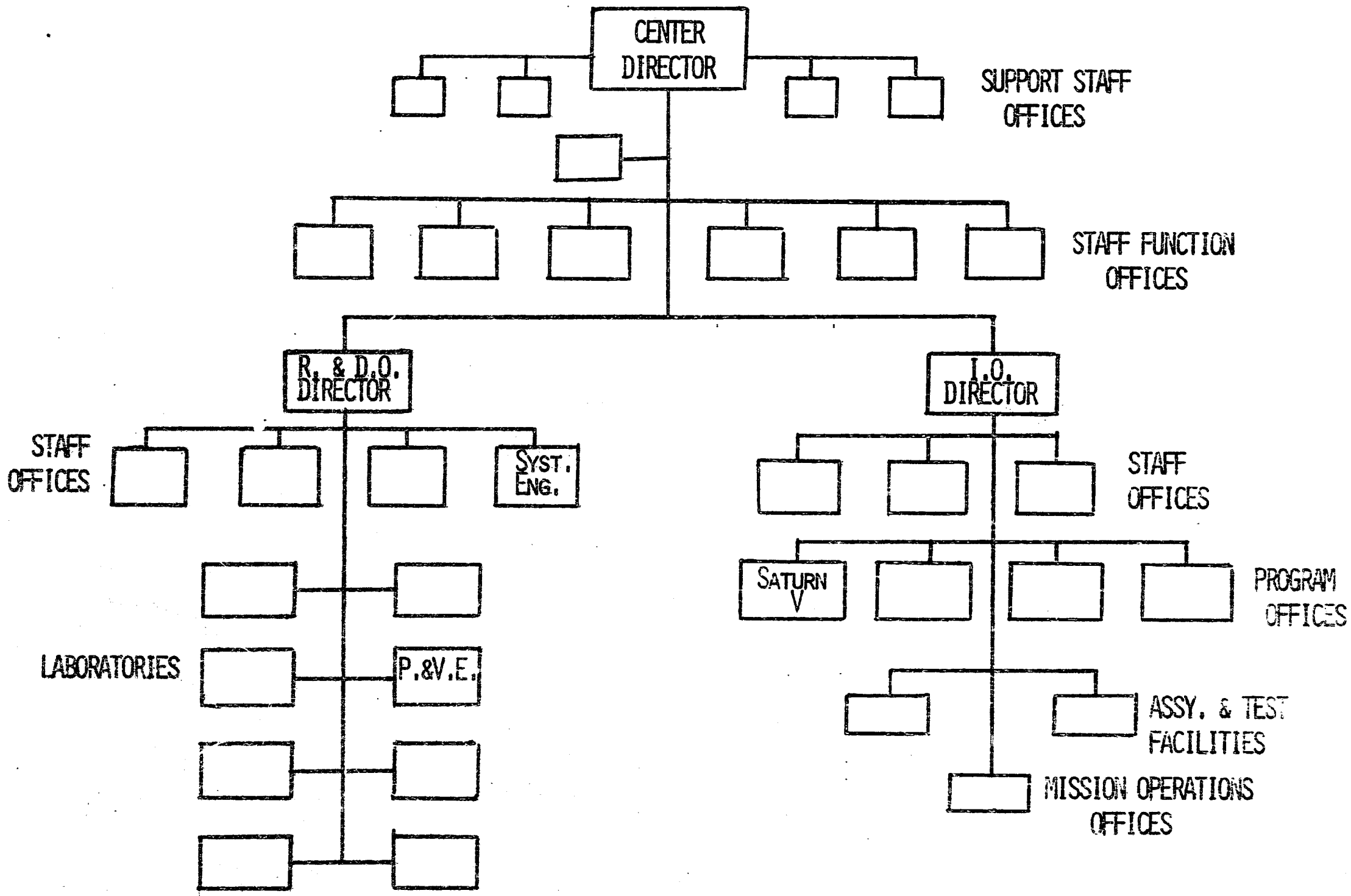



FIGURE I CENTER ORGANIZATION AT MSFC

(As of October, 1968)

B.D.WOOD

no means equal in scope nor were they all programs in the usual sense.

A project manager in the Apollo program has responsibilities to his superiors in the line organization of the Center and he certainly has responsibilities to the program itself. The apparent conflict of loyalties, to the Center and to the Program, is partly resolved when we recall that the Director of the Marshall Space Flight Center had been given the responsibility "for the development, fabrication, assembly, and testing of the large launch vehicles required in the Apollo program." Also, the Director of Industrial Operations at MSFC was responsible "for conducting and managing Launch Vehicle System Projects" and he "acts as the Apollo Program Manager at this Center." Both of these men oversaw other projects as well, but they had specific places in the Apollo program organization.

A generalization frequently encountered in discussions about the two directorates at MSFC was that Industrial Operations was essentially task oriented, primarily concerned with performance, schedule, and cost, while Research and Development Operations was discipline oriented, concerned only with performance. This is a gross over-simplification. We have found many examples of cost consciousness originating with R&DO personnel, and certainly we have found an understandable concern with schedule deadlines in addition to a pride in performance in that same side of the house. Nevertheless, it is true that the final responsibility for cost and schedule rested with the program and project managers, and it was inevitable that some of the more bitter conflicts between the two directorates stemmed from that formal responsibility which sometimes forced the managers to make a decision contrary to the advice of their own in-house experts who were in

R&DO. The existence and indeed the use of conflict in the management of Apollo is dealt with in Chapter III.

Perhaps the best way to appreciate the complexity of relationships between the two directorates at MSFC is to examine those directorates down to their smallest working elements, the sub-system manager in I.O. and the laboratory section in R&DO. For this purpose, Figure 2 illustrates an arbitrarily selected example of a sub-system manager in the Engineering function of the S-II stage (project) of the Saturn V program, who may wish to communicate with a quite arbitrarily selected specialist in the Environmental Control section of the Mechanical Systems branch of the Propulsion division of the Propulsion and Vehicle Engineering laboratory. To trace formal relationships, it has been necessary to identify also the Project Support Office within the Systems Engineering Office, a staff office in the R&DO directorate. Further, one must note that there was a Systems Engineering/Project office within the P.& V.E. laboratory. Although we did not find it referred to as such, this is an example of a functional office being "co-located" in another organization, reporting both to the director of that organization (the P.& V.E. laboratory in this case) and to the parent office (Project Support in Systems Engineering).

Again to emphasize the complexity of the whole organization, we should note the following:

1. Saturn V was one of four program offices then in the I.O. Directorate. The others were:

   Saturn I/IB

   Saturn/Apollo Applications

   Engines

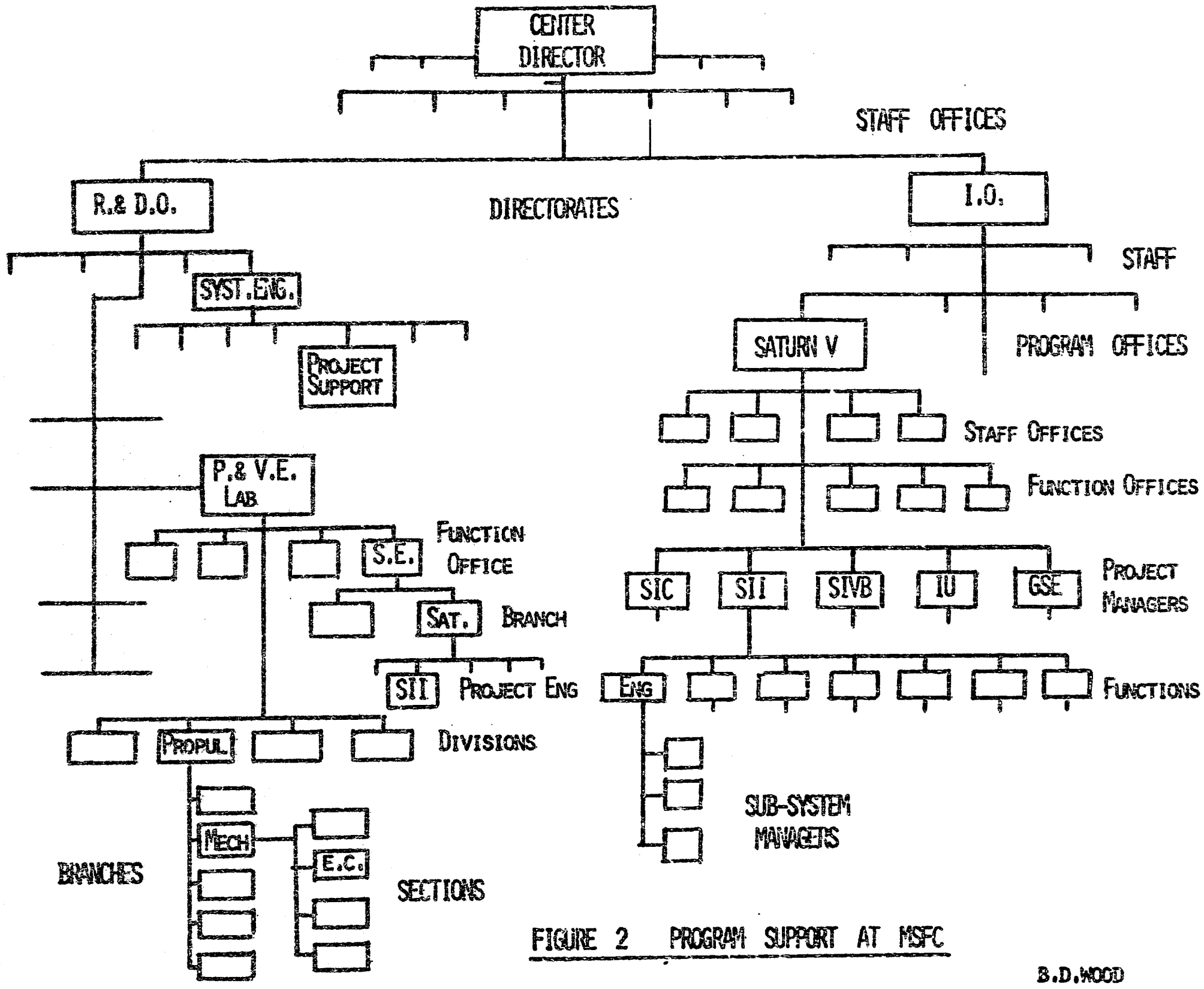



FIGURE 2 PROGRAM SUPPORT AT MSFC

B.D.WOOD

2. The S-II project manager was one of five project (or stage) managers in the Saturn V program. The others were:

   S-IC

   S-IVB

   Instrument Unit (IU)

   Vehicle Ground Support Equipment (GSE)

3. Engineering was one of seven stage functions of S-II. The others were:

   Program Control

   Test

   Reliability and Quality Assurance (R&QA)

   Manufacturing

   Configuration Management

   Logistics

4. Three sub-system engineers are shown on the chart, but in this particular office there was also a chief engineering manager (not shown). Other offices had either more or fewer sub-system managers.

5. In R&DO there were eight laboratories:

   Aero-Astrodynamics

   Astrionics

   Computation

   Manufacturing Engineering

   Propulsion and Vehicle Engineering

   Quality and Reliability Assurance

   Space Sciences

   Test

6. In the P&VE Laboratory there were four divisions:

   Vehicle Systems

   Propulsion

   Structures

   Materials

7. The Propulsion division of P&VE Laboratory had five branches:

   Engine and Power

   Fluid-Thermal Systems

   Mechanical Systems

   Applied Research

   Propulsion Systems

8. Not shown on the chart is the Projects Office for the Propulsion division which had three engine project engineers (F-1, J-2, H-1) as well as project engineers for Saturn V, Saturn IB, S-IC and S-IB, S-II, S-IVB, and AAP. These were liaison men for the corresponding program and project offices in I.O.

9. The Mechanical Systems branch had four sections:

   Advanced Design

   Electro-Mechanical Systems

   Environmental Control

   Fluid Control

   Fluid Feed

10. Sections, branches, and divisions had chiefs; laboratories had directors; programs, projects and stages had managers; and all these men had deputies and assistants.

11. These were all in addition to all the staff support and functions offices that were shown in Figure 1 and that were quite complex in themselves.

The obvious overlay of program requirements, managed from within I.O., on the existing strong line-and-staff organization of the Center's R&D laboratories presents a classic example of matrix management. The concept of management matrices was not unique to the Saturn V office, but the development of such complex matrices, the insistence on their being up to date, and the heavy reliance on them in day-to-day operation constitute a management innovation peculiar to the Saturn V program and represent a real contribution to the technique of managing complex technological programs.

The contacts between I.O. and R&DO necessary in the operation of the Apollo program followed both formal and informal channels. For instance, no formal agreement for the R&DO laboratories to provide time or facilities to a project (which, after all, would require an allocation of funds) could be made without the knowledge and agreement of the Projects Support Office of Systems Engineering/Project Office located in that laboratory. The Change Boards represented another formal communication channel at various levels. But since formal agreement for time and facilities allocations could be made only after it had been determined what the requirements were likely to be, there had to be informal as well as formal contacts between the two directorates and between these two and the contractors at all stages of the program.

The very large number of individuals in I.O. who had to communicate with various individuals in R&DO required the construction of formal matrix charts to delineate points of contact. For the Saturn V program alone, the R&DO points of commitment (persons who could officially commit the laboratories for services), the designated technical persons (who could not), the contractor counterparts and resident managers, the I.O. program, project, and sub-system managers, all were noted on 23 separate matrices which stated who was officially to interact with whom.

The telephone was an indispensable instrument in the whole management scheme. The frequency of telephone contact between individuals in I.O. and in R&DO (as well as between these men and their counterparts at the contractors' sites and at the other centers) was unbelievably high. And more often than not, these phone calls were by-passing official channels. The routes of formal communication, so carefully layed out to ensure maintenance of technical and financial responsibility, were too complex and time consuming for a time-critical program such as Apollo. Knowledge resides with people despite their office locations. Technical assistance and the willingness to expedite a solution with or without official direction often depended on mutual trust and respect and on personal commitment, dedication, and enthusiasm for the program. Nevertheless, formal documentation necessarily followed all agreements or strong disagreements.

Thus, the Project Support office of Systems Engineering in R&DO communicated informally with the Saturn V program office, and served as a channel for the Saturn V program to get to Operations Management and Experiments, which were two other staff offices in R&DO. Similarly,

Project Support dealt directly with sub-system managers in I.O. and with designated or undesignated engineers in the various laboratories.

How frequently did a man by-pass his own superior or the superior of a man he wished to contact? This depended primarily on their individual personalities and style. Personality, style, and technical competence of project managers is dealt with in Chapter III of this report. It depended as well on where a man had worked previously. Many sub-system managers in I.O. came from R&DO and knew the men they had to talk to very well. This was an obvious advantage to both parties. One laboratory manager in commenting on the move of one of his own subordinates to a sub-system manager's position in I.O. said, "It is useful to have a friendly Indian over there." A project or sub-system manager who came from industry or another NASA Center (and many did) had the problem of penetrating the R&DO directorate added to his already complex job. Some of these men have commented on the substantial time necessary to establish informal contacts.

One organizational tool that cannot be shown on the fixed organization charts is the use of a "lead laboratory." It was in the nature of all the programs at MSFC that many problems either identified in the early stages of conception and design or encountered during testing and actual missions were likely to cut across the boundaries of the disciplines around which the laboratories were organized. When such unforeseen problems arose in Apollo, they were dealt with as crises because of the ever-present concern with schedule throughout the program.

For these multi-disciplinary problems, a lead laboratory was designated by the director of R&DO. It seems that the selection of a lead

laboratory depended primarily on the individual chosen to lead the investigation and on his particular affiliation rather than following from the selection of a logical laboratory, though the two considerations are hard to separate. The lead laboratory then put together a team, primarily from R&DO, and the other laboratories involved became supporting laboratories. An engineering manager was designated by the lead lab director and each supporting lab designated a project engineer for the particular problem. This practice of drawing a working group from all concerned laboratories provided the flexibility in R&DO necessary to manage the solution of unexpected problems.

The changes made at MSFC in February, 1969, which have already been referred to, were quite significant. They primarily were instituted to provide more flexibility in the Center for adaptability to new programs, none of which could be allowed to dominate the Center as Apollo, of necessity, had done in the past. Provision was made also for the encouragement of the generation of new programs.

The Industrial Operations Directorate was renamed "Program Management." This was certainly a more descriptive term for the situation at that time, although it is understandable that "Industrial Operations" had been a logical name when the Center's great concern was its relationships with industry through contracts that were larger than any government peacetime contracts had ever been. However, the program offices remained unchanged in that reorganization.

The more significant change in February, 1969, was the renaming of the Research and Development Operations Directorate as "Science and Engineering"

along with the creation of a new directorate called "Program Development." The latter essentially took over direction of those functions which would lead directly to the conception and development of new programs while leaving Science and Engineering in a predominantly supportive role for both Program Development and Program Management. Looking ahead to the next decade, Program Development (P.D.) provided a much needed home base for embryo programs not yet sufficiently developed or funded to be moved over to Program Management (P.M.). As a proposed program became a reality, its management could be taken over by P.M. It remains to be seen how smooth this transition of each program from P.D. to P.M. will be.

A fourth Directorate, Administrative and Technical Services, was created at the same time. It brought together a large number of Center staff offices and put them organizationally under a director who would be on a par with the three other directors. This took much of the day-to-day management of the Center off the shoulders of the Deputy Director for Management to free him for consideration of policy matters. It is not surprising that, in a year which foresaw declining NASA budgets and a general maturing of the whole space program, a Cost Reduction Office was created in A. & T.S. Of similar significance was the creation of a new Center staff office called Procurement Policy and Review. That function, carried out until then by Center and Program management needed a more formal locus of responsibility at the Center level as more programs could be foreseen competing for limited funds and making competitive demands on contractors.

## D. CENTER ORGANIZATION AND APOLLO PROGRAM SUPPORT AT THE MANNED SPACECRAFT CENTER (HOUSTON)

The Center organization at the Marshall Space Flight Center (MSFC) was described in some detail in the previous section. Therefore here, the description of the organization at the Manned Spacecraft Center (MSC) can be briefer with concentration on differences between the two. Again, the charts shown represent the situation as of the end of 1968, and again, very little change in working relationships was found after that date.

The organization of MSC is shown in Figure 3. In contrast to Figure 1 which represented MSFC, this shows five Center directorates. Three programs are shown, but they are not in a "Program Management" or "Industrial Operations" directorate as at Huntsville. Officially they reported directly to the Center Director.

There were substantial differences between the Apollo Spacecraft Program Office (ASPO) at MSC and its counterpart, the Saturn V Office, at MSFC. These are evident in Figure 4 in which the organizations of ASPO and of one of the functional directorates, Engineering and Development, are depicted to illustrate program support at that Center.

While there were under the Saturn V office at MSFC five projects or "stages" each with a project manager in charge, the office of the ASPO manager at MSC actually contained the Lunar Module (LM) manager and the Command and Service Module (CSM) manager. The implication is that these two men functioned as assistants to the ASPO manager with responsibility for their respective projects. Technical management of those two projects was accomplished with the aid of the CSM and the LM

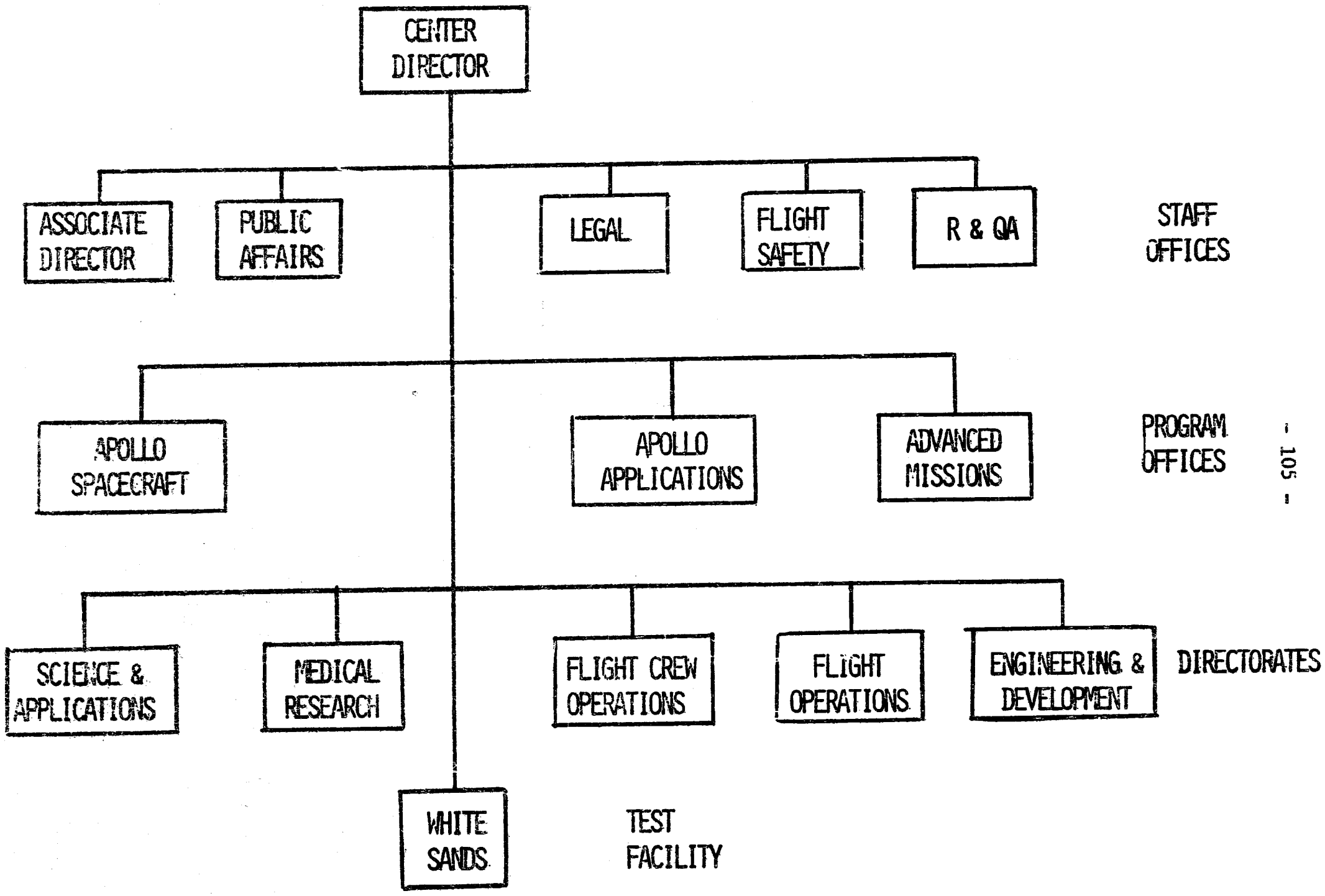



FIGURE 3 CENTER ORGANIZATION AT MSC
(AS OF DECEMBER, 1968)

B.D.WOOD

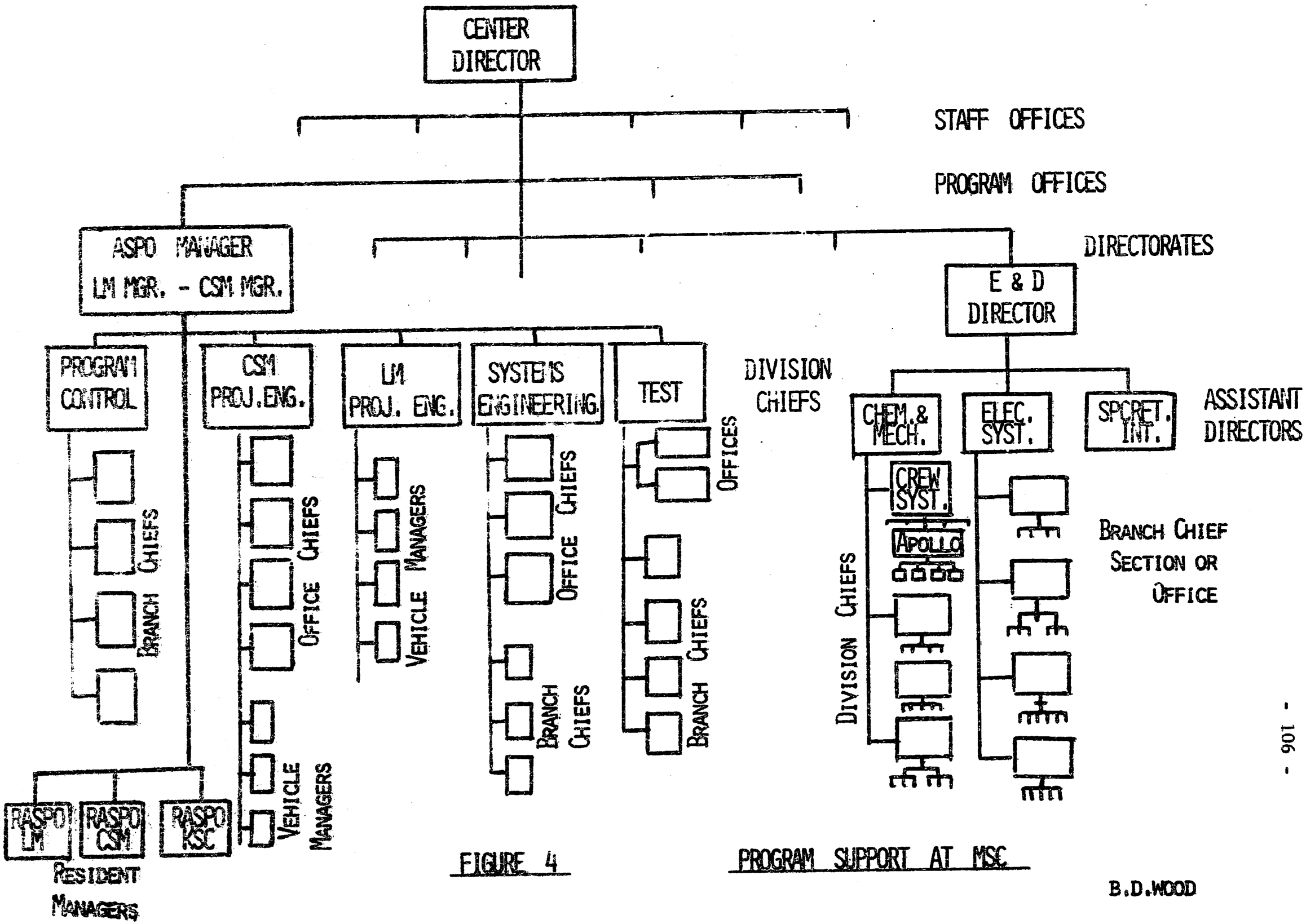



FIGURE 4 PROGRAM SUPPORT AT MSC

B.D.WOOD

Project Engineering Divisions aided by the Systems Engineering Division and the Test Division. Parallel to these four divisions was the Program Control Division which played a key role in contract management for ASPO.

Program Control essentially performed a staff function for ASPO. Each branch chief in Program Control, for instance the LM Contract Branch Chief, acted as a "project Officer" for the designated contracts. He had sign-off authority on directions to contractors for particular sub-systems, but did not make decisions on the technical aspects of change orders. This function was necessary because the sub-system managers at MSC, unlike their counterparts at MSFC who were in the project management offices, were to be found in one or another division of the functional directorates such as Engineering and Development. Consequently, the Program Control branch chief who was a project officer and the sub-system manager in say E&D, formed a team to direct the contractor on a particular sub-system. Similarly within ASPO, the individual vehicle managers in LM and CSM Project Engineering had "complete authority" for their particular vehicles except for official contract control which resided with the project officer (branch chief) in Program Control.

A very useful function performed by Program Control was the development of cost estimates in parallel with the contractor's cost estimate for any change. If P.C.'s and the contractor's figures were very different, there was a strong indication that one or the other misinterpreted the job to be done. This gave an early warning of misunderstanding which, if not rectified, could cost the program in terms of both money and time.

To pursue the illustration of program support at MSC, Figure 4 shows also the organizational structure of the Engineering and Development (E&D) Directorate since this was the prime source of support for hardware development. Within this directorate there was a strong line organizational structure under two of the three assistant directors. This differs from the organization of the "laboratories" in R&DO at Marshall in that the E&D Director at MSC is one of five reporting directly to the Center Director, while all laboratories at Marshall were under the R&DO directorate.

The Crew Systems Division of the Chemical and Mechanical si of E&D was chosen to illustrate that a division chief here had several branch chiefs under him and that each branch might have several sections or offices. Crew Systems was unusual in having an Apollo Branch; only one other division of E&D had such a branch. It was in the various branches of the eight divisions of E&D that typical sub-system managers were to be found. They had responsibility for technical and administrative aspects of the management of their own sub-systems, and they generally had their own project engineers. However, their authority did not extend to sign-off authority in the direction of a contractor; that was reserved to the branch chiefs of Program Control in ASPO.

A few sub-systems in the Apollo program at MSC did not fall specifically into the LM or the CSM projects. The managers of these sub-systems therefore reported directly to the ASPO manager and were essentially project managers with full responsibility for their systems. However, they were organizationally located in the functional directorates (as were all sub-system maragers) and stand as an anomaly in project management schemes.

While located in a directorate such as E&D, the sub-system manager at MSC had a prime responsibility to ASPO. He was assigned with the concurrence of the directorate and ASPO, and could not be removed from that responsibility by the unilateral action of either one. Project managers to whom he reported could certainly recommend his advancement in Government Service rating but his promotion depended on action by his own superiors in the line organization of the directorate. He was thus tied to the functional organization which was his "home," and consequently his presence there was not likely to be resented.

Although sub-system managers were far down the organizational structure, their location at MSFC and at MSC respectively is a key to the difference in the management of the Apollo program at the two Centers. At Marshall, sub-system managers were completely outside the supporting laboratories while at the Manned Spacecraft Center, they were nominally and actually a part of the technical support group. Both systems have their merits and both have disadvantages to be summarized later.

## E. CENTER ORGANIZATION AND APOLLO PROGRAM SUPPORT AT THE KENNEDY SPACE CENTER (FLORIDA)

The organization and operation of the Apollo program at the Kennedy Space Center (KSC) is of interest in itself as an example of various kinds of project management systems. It is of interest also in what it reveals about the differences between the Marshall Space Flight Center (MSFC) and the Manned Spacecraft Center (MSC) through their differences in procedure at KSC.

The Kennedy Space Center was not responsible for development of either the launch vehicle, which was MSFC's responsibility, or the spacecraft, which was MSC's responsibility. KSC developed only what was not peculiar to a particular stage of the launch vehicle or to the spacecraft. MSFC and MSC could specify what could be changed prior to launch, but KSC had to say how and when. Thus the launch personnel at KSC, when a revision in hardware was required, had to get the developer of that particular component to "sign-off" on the change. This would apply as well to hardware developed at KSC by one of Launch Operations' sister directorates such as Design Engineering.

Certain offices in the organization of KSC as well as in the Apollo Program Office there are shown in Figure 5, as selected offices for the other two Centers have been shown in previous diagrams.

As might be expected, stage managers were found within the Saturn Systems office in the Apollo Program Office. These were not in fact the equivalent of project managers as the stage managers had been at MSFC. They served primarily as liaison officers between the two centers in all

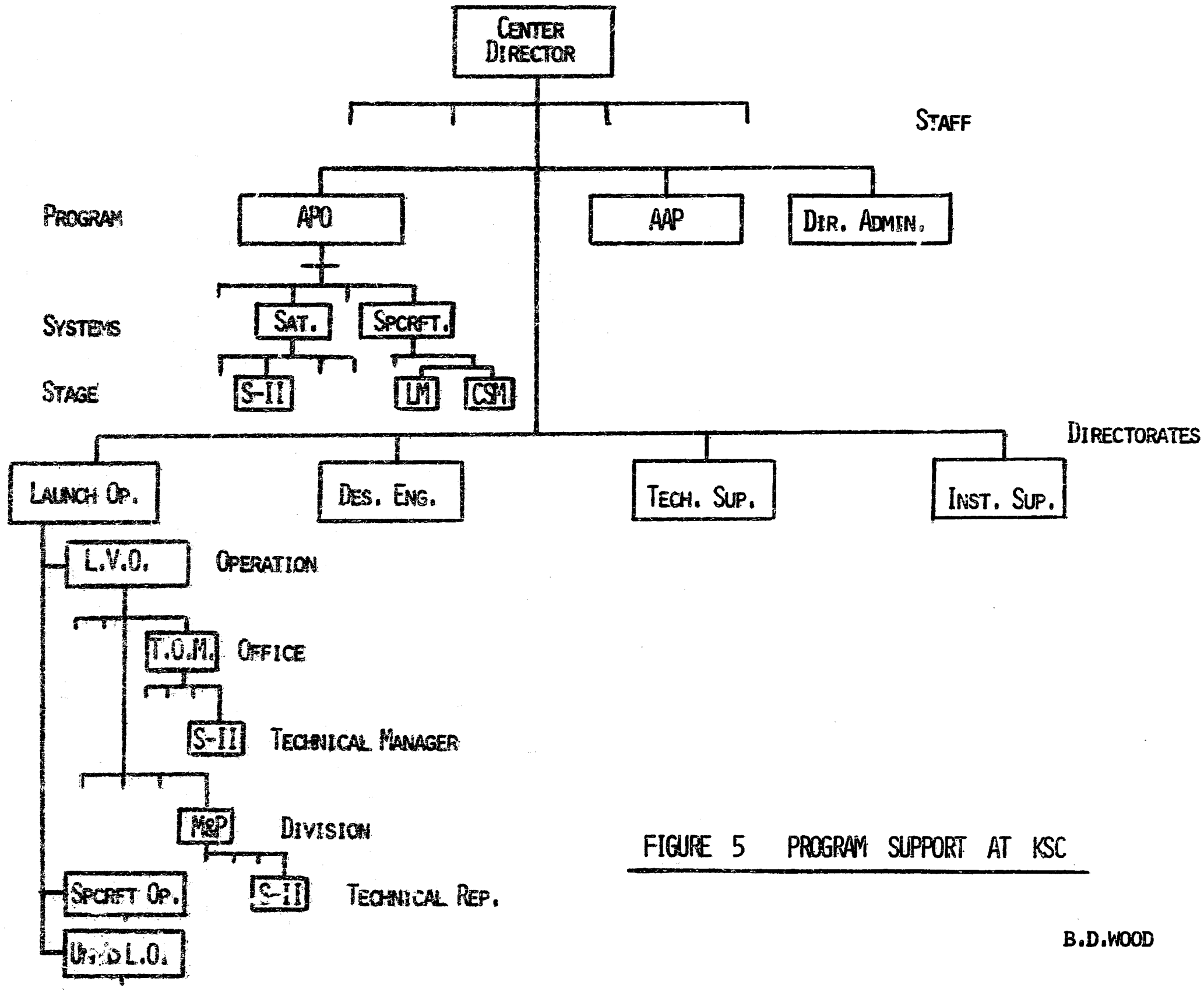



FIGURE 5 PROGRAM SUPPORT AT KSC

B.D.WOOD

matters pertaining to their own stages. The purpose of the Saturn Systems Office was to "provide program management and coordination . . ." but it had no authority to approve. These stage managers did not deal with contractors directly, but worked through MSFC.

By contrast, the Apollo Spacecraft Office within the Apollo Program Office at KSC "provided overall control and coordination . . ." and "it approved KSC commitments involving Apollo Spacecraft. . . ."

The real project managers for Saturn at KSC were found in the Test and Operations Management (TOM) Office of Launch Vehicle Operations (LVO) under the Launch Operations Directorate. These men could and did interface with the contractors. Under TOM there is, for instance, an S-II Technical Manager for the S-II contract. The Technical Representatives in, for instance, the S-II Section of the Propulsion and Vehicle Mechanics Branch of the Mechanical and Propulsion Division of TOM were essentially sub-system managers working directly with the S-II Technical Manager for contract direction at KSC. Of the four divisions in LVO, the Mechanical and Propulsion Division was one of three divisions that were each organized according to stages of the Saturn V vehicle.

The differences in delegation of authority and general style of operation was shown by the fact that MSFC maintained a relatively large resident office at KSC, but that office could make no decisions of any substance. When a problem developed, MSFC deployed their resources in depth, or as one manager expressed it, sent a contingent of MSFC specialists down to KSC who "swarmed all over" the problem. MSC on the other hand apparently had great trust in one man who was their representative at KSC and who had

a small staff; they did not send relatively large numbers of men from MSC to study a problem. By implication they trusted their contractors to solve problems more than Marshall did.

Internally, to provide the flexibility not possible in the large line and staff organizations of the functional directorates, KSC frequently used "Tiger Teams" or task groups, particularly to track changes. A task leader would be assigned by one of the managers, for instance in Design Engineering, and technical managers would be drawn from appropriate sections of the functional directorates. Although some managers were not pleased that this had to be done, there was little alternative because of schedule pressures.

While some balance of power was maintained at both MSFC and MSC between program management and functional directorates, it would seem that Launch Operations at KSC was much stronger than the Apollo Program Office. The opinion was expressed that this power in LO was created deliberately to prevent one program from dominating that center.

## F. CHANGE BOARDS IN THE APOLLO PROGRAM

Throughout the Apollo program, at Headquarters, MSFC, MSC, and KSC, Change Control Boards and Configuration Control Boards were set up in parallel to the whole management structure of the program. These provided for formal contact across centers, from centers to contractors, and within centers at all levels. Their employment by the Office of Manned Space Flight helped to make the Apollo program a successful undertaking, bringing together all the resources which otherwise might often have worked at cross-purposes. In the same way that the in-house competence of NASA provided one of the strongest factors in Apollo, the form and use of the control boards constituted one of the boldest and most significant management tools in the Apollo program.

The point is made in Chapter V that the job of the project manager is most active during the period of activity of the major contracts, after the basic goals of the program and its components have been set. The program and project managers' jobs would be much less complex if the whole program could be conceived at once and no deviations or changes allowed. This obviously cannot be achieved in a research and development program, so that the major responsibility of management through the contract period of the program is to consider, assess, refuse or approve, and track all change requests and proposals. In Apollo, this was done by means of the Change Control and Configuration Control Boards at the management levels shown:

| | |
|---|---|
| Level 0 Boards | NASA Administrator |
| | Manned Space Flight Office |
| | MSF Management Council |
| | Science and Technology Advisory Committee |
| | MSF Experiments Board |
| | Apollo Executive Group |
| Level I Boards | Apollo Program Office, Headquarters |
| Level II Boards | Manned Spacecraft Center Director |
| | Marshall Space Flight Center Director |
| | Kennedy Space Center Director |
| | Program Managers |
| | Functional Directorates |
| Level III Boards | Project Managers |
| | Functional Directorates |
| Level IV Boards | Sub-System Managers |
| | Contractor Resident Managers |
| | Technical Personnel from Center |
| Level V Boards | At Contractor's Plant |
| Additional Level | At Sub-Contractor's Plant |

While the contract is active there can be many requests for changes in detail within the scope of the contract. Occasionally there may be requests to go beyond the scope. Both types may be quite reasonable in an extremely innovative program continuously pushing to the limits of the state of technology. The need or desire for a change may come from the

contractor, in which case he submits an Engineering Change Proposal (ECP). It may come from within the functional directorates of one of the centers, in which case an Engineering Change Request is drawn up. These proposals or requests naturally follow lengthy informal discussions in the critical team made up of the sub-system manager, the functional directorate's designated technical person in the case of MSFC, the project officer from Program Control in the case of MSC, and the contractor's engineer who is the counterpart to the particular sub-system manager. There is continuous interplay within the team with any one of the members taking the initiative, usually by means of a telephone call.

Configuration Control Board directives to implement a change will come from the C. C. Board at the appropriate level, established by what other elements are affected (impacted) by the change. But these directives follow the decisions of the Change Boards after all arguments from management, laboratories, and contractors have been heard.

Naturally, there will be differences of opinion concerning almost all changes, and it is not always possible to reach compromises satisfactory to every party. It is fundamental to project management that the appropriate manager in the program or project office (for levels IV and III) or at Headquarters (for Levels II, I, and 0) must assess the merits of each argument and make the final decisions. Where a man in a functional directorate disagrees at a particular level, the problem can be forced to a higher level for decision if the line management within that directorate is willing to push it. In other words, whether a technical person can pursue his minority report, taking it to a higher

level, apparently depends on his ability to convince his own superior within the line organization of the directorate in which he works, and whether a center pursues an argument up to or beyond level II may depend on someone's ability to convince a program manager, the head of a directorate, or a center director.

The resolution of conflicts by means of change board reviews provided for an active exchange of views among all concerned parties. Appeal to a higher level was necessary only where compromises or agreement were impossible. To draw an analogy with counter-flow towers in chemical process industries: change requests and proposals bubbled up through the organization in such a way that resolvable conflicts were filtered out at each level; management decisions cascaded down through the same organization only after a thorough evaluation at the highest necessary level; consequently directives and requests were never too far from an equilibrium state.

It is an extremely important function of Configuration Control, at Headquarters and at the Centers, to be certain that each change is properly documented, that no affected element in the whole program has been disregarded, and that all affected parties are properly notified. In the dynamic situation that characterized Apollo, the strength of the Configuration Control offices has at times been weak. The importance of Configuration Control in the program has been emphasized with each mishap, but its imperative position in the program has at times been overlooked.

## G. CONCLUSIONS

The following conclusions are a summary of our more important observations of the project management systems in Apollo with regard to the effective use of in-house technical competence.

1. Maintenance of a strong in-house technical competence is essential in a large, complex, technological program even when the vast majority of the budget goes to outside contractors. The great strength of project management in the Apollo program came from the fact that each project manager, in dealing with contractors, was backed up by an in-house technical competence the equal of which probably no industry or government manager had ever enjoyed. Beyond that, NASA's own people had conceived and refined a large percentage of the systems involved and could not be misled by others.

2. The establishment and use of change control and review boards at every management level were extremely important in maintaining a coordinated management overview of the whole broad program. Through these boards all differences could be aired, all changes scrutinized, and all concerned parties apprised of progress on difficulties. In addition, "management by exception" was possible since differences already resolved at one level did not have to be dealt with at a higher level.

3. Center personnel outside the Apollo program as well as those officially working in it were equally dedicated to the superordinate goals of the program. This made a very difficult management job easier.

In fact, it may have made an impossible job feasible. It certainly made the whole system somewhat tolerant of minor flaws in the management scheme.

4. The whole Saturn V program office at MSFC achieved a better management overview of the operations for which it was responsible than did ASPO at MSC. This was partly a result of keeping the sub-system managers in the project management offices. It also followed from the deployment of technical expertise in depth in the solution of any problem. It may have followed from MSFC's inherent distrust of contractors.

5. The Apollo Spacecraft Program Office at MSC drew more effectively on the total resources of the Engineering and Design directorate without feeding resentments at the level of the working engineers than did PM at MSFC. Leaving technical specialists in E&D when they became sub-system managers enhanced this relationship without weakening the functional organization. At the same time it must be noted that the project managers in ASPO at times regretted their lack of direct control of sub-system managers.

6. The delegation of responsibility was more important than the delegation of authority in establishing a project manager's effectiveness within and beyond his own center. In the complex management schemes at the three Centers, MSFC, MSC, and KSC, a true project manager could only be identified by studying his job rather than his title or his place in the organization.

7. Matrix management was used with great deliberation and effectiveness both throughout the centers and into the contractors' organiza-

tions in the Apollo program. To superimpose this tremendous program on the solidly built line organizations of the centers' functional directorates and of the contractors required the conception and implementation of an extremely complex matrix system. Only through this identification of points of responsibility and points of contact could the project manager's job be accomplished.

8. The necessary informal communications must be backed up by more formal agreements in all significant decisions. With the necessity to bring intelligent judgment very rapidly to bear in innumerable changing circumstances, it was necessary in the program to depend on informal telephone and direct person-to-person communication. It was necessary to deploy manpower before formal authority could be obtained. This was acceptable, and in most instances proved satisfactory. In a relatively few but significant number of problems, the formal follow-up was not sufficiently well documented to prevent later difficulties. Despite frequent complaints from technical support personnel that the paperwork was overburdensome, it was largely indispensable.

9. It is a project manager's responsibility to ensure a balanced flow of information to himself for the purpose of decision making. It must be his responsibility to make a final decision (or pass it to a higher level). Only he can weigh one factor against another and perhaps make trade-offs with the overview of his whole project. However, he must have the best advice possible from his sub-system managers, the functional directorates, and the contractor, and if that is not forthcoming, he must force the flow by regular review meetings or any other device.

# CHAPTER V

## THE PROJECT MANAGER-CONTRACTOR INTERFACE

by

Eugene E. Drucker

A. Introduction

B. The Nature of the NASA/Contractor Interface

C. Contract Negotiation

D. Contractor's Organizations

E. Support and Integration Contractors

F. Resident NASA Organizations

G. Some Specific Contractor Grievances

H. Some Points of Comparison: NASA and Contractor Project Management

## A. INTRODUCTION

Quite early in the manned spaceflight program NASA decided that the major hardware components required in the program would be procured in the traditional way, namely by government contract with private industry. There is reason to believe that, permitted to do so, MSFC could have built all of the boosters and spacecraft to be utilized in Mercury, Gemini and Apollo. Of course, this would have required a tremendous increase in manpower and facilities. However, with the in-house expertise and cumulative experience at Marshall, there is no reason to believe that the three manned flight programs would have been any less successful than they were.

It has been Federal government policy for many, many years to utilize private industry as the main source of procurement, not only for off-the-shelf products, but for the bulk of its research and development needs. It was more or less to be expected therefore, that NASA would utilize the aeronautics (consequently becoming "aerospace") industry for the major portion of the development and production work associated with the massive manned spaceflight program.

In many respects, then, the procurement of Apollo hardware was similar to government procurement of other advanced technological products, notably weapons systems by the Department of Defense. In fact, the DOD system was the procurement model utilized by the rapidly expanding NASA organization, not only because of the early Army affiliation of the Huntsville booster group which made up a large portion of the new NASA space core, but because in its quest for manpower, NASA reached out to the DOD for people with

management experience in large projects or programs.

Unlike the DOD, however, the NASA field centers contained large numbers of technical personnel--engineers and scientists from many disciplines. At MSFC, these comprised the Army Ballistic Missile team under von Braun, and at MSC a large group was assembled around a core of NASA's Langley Field people, such as Gilruth, Faget, and Kleinknecht. With the technical expertise and curiosity of experienced scientists and engineers such as these, it was inevitable that the nature of the NASA/contractor interface would evolve into something quite different from the DOD/contractor relationships from which they had sprung. If one could loosely characterize the latter as a buyer/seller relationship, then the NASA/contractor relationship was more of a cooperative, team involvement. This is not to say that relations were never strained. The team atmosphere was one which only developed after feelings of caution and suspicion gave way to mutual feelings of trust and respect. It was certainly true in many cases that both organizations were learning and one could hardly identify which of the two possessed the "expertise."

Whether the Apollo program would have succeeded as it did, meeting the performance, schedule and cost objectives set up for it at a very early stage in the program without the degree of NASA involvement in contractors' affairs which took place is somewhat dubious. The well known performance failures and cost overruns in many DOD programs, however, probably is a reflection of the lesser degree of involvement of government agencies in the management of industrially contracted programs.

It has been amply stated that the NASA project manager has working relationships, or "interfaces" with several groups of people. In the previous Chapter, the internal relationships at the Field Centers have been examined in detail.

The assessment of the relative importance of these interfaces is a difficult one to make. Therefore, it is best to avoid the argument of whether the contractor interface is more important to the NASA project manager than his other interfaces. Clearly, though, in terms of actually designing, fabricating and testing hardware systems and individual items, the success of the project is directly related to the performance of the contractors. In no small part, the performance of the contractor in turn is strongly influenced by the NASA project manager; that is, by his suggestions, reviews, and his ability to modify contract specifications and to change the amount of resources made available to the contractor. The key nature of the interface is "change." Indeed, if the conduct of a NASA contract were very routine the function of the NASA project manager would be little more than clerical monitoring. And under these circumstances, there is no reason to believe that NASA could continue to enjoy the affiliation of technical and managerial personnel of clearly superior competence to that of most other governmental agencies. The nature of development projects, which by and large most Apollo program contracts were, is such that constant communication between contractor and contractee is necessary if a reasonable compromise between performance, schedule and cost is to result. Otherwise, almost any specified performance may be obtained given sufficient time and money.

The handling of changes requires a certain formality to satisfy contractual requirements and to provide the very basis of a workable configuration control system. In the case of a completely in-house NASA or industrial company project, the formal requirements are minimized. But with the expenditure of large amounts of public funds and the responsibility for flight safety, the formal necessities are considerable, and correspondingly time consuming. Were the Apollo changes to rely solely on formal channels however, there is no doubt that the Program would have extended over many more years than have actually elapsed. Nevertheless, despite the heavy consumption of time and effort, the complaints of industrial contractors, the comic portrayal of the paperwork overweighing and overshadowing the hardware, painstaking documentation of changes to hardware and software is the only known method to insure control of a complex engineering system.

In the end, a NASA/contractor interface consists not of a series of communications, encounters, and disagreements between two organizations, but of a myriad of people, pairs or triads who engage in various oral and written communications or information exchanges. So, although contractually there were only a small number of designated personnel who could issue orders or "sign-off" on official, legal documents, the actual NASA/contractor interface consisted unofficially of a large number of people in both organizations who had hourly, daily or weekly contact with each other.

## B. THE NATURE OF THE NASA/CONTRACTOR INTERFACE

The basis for the NASA/Contractor interface is a contract, which defines in a legal way the mutual commitments and obligations of the two parties, such as the hardware, software or services to be produced and delivered by the contractor, and the resources (funds, tools, buildings, plants, etc.) to be provided by the government. By "interface" is meant the entire set of contacts made by various members of the two organizations. Of course, it is true that substantial discourse may be had between the two parties prior to the execution of a contract, i.e. during its negotiation. However, it is the contract period which is of primary interest, as far as the role of the project manager is concerned. The relations between the NASA project manager and his prime contractor undergo distinct changes with time for two reasons. One is purely a humanistic proposition; there is a learning curve necessary for people to learn about each other and each other's organization and method of operation. Naturally, relations are more reserved and formal in the beginning. With time, however, in most cases, a more informal relationship develops which is more of a partnership than a vendor-customer nature because of the phenomenal appeal of Apollo to all concerned. With most other government procurement operations, though, the latter format is retained throughout.

Secondly, there are different requirements and emphases as the work progresses through the different phases of concept definition, design, manufacturing and testing. For example, schedule establishment and cost estimation is very difficult in the early phases, becoming less of a

problem at the end of the contract cycle when schedule maintenance and cost control problems predominate. The fact that different contracts may be in effect for Phases A, B, C, and D is of minor consequence, since the same contractor usually is engaged for all of the phases. The nature of problems and subject matter discussed and acted upon are quite different in the concept phase than in the manufacturing phase, for example. In the former case there is significant communication in terms of predominantly technical matters, that is, of matters based on engineering or scientific information which affects the working or performance of a piece of hardware, a computer program, a flight plan, and so forth. In manufacturing, on the other hand, major concern shifts toward industrial matters: delivery schedules, minor engineering changes, quality assurance and check-out procedures. Not only does the subject matter of the NASA/contractor interface change with time, but different people, in both organizations become the centers of action. This is true despite the fact that the NASA and the contractor project managers always have the nominal responsibility for all facets of the conduct of the contract.

NASA/contractor interface activity generally takes the form of action items requiring NASA decisions, on the part of the NASA project manager. It is very convenient and indeed quite common to think that his responsibility and therefore his decisions can be neatly divided into technical, schedule and cost categories.

"Technical" decision implies a decision based on engineering or scientific information which affects the design or operation of a piece

of hardware, computer program, or flight plan. There is no doubt that the three elements, performance, schedule and cost exist and are identifiable in most actions. But they are rarely, if ever, independent of one another. A "technical" decision can never be made without considering its influence on cost or schedule. It may have no influence, but certainly the project manager must think about it and make a judgement in the matter. Similarly, a change in schedule can seldom be made without any impact on cost and often performance.

Rather than trying to identify a decision as "technical", "schedule", or "cost" according to the major subjective content of the problem, it is perhaps more rational to indicate the type of problem and decision by its origin. The need for a decision arises when a problem materializes and one of several alternative solutions must be chosen. The problem will commonly be of the nature of an indicated failure to meet performance specs, a schedule slippage or a potential cost overrun. These are clearly identifiable by source, but the solution to each (or decision making) will surely involve all three classical elements. Decision making is nothing more than the selection of one of alternative solutions. The function of the project manager is to examine and evaluate the alternatives and make the most rational choice. The manager has staff personnel who gather and prepare basic information concerning performance (systems engineer, sub-system manager, or R&D liaison person), schedule (program control) and cost (contracts and pricing). This does not imply that program control is concerned only with scheduling; it performs several other important functions as well.

Managers have various degrees of familiarity with the technical details of their project, depending upon the nature of the individual and to some degree upon the historical philosophical tradition of the particular center. For the larger projects and systems, it is literally a physical impossibility for a project manager to be intimately familiar with every detail of every sub-system in the project. He must therefore rely upon his sub-system managers, resident office managers and contractor representatives for processed rather than raw information. There is, thus, no systematic way for the project manager and his contractor counterpart to avoid wrong decisions, as in the case of the Apollo 13 oxygen tank failure, when incomplete or erroneous information is provided to them.

In matters of technical origin, the MSFC project manager relied very heavily on the in-house R&D people for engineering evaluation. His activity has been characterized aptly as a "lateral management," as a Chairman of the Board, as a mediator of the technical laboratory representatives and perhaps more of a coordinator than an independent decision maker. Contractors consider this style to be a consequence of the strong laboratory orientation of Huntsville, in turn a historical institutional development, by no means devoid of personality factors. As far as the contractor is concerned, this managerial style makes for a lengthy decision making process, but also a carefully considered one. This is so because the style is dependent upon the concurrence of many people.

The strong project management style, in a rather general sense, is characteristic of MSC project management. Inherent in this generalization is the danger that the style attributed to the Center is in fact a reflection only of one or two individuals at MSC. Regardless of the underlying causative factor, however, the empirical observation of contractors and researchers alike is that the MSC manager sits astride a pyramidal organization, takes more of the decision-making responsibility upon himself. This may require, or it may follow from a greater participation of the manager in the technical details of the problem and its solution.

A point of similarity between both Centers and the contractors is the technique of the CCB's (Configuration Control Boards). All organizations have parallel CCB's at different program levels. Engineering change proposals (ECP's) are processed more rapidly at Houston than at Huntsville because of the greater degree of centralized project management at the former center.

Given the dependence of the project managers (both NASA and the contractors) upon the subsystem managers, the effectiveness and thoroughness of the latter are obviously of the greatest importance to the success of the project. A large degree of responsibility and authority assigned to the sub-system manager tends to sharpen his motivation. The rigidity of the Apollo time schedule tended to foster strong centralized control and decision making, in some cases with an adverse effect on the morale of the subsystem manager with laboratory orientation. Permitted a some-

what more flexible time schedule, a slower but more deliberate handling of ECP's, on the Huntsville style, is more satisfactory in general.

## C. CONTRACT NEGOTIATION

It is the NASA project manager and his contractor counterpart who have the responsibility for making program decisions, but only the contracts or procurement office has the legal authority to translate these decisions into contractual documents, or changes thereto. In their anxiety to get the job done, verbal authorizations have been given to contractors by NASA project personnel in many cases. Although most of these work modifications or additions were honored by subsequent written authorizations by appropriate contracting offices, there were some cases early in the program in which contractors could not recover their costs because of the insistance of some NASA contract officers on prior NASA written authorization for the contract change.

It has been a frequent complaint that the NASA legal procedure for contract change is time consuming and therefore tends to restrict technical improvements and innovation. However, the formal procedure assures several important consequences:

1) that the indicated change enters the configuration control system

2) that the change is made known to many other persons who can view it in terms of impact on other systems,

3) that suggested changes not in consonance with the established budget or financial resources are avoided,

4) that since the indicated change is scrutinized by others, its justification by the originator must be well thought out and strong.

Therefore, despite the frustrations and impatience of dedicated engineers, quick verbal requests for changes or additions by subsystem managers, engineering laboratory personnel, resident engineers, astronauts, etc. should not be honored by contractors. Since, in the technical world of NASA, decisions and negotiations are of a highly sophisticated nature, and since contracting personnel are generally not engineers by background, there tends to be a natural communication and understanding barrier between project manager and contract administrator. This is not to say that the barrier is insurmountable; it is simply inherently there.

At MSFC, the Contracts Office is not a subdivision of the Apollo Program Office, but is an independent staff or functional group of the conventional procurement type. The manager-contract administrator relationship therefore tends to be somewhat formal and somewhat far apart, and the process of translating program needs into legal documents tends to be lengthy and needful of better coordination.

At MSC, the contracting and technical people have a less formal and more closely allied relationship, and as one contractor respondent aptly put it "are closely in bed with each other." The NASA contract people participate in technical negotiations between NASA and Contractor managers, a practice not followed at MSFC. As a result of the close liaison there generally is quicker contract action. Organizationally, this takes place through the Contract Engineering Offices, which are jointly responsible to the Program Office (via Program Control) and to the Director of Program Control and Contracts on the staff side of the

house. This is a practice which is innovative and very much appreciated by contractors. This feeling is illustrated by the statement of a Contractor Executive who had had experience with both Centers: "I have never yet had a verbal commitment out of Houston sitting in this office with the contracting people and the technical people that wasn't lived up to by the contracting people." By implication, there were experiences with Huntsville in which, at the very least, there were difficulties with NASA contract follow-up of prior technical agreements.

From the point of view of NASA, it was pointed out by an MSC co-located person: "We think we benefit by our direct association with the program office. There's no question as to where your primary functional interface is located and we feel that we occupy a more prestige position in dealing with the contractor. . . .But in dealing with defense contractors they always tend to focus in on where the power lies. . . . And in a development program, R&D, the power should lie in the program office."

## D. CONTRACTORS' ORGANIZATIONS

The contractors are for the most part organized around lines similar to the MSC and MSFC "matrix" organization. Virtually every contractor has indicated that NASA has had some influence in bringing this about, although to many, this organizational form was not new. NASA liked to see a strong program office utilizing fully the functional resources of the company. Some contractors resisted but all seemed to have evolved a strong program office. Ironically, these contractor program offices appear to be considerably stronger than those in NASA itself, the very stimulant to the emergence of the aggressive, action-oriented management format. There undoubtedly also has been some influence on the NASA organization by contractors, but this is much more difficult to assess.

The notion that the NASA and the Contractors' program offices have corresponding or counterpart positions is widespread in NASA. However, it was found that the Contractor's program manager in general does not have a single counterpart in the Space Agency, in spite of efforts to bring this about. The desirability of counterpart personnel throughout the affected organizations is clear, in that it makes obvious points of contact and promotes ease of communication and pinpointing of responsibility. It was found, though, that there is an overlap, rather than a clear cut matching of responsibilities. Correspondingly, it was indicated that particular contractor managers had several alternative points of contact in NASA, at different authority levels. This is particularly conspicuous at MSC, where despite the official designation of only one program manager for Apollo,

there are assistant and subordinate persons whose responsibilities although not titles, correspond closely to those of a project manager.

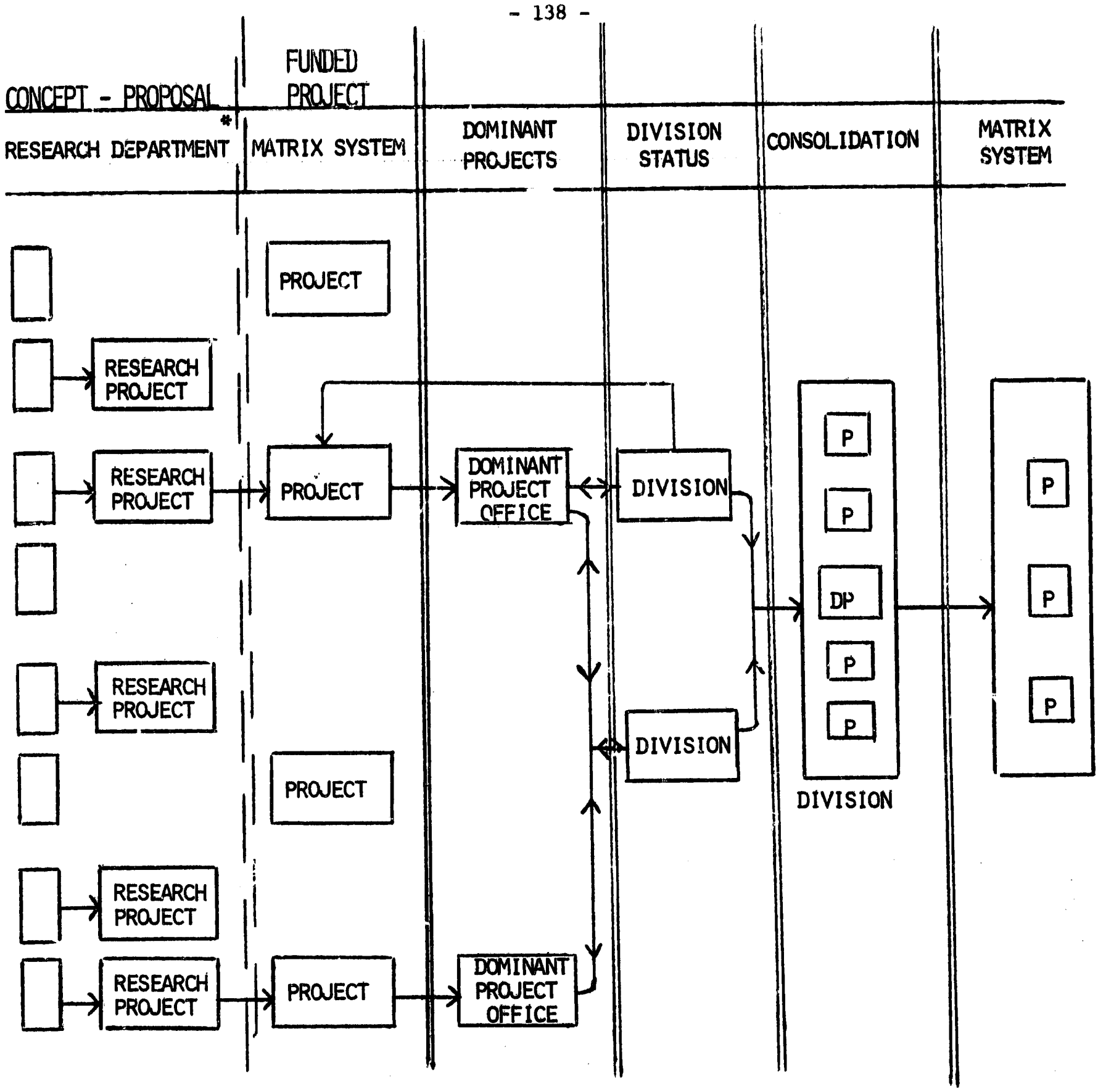
There appears to be no really important reason, other than symmetry of the organizations, why the objectives indicated above could not be met without one to one correspondence of positions. The problems faced by a NASA program office and a contractor's program office are by no means the same (as will be discussed later) and therefore there is no compelling reason for the organizations to be the same.

It is understandable that each NASA project and sub-system manager desires to see his Contractor's manager occupy a position of great authority within his Company. This insures the assignment of a generous share of the Company's resources to the project involved and a high standing on the Company's priority list of in-house work. However, the strength of the Program Manager within his Company depends on the relative value of the Contract to the Company, measured not exclusively in dollars but in terms as well of the future potential of the product concerned or the technical capabilities acquired. Some of the Contracts were so large and important that the Program organization quickly assumed the actual, but generally not titular, status of a separate division of the Company, physically not continguous to the Company and having most of the staff support usually associated with a parent company. A good example of this arrangement is the SII Stage Program, conducted by the Space Division of North American-Rockwell Corp. at its separate facility in Huntington Beach.

On the other end of the spectrum, where there are several projects of relatively small and equal size, the company resources are economically distributed to the project in the recently designated "matrix form." That is, the several projects draw on functional services of Company Departments, and personnel have joint responsibility and loyalty to both programmatic and functional organizations. In contractor parlance, this process is known as "projectization." This format is particularly well adapted to handle the early stages and the phasing out of projects. Since functional support can be provided in continuous increments (such as .25 or .75 of a man), it can be provided according to need and it can change relatively rapidly. If a project grows to the size of a LM or SII, then it in essence becomes a "company within a company" and the advantages of projectization are not as obvious as they are with smaller projects.

Industrial project organizations go through a life cycle, as depicted on Figure 1, starting with a small research group developing a technical concept. If the concept survives and is funded, a project team is assembled in a matrix format. If the project continues on and grows, it may become the dominant project office in the matrix and ultimately achieve a Division status, such as Atomics International, Rocketdyne and Autonetics in the North American-Rockwell Corporation.

The growth of a project may be arrested and even reversed at any of the stages described above. Typically, many of the projects existing at the matrix stage, with more or less equal magnitude and importance, will not grow beyond that level and will phase out sooner or later. A similar fate will befall most dominant programs, either directly or going back




*OR ADVANCED PROJECTS OFFICE

P = PROJECT
DP = DOMINANT PROJECT

FIGURE I LIFE CYCLE OF PROJECTS

E.E. DRUCKER

through the matrix level. Faced with the practical necessity to economize, waning projects or Divisions are consolidated. Inevitably, the specialization and expertise assembled in the growing project or Division is quickly dissipated during phase-out. Recognition of the stages of project metaphorsosis should be an important feature of NASA decision making with respect to industrial contractors.

The history of a "project" does not, therefore, appear to be always describable as the simple combination of a creation, a work, and a phase-out process. The project has a life cycle, starting from and often ending in stages which are organizationally quite different from the "adult" phase of the project. By this is meant the matrix stage, in which most of the unique features of project organization are manifested. At stages before and after this one, the difference between project organization and ordinary organization are rather indistinct.

## E. SUPPORT AND INTEGRATION CONTRACTORS

In addition to the development and production contractors who were engaged in Apollo hardware and software, a number of other Contractors were engaged by NASA to provide a variety of support services to the Field Centers and particularly to the ASPO in Washington. In most cases, these contractors were extensions of NASA itself, performing technical consulting services and management information services such as the maintenance of the Apollo Action Center in Washington.

The Boeing Technical Integration and Evaluation (TIE) contract was concerned with the control of technical interfaces and configuration management. Because of resentment towards and suspicion of an outside organization by field center and prime contractor personnel, however, the contract was largely ineffective. In addition it was difficult for a new organization coming into the middle of the program to assimilate all of the background of the extremely complex Apollo enterprise.

While supportive, staff-type work by industrial contractors appears to be useful to and harmonious with NASA personnel, the assignment of a supervisory role, whether actual or apparent, to a private company has little chance of success in the NASA environment.

## F. RESIDENT NASA ORGANIZATIONS

Intermediate between NASA Field Center Program office and prime contractor is the resident NASA office. The resident manager is intended to be an extension of the NASA program or project manager at the contractor's site. His role is to maintain close contact with the contractor, and to expedite the progress of the contract by making certain classes of decisions on the spot in behalf of Field Center managers.

As a natural consequence of the differences in project management organization and authority at the two NASA field centers, the resident NASA personnel at the Contractor sites also exercised correspondingly different degrees of authority, although in terms of the charters of the resident managers, the differences were not large.

The MSC RASPO (Resident Apollo Spacecraft Program Office) is directly responsible to the Apollo Program Manager in Houston, although the LM and CSM managers possess some functional authority over the resident.

In the case of MSFC, resident management offices (RMO) were attached to both the Saturn and the Engine Program Offices, received their principal authority from individual project managers rather than the program manager, but were in the sensitive position of also having to represent the MSFC

Laboratory Directors.[1] Despite the explicit instructions in the RMO charter, however, the dual responsibility of the Resident Manager to the IO and R&DO sides of the house was often ambiguous or incompatible. This accounts for the greater difficulty that the RMO's had in operating than the RASPO's and as a consequence the greater effectiveness of the latter over the former on site.

The role of the resident office is an unusual one in an organizational sense. Obviously, the office's primary role is to act as a representative of the center at the contractor's site, but in addition the resident office must, in order to be effective, become the contractor's ally and confidant. This is indeed a difficult role, and not surprisingly leads to many of the resident manager's dilemmas.

The resident office also acts as the communications link between the center and the contractor. It is through the resident office that all

---

[1]"These (RM) offices are an extension of MSFC program management, established to assist in the execution of the MSFC mission by providing on-site representation. In this role, the Resident Manager projects the on-site MSFC/NASA image and is the official on-site spokesman for the Center. His office is the official channel of communication between MSFC and the contractor. Every effort must be made to strengthen the Resident Office by working through the office and in particular through the Resident Manager.

The Resident Manager is responsible to MSFC through both line and functional management channels and must represent and satisfy all MSFC interests. His principal responsibility is to the Program and Project Managers. He must, however, also assure the effective execution of all other on-site functions and, consequently, must satisfy all MSFC functional managers. In each functional discipline, business and technical, he must assure accomplishment, communications and execution of functional policies. It is the responsibility of each MSFC manager; i.e., Program Manager, Project Manager, Lab Director, Contract Office Chief, etc., to clearly define his resident requirements and communicate them to the Resident Manager."

MSFC Management Policy Statement #3 (Revised), August 29, 1966.

official correspondence flows. This means that the resident office becomes actively involved in any contractual changes; a very important role.

Two other roles played by the resident office which are less tangible than the others, but which are nonetheless significant to the NASA-contractor relationship are: 1) the development of mutual respect between NASA as a whole and the contractor; and 2) the role of keeping the contractor alert. Of course, the former may backfire if the contractor-resident manager interface becomes abrasive, and a mutual disdain may result instead.

Without doubt, it is this wide divergence of roles which makes the resident manager's job sensitive, difficult and at times frustrating.

The establishment of large resident offices early in the program understandably aroused the suspicions of the contractors, despite their previous experience with on site government personnel via DOD contracts. In prior instances, though, concern for the most part was for quality control, inspection and product acceptance purposes.

With the Apollo contracts, where the contractor's work was of a highly developmental nature and schedule maintenance and extreme safety consciousness was especially important, the NASA resident personnel played a more intimate role in the contractors' affairs than ever before. It is not surprising that the contractors felt that they were living in a closely monitored, transparent environment, entirely alien to the normal concepts of company-customer relations.

The feelings of animosity created in some instances by the two organizations being thrust together could be and were dissolved to various degrees by

efforts primarily on the part of the resident manager, since in a sense it was he who could be considered the alien member of the association. A sense of mutual trust is reached in time when there is professional respect and complete open-handedness between the resident manager and the contractor manager, and when the latter becomes convinced that the resident office can be helpful to him in accomplishing the objectives of the contract. One contractor manager interviewed said:

> At first our Company was dismayed and alarmed at the amount of on-site customer participation...the most significant aspect of that thing which is mutual trust and the realization that it was absolutely pointless to try to play any set of cards close to the vest.

Easily detectable here is the feeling of early alarm but subsequent and not altogether unhappy resignation to the situation as it exists.

In what way is the resident manager useful to the contractor? The resident manager is in almost constant communication with the contractor, and is, therefore, aware of problems immediately as they arise. He is capable of bringing these problems to the attention of the center project manager, not for punitive purposes, but to seek technical or financial aid or authoritative support as necessary. The resident manager can often expedite certain center decisions which the contractor is waiting for. The resident staff can also identify problems which can be corrected at early stages.

In its attempt to keep informed of contractor progress and to input guidance and technical direction to the contractor's work, resident NASA personnel of the RMO or RASPO staff, or more usually, laboratory representatives can easily overstep the bounds of their contractual authority, and

overpenetrate the contractor's organization. There is little chance for a congenial relationship to exist under these conditions.

The problems discussed here are really part of the overall task of establishing a viable working environment between the resident office and the contractor. They are the most important problems that face the resident manager in dealing with the contractor. Without solutions to them, the usefulness of the resident office to NASA would be very questionable.

Equally essential to the viability of the resident offices is the maintenance of proper relations with the Centers. The main problem which must be avoided is the undermining or ignoring of the resident manager's authority by Center personnel, who may by-pass the resident office and deal directly with the Contractor, thereby placing the Contractor in an uncomfortable position as well. Resident office charter notwithstanding, Center project or functional managers may simply refuse to delegate certain authority. This was concisely put by a contractor representative:

> I would say that the problem that had been most severe would be the amount of authority that we could construe that has been placed in the office. Now NASA and we have exchanged contractual documents which said he has the authority to do this and this and this and this. But there is one thing, to look at the printed word and then say now let's get into a specific thing.

The only way for the resident manager to combat this tendency is to vigorously assert the authority which has been delegated to him by the Center Director, with the full backing of the Director being virtually assured.

The inability or lack of desire of the RMO organization to obtain the necessary delegation of authority is one of the reasons why the RMO organization appears not as effective as the RASPO organization. Reading between

the lines of Management Policy Statement #3 and a contemporary agreement between IO and R&DO directors, it is clear that early in the program the Huntsville program/project managers generally did not delegate sufficient authority to their resident managers and never insisted that all official communications go through the resident office.

Ironically, close cooperation with his contractor may alienate the resident manager from his Center, appearing as it might that the resident had "sold out" or was assimilated into the contractor's organization. Given compatible personalities and lengthy on-site service, it is quite possible for a strong alliance to develop. For example, a contractor representative said:

> There have been many instances where they have done things for us that I am sure have enhanced our ability to get certain decisions made because, let's face it they are closer to us than they are to their own people.

He also felt that Center management preferred to deal directly with the Contractor because of the lack of trust in the resident office.

The view expressed by the above interviewee was by no means a unanimous one. Some contractor people felt they could manage nicely without resident offices at all.

Interface problems are discussed in greater detail in a NASA/SU working paper by Barry L. Kelmachter, "The NASA-Apollo Contractor Interface: The Resident Management Operation," Working Paper #24, Syracuse University, February 1970.

The clear consensus of the NASA interviewees is that troublesome as relations have been with Contractors and with Centers alike, the resident offices have performed a significantly useful function in the Apollo Program. And despite many specific complaints, the contractors, freely or grudgingly, have by and large acknowledged this assessment. Because the RASPO's operated from a center with less internal conflict between programmatic and functional organizations, they could and did represent their Center with greater effectiveness than the RMO's. They obviously enjoyed more authority, made more on-site decisions, and consequently had a closer relationship with the contractor. Those contractors who have had experience with both Centers indicated preference for working with the RASPO's rather than the RMO's. This is surprising to some degree because RASPO is considered to be more demanding in their monitoring functions than is RMO, but at the same time it verifies the importance of good resident-contractor relations in maintaining an effective resident office.

The most important period of the development and production cycle for the resident office is that which takes place between the completion of concept and preliminary design work, and the last production runs. This was especially true in the Apollo Program where schedule pressures were very great. It is the period where efficient communication between Center and Contractor is absolutely necessary to make schedule mileposts.

Given smaller projects with less demanding schedule restraints, then the necessity and utility of resident offices beyond QC and acceptance duties may become marginal.

## G. SOME SPECIFIC CONTRACTOR GRIEVANCES

It is inevitable that the forced intimacy of a public agency and a private corporation will produce certain tensions, points of friction and irritation. After all, there are substantial differences in motivation, tradition and style between the two organizations, as discussed in the next article.

The conclusion of the previous article is well worth emphasizing here; namely, that the general nature of the NASA-Contractor relationship is not only satisfactory, but has helped more than hindered the achievement of program objectives while fully protecting the public interest. The complaints made by the contractors should be viewed against this background, and perhaps considered as suggested areas of potential improvement in the NASA-Contractor mode of operation.

1. There is excessive monitoring on the part of NASA, and undue penetration into the internal affairs of the Company. This is partly due to a well meaning, paternalistic attitude on the part of NASA toward its contractors, partly to the extreme schedule pressures in Apollo, partly on the desire of NASA engineers to head off problems and to see their own ideas and expert knowledge incorporated into contracted hardware and software. Nevertheless, it creates in the contractor organization a "goldfish bowl complex." Monitoring activities have, of course, decreased as projects near completion.

2. There is a general feeling that NASA is overmanned at the resident office level. Because the contractors are producing hardware and software, they tend to think of themselves as the "doers" and NASA as the monitors

and administrators to a large extent. The necessity of phasing out contractor personnel toward the end of the program, but not resident personnel contributes to the feeling of surplus NASA manpower.

3. There are excessive requests by NASA for information, briefings, proposals, etc. as a result of the excess of NASA manpower over needs. The tendency to have meetings increases in inverse proportion to the amount of work that people have to do. At the same time that pressures on NASA personnel are relaxed, the work load on contractor personnel tends to increase in view of the phasing down of manpower toward the end of the contract period. This accentuates the time demands placed on contractor personnel by NASA in the final project phases.

4. There is some ambiguity in NASA management, compared to a company's clear lines of authority. Whom to go to to get particular decisions? Who is authorized to require the contractor to make changes? There is a whole spectrum of changes, from those lightly suggested by intermediate level NASA people to those demanded, authorized and contracted for by top level NASA managers and contract officers. On the surface, this ambiguity does not appear, because in a legal sense there is a formal, well defined procedure for bringing about not only hardware changes, but schedule, cost, contractor personnel and other changes as well. However, one cannot ignore the intangible effects on contractors of suggestions and requests specifically voiced or implied by NASA representatives from various organizations. For example, although many contracts are funded and monitored by Centers, much of the authority for approving the contracts, changing them, renewing them, etc.

lies in Washington. Therefore, the contractors find it difficult to resist their natural tendency to satisfy various members of the Headquarters establishment. Directions thus indicated sometimes caused conflict with Center or project managers.

5. Contractors sometimes were caught in the middle of an inter or intra-center dispute, very much like the resident managers. In particular certain NASA internal personality conflicts, which have been difficult to keep concealed, have had adverse effects on some contractors.

6. Ordinarily, hardware in production at a contractor plant is subjected to quality control checks by both plant personnel and NASA resident QC personnel. In some cases, however, other federal agency QC personnel are utilized in a plant at which other than NASA projects are also in progress. These might be Army, Navy or Air Force civilian QC personnel, who are responsible directly to their own agency supervisors, although they are representing NASA in their relations with the Contractor. In effect, then, there are three parties involved in QC affairs in the plant, and since many of the QC judgments which must be made on the floor are subjective in nature, a good deal of friction can easily be generated.

7. NASA does not designate a chief engineer in their own management organization, as industry invariably does on a project or program. It is true that the NASA project manager was himself in many cases the chief engineer, in effect. During the life of the project different people at different times performed the functions of chief engineer. In industry, the necessity for separating the functions of program manager and chief engineer are clear. The manager has many areas of concern other than the strictly engineering one, and cannot deal in the fine details of the project.

The NASA manager, on the other hand, has fewer business and personnel problems, and can deal in greater depth in engineering. Then again, the amount of engineering work done is much less in the NASA project group than in the much larger contractor group.

These considerations are further amplified in the next article and lead to a partial mis-match of the roles of the NASA and the Contractor project managers.

The designation of a single chief engineer in a large NASA project organization appears to be a desirable modification of NASA practice, because it frees the project manager to deal with broad project matters and presents an unambiguous technical liaison point for the contractor.

## H. SOME POINTS OF COMPARISON: NASA & CONTRACTOR PROJECT MANAGEMENT

There are a number of similarities between NASA and Contractor project management, but more importantly for their impact on the NASA/Contractor interface, there are salient differences. Some simply require recognition, but others form the roots of problems or at least of contractor grievances as described in the previous article.

1. The contractor's fundamental motive is profit, whether it be direct or the acquisition of an expertise and experience base from which other enterprises may be launched. This is not to deprecate industry; on the contrary, the indirect motive is the very vehicle by which NASA-funded technological developments are most effectively transferred to the industrial community.

Obviously, NASA's function is not to earn money but to insure the meeting of performance and schedule goals set in the early stages of each project. While project managers operate under money constraints, they are generally less concerned with effecting economies than they are with obtaining the greatest performance and reliability of their hardware in a given time.

While there is no conflict between NASA and contractor by virtue of basic motives, these do influence the general philosophies of the two groups.

2. The contractor's major problem areas are detailed design in the early phases; manufacturing, labor, union and associated difficulties in the latter project phases. In the early stages of most project developments, the NASA manager often participates in technical evaluation and critique, but as the project matures, his concerns shift to scheduling, supplementary funding and controlling changes. Thus, the roles of the NASA and contractor

managers are not the same and they diverge to some extent with time. The managers are therefore not "counterpart" in the sense of performing similar or parallel tasks, but are complementary to each other and act more as members of the same rather than competing teams.

3. The contractors' program organizations are strong and highly pyramidal in shape, at least in the case of major prime contractors. NASA's influence in this direction has been large, but by the nature of private enterprise, supervisors have more authority over subordinates than in public service (with the exception of military and police types of functions). The NASA program organization appears to be weaker in terms of line authority, having the nature more of a coordinating, monitoring and advising group. However, there are exceptions; there have been particular project managers who were highly authoritarian, even bordering on dictatorial.

4. Contractor project organizations of any size have designated chief engineers (generally called Project Engineer). The project manager relies heavily on his chief engineer for detailed engineering work and technical judgements concerning himself with overall decision making involving not only engineering but schedule, cost, contract and change negotiations, production, quality, and customer relations.

The NASA project manager in effect has many engineers, but no chief engineer. Some individual may, by virtue of his personality or stature, take on the responsibilities of a chief engineer, but there is no formal structure of this kind, nor does the "acting chief engineer" remain the same person for the life of the project.

5. Contractor program managers tend to delegate more authority to their staffs than do the NASA managers. The reasons are to be found in the traditional patterns of industrial management compared to the more academic atmosphere of NASA. Industrial management holds delegation of authority to be an important characteristic of good management.

6. It could be predicted from observations 4 and 5 that NASA managers tend to engage in greater amounts of technical detail than do the contractor managers. Indeed, this has been found to be the case, as was pointed out in earlier references, particularly with regard to the MSC management style. Contractor managers, it was shown, depend heavily upon their chief engineers for technical detail, because there is a formal staff structure and because the managers themselves have decision making responsibility in many different areas.

7. The prime contractor is a middle man with respect to sub-contractors; that is, he is both contractor and contractee. This position can create certain problems which the NASA managers do not encounter with their single outside interface. Of course, it is also true that NASA managers do assume active relationships with many sub-contractors. But these relationships are different from those of the prime contractors, because NASA does not have the authority to issue directions to a subcontractor. Informally, though, NASA resident and center personnel do interact directly.

# APPENDIX A

## LIST OF INTERVIEWEES

NASA HEADQUARTERS, WASHINGTON, D. C.

| | |
|---|---|
| Alibrando, Alfred | - Public Affairs Officer<br>Office of Manned Space Flight |
| Barber, Godfrey E. | - Chief, Research and Development Branch<br>Resources and Analysis Division |
| Behun, Michael | - Spacecraft Test, Apollo Test |
| Bingman, Charles | - Special Assistant to Associate Administrator<br>of Office of Organization and Management |
| Bogart, Lt. Gen. Frank A.<br>USAF (Ret.) | - Deputy Associate Administrator (Management)<br>Office of Manned Space Flight |
| Carulli, Len | - Office of Management Development |
| Chapman, Richard | - National Academy of Public Administration |
| Cohen, Nat | - Management Development Section |
| Constantino, Jim | - O.M.S.F. |
| Cramer, Jack V. | - Legislative Liaison Officer<br>Office of Legislative Affairs |
| Diller, Dick S. | - Checkout, Apollo Test |
| Duggan, Jack | - PMIS |
| Emme, Eugene | - NASA Historical Office |
| Flint, Walter | - Apollo Action Center |
| Foster, Willis | |
| Francis, Lebert | |
| Gay, Clarence C. | - Spacecraft Test, Apollo Program Office |
| Gessow, Alfred | - Ass't. Dir. Physics & Math., Research Division |
| Greenglass, Bert | - Acting Management Systems Division Director<br>Office of Technology Utilization |
| Hage, George H. | - Deputy to Apollo Program Manager (Gen. Phillips) |
| Holmes, Jay | - Technical Staff, OMSF |
| Kinney, Col. Arch | - OMSF, Apollo Advanced Planning Group |
| Krulwich, Lewis J. | - Deputy Chief, Resources Control<br>Apollo Program Controls |
| Kubat, Jerry | - Program Control, OMSF |

NASA HEADQUARTERS, WASHINGTON, D. C. (Cont'd.)

| | |
|---|---|
| Liebermann, Carl R. | - Program Planning, Apollo Program Control Acting Chief |
| Lilly, William E. | - Assistant Administrator Office of Administration |
| Low, Dr. George | - Acting Administrator, NASA |
| Newman, Charles T. | - Resource Analysis Division, Deputy Director |
| Nolan, Jim | - Office of Management Development |
| Poore, Ernest W. | - Research and Development Branch Research Analysis Division |
| Preacher, Bert | - Director, Cost Reduction Program |
| Roth, Gilbert Lee | - Apollo Configuration Management |
| Seaton, Donald E. | - Chief, Program Integration and Reports |
| Skaggs, James B. | - Program Control Office |
| Smolensky, Stanley M. | - Office of Assoc. Administrator for Policy |
| Stephens, Richard | - University Affairs |
| Sullivan, Edward | - Apollo Data Management |
| Webb, James E. | - Former Administrator National Aeronautics and Space Administration |
| Fulton, James G. | - The Honorable, of Pennsylvania Subcommittee on Manned Space Flight Committee on Science and Astronautics U.S. House of Rep. |
| Miller, George P. | - The Honorable, of California, Chairman, Committee on Science and Astronautics, U. S. House of Representatives |
| Teague, Olin E. | - The Honorable, of Texas Chairman, Subcommittee on Manned Space Flight and NASA Oversight Subcommittee, Committee on Science and Astronautics, U. S. House of Rep. |

MANNED SPACEFLIGHT CENTER, HOUSTON, TEXAS

| | |
|---|---|
| Battey, R. V. | - Assistant Chief, LM Engineering |
| Bolender, Brig. Gen. C. H. | - Manager, LM |
| Bradford, W. C. | - Chief, Checkout System Branch Engineering and Development Directorate |

MANNED SPACEFLIGHT CENTER, HOUSTON, TEXAS (Cont'd.)

| | |
|---|---|
| Carson, Maurice | - Chief, Portable Life Support System |
| Cohen, A. | - Chief, CSM Project Engineering Division<br>Asst. Chief CSM and Integration Engineering |
| Faget, Maxime A. | - Director, Engineering & Development |
| Farmer, N. B. | - Subsystem Manager<br>CM and LM, R&D Instrumentation |
| Freitag, Robert F. | - Director, Manned Space Flight Field Center<br>Development |
| Gardiner, Robert A. | - Assistant Director for Electronics Systems<br>Directorate of Engineering and Development |
| Gilruth, Robert R. | - Center Director |
| Hood, Robert C. | - Chief, CSM Contract Engineering Branch |
| Kleinknecht, Kenneth S. | - Manager, CSM |
| McBarron, J. W. | - Apollo Space Suits |
| McClintock, J. C. | - Chief, Program Control |
| McDivett, James A. | - Manager, ASPO |
| Morris, Owen G. | - LM Project Engineering Division |
| Nebrig, Dan | - Project Engineer, CSM 108 |
| Presnell, John | - LM Project Engineer (Vehicle Manager) |
| Shannon, James J. | - LM Contract Engineering Branch |
| Slayton, Donald K. | - Director, Flight Crew Operations |
| Small, John W. | - Manager, Lunar Surface Project Office<br>Directorate of Science and Applications |
| Weiss, S. P. | - Subsystem Manager - LM Reentry and Descent<br>Structure Subsystem |
| Young, Wayne | - Program Control |

MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALABAMA

| | |
|---|---|
| Abraham, Ron | - Subsystem Manager - S-1C Instrumentation |
| Aden, Robert | - R-ASTR-ES |
| Andressen, Christian | - Planning & Resources Office |
| Blevins, Calvin B. | - Chief, Engineering Branch, S-1C Stage |
| Bostwick, Leonard C. | - Deputy Manager, F-1 Engine Project |
| Bucher, G. | - Deputy Associate Director for Science |

MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALABAMA (Cont'd.)

| | |
|---|---|
| Bramlet, James B. | - Deputy Manager, Saturn V Program Office |
| Bridwell, Gene P. | - S-II Subsystem Manager, Propulsion, and Acting Chief, Engineering Group |
| Birdwell, Porter | - 1-V-S-II (Propulsion Subsystem Manager) |
| Brown, R. | - Chief, Program Control, Engine Program |
| Burks, Alfred | - I-E-MGR |
| Clark, Adrian | - Project Engineer, S-1C-R&DO |
| Cook, Richard | - Deputy Director of R&DO |
| Crossman, Robert L. | - Chief, Contracts Management Branch, Contracts Office |
| DeNeed, Carl | - I-PL-MGR |
| Dodd | - Test Laboratory |
| Drummond, Floyd M. | - Manager, Airlock Module, AAP |
| Duerr, Friedrick | - Manager IU Stage |
| Dunlap, Porter | - Manager, Group Support Equipment - AAP |
| Farish, P. T. | - Manager, Systems Safety |
| Ferrell, Toon | - I-E-J |
| Foster, Jay | - Executive Staff |
| Fritz, Carl | - Program Development |
| Fuhrmann, Herbert W. | - Branch Chief, Mechanical Systems Branch Propulsion Division, P&VE Laboratory |
| Godfrey, Roy | - S-IV-B Project Manager |
| Griner, Robert F. | - S-IV-B Project Engineer, Systems Engineering/ Project Office, P&VE Laboratory |
| Haenish, Hilmar | - Apollo Applications Program Office |
| Hagen, William A. | - Executive Staff |
| Hallisey, Harold W. | - Chief, Project Control Branch, S-1C Stage |
| Hughes, Ned | - Project Engineer S-11, R&DO (P&VE) |
| Ise, Rein | - Manager, Apollo Telescope Mount, AAP |
| James, L. B. | - Director, Program Management |
| Jean, Otha C. | - Deputy Director, Aero-Astrodynamics Lab R&DO |
| LeBerte, Peter | - I-S-IV-B Subsystem Manager |

MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALABAMA (Cont'd.)

| | |
|---|---|
| Lucas, W. R. | - Deputy Center Director |
| Marshall, Larry | - GSE |
| Mathews, Charles | - Deputy Associate Administrator |
| McCool, A. A. | - Chief, Systems Eng/Project Office |
| McCulloch, James | - Saturn-IV-B Stage Manager |
| McInnis | - OWS |
| Messer, D. | - Chief, Projects Support Office |
| Murphy, J. T. | - Director, Program Development |
| Naumcheff | - Huntsville Operations Support Center |
| Pace, Robert E. | - Program Engineering and Integration, AAP |
| Paetz, Robert | - Deputy Manager, S-1C Stage |
| Reed, Joe | - Member of Executive Staff |
| Rees, E. F. M. | - Center Director |
| Reinartz, S. R. | - Deputy Manager, Skylab Program |
| Richetti, Gary | - Assistant to Head of Manpower Office |
| Rodgers, Richard | - R-P&VE-PAX |
| Rudolph, Arthur | - Saturn V Program, Former Manager |
| Simmons, William K. | - Manager, Orbiting Workshop - AAP |
| Smith, Gene | - R-ASTR-PE |
| Smith, Robert A. | - Executive Staff |
| Smith, T. P. | - Manager, J-2 Engine Project |
| Sneed, B. H. | - Director Program Planning |
| Stewart, F. M. | - Project Manager F-1 Engine |
| Stewart, Rodney D. | - Manager, LM/A - AAP |
| Stone, John F. | - S-II Stage, Deputy Manager |
| Sweat, S. J. | - IBM Resident Office |
| Tanner, Roy | - S-IV-B Project Engineer<br>Astrionics Project Office |
| Thomason, Herman E. | - Research and Development |
| Thompson, Arthur W. | - Former Manager, S-1/1B Stage |
| Urlaub, Matthew W. | - Project Manager S-1C Stage |

MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALABAMA (Cont'd.)

| | |
|---|---|
| Vreuls, F. E. | - Deputy Director, Products Office |
| Waite, Jack H. | - Manager, AAP Experiments |
| Webb, Horton | - Saturn V Program Control |
| Westrope, Dewitt | - R-P&VE-PAX |
| Wheeler, L. | - Sub-system Manager F-1 Engine Project Office |
| Williams | - Manufacturing Engineering Lab R&DO |
| Wood, Charles L. | - Deputy Manager, Airlock Module, AAP |

KENNEDY SPACECRAFT CENTER

| | |
|---|---|
| Beddingfield, S. T. | - Apollo Spacecraft Office |
| Clark, William | - Stage Manager IU |
| Clearman, Bill | - Systems Engineering (Deputy to Director J. C. Wooton) |
| Hecker, Ed | - Stage Manager SIC |
| Hock, Robert C. | - Deputy Manager AAP |
| Mathews, Ed | - Deputy Director, Apollo Program Office |
| Noyd, J. W. | - Staff of Apollo Program Manager |
| Popovich, Ed | - Stage Manager S-2 |
| Rock, William | - Reliability & Quality Assurance Office |
| Schnoor, Richard | - Management Systems Office |
| Scrivener, James | - Resources & Financial Management Office |
| Spencer, Dwight | - Operations & Support Office |
| Sweida, Ernest | - Executive Staff |
| Williams, Grady F. | - Deputy Director, Design Engineering |

GODDARD SPACE FLIGHT CENTER

| | |
|---|---|
| Mackey, J. O'Neil, Jr. | - Chief of Procurement |

CONTRACTORS

GRUMMAN AEROSPACE CORPORATION

| | |
|---|---|
| Barzelay, Arthur | - Special Corporate Management Team |
| Fisher, Lewis | - Asst. RASPO Manager for Engineering |
| Gavin, Joseph G. | - Vice President, Space Affairs |

GRUMMAN AEROSPACE CORPORATION (Cont'd.)

| | |
|---|---|
| Hobokan, Andrew | - RASPO Manager |
| Kelly, Thomas J. | - Assistant LM Program Director for Engineering |
| Leahy, Jack | - Business Development |
| Markarian, Donald J. | - Deputy Director, LM Program |
| Miller, Howard E. | - Former Spacecraft Director, LM 4 |
| Tripp, Dr. R. | - Director, LEM Program |
| Wright, Howard T. | - Deputy Director, LEM Program |

LTV CORPORATION, DALLAS, TEXAS

| | |
|---|---|
| Fuller, Robert | - Program Manager of Reliability Assurance & Environmental Test |

MCDONNELL-DOUGLAS ASTRONAUTICS COMPANY

| | |
|---|---|
| Bauer, H. E. | - Director and Assistant General Manager Saturn/Apollo and Apollo Applications Programs |
| Button, M. C. | - Director - Systems Development Saturn/Apollo and Apollo Applications Programs |
| Manson, G. F. | - Director - Productions Saturn/Apollo and Apollo Applications Programs |
| Pakiz, J. J. | - Deputy Director Program Control Saturn/Apollo and Apollo Applications Programs |
| Prentice, R. W. | - Deputy Director, Systems Development Saturn/Apollo and Apollo Applications Programs |
| Robins, N. B. | - Deputy Director - Systems Safety and Product Reliability, Saturn/Apollo and Apollo Applications Program |
| Tyson, O. S. | - Resident Manager, Resident Management Office |
| Yarchin, S. | - Program Director, Saturn V Workshop |

NORTH AMERICAN ROCKWELL CORPORATION, DOWNEY

| | |
|---|---|
| Briggs, Glenn W. | - Deputy Resident Manager, Resident Apollo Spacecraft Program Office |

NORTH AMERICAN ROCKWELL CORPORATION, DOWNEY (Cont'd.)

| | |
|---|---|
| Carroll, R. E. | - Vice President, Contracts and Pricing |
| Fagan, G. R. | - CSM Program, Planning and Control, Apollo CSM |
| Gray, L. B. | - CSM Program, Manager, CSM Reliability |
| Kehlet, A. B. | - CSM Program, Space Shuttle |
| Lindeman, R. | - Chief, Configuration Management Resident Apollo Spacecraft Program Office |
| McDermott, T. C. | - Vice President, Quality and Reliability Assurance |
| McNamara, J. P. | - Executive Vice President, Space Division |

Power System Division

| | |
|---|---|
| Crossland, W. D. | - Division Director, Facilities and Industrial Engineering |

Rocketdyne Division

| | |
|---|---|
| Aldrich, D. E. | - F-1 Program Manager |
| Armstrong, Jack L. | - Vice President and General Manager Small Engine Division |
| Ek, Matthew C. | - Chief Engineer, Design and Development Engineering |
| Girard, D. M. | - Manager, Management Technology |
| Greenfield, S. | - Program Manager in IR&D and Technology Utilization |
| Hargiss, W. C. | - Director, Quality Control |
| Johnson, N. D. | - H-1 Program Manager |
| Mulliken, F. R. | - Project Engineer, F-1 Development |
| Revel, Norman C. | - Assistant General Manager Liquid Rocket Division |
| Stratton, Harold S. | - Assistant J-2 Program Manager |
| Vogt, P. R. | - Engineer and Test Vice President |

Space Division

| | |
|---|---|
| Beat, R. H. | - Manager, Contracts and Pricing |
| Brennan, R. C. | - Electrical/Electronic Design Engineering Saturn S-II Program |
| Cutler, H. H. | - Deputy Manager, Saturn Derivatives Office |

Space Division (Cont'd.)

| | |
|---|---|
| Dean, W. E. | - Manager, Business Operations |
| Drucker, M. I. | - Director, Contracts and Pricing CSM Programs |
| Eaglen, R. L. | - Saturn S-II Quality & Reliability Assurance Manager |
| Ezell, W. F. | - S-II Program, Chief Engineer |
| Goldsby, W. | - S-II Resident Contracting Officer |
| Long, W. M. | - Manager, Structural Systems |
| Matteson, E. L. | - Manager, Project Engineering |
| Merrick, G. B. | - Chief Program Engineer, Apollo CSM Program |
| Mihelick, J. F. | - Manager, Apollo CSM Material Management |
| Miller, Ford | - Chief, Project Engineering, Resident Apollo Spacecraft Program Office |
| Myers, Dale D. | - Vice President and General Manager, CSM Programs |
| Olsen, R. E. | - Deputy Manager, Business Operations |
| Olsen, M. R. | - S-II Program Manager, Test Operations |
| Oslund, J. | - Supervisor, Stage Mechanical Design |
| Parsch, D. R. | - Material Manager, Saturn S-II Program |
| Raiklen, H. | - Vice President and S-II Program Manager |
| Rubadeau, J. A. | - Manager, S-II Manufacturing, Engineering and Controls |
| Schwartz, R. | - Manager, Mechanical Systems |
| Tondre, G. J. | - S-II Program Manager, Engineering Operations |
| Twight, F. F. | - Manager, CSM Test Operations |

RCA (Camden and Moorestown, New Jersey)

| | |
|---|---|
| Botkin, Charles C. | - Manager Equipment Programs, Missile & Surface Radar Division |
| Goldman, Max | - Manager Program Management, Defense Communications Systems Division |
| Holt, S. B. | - Manager Aerospace Programs, Defense Communications Systems Division |
| Piro, Phillip A. | - Division Vice President & General Manager Missile & Surface Radar Division |

RCA (Camden and Moorestown, New Jersey) Cont'd.

| | |
|---|---|
| Schnapf, Abraham | - Manager TIROS & TOS, Astro-Electronics Div. |
| Waddington, Willian | - Manager Program Planning and Control, Missile & Surface Radar Division |

# APPENDIX B

## PUBLICATIONS LIST

| Working Papers | Role of the Project Manager |
|---|---|
| 6223-WP-1 | "The Role of the Project Manager and Management Systems in the Management of the Apollo Program," Richard J. Hopeman and David L. Wilemon, December, 1968. 10 p. |
| 6223-WP-2 | "Systems Analysis and Management," Richard J. Hopeman, December,1968. 49 p. |
| 6223-WP-3 | "The Spectrum of Project Management," John P. Cicero, December,1968. 13 p. |
| 6223-WP-4 | "The Apollo Project Manager-Contractor Interface," Eugene E. Drucker, October, 1969. 17 p. |
| 6223-WP-5 | "Project Management Authority: Some Preliminary Insights," David L. Wilemon, December, 1968. 29 p. |
| 6223-WP-6 | "A Concept of Project Authority," John P. Cicero, March, 1969. 24 p. |
| 6223-WP-7 | "A Concept of Project Authority: The NASA/ Apollo Programmatic Environment," John P. Cicero and David L. Wilemon, June, 1969. 42 p. |
| 6223-WP-8 | "NASA and the Apollo Program," William Pooler and Alphonse Sallett, July, 1969. 24 p. |
| 6223-WP-9 | "Project Management: A New Dimension in Complex Task Management," David L. Wilemon, July, 1969. 43 p. |
| 6223-WP-10 | "The NASA Scheduling System: Scheduling in the Apollo Program," (Part 1 of 6), R. J. Hopeman, July, 1969. 34 p. |
| 6223-WP-11 | "The NASA Scheduling System: Scheduling in Project Management," (Part 2 of 6), R. J. Hopeman, August, 1969. 28 p. |

| Working Papers | Role of the Project Manager |
|---|---|
| 6223-WP-12 | "The NASA Scheduling System: The Techniques of Scheduling in the Apollo Program," R. J. Hopeman, May, 1970. 21 p. |
| 6223-WP-16 | "Project Management at Houston," Henry J. Anna, August, 1969. 18 p. |
| 6223-WP-17 | "Project Authority: A Multidimensional View," John P. Cicero and David L. Wilemon, December, 1969. 18 p. |
| 6223-WP-18 | "The Apollo Project Manager: Anomalies and Ambiguities," David L. Wilemon and John P. Cicero, December, 1969. 21 p. |
| 6223-WP-19 | "Relationships Between Research and Development Operations and Industrial Operation at MSFC," Bernard D. Wood, April, 1969. 27 p. |
| 6223-WP-20 | "Project Management and the Organization, Part I," Henry J. Anna and H. George Frederickson, August, 1969. 66 p. |
| 6223-WP-21 | "Project Management as a Transferable Management System," David L. Wilemon, September, 1969. 24 p. |
| 6223-WP-22 | "Project Management and the Organization, Part II," Henry J. Anna and H. George Frederickson, October, 1969. 51 p. |
| 6223-WP-23 | "On the Application and Dissemination of Space Age Management Technology," D. L. Wilemon, January, 1970. 21 p. |
| 6223-WP-24 | "The NASA-Apollo Contractor Interface: The Resident Management Operation," B. Kelmachter, February, 1970. 16 p. |
| 6223-WP-25 | "NASA Priorities in Orbit: The Waxing and Waning of Moon Mania," H. G. Frederickson and R. Loverd, February, 1970. 11 p. |

| Working Papers | Role of the Project Manager |
|---|---|
| 6223-WP-26 | "The Power Spectrum in Project Management," G. R. Gemmill and D. L. Wilemon, February, 1970. 17 p. |
| 6223-WP-27 | "Transferring Space-Age Management Technology," D. L. Wilemon, July, 1970, 17 p. |
| 6223-WP-28 | "Dimensions of Interpersonal Power in Project Management," David L. Wilemon and Gary R. Gemmill, November, 1970, 25 p. |
| 6223-WP-29 | "Program Innovation in a Complex Organization (MSFC's Program Development Operation)," David L. Wilemon, July, 1971. 29 p. |
| 6223-WP-30 | "Project Management: A View from Apollo," David L. Wilemon, October, 1971. 24 p. |

Occasional Papers

| | |
|---|---|
| 6223-OP-1 | "The College of Business Administration--Circa 1985," Richard J. Hopeman, October, 1968. 17 p. |
| 6223-OP-2 | "Reflections on Interdisciplinary Research," Richard J. Hopeman and David L. Wilemon, June, 1969. 20 p. |
| 6223-OP-3 | "Interdisciplinary Research in a University," Bernard D. Wood, April, 1969. 12 p. |
| 6223-OP-4 | "Managing Product Development Systems: A Project Management Approach," David L. Wilemon, Rev. October, 1969. 18 p. |
| 6223-OP-5 | "Bureaucracy and the Urban Poor," H. George Frederickson and Henry J. Anna, August, 1969. 20 p. |
| 6223-OP-6 | "Interdisciplinary Effort: Research or Problem Solving?", Eugene E. Drucker, September, 1969. 10 p. |

Occasional Papers

| | |
|---|---|
| 6223-R-1 (Interim Report) | "Project Management in the Apollo Program," E. E. Drucker, W. Pooler, D. L. Wilemon, B. D. Wood, April, 1970. 34 p. |
| 6223-TD-1 | "Impact of Budget Execution on Management Behavior: A Study of Managerial Perception, Interim Report #1," Harry J. Lasher, December, 1968. 117 p. |
| 6223-TD-2 | "Impact of Budget Execution on Management Behavior: A Study of Managerial Perception, Interim Report #2," Harry J. Lasher, December, 1968. 11 p. |
| 6223-TD-3 | "The Professional and Technical Qualifications of Apollo Project Managers," John P. Cicero, August, 1969. 151 p. (Master's Thesis). |
| 6223-TD-4 | "The Career Development of NASA-Apollo Project Managers and Their Industrial Counterparts," Barry L. Kelmachter, April, 1971. 133 p. (Master's Thesis). |
| 6223-TD-5 | "Non-Hierarchical Public Management: A Study in Science and Technology," Henry John Anna, August, 1971. 268 p. (Doctoral Thesis). |
| 6223-TD-6 | "The Relation of Five Personality Traits to Participant Attitudes Toward Simulated Project and Traditional Management Procedures Within a University Environment," John P. Cicero, October, 1971. 124 p. (Doctoral Thesis). |

Articles Published by Team Members

a) "The Project Manager: Anomalies and Ambiguities," D. L. Wilemon and J. P. Cicero. Academy of Management Journal, September, 1970. This article was reviewed in the Jan/Feb 1971, "Innovation/Search supplement to Innovation. The article also has been accepted for publication in the book entitled, Readings in Business Policy, by Bonge and Coleman to be published by the Macmillan Co. in late 1971.

b) "Transferring Space-Age Management: Are There Potentials for Environmental Problem-Solving?", D. L. Wilemon. Conference Board Record, October, 1970. An abstract of this article appears in the January issue of the Department of Commerce's Marketing Information Guide.

c) "The Power Spectrum in Project Management," G. R. Gemmill and D. L. Wilemon, Sloan Management Review, Fall, 1970. College of Business Administration, Syracuse University.

d) "Managing Product Development Systems: A Project Management Approach," D. L. Wilemon, July 1969, published in Business and Economic Dimensions, May, 1970.

e) "Project Authority: A Multidimensional View," J. P. Cicero and D. L. Wilemon, published in Transactions on Engineering Management, May, 1970.

f) "Bureaucracy and the Urban Poor," H. George Frederickson and H. J. Anna, published in Urban Social Changes Review, 1970.

g) "Interpersonal Power in Project Management," D. L. Wilemon and G. R. Gemmill, Journal of Management Studies, October, 1970.

h) "Project Management: A View From Apollo," D. L. Wilemon, Proceedings of the Third Annual Seminar/Symposium of the Project Management Institute, October, 1971.