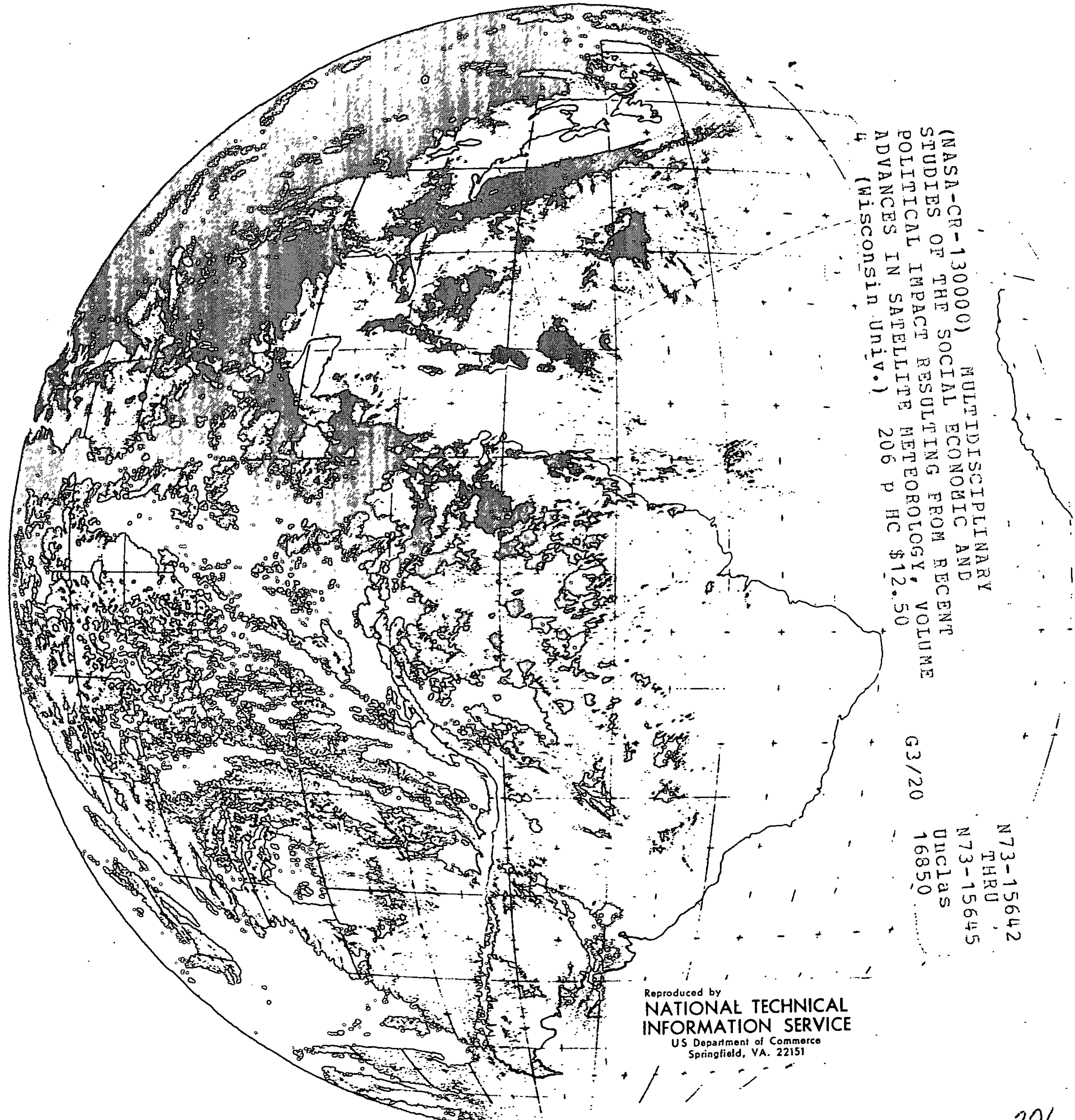
multidisciplinary studies of the social, economic, and political impact resulting from recent advances in satellite meteorology

an interim report
volume four
space science and engineering center
the university of wisconsin
madison, wisconsin



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MULTIDISCIPLINARY STUDIES OF THE SOCIAL, ECONOMIC AND POLITICAL IMPACT RESULTING FROM RECENT ADVANCES IN SATELLITE METEOROLOGY

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Volume IV

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PREFACE

This research is providing a detailed analysis of the social, legal, organizational and economic benefits of satellite meteorology. The multi-disciplinary team at the Space Science and Engineering Center at the University of Wisconsin has undertaken to ascertain and isolate these benefits in an in-depth research effort. This effort was begun in 1969 and a two-volume interim report was issued in June 1971 consisting of some 890 pages.

The reports contained in the present two volumes include continued work on economic benefits, legal implications, management systems, and agricultural impacts. This research area which combines a working knowledge of satellite meteorology with expertise in various related software areas promises to, for the first time, produce data on the practical effects and impact of meteorological satellites.

We are grateful for the continued support of NASA and are looking forward to further research which we hope will benefit the entire nation.

Verner E. Suomi
Delbert D. Smith

MULTIDISCIPLINARY STUDIES OF THE SOCIAL, ECONOMIC AND POLITICAL IMPACT RESULTING FROM RECENT ADVANCES IN SATELLITE METEOROLOGY

Summary Table of Contents

MULTIDISCIPLINARY STUDIES OF THE SOCIAL, ECONOMIC AND POLITICAL IMPACT RESULTING FROM RECENT ADVANCES IN SATELLITE METEOROLOGY

VOLUME IV

Detailed Table of Contents

A STUDY OF THE WEATHER SATELLITE PROGRAM MANAGEMENT AND ORGANIZATION SYSTEMS

André Delbecq
Alan Filley

Introduction

The purpose of this study is to describe the management and organizational system utilized by the Meteorological Satellite Program at NASA. The study focuses on the structure, process, and functioning of the program, making possible the successful linking of multiple systems of space science technology. By explicating the methods used and the conditions surrounding their usage it is expected that the lessons learned from this program will be of benefit to other organizations concerned with complex, developmental planning.

Indeed, the relative newness of a science linking space technology with meteorology parallels the relative newness of the management and organization systems utilized. The characteristics of nonbureaucratic organizations, on the other hand, have not been studied until recently.

The development of any science, including the science of organization, tends to follow a natural development from description and explanation of phenomena, to prediction of phenomena or events, to prescription of methods leading to described results. The matrix organization and project management methods utilized in space science and in other rapidly changing technologies today have not been adequately described and documented. Thus, the present study represents part of the essential first step: description and explanation.

Methodology

In keeping with the objectives of the study, the following steps were taken in the development of this document:

(a) Orientation and background review. The historical evolution of NASA and the Weather Satellite Program were reviewed in published documents. The general structure of the program was identified from these documents and from interviews with members of the Space Science Center, University of Wisconsin. Of particular interest at this stage was the identification of key administrators, major organization units, organization interfaces where coordination and interface mechanisms might be found, and historical antecedents to the present structure.

(b) Comparison of organizational features with known theory and research.

(c) Identification of critical issues for investigation. The features of the weather satellite program were compared with other matrix and project management systems. This process suggested five key areas of investigation: organization mission, interfaces with other units and agencies, planning strategies, structural design, and participant characteristics.

(d) Preparation of interview schedules and data gathering. Using a clinical interview schedule designed to probe the five areas mentioned above, interviews were conducted with eleven people in NASA and twelve people in ESSA (now NOAA) at both the headquarters and project levels. Interviews all took place between October, 1970, and December, 1970, and lasted approximately one and one-half hours each.

(e) Data analysis and presentation. The report which follows contains nine chapters. The first four are essentially theoretical, while the last five are empirical. The theoretical chapters present the overview of matrix structure, program management, and the program and project offices. The remaining empirical chapters serve to illustrate the theoretical material by presenting a case study of the weather satellite program. Since the focus is upon project and matrix organization systems, the study focuses primarily upon the program and project offices in NASA.

It should be noted that case material and other examples are used to illustrate, not to prove. One can never prove a point by citing an example, but one can clarify by showing how a concept exists in practice.

Limits of the Study

We have made an attempt to describe and explain the system. As such we have been careful not to confuse the normative "ought" with the positive "is." That is, we are not suggesting how the organization should behave, since to do so would be speculative and premature. In addition, the system described here should be considered that of the satellite program, not the system of all program management, nor necessarily the system of other programs in NASA.

The system described in this study exists concomitantly with a successful technical program. It may or may not be causally related to the success of the technical activities. In any case, no causation is claimed. Finally, no study of this kind can be free from the dangers of interviewer interpretation. We have attempted to let the systems speak for themselves and to avoid imposing preconceived models.

Chapter One

A PERSPECTIVE ON MATRIX ORGANIZATION STRUCTURE

Until the post World War II period, most organization structures could be classified rather handily into a few types. These structures probably devolved without much conscious planning and were most suitable for environments viewed as stable and predictable. In the later period, however, newer structures had been developed which were less than the natural evolution of an organization and more the result of conscious planning to meet specific needs. With the advent of advanced technology, particularly in the aerospace industry, and the requirements of short-term research and development projects, organization planners have aided in developing structures which differ from their predecessors in kind as well as in degree.

Goal and Process Departmentation

Until recently there were two main alternatives available for organizing. The first was by function or activity, the second, by goal or product. When function or activity is the basis for grouping, one would find a business divided into sales, manufacturing, engineering and the like. In a research and development organization, one might find departments devoted to systems, procurement, engineering, testing and the like. Such an arrangement permits division of labor within a specialty (Filley, 1969; Galbraith, 1971) since, for example, the engineering department could have both an electro-mechanical engineer and an electronics engineer. By having departments grouped by skill, there is an opportunity for specialists to advance within their skill area. Such an arrangement also reinforces "professionalism" since interaction is with other specialists of the same type.

The functional organization facilitates the time-sharing of specialists on a variety of projects or products in the same sense that product batches are scheduled in and out of the machine capacity of a drill press department.

The functional organization also has certain inherent problems. The difficulty of scheduling and coordinating activities within and between departments is severe. As Galbraith (1971) points out, "The problem of simultaneously completing all tasks on time, with appropriate quality and while fully utilizing all specialist resources, is all but impossible in the functional structure." In addition, the emphasis on professionalism often causes specialists to concern themselves with stature in the eyes of their professional colleagues rather than with meeting organization goals. Finally, the sharp differences in activity, philosophy, and perhaps education and jargon, between departments increases the likelihood of conflict and misunderstanding between those organization units.

In contrast with the functional structure, the goal-oriented structure groups activities into departments or divisions according to common product, common customer, common geographic area, or common project. In a business organization this might mean that each product division would have its own engineering, sales, and manufacturing activities. In the research and development division it might mean that each project would have its own engineering, sales and manufacturing activities, and its own systems, engineering and test people. In the research and development division it might mean that each project would have its own systems, engineering, and test people. Under this arrangement all of the work can be grouped under a single management and reliance on separate division or departments is reduced. Such an organization makes scheduling and coordination easier and facilitates completion on scheduled dates. It increases attention to the goals of the division or department and reduces attention to professional role.

The chief disadvantage of the goal-oriented unit is the necessity of duplicating skills or equipment in each unit. As such, the people or equipment may not be fully utilized since, unlike functional units, work and time are not scheduled against available capacity. Rather, they are present because of simple need. A related problem stems from the fact that there are not larger numbers of specialists grouped together, and consequently a reduction in ability to develop a division of labor within the specialty. If two projects are present, management must hire two electrical engineers, reducing specialization, or four engineers (two electronics and two electromechanical) causing duplication (Galbraith, 1971).

In the sense that goal-oriented units are directed to client service rather to professional expertise, they are often superior to functional units in meeting client needs. Since they are self-contained, however, they may suboptimize as far as the superordinate goals of the total organization are concerned. The parent organization containing the project or product divisions

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may have difficulty controlling behavior in the units and in balancing resources between divisions to the satisfaction of project or product division leadership.

Given only the alternatives of functional- or goal-oriented units, then, organization management has historically been faced with the choice between operations which maximized technical or professional skill but which failed to meet schedules and deadlines, or operations which met scheduled needs, but which failed to develop or utilize professional and technical resources. As will be shown later, it was the matrix organization which faced this dilemma and which attempted to gain the advantages of both goal and functional units while avoiding the inherent problems in each.

Research on Goal and Process

Several studies shed further light on the difference between the two organizing strategies. Kover (1963) describes the reorganization of an advertising agency from function to goal units. According to Kover:

> . . . the existing services were disbanded and their personnel were formed into heterogeneous marketing or creative groups to help fulfill the goal of more tightly-integrated client service. Service was now provided by formal, permanent, client-oriented groups in place of less structured, shifting client assignments in functional departments.

As a result, client-agency communication was greatly simplified, though communication among specialists was severely reduced. Also, in changing from technical supervision to project or client supervision, the specialists were judged by nonprofessionals. The reorganization reportedly increased efficiency in terms of coordination with fewer delays, mistakes, and omissions. It made performance evaluation of specialists more difficult since they could not be meaningfully compared with each other, and it changed from a dual evaluation of work in terms of both profession and client to a single client-satisfaction criterion. Organization members who were exclusively "craftsmen," i.e. oriented to profession, became alienated in the new structure, while those oriented more to organization goals made the shift satisfactorily. In short, the study indicates that a shift from function to goal-oriented units increased customer service and reduced professional emphasis.

The relative value of goal or functional emphasis probably depends upon the degree to which institutional goals and professional goals are similar. Glaser (1963) reports a study of 332 members of a medical research organization. Using survey data, he found that where organization and professional goals are the same, as might well be true in a medical research institution, loyalty to the organization is accompanied by a high degree of professional achievement. Unlike the craftsmen mentioned in the previous study who had to choose between professional or institutional goals, the professionals here did not face such a choice. Instead, the scientist was rewarded by superiors for scientific expertise.

A third study (Brown and Shepard, 1956) is consistent with this view. In this case a research organization changed from a process department structure to a goal-oriented structure, and a change in emphasis from research to development. Under the new structure,goals were dictated externally by a government agency and the members were less able to seek their own goals. Those opposing the change felt the "pencil pushers" in Washington were telling them what to do and that the change interferred with their ability to do scientific work. Those who favored the change did so for three main reasons: (a) they were professionally interested in development, (b) they accepted Washington's right to set policy and felt a duty to follow it, or (c) they expected personal gains in rank, salary, and control of personnel with the new arrangement.

The final study to be mentioned here (Walker and Lorsch) provides more detail about goal and function. Comparing two manufacturing organizations which were essentially alike except for their method of departmentation, they found the following characteristics. In terms of the kind of goals emphasized, the functional plant emphasized professional goals, while in the product division plant dual concern for professional and organizational goals was expressed. Comparing time horizons in each, they found a general concern for short-run goals and daily problems in the functional structure, and a variety of time horizons in the goal-oriented structure. Comparing the formality of structure, i.e. explicit job relationships and emphasis on rules and procedures, they found the functional organization to be more formal. There was a uniform structure and great emphasis on rules and procedures. Under the goal or product structure, arrangements were more varied with formality in some areas and loose arrangements in others. In all, there were less clear differences between jobs or specialties in the product division.

In considering integration and communication, Walker and Lorsch found that the goal-oriented structure had better integration even among a wide variety of skills and that communication among employees was more frequent, less formal, and more often face-to-face than in the functional structure. In the functional organization the formal boundaries between specialized departments blocked communication. Comparing performance in each, they found that the functional structure was better at maximizing current output, but was far less flexible in terms of improvement or consolidation of jobs. Finally, contrasting employee attitudes in each, they found that in the goal-oriented plant there was more involvement in work as well as more stress and pressure. In the functional structure people were more satisfied with work, possibly because of stability and less pressure to meet deadlines.

In general the evidence is quite consistent. Given only the two alternative forms of organization the functional arrangement permits the greatest use of technical knowledge but makes collaboration and control between units a difficult task. The goal-oriented structure is less formal, makes less efficient use of resources, but meets schedules and targets better.

Modifying Factors in Goal and Process

Before turning to the matrix organization, it is useful to note certain factors which seem to modify our generalizations about goal or functional departmentation.

(a) Size of unit. It may be observed that the size of a process-oriented unit can affect its tendency to subgroup by profession. For example, a large organization might have fifteen engineers in a functional department. In reorganizing along project lines, three engineers might be assigned to each of five projects. The effects of a goal-oriented unit described earlier might be expected to follow. But, what would happen if a project group grew sufficiently large to warrant fifteen engineers on a single project? Very likely the engineering group would return to its focus on professional values and norms.

(b) Client emphasis. Another factor which tempers the effects of goal or process departments is the extent to which the unit is free from direct influence or control by the client. As Etzioni (1964) has pointed out, an organization is less likely to attend to client needs to the extent that it is independently financed by other than the client directly and is a monopolistic source of client services. Thus, if the unit is competing for a client with other similar sources of service and depends upon the client for its income, it will be more attentive to goals defined by clients. Where opposite conditions are true, it will be more calloused toward its clients.

(c) Work flow. The extent to which functional units are highly differentiated depends on how mutually dependent units are on each other. If the work flow cuts across units, then they must be more integrated and the necessity for cooperation is increased. In the case of goal-oriented units, if the work flow is highly programmatic in nature as in line-balanced production or in straight line assembly, then the flexibility usually attributed to goal units might be considerably reduced.

Without noting these modifying factors, one will generally suppose that the answer to inherent problems in functional structures is merely a shift to product, client, or project forms of goal-oriented units. Yet large goal-oriented units where work flow does not encourage integration will not induce the marked efficiencies and economies that may be desired.

Matrix Organization

It should be made clear at the outset of this discussion that a project doth not a matrix make. In some cases a project may be a temporary or permanent goal-oriented form of departmentation. For example, in the construction industry it has been customary to establish a project to construct a dam, air base, or a building. When project management is related to matrix structure, it is a secondary organization, linking people and systems who already have a defined position in a primary organization. That is, while the primary organization may be functional in nature, the projects relate people from these functional units for purposes of goal achievement (Davis, 1962).

Certain characteristics appear frequently where project management is used. First is the time priority of meeting scheduled dates. Second is organizational complexity involving two or more major elements or units in the structures or technical complexity involving two or more distinct technical disciplines. Third is a major dollar commitment to a project requiring cumulative expenditures on a time scale. Fourth is a significant interest by a power source external to the organization: Congress, a major customer, an institutionalized group of people in the community.

Where these conditions are present, one can frequently trace an evolution toward matrix organization in a functional structure. For example, a scientific breakthrough may indicate program feasibility. Near-term targets for schedules and longer-term commitments of money may be generated by an external power source. The functional organization may respond by establishing a program or project "task force" composed of representatives from several organization units. Such a task force will be charged with determining the feasibility of a major organizational commitment, with planning schedules and resources, and with pilot projects.

The usefulness of this approach is suggested by natural alternatives to it. One alternative is for the chief executive to take the responsibility for these activities himself. That is, since unusual issues tend to move to higher levels in an organization, the executive may drop his normal duties and deal with the immediacy of the problem. Even if he assigns the project to a staff assistant, he still undertakes a major commitment of his own time and resources.

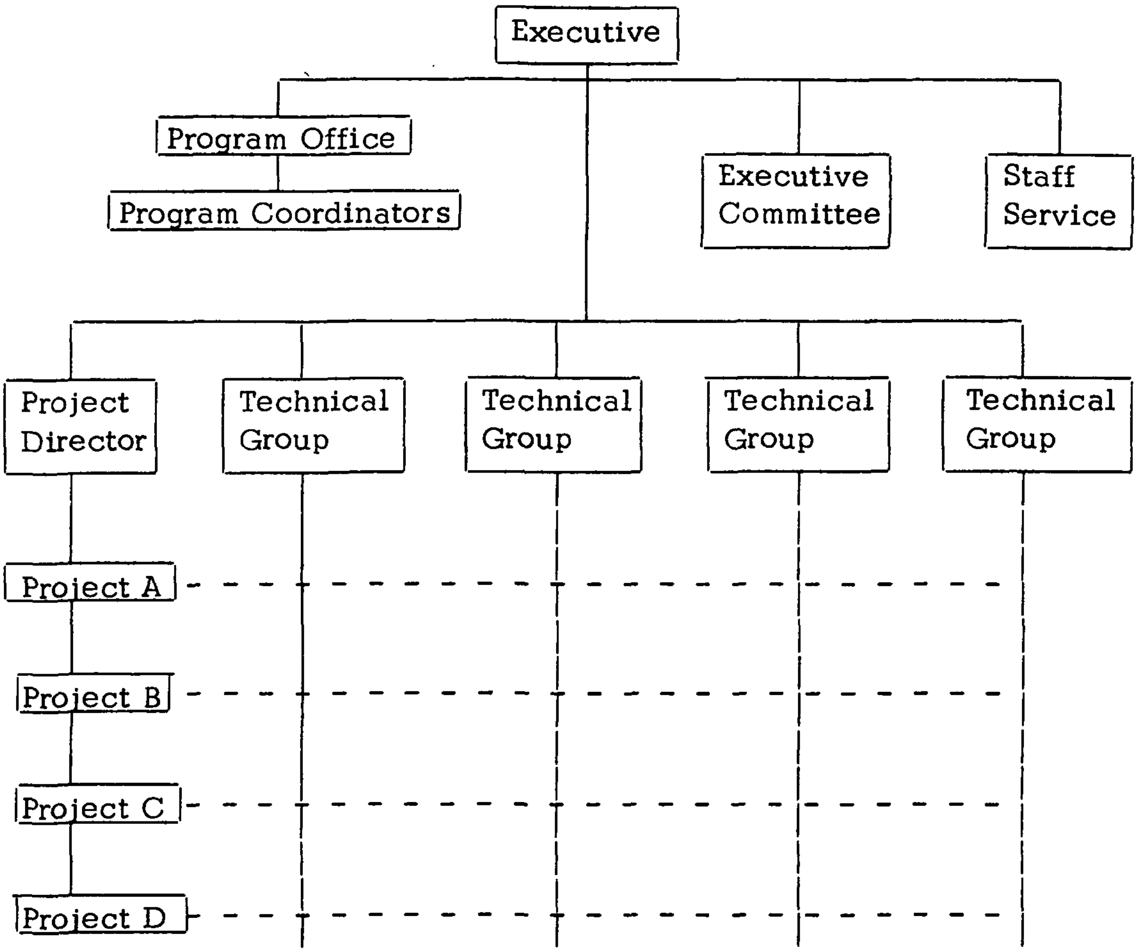
On the other hand, he may try to "decentralize" the issue by asking functional units to investigate their specific interests as they relate to the problem at hand. This has the advantage of closeness to the issue but necessarily limits the scope of view by the specialists. Moreover, there still is no coordination between plans generated from functional departments. The task force is thus a natural solution to the need for action on such a problem. Galbraith (1971) points out that the task force should be composed of people who have enough authority to commit their units to action, but are not so high in the structure that they do not have immediate technical knowledge regarding the problem.

The label "task force" as it is currently used, generally refers to a cross-functional planning group whose existence ends once it files its report. Thus, a task force may be established to develop a cost reduction program and ends its existence when top management takes over to implement the plan. Where a similar cross-functional group continues on a permanent basis, it tends to be labeled a "team," a "coordinating committee," or a "project group." Thus, a company may have a new products team with representatives from several departments, meeting on a regular basis to investigate and plan for new products.

Eventually an organization may find that temporary task forces or permanent project teams do not provide sufficient focus, balance, or predictability, causing the organization to shift into a full matrix organization framework. A simplified example of such a structure is shown in Figure 1. At

Figure 1

Matrix Structure



the top of the chart are shown the executive offices. The program office contains program managers representing project or product groups. These are staff offices operating under the areas of the chief executive, and chiefly concerned with planning, budgeting, scheduling, and control. The program office has a long-range time horizon. It is chiefly concerned with administrative coordination of technical departments and with maintaining balance between project requirements and the needs of the technical groups.

Technical groups themselves are functional departments, much as described earlier. They provide for association of specialists and the advancement of the state of the art in a specific functional specialty. The project groups, on the other hand, are goal-oriented units. Individuals from the technical departments are assigned to project groups, for all are part of the project. Common patterns of assignment include the following: (a) full-time assignment of technical staff member for the life of the project, (b) full-time assignment for project phase, (c) part-time assignment, and (d) contract for services. Under the latter the project leader merely arranges for services from the technical group and the technical group member never really becomes part of the project team.

As will be discussed in a later section, power balances are subtle and difficult to maintain in matrix structures. In some matrix organizations the technical departments depend upon funds generated from assignment of personnel to projects. In other cases the technical departments are financed independently and the project leaders must rely upon contractual agreement, persuasion, or interest by a technical department member to get support for the project. Administrative evaluation of technical performance on projects may also enhance the power of projects vis-à-vis technical departments.

The project manager's role is also that of balancing power and resources. By representing the interests of the projects in the executive committee, the project director can preserve the needed support for projects. Working properly, the matrix structure provides for both the coordination and control formerly available in goal-oriented structures <u>and</u> the professional depth available in functional structures.

Such a structure has many advantages. It specifies that a single individual is the focal point for all activities related to a single project. It permits flexible utilization of manpower since technical personnel may be drawn from readily accessible sources in the functional departments, and because such personnel may be shifted between projects. It gives the technical personnel a home base in which they can get professional reinforcement and to which they can return between projects. It minimizes the number and use of bureaucratic channels for communication. It contains built-in checks and balances between money and cost considerations and technical considerations throughout the project because of the functional relationships (Cleland and King, 1968).

In the chapters which follow we shall enumerate both the theoretical and the empirical considerations of matrix organization and project management. In Chapter 2, we shall look at program management as a subsystem of matrix organization. Then, in Chapters 3 and 4, we shall deal with the details of the program and the project offices. This perspective will provide the cognitive map for considering the Meteorological Satellite System in NASA, the principal focus of Chapters 5 through 8. Finally, we shall discuss the implications of the Satellite program experience as it might be applied in social planning systems.

Chapter 2

A PERSPECTIVE ON PROGRAM MANAGEMENT

The purpose of this chapter is to move away from the dynamics of total matrix structure, to focus in detail on the program management (hereafter abbreviated PM) subsystem within matrix. The chapter itself will be divided into sections, with each section containing a propositional summary.[1]

Two Semantic Clarifications

Two semantic confusions must be clarified immediately. Unfortunately, the very name "program" introduces an ambiguity for many readers not familiar with organizational literature. "Program" in contemporary systems argot is often associated with a situation where the character of the problem or mission is understood, causation in terms of means—ends relationships has been diagnosed, and a routinized solution strategy is available in a standardized action path known as a "program."

Paradoxically, the genotype PM to which we refer is an organizational design for a directly opposing situation. We conceive PM to be a strategy for organizing when the problem is only vaguely understood, solution strategies do not yet exist, and resources are not yet organized. The output of PM is the development of a program, rather than the management of a routinized

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[1]We are using propositions here to mean statements dealing with the organic nature of PM, rather than the more restrictive notion of a proposition as the specification of a functional or casual relationship.

program.

An additional problem semantically is the distinction between "program" and "project" management. We define the genotype PM form as encompassing both "program" and "project" functions and structures, an issue which we will take up in greater detail at a later point.

With these semantic clarifications, we can now proceed to discuss the causes for the emergence of PM as an organizational design.

Causes for the Emergence of PM

We postulate that the underlying cause or need for PM is the need for "integration" (bringing together); or put negatively, the reality of "fragmentation." Thus, we see program management emerging where the heavy cost of an elaborate system of coordination must be incurred in order to facilitate the development of a new program. The need for coordination may relate to all or at least several of the following causes.

User Group Needs[2]

Many times actual or potential user groups—the potential beneficiaries of the program—are poorly linked and relatively uncoordinated. Each of the relevant user groups may have specialized concerns, but no mechanism or umbrella for coordinated planning for these differentiated groups exists. One

[2] By user groups we mean both intra-organizational and extra-organizational groups who ultimately adopt the new technology developed by the experimental program into their line or functional activities.

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aspect of PM, therefore, is the function of serving as the agency for studying the perceived needs of the varied user groups, and providing for comprehensive planning to meet these needs.

Institutional Focus

The presence of unmet user group needs of sufficient scope to justify programmatic planning implies that the present allocation of effort by existing line or functional organizations is either inadequate or their mandate does not focus attention on the need area. As a result, the initiation of PM implies that new resources are to be developed or present resources are to be reallocated. (Budgetary relations between program and line units will be discussed later.) PM, therefore, becomes an agent for defining new funding needs and/or a channel for reallocation of existing funding toward a new mission.

Technological Changes

However, (re)allocating resources does not guarantee that innovative technologies will be developed to deal with user group needs. The ability of traditional, functional organizations to "repackage" old answers in order to entice new funding is renowned. Therefore, PM is an organizational-design which seeks to assure that a "new" program emerges to meet the defined mission or problem. By "new" is meant innovative or substantially different from programs which presently can be or are being delivered by functional organizations.

Complexity

"New" programs are often complex from two standpoints. First, they may be technically or conceptually new, which implies complexity in a cognitive sense. Second, since no existing institutional arrangement is meeting the need they often require pooling of existing resources and capacities which implies "political" complexity.

With respect to conceptual complexity, it is almost trite to mention buzz words such as "information explosion" and "multidisciplinary." Nonetheless, these buzz words exist and are in vogue due to the underlying reality of conceptual specialization by discipline and function, and theoretical and empirical proliferation within disciplines and functions. Further, the greater the complexity of the task and the greater the lack of integration between specialized organizational units, the greater is the need for formal integrating mechanisms such as PM (Lawrence and Lorsch, 1967, p. 145).

Inasmuch as "new" missions often are not the focal orientation point of "older" disciplines, or older line functions, a critical aspect of PM is the development of a planning process which brings to bear on the development of new solution strategies expertise from multiple disciplines and differentiated functions.

However, disciplinary and functional experts are not free agents. They are housed and supported by specialty and functional organizations who have need for their services in connection with ongoing activities. As a result, a second aspect of complexity which the program manager faces is the wooing of needed specialists from existent organizations, and the utilization of this scarce specialist talent for temporary periods at discrete phases in program planning.

As a result of this complex conceptual and political context, PM must be a vehicle for penetration of existing specialty and functional groupings.

Experimental Character

Inasmuch as all of the above involve integration and planning around a new mission, the character of PM must be experimental. However, experimentation cannot be an end in itself, since PM is essentially mission-oriented. Therefore, a conscious system of demonstration and spin-off must be part of the PM design. In the absence of such a conscious system, there will be increasing pressures to "bureaucratize" the PM structure, convert it to an "operating" organization, or to perceive it as competing with other functional units.

Given these underlying causes for the emergence of PM, we can now turn to the basic mandate and guiding norms for the genotype PM design.

Guiding Norms and Basic Mandate for PM

Proposition 1: The primary function of a PM design is to provide an integrative mechanism for bringing together resources facilitating a program.

Proposition 1 summarizes the basic mandate for PM. The two essential concepts in the above statement of mandate are integration and developmental.

With respect to integration,[3] the fundamental cause of developed PM structures as we observe them relates to fragmentation of user groups, functional and specialist groupings, resources, etc., as discussed in the prior section. Therefore, the primordial feature of PM designs as reflected in structure, roles, budgets and planning cycles is the necessity of creating linkages across separated groups. If this were not the case, program development would be assigned to an existent functional or specialist group. Thus, we posit "integration" as the basic raison d'être for a PM design (Burns, 1970, p. 142; Anna, 1970, p. 6).

Proposition 2: The essential activity spheres of the PM organization will be:

1. Problem exploration: bringing into a planning process all critical user, scientific and technical groups who have a contribution to make to problem definition;

2. Knowledge exploration: establishing linkages with internal and external scientists and specialists who have insight in order to explore alternative solution strategies;

3. Resource development: legitimatizing and seeking funding for the emergent program;

4. Project administration: division of the developmental program into individual project groups, each responsible for the design, development and testing of prototype solutions, and control of these project groups;

5. Project Spin-off: assistance to line or operating organizations in adapting proven technologies.

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[3] We are using "integration" in the tradition of Lawrence and Lorsch (Lawrence and Lorsch, 1967). As such, it is consistent with the concept of "linking" as used by Lynton (Lynton, 1969).

The key sense of Proposition 2 is that PM is essentially a design for the management of a developmental process, rather than the design for the administration of an established program. Some exploration concerning the above activity spheres will make the character of PM clearer.

Problem and Knowledge Exploration—There is both a proactive and reactive aspect of the functioning of the PM unit with respect to activities 1 and 2 above. Reactively, the PM unit responds to and coordinates requests from outside agencies, and sees that appropriate organizational resources are brought to bear in order to respond to these outside requests. Further, internally, the PM unit becomes the information center and intelligence unit with respect to all matters surrounding the program mission.

However, and perhaps more importantly, the PM unit becomes a proactive force to create connections between internal and external groups who possess important information or insight, but do not generally communicate with each other (Burns, 1972). Some of these communications will take the form of formal seminars, institutes or problem-solving sessions sponsored and paid for from the operating PM budget. Other situations will be more informal problem-solving meetings, task force groups, etc. However, such communication linkages are not created without cost and these activities imply that a significant portion of PM staff time is devoted to these communication functions.

Resource Development—The very existence of the PM unit implies some commitment of resources to the program. However, the PM budget itself as a line budget often funds a truncated PM structure,[4] rather than the cost of specific projects. As a result, liaison with financial resource controllers is another major communication linkage. In those instances where the financial resources are external to the organization (e. g., legislative bodies, foundations, etc.), a major PM function is the articulation of the program mission and specific funding requirements for individual projects and the translation of the overall program and individual projects into a format compatible with requirements of the available funding sources. Since the developmental character of the program takes it outside line funds, this process often involves the formulation of pooled funding arrangements and joint ventures.

Project Administration—Once the problem has been generically defined, alternative solution strategies explored, and funding feasibility developed, the solution package conceptualized by program planning is normally divided into discrete projects.[5] The project unit itself is a unit dedicated to the attainment of a limited and specific operationalized goal, which is but one

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[4]By "truncated" organization we mean an organization in which one level of the organization—in this case the project level—is not permanently stored within the organization (Becker and Gordon, 1966, p. 328).

[5]Thus, "program" in PM refers to the entire related series of undertakings which continue over a period of time, and which are designed to accomplish a broad scientific or technical goal. Included in these undertakings are planning processes together with projects (Mandeville, 1969, p. 10).

portion of the total set of solutions encompassed by the program, generally the successful completion of a developmental product on prototype service on time, within a budget, and in conformance with predetermined performance specifications (Gaddis, 1959, pp. 89-97). Often the user group and specialist personnel involved in the evolution of an individual project specification are quite a different reference group from the technical personnel who develop the design details of the prototype product or service. Therefore, in order to assure that a project group does not distort original specifications, and in order to facilitate connections between projects, coordination between project groups and the total program is necessary. This, once again, is a communication burden for PM.

Project Spin-off—Finally, a major concern is that successful program innovations developed and tested by project groups are spun-off to operating or functional organizations. This transfer of prototype products or services to operational units is desirable for two reasons. First, presumably the structural characteristics of functional organizations should be less organic than the PM structure, and therefore should facilitate increased efficiency in operations and/or duplication of new products or services. Second, if spin-off does not take place, pressures for operational or productive efficiency would tend to bureaucratize the PM structure itself. Therefore, it is desirable that the relationships between ultimate user organizations and the developmental program operationalized by project groups be attended at all phases of program and project development, in order to promote smooth adaptation and transfer of successful prototypes to operating organizational units.

Two key mechanisms for facilitating this spin-off are the involvement of key personnel from user or operational organizations in program development and project design and requiring the user or operating organization to share in partially underwriting the cost of the developmental program.

Proposition 3: Effective PM avoids creating manpower or facility redundance.

At the core of PM design is the notion that PM substitutes cross-functional integration for self-possessed resources (Ruedi and Lawrence, 1970, p. 78). Indeed, the fact that PM is responsible for and needs the cooperation of people and facilities outside of its own direct control is probably the most singular characteristic of the design (Clelland and King, 1968, p. 151). It is in this sense that PM is generally schematically diagrammed as a horizontal rather than a vertical structure, which cuts across other functional and specialist organizations.

Not to possess one's own resources or personnel is, of course, a difficult psychological position. As a consequence, a number of norms and careful control over personnel and facility acquisitions are typically imposed on the PM organization.

In general, these guiding norms for PM can be summarized as follows:

a) Coordinative and liaison personnel must necessarily be the primary "permanent" personnel for PM.

b) In program planning (normally carried out by task-force or committee assignments), the primary labor force will be obtained by utilizing released time personnel from administrative, specialist and/or functional groups.

c) At the project level, only the project director and certain administrative support positions are directly budgeted as full-time PM personnel. Other project participants are temporary full-time or part-time participants.

d) Different personnel are cycled into program planning or project implementation at different phases; therefore, assignments to program or project groups on a permanent basis should be restricted to coordinative positions.

Organizational Preconditions for PM

We will, of course, be taking up in detail the manner in which this process of program and project administration is worked out when we discuss the role of the various types of personnel, and the inducements which underlie individual motivations to participate in program and project assignments. However, at the organizational level of analysis, the PM strategy is predicated on a number of preconditions.

Proposition 4: The organizational preconditions for effective PM include: 1) the need for a mandate which legitimizes the PM organization as equal in status to functional and specialist organizations; 2) an intermediate budget which assures cooperation but not self-support; and 3) a style of conflict resolution which bases exchange between PM and other organizational structures on negotiation and problem-solving.

First, the PM unit itself must be perceived both by top management and by administrators of specialist and functional units as a critical and vital part of the organization. If PM is seen as an appendage or minor addition to specialist or functional units, PM will have a minimal effect upon the organization (Lynton, 1969). Therefore, we would expect that a clear statement of the domain of PM would exist to facilitate consensus within and/or between organizational units (Thompson, 1967, pp. 25-28). Further, we would expect that the status of PM would be reinforced by specifying that the chief program administrator would report at an executive level equal to the level at which line and specialist administrators report. Finally, we would expect that some opposition from line and specialist administrators would be co-opted by having key personnel from these organizations serve on a policy review board for the PM organization.

Second, the budget of the PM unit itself must be sufficient, so it can induce cooperation of specialist and functional groups on the basis of funds which otherwise would not be available to these units' personnel. There is no question that dollars are one of the key seduction mechanisms for eliciting cooperation of functional and specialist groups. On the other hand, if PM is allowed relatively unlimited resources and support, it will tend to evolve into an independent unit, will try to hire its own permanent staff or contract outside for services, and cease to be an integrative organization. The balance in funding, therefore, should be such that the PM has sufficient funds to induce cooperation, but insufficient funds so that joint ventures with functional and specialist units are necessitated.

Third, although a network of political affiliations and high interpersonal skills will be part of the inducement process, there also must be action based on joint problem-solving and negotiation—not simply on smoothing or resort to authority (Lawrence and Lorsch, 1970, p. 12). The mechanism for manpower and facilities negotiations which we observe most often is a committee made up of key administrators, functional and specialist administrators, and program administrators who confront differences of opinion so that personnel assignments and facilities utilization in PM are the result of problem solving and negotiation, with no group having absolute veto. Finally, we expect that the key instrumentality or vehicle for these negotiations is a proposal, which when agreed upon becomes an internal contract—more or less formal—specifying the nature, timing, and performance expectations with respect to both manpower and facilities (Burns, 1951, p. 151).

A Matrix Management Structure for Program Management

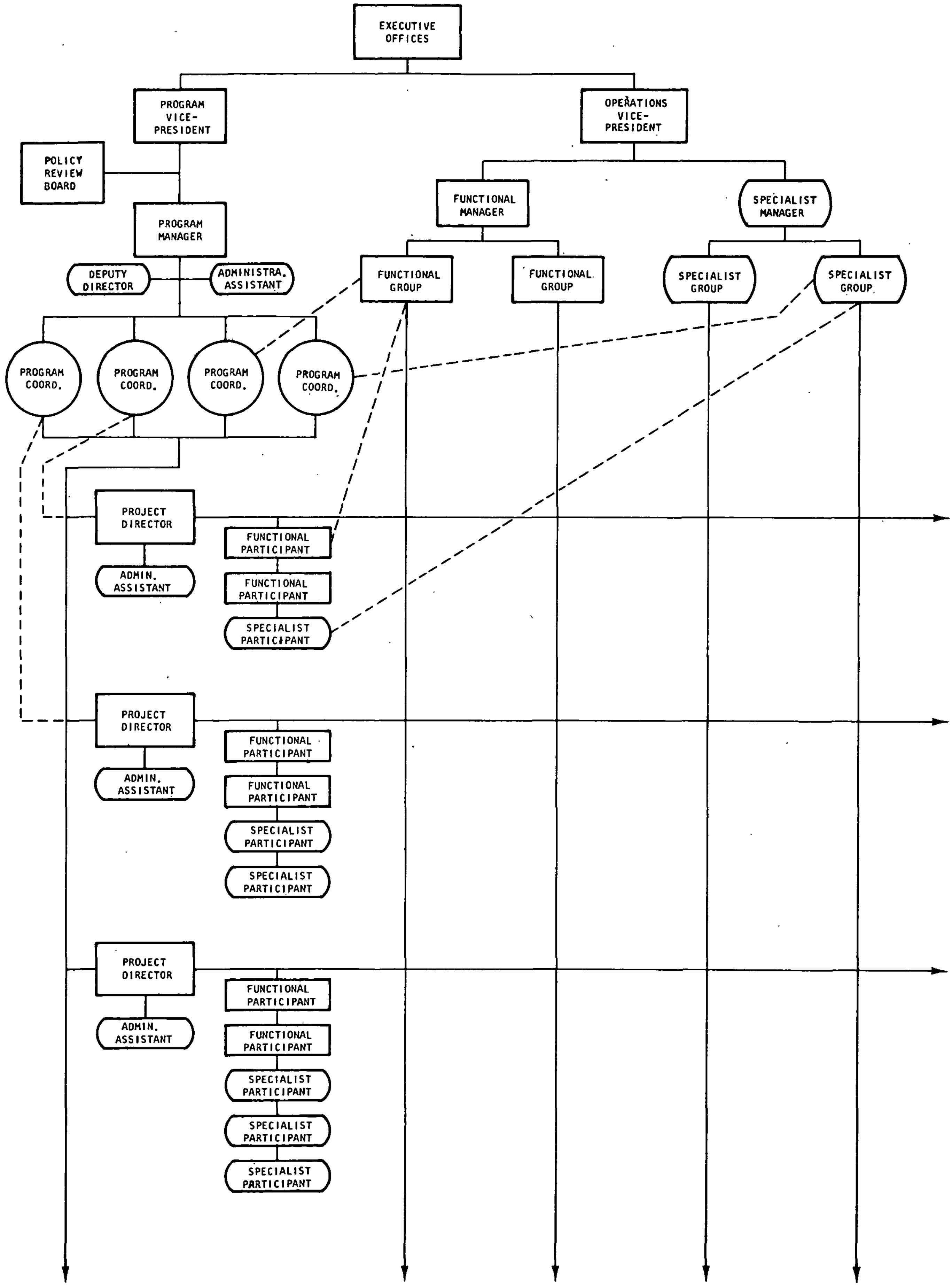
Figure 2 presents a typical matrix management structure for program management. For those not familiar with such structures, some brief introductory comments are in order. However, the detailed dynamics of the structure will become clearer as we describe the functional role of each unit or position represented in Figure 2 in subsequent sections.

The Horizontal Matrix

Organization charts typically diagram PM units as cutting horizontally

Figure 2

PROGRAM MANAGEMENT ORGANIZATION CHART [33]



across functional and specialist groupings. The intent of this diagrammatic matrix is to emphasize the fact that in planning, development and testing new programs, the predominant mandate of PM is to work with and through existing functional and specialist groups.

We are using "functional" here to mean units specializing in particular operational tasks. (There is, of course, the possibility that the organization will contain units based on process or geography as opposed to function.) We are using "specialist" in the sense of scientific, clinical, engineering, or technical units. Finally, we are deliberately avoiding the notion of "line and staff" groups since either functional or specialist units can contain the organization's core technologies and thus be the basic utility-adding units to which the developmental PM structure must relate.

Structural Consistency of PM Across Technologies

The question will naturally arise as to whether one can develop an "ideal-type" program management structure, since PM is found in a variety of organizational settings. Would, for example, the organization chart for PM in a physical technology be similar to or different from PM in a human service technology?

We would suggest that the key features of the structure of the PM unit (the left side of Figure 2) will occur because of the developmental mandate of the PM unit itself. Therefore, these key features will not be eliminated because of differences in the technology of the total organization, although secondary features (such as disciplinary backgrounds, career paths, control technologies, etc.) will certainly be modified by the "core" technology of the organization in which the PM unit is embedded. This is important, since it suggests that the structural features of PM are a function of the technological imperatives of planning, development and testing of experimental programs, rather than a function of the technology which typifies the "core" units of the total organization.

Once you assume that position, the interrelatedness of the norms and mandate set forth earlier and the structural features of PM becomes apparent. We would expect movement away from our "ideal-type" PM structure, then, to reflect an organizational mandate for the PM unit at variance from our earlier norms. The most probable mutation would be for the PM structure to begin to operate or produce products or services which it earlier developed, as opposed to being a purely developmental organization. To the extent that this occurs, we would expect changes in the PM organization toward a structure which contained units that are less organic and temporary than the project units in order to increase efficiency and economy for these more programmed and operational tasks. One can speculate axiomatically: 1) the less experimental the PM mandate, or the more the PM organization engages in operations, the greater the tendency for the PM unit to take on characteristics consistent with the "core" technology of increasingly routinized program; and 2) the less the PM structure has to rely on functional and structural units for resources, the greater will be the tendency to take

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in permanent personnel, and the less integrative roles and functions will be emphasized.

Our "ideal type" PM structure, then, flows from the developmental character of the PM mandate, the emphasis on integration and communication required because of the complexity and newness of the program mission, and the intermediate resources provided the PM unit in carrying on its task. To the extent these organizational features follow our earlier discussion, we can summarize our feeling about the consistency of PM across technologies by the following proposition:

Proposition 5: The central features of a pure-type PM unit will be consistent across organizations, since the determining imperative is the technology of development as opposed to the technology of the organization in which the developmental unit is embedded, or the "core" technology of the prototype program.

Organizational Levels within Program Management

A final comment is in order concerning the levels within a PM structure. In our view, the levels within PM are not uniquely different from hierarchy in conventional organizations, although the manner of functioning will differ due to the developmental character of the PM organization.

For example, James Thompson has elaborated upon Parsons' framework of complex organizations having three inherently different spheres of responsibility: technical, managerial and institutional (Thompson, 1967). The division of responsibilities in the structure sketched in Figure 1 is as follows:

Proposition 6: The institutional and managerial service spheres will be housed in the office of the program manager.

Proposition 7: Technical administration will be housed in the office of the project manager.

Proposition 8: Because of the developmental nature of PM, status and power differentiations between these two levels will be modest, and the differentiation will reflect a hierarchy based on division of responsibility rather than inherent superordination-subordination.

By institutional responsibilities, we mean managing the boundary or interface relations with policymakers, resource controllers, user organizations, and the executive structure of the organization in which the PM structure is housed. By managerial services we mean coordination between program, functional and specialist groups, as well as services for the project group. With respect to the project group, the program office concerns itself with procurement of resources for technical subsystems, and certain control functions relative to both the technical subsystem and resources partially assigned to the program from functional and specialist groups. By technical administration we mean management of the design and implementation of the specific prototype products or services which are developed within the overall program mission.

Our speculation with respect to the moderate status differentiation between program and project levels reflects the fact that developmental endeavors will almost always require the most competent technical specialists. As a result, the project office will have considerable power based on expertise. On the other hand, since stable funding and resources do not surround developmental endeavors, considerable organizational and environmental understanding must be brought to bear to legitimatize the program and its component projects. Consequently, control over resources and legitimacy places the program office in a strategic power position. As a result, it is doubtful that either level of the total PM structure is in a position to exercise "command" or "superordinate" power on all decisions, and the diagrammatic placement of the program offices "above" the project office reflects hierarchy in terms of "integration" much more than hierarchy in terms of status differentiation. The exact character of the function, power, and status of each position and unit in the PM structure can now be elaborated upon.

Chapter 3

A PERSPECTIVE ON THE PROGRAM OFFICE

Proposition 6 in Chapter 2 indicated that the institutional and managerial service function are housed in the office of the program manager (hereafter program officer). In the following chapter we will detail the functions performed by this office, the roles likely to be played by different personnel in this office, and the relation of this office both to the total organization and to the project level of the PM unit itself.

Before beginning we should specify that we are assuming a sufficiently large PM organization to warrant differentiation of roles within the program office. Admittedly, in the very small PM organization, a single program manager may perform all of the roles ascribed to a variety of personnel below. In the larger unit, however, some differentiation of roles is likely to occur, although the amount of role specialization is limited.

Indeed, Lynton suggests the character of the program office requires that differentiation be intermediate, and distinctions between superiors and subordinates in a hierarchical sense be limited (Lynton, 1969, p. 410). With respect to the two key roles, we will shortly suggest that the distinctions between the program manager and program coordinator[6] which do exist reflect

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[6]There is also some disparity of titles between the private and public sectors with respect to position in program management. The private sector program manager is often called program director in the public sector. The private sector assistant program manager is often called deputy director in

a division of labor much more than differences based on command power. The overview of each position which follows should make the differences between the two key roles understandable.

The Program Manager

Proposition 9: The primary functions of the program manager are: 1) program legitimatizing, 2) obtaining of resources, and 3) overall planning and coordination.

Program legitimatizing—With respect to program legitimatizing, we see the program manager as the principal spokesman who legitimatized the developmental program to key reference groups. As the "top administrator," he must often serve as spokesman for the total program, or specific aspects of the program, or for individual projects. The principal boundaries to which he relates are policy-making bodies (both internal policy board and external bodies such as Congress), resource control groups, key administrators of functional organizational units, the top executive structure of his own organization, principal suppliers, scientific groups, and client or user organizations. The program manager will share with other members of his staff routine communication liaison activities with those constituencies. How-

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the public sector. The private sector program coordinator is often called program manager in the public sector. These differences in title, however, are not generally indicative of differences in functioning. The reader, thus forewarned, will be able to make the translation without difficulty.

ever, at critical stages of program evolution, such as termination or major modification of program activities, he will serve as principal spokesman (Cleland and King, 1968).[7]

A recent study supports the primacy of this program legitimatizing function. Mandeville points out that making recommendations for final approval and presenting these recommendations takes up a greater proportion of the program manager's time than approving recommendations from below (1969, p. 80).

Obtaining Resources—A second major boundary role of the program manager is to facilitate the commitment of latent human and financial resources to program activities. Thus, in addition to legitimatization, the program manager must often cross the boundaries of critical reference groups in search of support.

Planning and Coordination—The third primary function of the program manager is planning and program coordination. It is important to recognize, however, that this is planning at the policy or total program level. (Monitoring technical planning, together with coordination and control of individual projects, will be delegated to the program coordinators.) The concern of the program manager is the direction and thrust of the total program. He must see that the development of individual projects progresses in a manner as to

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[7]Proposition 2 suggests nodal stages of program evolution in which various reference groups must be brought into program planning.

add up collectively the achievement of the PM unit's mandate or charter. In carrying out these planning and coordination activities, the primary mechanism of the program manager is the problem-solving or decision-making conference—not the exercise of authority (Burns, 1970, p. 142; Davis, 1965, p. 4). The reason, of course, is that decisions must be based on detailed information not possessed by the program manager himself; but bringing together key individuals at critical decision points to participate in overall planning _is_ the obligation of the program manager.

Proposition 10: A secondary function of the program manager is to oversee informational, administrative and personnel services located in his office.

The PM organization, like any other organization, must contain certain maintenance systems. The program manager, like most top administrators, will tend to delegate administration of these maintenance systems to aides.

Information System—The program management office is the communication center or information depository for all information directly or indirectly related to the programs which the program office coordinates. Information concerns include theoretical knowledge, studies, and data relating to the problems to which the program addresses itself, and information about related resources (including scientific, technical, organizational and financial resources). A critical source of power for the program manager is control of the flow of information with respect to all program concerns (Davis, 1965). This is particularly true because of the developmental character of the program itself. Since the program relates to a new technology or service, knowledge is likely to be a scarce resource and expertise a source of power.

The program manager, therefore, will be very concerned that his staff keeps him up to date on all salient developments in fields relating to the program. In addition, he will attend conferences and seminars and maintain close ties with other organizations, so when he crosses boundaries to represent the program he is armed with the latest information.

However, certain responsibilities for obtaining this information are likely to be delegated. Obtaining technical information will largely be the responsibility of program coordinators and project directors. The program manager will call upon these individuals for briefings where necessary, or even take them with him to participate in boundary negotiations where their technical knowledge is pertinent. In addition, the program manager will want to maintain close contacts with the scientific community, and may employ a science adviser. Finally, it is not unusual to find a librarian or technical assistant whose function is to pass on to the program manager critical information obtained from technical reports and literature reviews.

Administrative Services—Office services (e.g. reproduction, secretarial, etc.) together with preparation of administrative budgeting will generally be delegated to an administrative assistant. In like manner, an administrative assistant will deal with personnel records and services, and necessary administrative documentation.[8]

Control and documentation of projects, and administration of approved project budgets, however, are usually the responsibility of program co-ordinators. It is the program coordinator who prepares regular progress reports relative to projects, analyzes the effectiveness of project operations, and prepares the rationale for revised project budget requests.

Based on these materials, prepared by subordinates, the program manager negotiates with higher management relative to the allocation of funds for program or project activities.

Proposition 11: An assistant program manager will often be appointed as an alter-ego, but will focus somewhat disproportionately on downward relations.

Program legitimation together with planning and coordination requires that a great deal of the program manager's time will be spent dealing with upward relations (top executive and policy board), outward relations (resource controllers, scientific, and client groups), and horizontal relations (relations with functional organizational units). These outside boundaries will be particularly critical since PM is a truncated organization not possessing all its own resources. As a consequence, internal boundaries (relations with administrative assistants, program coordinators, and project directors) may suffer. Since the absolute number of meetings or liaison contacts may

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[8] And in cases of maladministration, an executive director will deal with the administrative assistant.

exceed the capacity of a single individual, the program manager will often have an assistant program manager.

The assistant program manager will appear together with the program manager with sufficient frequency at external boundaries, so that he can substitute for the program manager in these relationships when inevitable scheduling conflicts occur. However, as upward and outward boundaries absorb great amounts of the program manager's time, the assistant program manager will serve with even more frequency relative to downward relations so that internally "management by exception" can be practiced.

Proposition 12: The essential skills of the program manager are verbal, interpersonal and political.

The critical feature of the program manager's role is his position as top executive of a truncated organization, where the major concern is garnering and coordination of resources assigned for a temporary developmental period, rather than command over a stable resource. Further, we indicated above that his principal obligations were directed toward interfacing with upward and outward boundaries. While attempts to specify distinguishing career profiles have been only moderately successful (Mandeville, 1969), a consistent "clinical" description seems to emerge from the literature.[9]

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[9]We would hasten to add, however, that this profile is not uniquely different from that associated with many boundary positions, particularly at what Parsons refers to as the "institutional representation" level of an organization.

Verbal and Interpersonal Skills—Descriptions of individuals serving integrative, boundary roles such as the program manager, often contain words such as: poised, enthusiastic, spontaneous and talkative (Lawrence and Lorsch, 1967). Since an essential function of the program manager discussed above was his role in conceptualizing and articulating the program mission to differentiated publics, it is hard to imagine an individual being successful without his being relatively forceful, active, and verbally aggressive (Lawrence and Lorsch, 1967, p. 150).

What is particularly critical, however, is the ability to relate to a number of differentiated reference groups. This requires flexibility—not simply verbal aggression. What is needed is the ability to deliver and receive messages via a multiple and relatively noisy sound track system simultaneously (Fisher, 1970). Each of the differentiated reference groups—clients, scientists, resource controllers, functional administrators, policy bodies, etc.—will have its own argot, style of relationships, value structure, and socio-emotional climate. Successful relationships across such diverse reference groups will require both sensitivity and flexibility. The essential challenge is for the program manager to secure resources from and solve problems with each of these groups according to its own rules.

Therefore, descriptions of persons successfully playing this type of role also include variables relating to flexibility along with verbal prominence. Both Filley (1970, p. 20) and Lynton (1969, p. 410) talk about intellectual breadth, a wide inventory of ways of thinking, and flexibility in shifting roles. Other writers, looking at norms or attitudes, show that the role requires intermediate orientations with respect to need for structure, time span of discretion, and interpersonal styles, when the attitudes of the integrator are compared with the attitudes of the extremes of the members of specialized departments or separated reference groups (Lawrence and Lorsch, 1967, p. 147; Lynton, 1969, p. 410; Seiler, 1963, p. 190-198). Some indication of sensitivity to the need for differentiated behavior is reflected in Fisher's proposition that effective program managers will prefer to meet with different reference groups at different times, rather than simultaneously (Fisher, 1970).

Political Skills—The interpersonal skills and role flexibility allows the program manager to move proposals successfully through the channels of complex systems. Several writers have commented on this skill dimension.

Wrapp (1967, p. 93) writes that the successful program manager can successfully plot the position of various persons and units on a scale of support to opposition, and thus move his proposal through "corridors of support and indifference." Further, he avoids futile efforts to try to push total packages through a resistant organization; instead he attempts to piece together incremental support into a program that moves at least part of the way toward his objectives (Wrapp, 1967, p. 95). This sense of timing, gradual movement, and avoidance of unnecessary conflict is echoed in Baum's writing (Baum, 1970). Such a style of political behavior implies low dogmatism, a tolerance for ambiguity, a long time span of discretion, and emotional stability. The effective program manager must be able to withstand the psychological strains and uncertainties of program development (Lynton, 1959, p. 413; Fisher, 1970).

Proposition 13: The background of the program manager will be characterized by: 1) a scientific or technical background, 2) a fairly lengthy stay of service with the employing organization, and 3) prior experience in developmental administration.

The upward and outward boundary role of the program manager set forth above together with the required socio-political skills required suggest some logical speculations concerning the career background of the program manager.

Clearly, the program manager must have adequate technical and/or scientific training in order to command the necessary expertise to coordinate and legitimatize a developmental project. In particular, his horizontal relations with functional managers and his liaison relations with the scientific community require that this be the case. In addition, he must oversee the progress of project directors who will generally be scientifically and technically trained. All these requirements suggest an earlier career and training in science and/or technology.

However, developmental activities, being high risk ventures, also require organizational trust. It is unlikely that responsibility for such a venture will be given to someone new to the sponsoring organization. Thus, we would expect the program manager to have been employed by the sponsoring organization for some time.

Socio-political skills, however, are largely associated with administration, not with task specialization. On the other hand the style of administration of a developmental project is not the style of administration of an operating line unit. It is much more dependent on collegial and political processes, as opposed to command processes. Thus we expect the program manager to have prior administrative experience in developmental administration. This prior administrative experience, together with prior tenure in the sponsoring organization, will help facilitate the necessary internal organizational contacts.

Scientific and/or technical achievement and education, prior administrative achievement, and tenure with the sponsoring organization, are also compatible with the salary and status of the office. When discussing the mandate and status of the program management unit earlier, we mentioned that the program manager should have a salary and status equal to key functional unit administrators. It is unlikely that a very young administrator would be acceptable in such a position from the standpoint of compensation equity.

This career stage and background profile is quite compatible with Mandeville's research which suggests the aerospace program manager had been with his employing organization for eight years, is forty-four to fifty-five years of age, well-educated in science or engineering, and had had prior experience in research and development (Mandeville, 1969, p. 72).

The Program Coordinator

The program coordinator position is primarily a coordinative staff position providing a linkage between the project office and the program office, and between the program office and functional and specialist units in the organization.

The need for program coordinators reflects three characteristics of the PM organization described earlier: 1) due to the developmental character of the PM organization, the need for new channels of communication must be developed; 2) the norm that the PM organization should contain a minimum of its own permanent personnel; and 3) the need to garner resources from multiple external sources. All of these features complicate the difficulty of planning, coordination and follow-up for the PM structure necessitating the establishment of a cadre of coordinative personnel we call program coordinators.

Proposition 14: In the early phases of a new program, dealing with problem knowledge, and design exploration (prior to establishment of a project office), the essential activities of the program coordinator are: 1) recruiting resource people; 2) proposal documentation; 3) support services for committees and task force groups.[10]

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[10] These early phases of program planning are described in detail under Proposition 2.

The "resource people" for planning in a truncated organization are simply latent resources. While the program manager may legitimatize the need for effort surrounding a new program sphere, someone must contact, provide background information, recruit and coordinate resource people from client, specialist, functional, and scientific groups, who eventually become working members of various study groups involved in initial planning activities. Some of the follow-through and detailed coordination of recruitment of these participants will inevitably fall to the program coordinator who must take the time to meet with both individuals and interested groups. It is true that certain key contacts and opening statements at initial meetings will also involve the program manager. As soon as possible, however, the activities will be turned over to the program coordinator for follow-through. The complexity of this coordination of early planning efforts is better understood if we re-emphasize that individuals being recruited: a) are located in a variety of groups geographically disperse from the program office; b) initially have only a vague idea of the connection between their skills and the problem, knowledge or design exploration meetings being undertaken; and c) have many other claims on their time so that careful follow-through and encouragement are necessary to secure their cooperation. Since the program office has no command power over these resources, the perceptual saliency of the emerging program activity depends on interaction with personnel from the program office. Many writers have underscored the importance of this face-to-face communication in getting the new program activity underway (Davis, 1965, p. 4; Lynton, 1969).

The problem, knowledge and design exploration stages of a new program sphere are also complicated because the very nature of the developmental activity requires the bringing together of personnel from diverse backgrounds and multiple specialties. The difficulty of coordinating such complex groups has been underscored by Hage, Aiken and Massett (1970). Unless, however, client, functional and specialist groups are penetrated, innovation is unlikely (Anna, 1970, p. 15). The most effective program coordinators, therefore, are those who structure their activities around resource group personnel (not hardware or task characteristics) in the early stages of a new program activity (Burns, 1970, p. 144). The essential first activity in program management is the concentration of effort on development of relationships with the key resource groups.

Personnel resources, of course, are not the sole requirement. There is also the need for financial, facility and equipment resources. A critical function of the program coordinator is to prepare the documentation which supports requests from the program office to resource controllers for financial support. The more effective new program spheres reflect a high percentage of time spent in gathering information through outside consultation, staff consultation and literature research in early exploratory phases in order to justify financial support (Allen and Andrien, Jr., 1965).

Finally, early exploratory phases of a new program sphere center around meetings, conferences and seminars. Given the limited time available from voluntary, or partial released time personnel, telephone contacts, background papers, visuals and handouts, agenda and minutes, and summary reports are normally the responsibility of the program coordinator. Anyone familiar with developmental task force groups recognizes that these support services often are a major determinant of a group's success.

Proposition 15: The program coordinator will provide assistance to the project director in recruiting the project group members.

Proposition 16: Subsequent to the establishment of the project group, the essential activities of the program coordinator will be: 1) monitoring the progress of the project; 2) providing summary reports of the project's progress to the program manager, client groups and resource controller; 3) coordinating problem-solving meetings to cope with emergent project difficulties; and 4) assisting in spin-off or new developments.

The project manager will normally have been part of the early study group activities. As the "manager," he will have final say concerning hiring of any members of the project group. However, the program coordinator, as the result of his extensive efforts in developmental planning, will have useful contacts which are normally helpful in recruiting activities.

Once the project group is established, the highly proactive phase of the program coordinator's efforts has ended. The project manager will have line responsibility for seeing that the goals or objectives of the project are achieved. However, some monitoring of progress and review of reports is necessary and the routine information flow moves through the program coordinator.

In addition, given the developmental nature of the project, snags, unanticipated difficulties, delays, etc. are likely occurrences. The program coordinator should be in close touch with the project director so that these occurrences are known in the program office, and necessary contacts with clients, resource controllers, and policy groups can be initiated to structure problem-solving meetings to deal with the emergent problems.

As the project draws to a close, the implications for either extended, new, or spin-off efforts will once again bring the program coordinator into a proactive phase preparing for either the finalization or renovation of the project activity.

Proposition 17: A critical judgmental feature of the program coordinator's monitoring of the project is to see that the execution of the project does not seriously deviate from the original objectives and design specifications of the study group.

It is very easy for the project group, which soon achieves quasi-autonomy from the program office, to begin to move away from the design or goal specifications of the original study group. One important function of the program coordinator, therefore, is to keep the project group "honest" in the sense of not violating the intent of the original project mandate.

Proposition 18: During the quasi-autonomous project stage of a program activity, the program coordinator will often be assigned to new or additional planning activities.

Since the essential proactive stages of the program coordinator's involvement are at the initiation and spin-off stages of projects, there is often sufficient slack in the intermediate phases of a project dominated by the project director to allow the program coordinator to undertake other activities. The extent to which this is possible will largely depend on the documentation requirements, the interdependency of projects, and the amount of reference group involvement with project progress, and the number of problems associated with the project. Since the program coordinator will be largely responsible for keeping clients, resource controllers, and policy-makers informed of project progress, the more intensive these information demands are the less the probability that the program coordinator will be able to undertake additional developmental duties. In like manner, the more bugs or difficulties plague a project, the more the program coordinator will be involved in structuring problem-solving conferences with key reference group personnel.

Proposition 19: The skills of the program coordinator will reflect 1) an adequate technical background, and 2) a high interpersonal orientation.

The essential requirement of the program coordinator position is that the individual playing the role must find his enjoyment in getting people together to work things through, and have skills in group processes. In the early study group stage of program planning, the group is the vehicle for activity, and a pleasant and enthusiastic personality is required to recruit group members. We would expect program coordinators, therefore, to have a high social-emotional loading. In several studies, effective coordinators were found to pay more attention to others and to their feelings; try harder to establish friendly relationships in meetings; and take on more assignments that offer opportunities for interaction (Lawrence and Lorsch, p. 50; Bass, 1970). They also possessed interpersonal skills that fostered a sense of team accomplishment and commitment, and improved task performance among project participants by relaying constructive information and immediate feedback (Zajanc, 1961).

At the same time, the people with whom the program coordinator is working will have strong technical backgrounds. Therefore, engineering, scientific or technical competence is necessary for successful integration (Lawrence and Lorsch, 1967, p. 147). Functional and specialist personnel will otherwise feel the coordinator is lacking in competence. Further, some similarity in technical training will help assure that the norms of the program coordinator are not significantly different from the norms of the specialists he is seeking to integrate (Burns, 1970, p. 147). What is required is not a technical expert, but a facilitator who is technically literate.

Proposition 20: The status of the program coordinator will be intermediate so as not to threaten or compete with the program manager, the project manager, or senior staff or functional specialists.

The role that we have described above is the role of a facilitator, or process leader—not that of a focal person. As such, the expectation is that one or several status clues will reinforce this facilitative character of the role and eliminate any dysfunctional competition for status or power between the program coordinator and other key personnel. We would expect that program coordinators would earn less than the project manager, top functional or specialist personnel, and of course, less than the program manager. We would expect them either to be relatively young (thus seen as administrative interns) or relatively senior (but not distinguished) members of the organization. In social service organizations, we would expect the individuals involved to see their role as "staff" rather than "line."

Chapter 4

A PERSPECTIVE ON THE PROJECT OFFICE

Proposition 7 in Chapter 3 stated that the technical administration of a project would be housed in the office of the project manager. Normally we would expect the project office to come into being at that point when the preliminary problem, knowledge and design explorations of a study task-force (under the aegis of a program coordinator) have been reviewed and approved, and funding for further development authorized. Obviously, the development of a complex project cannot forever remain the obligation of a task-force group. Rather, an action unit with personnel assigned to carry out the development must eventually emerge.

The project group is the action unit responsible for continuation of detailed design planning, prototype development and testing, and spin-off. The organization and control of this planning and implementation effort is the responsibility of the project manager (Davis, 1962; Cleland, 1964).

Inasmuch as the above sequence implies that the project manager is responsible for "action implementation" (Mandeville, 1969, p. 89), there are parallels between the project manager and the functional manager. The essential difference, however, is the temporary nature of the project group, and the developmental nature of the project mission. Both imply a style of management less command-oriented than in the case of the functional group, and with higher degrees of uncertainty and instability. Not only does the developmental task require more trouble-shooting and problem-solving, but the personnel themselves are functional and specialist personnel on temporary assignment to the project and therefore are less subject to traditional rewards and sanctions.

Proposition 21: In the early project stages the project manager's major responsibilities are: 1) recruitment of the project team; 2) coordination of detailed planning; and 3) finalization of a proposal containing budgetary and time bench marks, consistent with the level of funding authorized earlier.

Implicit in the above proposition is the notion that most developmental projects do not move from preliminary planning to implementation, but rather from preliminary planning to detailed planning in preparation for implementation. Further, the key personnel who will be responsible for implementation will want to share in the operationalization of the action plan.

The first step, of course, is to put the project team together. Although the program coordinator may have suggestions for individuals who might serve on the project team, final selection and interviewing are the responsibility of the program manager who will have to "live with" the members of the project group and will therefore have to have confidence in their technical ability. Obtaining personnel is not simply a matter of requisitioning people. Since the personnel being sought are presently assigned to functional or specialist units, the process involves considerable negotiation, juxtaposing the manpower requirements of the project with manpower requirements by functional and specialist units. These negotiations are often carefully monitored and reviewed at the policy level.

Once together, detailed operational plans will have to be developed for each phase or aspect of the project. During this period of activities the role of the project manager is much like that of senior investigator in a research organization.

Finally, the final operational plans will have to be incorporated into a document reviewed by various policy groups. The plan will contain the design specifications, budgetary requirements, manpower requirements, facilities needs, together with phased timing for critical stages of development testing, implementation, and spin-off.

Proposition 22: Once operational plans are stabilized, the critical functions of the project manager are: 1) coordination; 2) problem-solving; and 3) reporting and documentation.

With respect to coordination, the project manager is the focal point of all project activities (Mandeville, 1969, p. 12). This opportunity to influence the flow of information and to have superior knowledge of the project is, of course, a source of power. However, it is also a heavy burden since this is the final point of review for all drafts of reports, statements and technical documents with respect to the project (ibid., p. 93). In addition, he must frequently serve as a prime liaison person along with the program coordinator interfacing with the program manager, for policy levels of the organization, client groups, and scientific groups with respect to the progress, success and significance of the project (Cleland, 1967).

Because of the developmental character of a project, many unpredicted difficulties will occur as efforts proceed toward final implementation and spin-off. The project manager is the focal person in these problem-solving meetings wherein technical solutions must be weighed together with time, cost, resource and human constraint factors (Davis, 1965, p. 4; Mandeville, 1969, p. 10). Although he can and must involve related members of staff in these decisions, the bulk of the responsibility for budget, technical, resource and scheduling decision will fall on the shoulders of the project manager. Davis, 1962, refers to this fact, as do Ramo, 1965 (p. 4), and Mandeville, 1969 (p. 10).

Further, in temporary project units with unstable membership, group members report more need for leadership from the project manager because of the limited time for clear-cut group structure to emerge (Fine, 1970).

Proposition 23: The requisite skills of the project manager are, in order of importance: 1) socio-technical leader skills, 2) administrative skills, and 3) political boundary skills.

Socio-technical Leadership—The project manager is in an intermediate power position as leader of the project group. First, the project team is multidisciplinary. While the project manager must be comfortable with the various disciplines he is seeking to integrate, he cannot pretend that he is the team's expert in any one discipline (Hammerton, 1970, p. 55). Further, as the number of technical experts increases, thereby increasing structural diversification, there is an inherent strain toward decentralization of the power structure (Hage, 1965, p. 18). Second, since the functional and specialist personnel are only temporarily assigned to the project, normally control over rewards or promotion remains with their "back home" unit, limiting the reward power of the project manager. In fact, the ability to coordinate personnel over whom he has but limited direct control, is a distinguishing characteristic of the project manager (Cleland, 1964, p. 84; Hodgetts, 1968, p. 211). Third, because of the developmental character of the work of the project group, a participative colleague relationship is significant for problem-solving success (Davis, 1965, p. 20). All of these factors result in the project manager emphasizing norms and skills that facilitate collaboration and problem-solving as a style of administration (Buchanan, 1967, p. 64).

One should not infer from this, however, that project managers are re-active leaders. Quite to the contrary, the temporary and amorphic character of the project group requires that effective project leaders be aggressive, confident, and verbally fluent (Lawrence and Lorsch, 1967, p. 150; Fisher, 1970). The manner in which proactive behavior is coupled with collegiality is by means of problem-centered leadership.

The proactive function of the project manager is to keep the "eye of the group" firmly focused on the project task, and make sure that problems and difficulties are confronted rather than smoothed over. This may even involve some forcing behavior to see that issues are addressed and not avoided (Lawrence and Lorsch, 1970, p. 12; Burns and Stalker, 1961, pp. 87-89; Lynton, 1969, p. 410). The role of the project manager is to see that effective problem-solving meetings are held at the functional level of competence. In providing this problem-centered mode of leadership, the project manager provides for mobilization of efforts to accomplish the project mission and eliminate roadblocks, while at the same time incorporates the ideas of others in the project; thereby rewarding contributors to the problem-solving with a feeling of greater satisfaction, a sense of accomplishment, and an involvement in the emerging project (Bass, 1970).

Administration—There remains, nonetheless, the need for certain types of administrative controls, particularly those emphasizing budgetary, performance and time bench marks. This implies that the project manager should be balanced between managerial functions and technical problem-solving concerns. There is some evidence in the literature that the greater the project director's expertise and interest in technical details, the greater the risk he will overly involve himself in the technical details of the project and fail to provide the professional judgement required for decisions related to managerial coordination, particularly with respect to a) phased planning, and b) control systems (Burns, 1970, p. 171; Blau and Scott, 1962, p. 185; Wileman and Cicero, 1970, p. 277). The balance between technical involvement, and the less rewarding but nonetheless necessary aspects of administrative coordination and control, is a constant problem of project management.

To a certain extent, we would expect the project manager to delegate some features of routine budget monitoring, progress reporting and documentation to an administrative aide, and practice administrative intervention by exception. However, the need for control and intervention where budgets, quality standards, or time schedules are slipping is inevitably part of the project manager's role.

Political Interfacing with External Boundaries

The very early stages of the project office, particularly during the recruitment and formation of the project group, require that the project manager spend considerable time with functional and specialist administrators. In these resource negotiation sessions, however, the project manager will be assisted by the program coordinator and, where necessary, the program manager. As the project proceeds, the project manager will more and more direct his attention downward to the project group and its efforts to achieve the project mission (Davis, 1969, p. 29). As a result, while the project manager will often be present at meetings with outward and upward interfaces, much of the burden of these relationships will be taken on by the program coordinator, as already described. Since the matrix structure of PM sets up conditions to facilitate purposeful and continuing conflict between program and functional units, attention to these relations must nevertheless remain a part of the project manager's role (Cleland and King, 1968, p. 165).

Proposition 24: Project managers will have relatively high status reflecting high technical/scientific expertise, administrative authority, and organizational seniority.

We would expect the profile of the program manager and the project director to be quite similar. Both will have had extensive scientific/technical training, have been members of the organization for some period of time, will have had prior developmental administration experience, and will be balanced between cosmopolitan-organizational orientations (Mandeville, 1969; Davis, 1965, p. 19).

However, there are some specific differences. While the program manager is likely to be a more permanent position, the project manager may well occupy a position which is phased out at the end of the project. This implies that some project managers in riskier project spheres will have a very solid scientific/technical home base in either a functional or specialist unit. Thus, we would expect the project manager to be highly committed to the project, but less committed to the program. Further, the essential activity spheres of the program and project managers differ. The program manager is oriented upward and outward; the project manager is oriented downward toward his project group. The program manager may appear more political, and the project manager more scientific/technical in terms of value or norm structures. The greater degree of direct scientific/technical involvement of the project manager reflects the implementational character of the project level of the PM organization.

Finally, the risks at the two levels are different. For the project manager the principal risks are: a) at the project level, failure of the project to achieve its technical mission; and b) at the personal level, scientific/professional obsolescence due to heavy involvement in coordination and administration and absence from the functional or specialist unit. For the program manager, the principal risks are: a) at the program level the demise of the centrality of the program activities reflected in budgetary reallocations, and b) at the personal level, a reduction of power centrality in the political administrative system.

Thus, while looking at career profiles may indicate considerable similarity between the two managerial positions, the world of the project manager and program manager are quite distinct.

Project Participants

Proposition 25: The essential feature of the project participant position is its temporary character.

The entire thrust of our earlier propositions is that the project group is not a permanent "group," but rather a fluid set of working teams, each team focusing on a particular aspect of the project, and each team cycled into existence and out of existence as specified subphases of the project are completed.

Except for a few individuals assigned as staff to the project manager's office on a quasi-permanent basis for the length of the entire project, the remaining project participants are functional or specialist personnel assigned to a problem-solving team with a specific short-run technical problem to solve, design to develop, or prototype to implement, test and evaluate (Buchanan, 1967, p. 62). (Project participants involved in implementation, testing and evaluation probably have the greatest identification with the project since they are highly associated with the success of the prototype.)

The contribution of the project participant, then, is a focused instrumental contribution at a specific phase of design, project development, or implementation. As a result, the project participant's long-run allegiance will be to his home functional or specialist group, and his basic organizational identification is away from the project. This creates a number of unique personnel difficulties with which the project manager in collaboration with the program office must deal.

Proposition 26: Project participants report a number of career risks associated with participation in a project, all of which relate to the temporary nature of the project organization.

Although there are persuasive justifications for the adoption of project organizations, relief from human problems is not one of them (Reeser, 1969). The literature on project organization lists a number of career difficulties which project participants face as a result of ephemeral nature of the project assignment. These difficulties can be briefly summarized as follows:

1. Fear of Obsolescence—Individuals assigned for relatively long periods to project groups find themselves removed from developments in their functional field or area of specialization. Therefore, project partici-

pants on long assignments report fears that they will become obsolete if they stay in the project organization too long (Reeser, 1969, p. 466).

2. Fear of Inadequate Rewards—Since the long-run career and reward structure for the participant is in his back-home functional or specialist group, project participants fear that their contribution to the project may not be reflected in future rewards once they return home. Since the project is often askew from the priorities of the back-home career base, the contribution which is invaluable to the project may be seen as a mundane scientific, engineering or production accomplishment to the home group.

3. Uncertainty about Future Assignments—Project participants have several fears concerning future assignments. First, they fear the possibility that their "spot" may be filled by someone else in their absence from the back unit. Second, they fear a make-work assignment of frustrating duration between project phase-out and re-entry to their functional or specialist unit, or to another project group. Third, they fear the risk of joining a proposal team negotiating for a new project, since there is always the possibility of becoming attached to an unsuccessful proposal.

In essence, the exact situation at phase-out of their project team and re-entry into their functional or specialist unit or lateral movement into a new project is often seen as uncertain at best.

4. Project participants holding joint assignments both in their back-home unit and in the project face a different problem. While this multiple career base may provide some insurance that their back-home position is

not jeopardized, it also creates considerable ambiguities of another sort, and role overload. Individuals assigned part-time to projects are forced to have a divided loyalty to their functional or specialist group and the project group. Further, both groups try to seduce the participant to give greater attention to their needs, resulting in role overload (Reeser, 1969, p. 462).

As a result of the above difficulties, the more successful project organizations are careful that the above issues are surfaced before participation in the project group, and satisfactory solutions are negotiated between the project, program, functional and specialist managers prior to project participation. Indeed, effective project management identifies and assigns the next position of the project participant prior to his involvement in the project, if possible, and avoids "make-work" assignments after project phase-out (Avats, 1969, p. 82).

Proposition 27: The essential inducement for participation in a project is the opportunity for association with an exciting, developmental endeavor.

The above difficulties concerning career risks might seem to imply that it is difficult to recruit individuals to participate in project endeavors. In fact, they are mentioned first because in the excitement of project development recruitment proceeds very rapidly, and often easily, and the above difficulties may surface only toward the end of project involvement. That is to say, the career risks tend to be perceived only after involvement in the project is near to its completion. The important thing is for the project manager to anticipate some of the difficulties which will emerge at a later point in time, rather than try to sort out the difficulties when it is too late to negotiate creative solutions.

What, then, are the inducements for participation in a project? To begin with, the project itself is normally a source of excitment if early program planning has been carefully conducted. The problem, knowledge, and solution explorations will have achieved high visibility for the project, and the organizational mandate and supporting resources will indicate the centrality of the project in terms of broader organizational and inter-institutional values. As a result, considerable prestige often accrues to the project and to personnel associated with it.

However, the individual participant is normally interested in a specific technical or select aspect of the project. For the senior specialist or functional expert, project participation is often the opportunity to test advanced models or skills. For junior specialists, the project offers the opportunity for his support in advanced work and collegial interaction with a prestigeful set of colleagues. For everyone, the developmental character of the project normally provides greater flexibility and opportunity for experimentation than might be found in the back-home unit. Many participants see the project as a means to test ideas which are not funded in their own unit.

Finally, the project often is able to put together pooled funding which makes it possible to develop prototype programs of greater sophistication than would be possible within the back-home unit.

Thus, recruitment of project participants normally proceeds with reasonable smoothness (provided adequate career safeguards are built in to avoid the risks specified under Proposition 26).

Proposition 28: The essential payoffs making the difficulties of utilization of temporary personnel worthwhile are: 1) opportunities to obtain the most competent personnel; 2) utilization of personnel at appropriate points of time; and 3) avoidance of resource redundance.

In concluding the discussion of project participants we should mention three benefits of temporary assignments for the project organization. First, making use of temporary personnel allows the project to obtain the most competent functional and specialist personnel (Anna, 1970, p. 15; Reudi and Lawrence, 1970, p. 63). In many cases, these individuals would not be willing to leave their functional or specialist units on a permanent basis, but are willing and able to do a short "tour of duty" with a project group.

Second, by cycling in personnel at different stages of project development, individuals are involved at points where their skills are most relevant. This avoids the unwieldly organization form which tries to hold all types of competence simultaneously since "sometime we will need someone with that skill." Such organizations underutilize individuals whose timely interventions are only intermittent.

Finally, temporary personnel assignments allow the project group to make use of skilled personnel in functional and specialist groups without creating resource redundance.

Chapter 5

THE METEOROLOGICAL SATELLITE PROGRAM OFFICE

The purpose of this chapter is to summarize our observations of the Meteorological Satellite (abbrev. Met Set) Program Office at NASA Headquarters. The overall question to which the chapter directs itself is: Does the Met Set Program Office function in accordance with our theoretical overview presented in Chapters 1 through 4?

The Organization of the Program Office

Figure 3 presents an organization chart of the Space Science and Applications Office of NASA. The Met Set Program is a portion of the Earth Observations Programs Office. It includes the Experimental Satellite Program (Nimbus): the Operational Meteorology Satellite Program, the Meteorology and Sounding Rockets Program, and the Global Atmospheric Research Program.

Our interviews of program personnel included the Deputy Director of the Earth Observations Program, M. Tepper; and the program managers of each of the four program areas listed above: B. Schart, M. Garbacz, N. Durocher, and W. Spreen. In addition, for overview purposes, we will quote from interviews with J. Clark, director, Goddard Space Flight Center; and the Associate Administrator for Space Science and Applications, J. Naugle.[11]

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[11]The actual interview schedule is contained as Appendix I.

SPACE SCIENCE AND APPLICATIONS

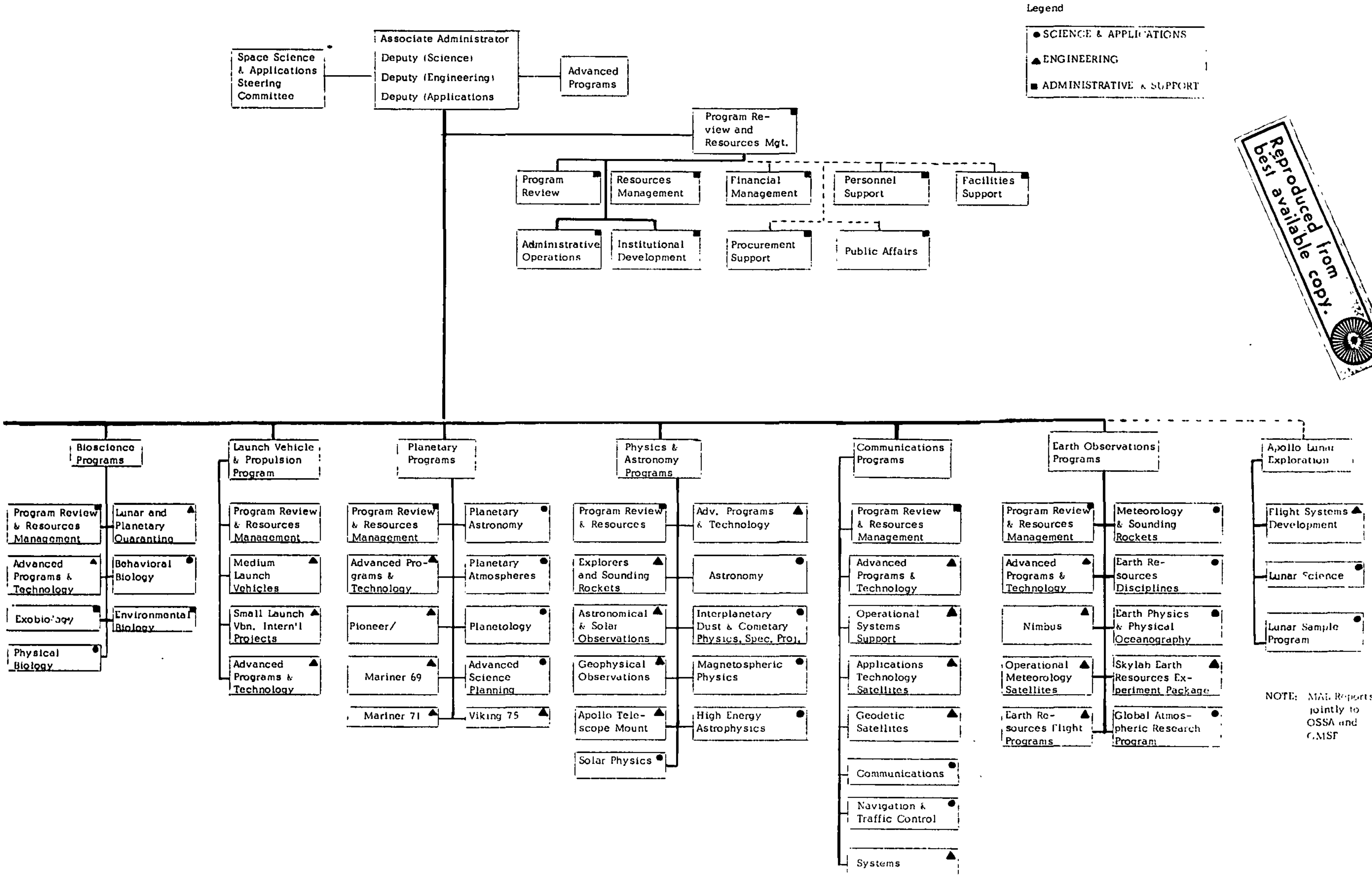

Figure 3

Obviously, given the limited number of individuals interviewed, our observations will have to be clinical and impressionistic, rather than statistical. Nonetheless, a sense of the organization, its method of operation, and its spirit were clearly communicated in the interviews. Our hope is to share this experience in abbreviated form with the reader.[12]

Our first sense of the difference between the various positions in the program office was formed when studying the reactions to the question: "What is the overall mission of your organization?"

Both the Associate Administrator, John E. Naugle, and the Deputy Director of the Earth Observations Program, M. Tepper (the senior program personnel), responded to this question in a very generic fashion.

In a low-keyed factual fashion, the associate administrator replied:

> There are three goals. First, to conduct research in meteorology to develop new instrumentation and techniques so that ultimately we can provide a model or theory of the dynamics of the atmosphere. Second, to support the work of ESSA by developing the prototypes for operational satellites, and to procure, launch, and check out these operational satellites. Third, a related objective is to fulfill the needs of GARP (Global Atmospheric Research Program).

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[12] The NASA titles are not directly parallel to our theoretical outline. The translation would seem to be as follows: The Associate Administrator, John E. Naugle, would roughly be equivalent to program vice-president in Figure 2, Chapter 2. The Deputy Director of Earth Observations Programs, Mr. Tepper, would roughly be equivalent to program manager of the Met Set Program. The program managers of the four programs would be equivalent to program coordinators in our theoretical perspective. For the remainder of this chapter we will use our theoretical titles rather than NASA titles for clarity for the reader not familiar with NASA positional structures.

In like manner, Dr. Tepper responded in terms of global mission objectives. In the terminology of our theory chapter, Dr. Tepper who is deputy director of the Earth Observations Program serves as the program manager for the entire Meteorological Satellite Program.

Dr. Tepper responded:

> We are a research and development organization. In the broadest language, our mission is to develop and apply space technology for applications to meteorological problems.

Further, both of these respondents talked about the strengths and weaknesses of the Met Set Program relative to overall scientific goals. For example, Dr. Tepper said:

> We have two weaknesses. One, our own scientific resources within NASA are limited. By contrast, our technological resources are tremendous. In terms of instrumentation and engineering systems, we can conduct tests with high reliability and confidence. However, scientific people who understand the scientific requirements behind the instruments are relatively limited within NASA. The scientific personnel we do have are excellent but there is little depth in this area. Second, we do not have an in-house feedback mechanism for data analysis. When we do experiments there is the need for data analysis and feedback in order to conduct further experimentation. We do not have this data analysis capability in terms of scientific results so as to produce a new generation of instruments. At the present time, even the depository of data that we have is underutilized. Under our present agency mandate it is not likely that this situation will change. It would require the establishment of a center which might be called a Center for the Research and Analysis of Satellite Data. This would require probably fifty senior scientists and fifty visiting scientists willing to invest their careers in this area. There does not seem to be any momentum for this type of development at the present time.

The critical point of the above quotation is that the associate administrator and the program manager directed their comments concerning mission to the overall program and its relationship to broad scientific concerns.

Indeed, Dr. Tepper's remarks show concern for further scientific developments building on the present technological capacity.

By contrast, each of the program coordinators in our theoretical language, restricted his discussions of mission to individual projects. For example, the program coordinator in charge of the Operational Meteorological Satellite Program would respond that:

> The mission is to launch, test and check out operational satellites.

The manager of the Experimental Satellite Program indicated:

> The mission is research and development in experimental meteorology.

It was very clear that our division of focus between the program management level and the program coordinator level did indeed exhibit itself at NASA. The program manager spoke of the global mission of the program and of new developments which should build on the present accomplishments. By contrast, the program coordinators suboptimized and were concerned only with the mission of their particular subprogram.

There was additional amplification of these separated orientations in the discussion of resources. The program manager and the Space Science and Applications administrator were concerned with the relationship of their programs vis-à-vis the Apollo program. They exhibited sensitivity to Congressional funding and the relative importance of earth observations vis-à-vis the other NASA activities. By contrast, the program coordinators talked about the technical issues surrounding their narrower program responsibility.

Not only were they less generic and societal in allusions to their mission, but they were also quite technical in terms of resources needed to achieve their more narrow program objectives.

It should not be inferred that this division of conceptual focus is a negative feature. Quite to the contrary: both Dr. Tepper and Dr. Naugle expressed their high reliance on the program coordinators for technical detailed information concerning the individual programs.

> I am not inclined to deal with details. I deal only on a review basis. I do not provide close monitoring of the individual programs. My policy is to rely on the --- program (coordinators) to provide me with detailed and up-to-date information concerning individual projects. (J. Naugle)

> Quality program (coordinators) could be considered technical specialists. Their function is program control and inter-unit coordination and communication within a particular narrow program area. They oversee what is going on and they alert myself and other headquarters personnel to important issues. They are key communication links in a particular technical program area. The strength of my staff is the excellence of each of the four program (coordinators) who function as a close team and who provide me with specific information when it is needed. (M. Tepper)

In conclusion, there is clearly a division of labor with respect to mission orientation between the program staff members. While the program manager is concerned with the total program and its scientific and societal accomplishments, the individual program coordinator sees his role as providing up-to-date communication concerning the specific program under his jurisdiction.

Thus, overall institutional program legitimization, overall planning and coordination, and overall review of resources is funneled through the

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Deputy Director of Earth Observations Programs, M. Tepper (program manager). This is consistent with our theoretical Proposition 9.

An Organizational Mandate

Proposition 4 indicated that the successful program mangement organization needed a mandate which clarified its relationship to the operational units or organization.

In the case of the program, the operational organization is NOAA. The function of NASA is to design, build, launch, and test operational satellites that are then turned over to NOAA for continued operation.

A clear mandate of the relationship between NOAA and NASA was worked out and formally agreed upon since 1963. The Secretary of the Department of Commerce and the deputy administrator of NASA signed the agreement which also covers the relationship to the Bureau of the Budget.

It was very clear in all the interviews with program personnel that this was a keystone document around which relationships with the operating agency (NOAA) were structured. It was also apparent that the agreement was reached with some considerable difficulty and that all parties felt that it was important to honor both the letter and the spirit of the agreement now that the agreement is established. In essence, the agreement makes NASA the research and development organization and NOAA the operating organization.

The agreement also provides a formal mechanism for coordinating the activities between the two agencies:

> The predominant reason that the relationship between NOAA and NASA works smoothly is because the role of each agency is clear. Thus, there is no competition between the agencies. The character of the role of each agency is spelled out in a formal document.
>
> The formal agreement also provides a mechanism whereby two agencies carry out the National Meteorological Satellite System. This mechanism is the Meteorological Satellite Review Board. The board meets once a quarter or occasionally more frequently. The agenda is prepared jointly. The purpose of the board is to coordinate programs for the coming budget period and to discuss the relationship of the program to GARP. (J. Naugle.)
>
> There has been a formal agreement since 1963. The Secretary of the Department of Commerce and the deputy administrator of NASA have signed this agreement. This clearly indicates that the Department of Commerce will coordinate meteorological programs. NASA's role is the design, development, launching, and testing of meteorological satellites. (M. Tepper.)

The importance of the agreement can be better understood when one examines the relative funding of the two agencies. The Meteorological Satellite Program is a small portion of the total budget of NASA. By contrast, the meteorological satellites are a very large portion of the budget of NOAA. As a consequence, the Department of Commerce (which houses NOAA), in effect, buys hardware developed and tested by NASA.

While NASA experiences pressures to enlarge the scientific engineering character of the satellite program, NOAA is concerned with minimizing the cost of effective operational satellites. The importance of the mandate is that it provides NOAA with the clear veto role concerning the character of operational satellites.

The Meteorological Satellite Program Review Board was mentioned by everyone as the ongoing mechanism for maintaining the essence of the agreed upon mandate.

> The MSPRB is the main vehicle for coordination. It functions very well on a regular basis. Each agency reviews the agenda and has the option to make suggestions for the agenda. Key individuals in each agency are present. It is a heavily attended meeting with twenty to thirty people. All program managers, functional specialists relevant to issues to be discussed, and scientific personnel with pertinent insight are welcome to attend. Each agency reviews all agenda items carefully and rehearses its presentation. Prior differences are openly discussed ahead of time. Issues that can be resolved at an appropriate scientific or technical level are resolved at lower levels and simply endorsed formally by the board. On other occasions, high administrative involvement is necessary where the matter is budgetary. The meeting is highly attended because of the visibility of the two principal agency directors and because it has become a key mechanism for the exchange of overall program information. (M. Tepper)

Proposition 4, dealing with the need for a mandate and a mechanism for conflict resolution together with a shared budget, seems to describe the situation which has emerged at NASA. There is a formal agreement between the agencies, the Meteorological Satellite Program Review Board provides a mechanism for formal resolution of differences, and both agencies share in the budgetary development of operational satellites.

Obtaining Resource Support

There are two principal areas of resource support with which the program office concerns itself (excluding the involvement and liaison with scientific personnel which will be discussed in a later chapter dealing with project planning). These two areas are funding from the Bureau of the Budget and Congress, and functional and specialist support from Goddard Space Flight Center.

With respect to relationships to Congress and the Bureau of the Budget, the very clear allocation of responsibility in this area is that funding is a program office function. The description of the relationship with Congress is perhaps best expressed in the words of the program staff themselves:

> We have been successful in making our case with the Bureau of the Budget for three reasons. First, the success of the program itself. The U. S. now has an operational Meteorological Satellite Program with great technological proficiency . . . . Second, there is international enthusiasm for the program. We have worked very closely with the international meteorological organizations to assure that the scope of our program is not simply national, but international. Third, we have established cooperation between the various agencies so that the Bureau of the Budget finds mutual support between programs. We do not play one agency against another. The Meteorological Satellite agencies jointly evaluate program proposals. Each fall the full programsof proposals are exchanged between NOAA and NASA and formal letters commenting on these programs are also exchanged. Further, because of the close cooperation at the field level between NASA and NOAA, when examiners from the Bureau of the Budget visit the program and project levels, they find a unified picture. (M. Tepper)

The close joint planning and collaboration between NOAA and NASA was mentioned at all levels in the program office. Clearly, the vehicle of the MSPRB is an important mechanism which makes it possible for the two agencies to iron out their difficulties before approaching the Bureau of the Budget and Congress.

However, it is not simply the legitimatizing mechanism of the MSPRB which makes relations with the Bureau of the Budget and Congress smooth. It is very clear that all levels of functional competence are invited into formal testimony before Congress.

> We believe in having functional specialists and scientific personnel testify at hearings before the Bureau of the Budget and Congress. (M. Tepper)
>
> It is not simply in the formal proposal development and testimony that relationships with Congress are important. Much of our time is taken up providing information to Congress about particular programs and giving them information about the relationship between our program and activities in their district. For example, recently a Congressman asked me for information concerning a program in his home state. I spent a considerable amount of time and was able to obtain information that provided an indication of the relationship between our activities and his state. It is this type of service to individual Congressmen that is important in maintaining relationships. (N. Durocher)

That the Met Sat Program has maintained a stable level of funding as a result of skillful management of relationships with Congress, a very successful program, international prestige in the area of internal resources, and continuous, dynamic programs for the Goddard Space Flight Center was articulated by all personnel.

In the NASA setup, projects themselves as well as scientific and functional organizational units are located in the Goddard Space Flight Center. All program staff were concerned about the number of functional and scientific personnel assigned to their individual program. Some representative quotes follow:

> The changes at the Goddard Space Flight Center into a matrix organization has had some impact on meteorological programs. They have taken the original group of functional and specialist personnel assigned to meteorology and merged it with other programs in order to fuse the talent. By removing personnel, they have detracted from the singular thrust of the meteorological program (M. Tepper).
>
> One of our problems is that the meteorological satellite program's signifiance vis-à-vis the other projects is not always recognized.

In particular, many of our programs suffer in comparison with glamorous programs such as the Apollo program when it comes to assignment of personnel resources. (M. Garbacz)

I'm not sure we're adequately funded and supported in terms of personnel and resources. We haven't done enough to build on the strengths of the early meteorological prototypes for other types of operational satellites. The division between the manned space program and scientific satellites means that oftentimes we do not receive the manpower resources that we need.

It's difficult to get functional support. Of course, every program and project will cry that it doesn't get enough support. Every project manager would prefer to have functional specialists assigned full time to his staff. The next best thing is to have them live with the project even if they are not assigned to it full time. This is a classic problem. To a certain extent, the role of the program office is to help the project group in a struggle to obtain financial support. (B. Schardt)

The character of the struggle for resources between functional and specialist groups at Goddard and the program office will become clearer when, in a later chapter, we deal with the project level. At the present time, however, these dynamics can be better anticipated by listening to the director of the Goddard Space Flight Center.

In 1965 the Goddard Space Flight Center was reorganized. The reorganization was based on the recognition that the center now had many more projects. This was the end of the maximum growth period of individual projects which had been permitted to develop according to the preferences of the project managers. Several projects, e.g. NIMBUS, had 100% assignments of functional and specialist personnel to the project. This meant that they could command in a line sense all the skills they needed.

As funding became tighter and more projects emerged, it was obvious that we could not afford such an arrangement. Projects tied up functional specialists full time, even though the functional specialists were under-utilized.

> The result of not assigning personnel full time to projects has resulted in more realistic early estimates of personnel needs by the project, an honest commitment of released resources from functional groups.
>
> This has resulted in the need for firm negotiation and realistic manpower estimates in planning. Our norm is to sharply fix the situation by manpower estimates due to the limitations in total manpower resources at the center.
>
> Without this manpower estimate, the functional and specialist groups tend to take on more work than they can handle and individual projects tend not to ask for what they will really need for fear the project will seem too expensive.
>
> The program office is not concerned with Goddard as an institution. It thinks in terms of the Office of Space Science and Applications Programs.
>
> On the other hand, headquarters cannot adjust manpower unilaterally. Thus, Goddard, in practice, budgets people and headquarters budgets dollars. Headquarters tries to persuade us they need more people in their program on individual projects. We try to persuade them we need more dollars for manpower resources. Each program is sure to do a better job with just a little larger manpower pool.
>
> Each of us has a veto. I can indicate we have too much work already. The program can reply they will take their work to another center. Thus, we are faced with the need to negotiate honestly. (J. Clark, director, Goddard Space Flight Center)

A very clear role, therefore, consistent with our earlier theoretical Proposition 14, is for the program office to actively enter into negotiations with respect to manpower resources. As M. Tepper stated:

> Where necessary, the individual program (coordinator) will make sure that I and other headquarters' people enter into negotiations concerning resources when someone at our status level is necessary.

It is obvious that the trade-offs between the basic research activities of functional and specialist units at Goddard, the amount of resources allocated to an individual project, a total set of projects in a program, and between programs are major concerns at the program office.

The program office, therefore, is a focal point in the early phases of proposal building in terms of obtaining resources both from the Bureau of the Budget and Congress, and later in obtaining functional and specialist support for a particular project. The program office will also necessarily be reinvolved if changes in resources are necessary.

The continuous dynamic between the functional and specialist resources housed in functional groupings at Goddard and the project and program office is a creative conflict which seeks to avoid manpower or facility redundance (Theoretical Proposition 3). It is interesting that the inevitability of these conflicts is dealt with, if not with pleasure, at least with grace. All parties indicated that the mode of decision-making, where possible, was problem-solving meetings. Harmful and destructive conflicts are generally avoided. Where the issue eventually becomes one of resource allocation of priorities, top administrators are involved in the clarification of these priorities.

Interpersonal and Political Skills of Program Staff

Obviously, the role of the program staff is not simply technical. Earlier studies have shown that the backgrounds of both program and project personnel show a high degree of scientific or technical training. Indeed, Mandeville's research shows little difference in the background of project managers and program managers. In our interview we asked each program manager to indicate his background, to specify areas in which he felt additional training was desirable, and skills he would look for if he were hiring someone to take his place. In each instance, a balance between scientific engineering and technical proficiency in a relevant field together with interpersonal and political skills were mentioned. A sense of the political and interpersonal skills necessary can be obtained from the interviews.

> The program manager had better be a flexible and patient guy. He has little real authority but great responsibility because he has to be the middleman in negotiations. It is the program manager who has to arrive at the total objective and obtain funding by Congress. He is also the middleman who must bring together the various user groups, scientists, and experimenters in arriving at an agreement about the payload.
>
> Obviously, these tasks mean he must operate in a political arena to sell headquarters, the Bureau of the Budget, Congress, and technical people in project organizations. His sailing is never smooth. Dollars are cut by funding sources, objectives are shifted by technical or political developments, and priorities are changed at headquarters.
>
> A program manager must know when to give up or go with half a loaf. Persuasiveness, technical knowledge, personality, ability to sell—these are his tools. (J. Clark)

> Relations between all the groups—Congress, people in the project, external scientists, liaison committees, the headquarters' resource controllers, and people at NOAA—take the majority of my time. Whenever problems arise, the unfavorable aspects of things focus on me. I'm the individual called and the trouble-shooter who is supposed to find a mechanism to resolve these differences. (B. Schardt)

> If you were hiring someone to be a program manager, the first prerequisite would be an individual who could work well in a situation of limited structure. You have to be diplomatic. You have to have

> a sense of timing. You have to have a well-rounded technical background. But most of all, you have to have a balanced perspective. (M. Garbacz)

> A good program manager has to have a degree of aggressiveness. He is an individual who has to be comfortable working independently, knowing when to call for help, when to push things up through the system, when to bring in someone of higher status in order to resolve a difficulty that can't be dealt with at the functional level. There's no magic formula for handling most of these problems. It's a matter of negotiation and give and take. (N. Durocher)

Not only did all the program staff members articulate interpersonal and political skills as being important but the character of these skills was readily apparent to the interviewers themselves. An aura of political and stylistic emphasis was a characteristic of all the personnel in the program office. By contrast, the focus on technology and engineering was much more characteristic of the project staff. All these observations and comments are consistent with our emphasis on interpersonal skills in the program office (Theoretical Propositions 12 and 19).

Liaison Activities of the Program Coordinators

Program coordinators are clearly men on the go. In order to be the middlemen as described above and maintain contact with all the various constituencies, their life is filled with communication richness. In the early stages of the project, the program coordinator is concerned with monitoring meetings dealing with selection of the payload, the funding of the payload, and early design activities. Once the individual project is funded, his work does not end since continuous monitoring of the project and reports to

Congress and the Bureau of the Budget, together with problem-solving meetings to deal with emerging difficulties, keep him in a position of hyper-activity.

> The life of the program coordinator is one of frequent contact, the maintenance of proximity to projects by constant visitations and easy accessibility to people. (M. Tepper)

> We operate on the principle of no surprises. Our informal communication system makes sure that if anything goes wrong,the program coordinator is immediately contacted and initiates necessary connections between headquarters project and scientific personnel. In the past, there might have been days before problems were identified. Now we know about it within the hour. The reason for this success is that these individuals (program coordinators) spend a great deal of their time in the field. They define their role as being close to field people. They have the knowledge of technical argot, they understand the technical requirements of the field, but they are also in a situation where they understand fiscal and headquarters requirements as well. (M. Tepper)

> My life is a series of continual meetings. Meetings with headquarters, in the centers with scientific panels, and steering group activities. (B. Schardt)

> Being a program manager is to be the focal point of all activities concerning experimental satellites. When the phone rings it can be a Congressman, a member of the public, a member of the project group at Goddard, a committee member from headquarters concerned with some problem with the payload, or a citizen who wants information about our program. My job is to have the information that is necessary ready for each of these parties and to find an appropriate way to structure meetings for us to get together. (B. Schardt)

Program coordinators clearly <u>work</u> at staying on top of important information. They are, so to speak, the vortex through which all information concerning their project is passed.

An important role articulated by the program coordinators was the role of protecting the original design specifications of consumers.

> The problems we have between user organizations and the project level are healthy problems. Projects, after all, are run by strong people who are very talented. From time to time, there is necessarily conflict which arises out of the short-run job dedication of the project personnel. Project personnel don't like to compromise in terms of technical and engineering issues. At times like this, it's the role of the program coordinator to arrange a meeting to resolve issues so that unnecessary costs or unnecessary scientific excellence is not built into the program.
>
> The essential way for carrying out these activities is to make sure that destructive conflict does not emerge. My role is to bring all the important people together, to make sure that communication is adequate, to make sure that personalities do not become the focus of attention rather than technical and scientific issues, and to make sure that all important hierarchical levels are involved early in the problem solving. (B. Schardt)

> One of my major responsibilities in the early stages of a project is to get my handle on user requirements. It is my responsibility to formulate some kind of a program which meets these user needs and to explain this situation to headquarters, the Bureau of the Budget, and Congress. It is also important that I represent these needs to the engineers at Goddard who have a tendency to develop things more with a research orientation than an operations orientation. (M. Garbacz)

It is also the program coordinator who becomes a focal person in the development of new technologies. Each of the program coordinators mentioned thoughts for further, technological extrapolations based on the present thrust of their program.

Finally, it is the program coordinator who provides the day-to-day information concerning changes in schedules or costs both to headquarters and to Congress. All of the program coordinators expressed some dismay at the amount of time taken up by documentation and formal reporting.

The Status of the Program Coordinator

It is interesting to understand the way in which NASA defines the relative status of the program coordinator and project director, and the role of the program coordinator to the program manager and headquarters staff.

With respect to the latter (internal relations at headquarters) there is indeed intermediate status between the program coordinators and headquarters personnel and the program manager. It is quite apparent that the program coordinator is expected to be a full participant in any headquarters discussions concerning his program.

> My office is a team and the success of my office depends on the excellent work of each of my program (coordinators). They are really the experts in their sphere of responsibility and I rely on them for the detailed information concerning their particular program. Only when it's important to have someone with higher status or where administrative interventions are critical do I intervene. Further, I intervene in their presence and we solve the problems together. (M. Tepper)

Program coordinators , however, are defined by NASA as the highest level staff officer whereas the project director is defined as the highest level line officer associated with the project. This "line"/"staff" distinction is really a bit murky, as usual. What is really at work is a division of labor with the program staff being responsible for mission definition, funding and information monitoring, and the project staff being concerned with the technical development, building, and launching activities. In many ways, this is much more a division of labor than it is a difference in status. It has not, however, been a division of labor that has always been comfortable.

> It used to be once funding was approved that we had very little contact with the project people. Indeed, they would often try to exclude us from developments at the center. It's only been with effort that we have arrived at the point at which new developments are communicated to us immediately. (B. Schardt)

One of the mechanisms for dealing with this intermediate status is for the program coordinator to involve other headquarters personnel in problem-solving meetings.

> I obviously cannot direct a project manager to do anything. I have to bring in headquarters personnel if there is going to be a redirection of funding. I have no authority to command and only the authority to recommend. The way you handle this is to involve people who do have appropriate authority rather than pretend that you yourself will be the agent for the resolution of difficulties. (M. Garbacz)

In the case of one program coordinator, whom we will not identify, this position of ambiguity caused great problems.

> It's very difficult to see the effects of your actions. In fact, you don't really have any real authority. Sometimes I think people are hostile towards me. I would prefer to be back in the field where I would have line authority.

The successful program coordinators were people who could move comfortably in an arena where they had great responsibility but only limited authority. The character of this relationship is quite consistent with our early theoretical propositions concerning the intermediate status of program office positions. (Theoretical Propositions 8 and 20)

Summary

How can one summarize the character of the program office at NASA with respect to the Met Sat program? Clearly, the operations of the Met

C2

Sat Office are consistent with our early theoretical development. The program manager is the generic institutional representative for all activities in the multiple programs under his direction. As a result, his orientation will be to headquarters and to the broad scientific community.

By contrast, the program coordinators are concerned with their individual programs. In the early stages, they are the proactive agents for the development and funding of a program proposal. Once the proposal is funded and assigned to a project group at Goddard, they are the key day-to-day liaison officers concerned with project developments. These developments involve problem-solving meetings, monitoring of progress, and changes in schedules and funding. In addition, the program coordinator is concerned with spin-offs from individual projects for future program activities.

The subtle feature of the program office at NASA is not so much in its structure, which is quite consistent with the literature and theory in the field. It is, rather, the spirit of the program office. First, one cannot help but be impressed with the sense of teamwork that exists both within the program office,and between the program office, the user agency (NOAA), the scientific community, and the field project center. In our first interview with M. Tepper we asked whether there was a philosophy of management that stood behind the success of the Met Sat Program. He indicated that there was no particular philosophy nor had anyone articulated the structural relationships in an orderly fashion. He then went on to say:

> The reasons the Met Sat Program works is that we're all devoted to making it work.

At the time this particular comment seemed gratuitous. By the end of the interviewing, the sense of what was meant by that comment became clear. In earlier stages in the evolution of relationships between project offices and program offices, user agency and the scientific community there has been a history of considerable stress and strain. Everyone alluded to prior times when communications were guarded, when individuals did not cooperate, when information was withheld, and when unfortunate surprises between groups occurred. As the Met Sat Program evolved, the high cost of under-communication became apparent to everyone. The sense of, "We make it work," is portrayed in the day-to-day relationships between all the constituencies by a conscious effort to maximize everyone's information about present developments. The first and pervasive norm then of the program system at NASA is one of involvement of all parties in all issues. The informal maxim is "A principle of no surprises." To a very great extent, the burden of maintaining this communication richness falls on the program coordinator. He facilitates communication intensity by hard work, constant phone calls, and moving out into the field to be close to where activities are taking place. This requires long hours, a mature individual who is willing to invite himself in, and a great deal of sensitivity.

The second success of the Met Sat Office seems to be related to the division of labor between the technical people at the project level and the liaison people at the program level. Very clearly, one speaks to Congress in a way one does not speak to fellow scientists. The program coordinators and the program managers are, indeed, individuals who can speak the multiple languages of diverse reference groups in garnering resources for the Met Sat Program.

Finally, a key element of success in the Met Sat Program is the norm of problem-centered meetings. One reads a great deal about "problem centeredness" in discussions of creative problem-solving. NASA is an example of problem-centered communication. Over and over, people indicated that tensions between the various units in the Met Sat Program were meliorated by many informal problem-solving groups, and more formal liaison groups such as the MSPRB. All of these meetings provide vehicles for honest confrontation of problems as early as possible. In one sense, the physical technology of NASA makes the problem centeredness easier than is probably true of program management in social agencies. Nonetheless, personality differences could easily intervene and become destructive. It is by great dedication to the broader social purposes of the Meteorolgical Satellite Program, and by a sense of teamwork and good will between the various offices that petty personality variables are relegated to at least a position that does not seem to be central in the management of disputation within the Met Sat Program.

In this sense, communication intensity, careful monitoring by the program coordinators, a multiplicity of problem-solving group situations, and a dedication to an objective task all contribute to "Making this program work." Thus, the statement by M. Tepper was not simply a gratuity.

Finally, the amount of effort required to maintain these communication links could easily be underestimated if one focused simply on technology. The work of the program coordinators is to provide the communication value between headquarters, the project office, and the user agency. Thus, the program coordinator's position is a vital link in achieving the connections between the various reference groups that are part of the Meteorological Satellite Program. The importance of this link, we feel, has been underestimated by other researchers such as Mandeville who came to the conclusion that there was considerable duplication between project and program personnel. Our clinical understanding based on our interviews is that the program office and the project office are clear and distinct separable divisions of labor and that this division of labor is one of the strengths of the NASA system.

Chapter 6

THE PROJECT OFFICE

The purpose of this chapter is to describe the characteristics of the project teams as it is found in the Meteorological Satellite Program. We shall discuss the composition of the project team with particular attention to the project manager's role, the interfaces experienced by the project with other parts of the organization, and the characteristics of a project as it is defined in the satellite program. We shall also describe common bases of power and then describe the subtle balances which exist between project groups and technical groups at Goddard and in other matrix organizations. Finally, we shall describe the changes which have taken place in project management matrix organization structure in recent years at Goddard.

NASA Project Team

A project team may be constructed in a number of alternative ways. First, it may be simply a loose and informal group primarily housed in functional departments which is coordinated by a project manager functioning as an assistant to a line executive. Secondly, it may be a temporary task force directed by a project manager serving as a staff support person for functional members. Finally, it may be a group of technical and support people assigned for all or part of the project development under the direction of a project manager who has line authority over the team's direction. This latter case is to be found in the Meteorological Satellite Program at Goddard.

Figure 4 illustrates the various members who may be assigned to the project team. In general, one will find the following types of personnel:

a. The project manager

b. Staff support personnel

c. Liaison personnel

d. Subsystem managers

e. Research and development personnel.

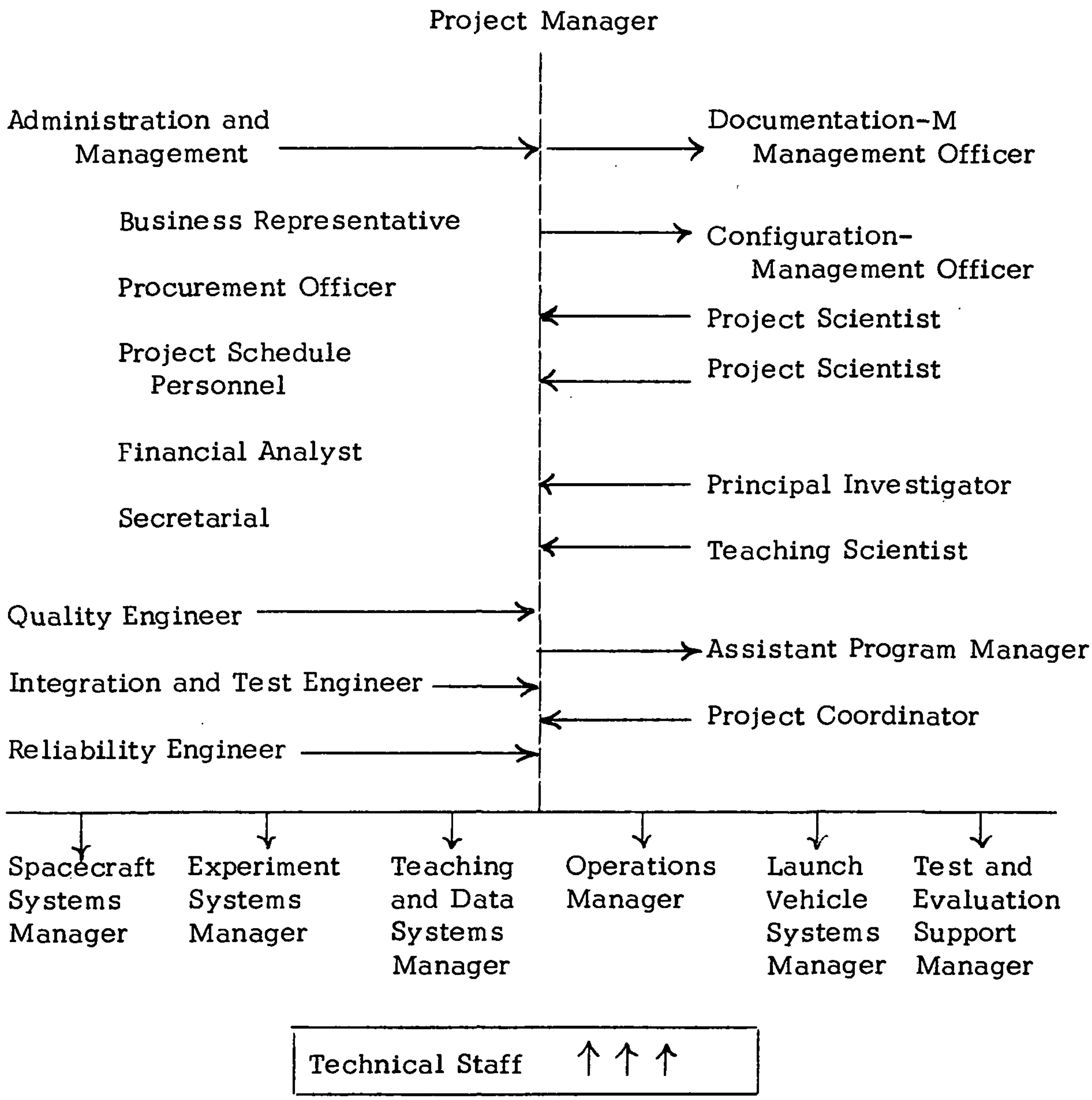
In Figure 4, arrows directed toward the project manager line signify assignment to the project by some outside administrative or technical department. An arrow is directed to the team member, indicating that the project manager himself makes this assignment. As illustrated, subsystem managers and personal staff of the project manager are generally assigned by his judgment and request. Most other administrative and staff support people are assigned to the project with the project manager exercising approval or veto power.

(a) The Project Manager—The project manager is the highest line official dealing with the project. He is nominated by the appropriate assistant director at Goddard and that nomination must be approved by the director himself. The responsibility of the project manager is described in the project manager's handbook (Goddard, 1968) as follows:

> The project manager is responsible for assuring the performance of all functions necessary for management of the project. In particular, he is responsible for project-wide planning and evaluation, systems engineering and design, systems integration, tests,

Figure 4

Project Management Organization



> reliability and quality assurance, scheduling, budgetary and financial planning, technical monitoring of contracts, and project reporting. The project manager has full authority to carry out these functions subject to limitations established by the director of GSFC. The project manager coordinates project requirements with other activities of the Center.

As suggested earlier in this report, the project manager's major concerns are development of the project team, coordination of detailed planning, and finalization of a proposal containing budgetary and time bench marks consistent with the level of funding indicated by the program office. In the words of Dr. Clark, "The project manager is concerned with the day-to-day life of the project, with its contracting, its cost control, and its scheduling."

The project manager probably performs a wider variety of skills than that normally found in middle or lower management in a bureaucratic hierarchy. His role clearly violates the classical prescription that responsibility should equal authority. He becomes the focal point for feedback loops from subsystems and staff activities, taking corrective action where necessary. He is the social facilitator of people from a wide variety of technical or administrative backgrounds. The relative importance of this latter activity is suggested by an interviewee who indicated that the technical problems are not particularly serious in projects but that the human problems are of major concern.

The project manager also provides some technical leadership though this appears to be nominal. As other descriptions of project management indicate, a technical background seems to be a basis of legitimization in the eyes of project team members rather than a necessary prerequisite for project success. The project manager is responsible for maintaining time and cost milestones during the project life cycle. He is relatively independent in the implementation of the project, being unable to pass on responsibility to someone higher in the hierarchy as is the case in the bureaucratic structure. Finally, the project manager is engaged in boundary negotiation both within the matrix structure at Goddard and outside the structure with various contracting agencies.

Personal evaluation of the project manager as the ongoing project administrator is minimal. He is evaluated much less by style than would be the case in a bureaucratic structure and much more on the basis of accomplishment—accomplishment both in terms of operating within constraints and according to milestones within the project cycle and, particularly, accomplishment in terms of meeting the well-defined goal to which the project addresses itself. For example, asked how his work is evaluated, one project manager responded, "I am judged according to whether the launch is successful or not."

(b) Staff Support Personnel—The staff support group for a project includes administrative and management support such as the procurement officer and project schedule personnel, scientific staff support such as the tracking scientists, and engineering support such as quality or reliability engineering. These people may serve a number of projects and serve to integrate the individual project under consideration into the larger systems at Goddard. The authority base for these personnel, therefore, lies outside the project itself.

(c) Liaison Personnel—In addition to individuals assigned to the project for liaison purposes from other agencies, the project may have an assistant project manager and a project coordinator who operate at the discretion of the project manager but who frequently serve in a liaison role within units of the project and with offices outside the project.

(d) Subsystem Managers—Subsystem managers are managers of subprojects and represent the second level of line authority below the project manager, supervising technical and functional personnel associated with the project. For example, the spacecraft systems manager or experiment systems manager will direct activities of technical staff members and will be assigned to those positions at the recommendation of the project manager.

(e) The Functional and Technical Personnel—People from specialist departments (functional or technical) in Goddard are assigned on a full- or part-time basis to the project. The kind and degree of association depends upon the project phase as well as policy of the center. Some personnel may be assigned to the project on a full-time basis. In other cases, the project manager negotiates with a functional department for their services. Where attempts to obtain services from technical departments are frustrated or where such services are not available, the project manager may hire project team members from outside the center or may contract out to other institutions.

The degree to which project personnel are involved in the project probably depends upon several factors. One is the attention to the project by top management. Given extreme interest and minimal budgetary constraints, project personnel can be assigned on a full-time basis to be available as needed. Another factor is economy. As suggested in the first chapter of this report, it is much more economical to schedule against available man-hours in a functional department than it is to assign project members on a need basis to the project itself. Thus, budgetary constraints are probably paramount in determining the relative extent to which personnel are more or less part of the project team. Another factor affecting degree of involvement is the extent to which the project manager himself can develop interest on the part of personnel in the project and its goals. Finally, personal interest of project members in the nature of the project or its personnel will be important. As indicated earlier, the individual participant in a project is normally interested in a specific technical or specialized aspect of the problem; thus, projects are probably characterized more by the degree of stress and involvement of participants rather than by the particular satisfaction with participation. We shall return to this issue of involvement later in this chapter.

Interfaces with the Project

Upon viewing the extent to which the project management interfaces with other agencies, one discovers how much the project manager must rely upon personal skills rather than utilizing organizational power and authority. He is guided and constrained by the program office from which he gets project proposals and approval documents, budgets, experimental constraints, and other controls. He must report administratively to the management of his center and look to it for reasonable allocation of personnel to his project. He must depend upon client agencies such as NOAA for money and statements of need. He must interface with scientific administrative and engineering groups for their approval and support. He must deal with contract agencies outside of his center and, finally, he must negotiate with managers of technical departments and skill groups within the center to obtain personnel and to accomplish certain work objectives. Little wonder, then, that the project manager is described by Dr. Clark as "someone who must be flexible and patient; an individual with little authority and much responsibility, and as someone who must be relatively untroubled by, though responsive, to the demands of his various interface groups."

Project Definition

The project with which a team must deal may be characterized according to certain criteria. First of all, it has a definite objective such as placing a satellite containing specified instrumentation in a specified orbit at a particular date within certain budgetary constraints. Secondly, a project generally has a time priority; that is, the emphasis on a project is more that of time than it is of money. Where, on the other hand, money constraints are predominant and time is less important, it may be scheduled through the normal channels of an organization. Thirdly, a project is generally supported strongly by one or more interest groups. This may be top management within the organization or the program office itself, but it will frequently be an external power group such as Congress, the Administration, or some organized segment of the population. Fourth, the project is generally characterized by cumulative expenses over time. Thus, the longer the project moves into its time cycle the greater the investment and the greater the cost of failure. Fifth, a project is generally characterized by its interdependence among several organizational units or several distinct disciplines. Finally, a project is often characterized by its difference from prior experience within the organization. That is, the project experience is often unique in the history of the organization.

Since a project builds momentum both in terms of expenditure and interest of personnel, certain problems are characteristic of project management. First of all, the necessity for control and minimizing the danger of spending money on a failing project requires that projects be divided into stages. These are described elsewhere in this report. On the other hand, by developing stages one finds an increase in paperwork and a decrease in the momentum leading to high morale.

A second problem endemic to project management is that of getting and keeping teams. As suggested earlier, project participants generally join because of their interest in the task, yet they risk professional obsolescence or inadequate rewards if they do not remain active local participants in their technical departments. Administrators, too, are reluctant to assign personnel on a full-time basis to projects when there is a possibility that such people will not be fully utilized.

Another problem faced by the project manager is that of dealing with contractors. Where the project can perform necessary work with its own staff, it can save a great deal of time and insure performance according to schedule needs. Where work must be contracted out, there is the necessity of negotiation, the requirement of paperwork, and the need to assure that requirements will be met. Finally, conflicts between project participants are to be expected since project members are present from diverse disciplines and with varying degrees of involvement. Specialists from different disciplines all have different expertise, jargon, philosophies, and behaviors and must work through these differences if a cohesive group is to be developed.

Power, Conflict, and Balance in Project Management

A major issue of project management and the relationship between the project and other units is understood more readily if we first identify the bases of power, authority and influence. As the terms are used here, power means the maximum ability of a person or group to bring about change in another individual or group. Influence refers to the actual degree of change induced by a person or group with power. Authority refers to legitimate power; that is, power which is generally acceptable to members of an organization and which is within the values and purposes of the institution.

Both theoretical (Simon, 1957; French and Raven, 1959; Bierstedt, 1950) and empirical (Filley and Grimes, 1967) attempts have been made to identify the bases for sources of power and organization. The following are frequently mentioned or identified:

a. Responsibility, i.e. the particular functions or types of decisions to be performed or made by a designated individual or group.

b. Authority, i.e. the legitimate area of discretion exercised by an individual or group in issuing directions and expecting compliance.

c. Control of resources, i.e. the ability to control information, money, or personnel, or other resources needed by one or more organization members.

d. Expertise, i.e. possession of superior technical knowledge which is valued by one or more organization members.

e. Control of rewards and sanctions, i.e. the ability to provide or control the provision of values desired or avoided by organization members.

f. Association, i.e. power derived from being near and interacting with another legitimate high-power source, e.g. a personal staff assistant.

g. Rapport or personal appeal, i.e. the personal liking of one or more organization members for another individual or group.

All of these bases of power may be observed in any organization. In a stable structure, the more formal bases of power such as responsibility and authority tend to be well defined. Role conflict is minimized by having each organization member report to one superior and by minimizing ambiguity of task expectations. In the stable environment levels of authority, channels and job definitions tend to be quite explicit. The only conflict endemic to such structures seems to be between line and staff employees. Line employees have legitimate authority, but staff employees lacking much formal authority have power derived from control of needed resources and expertise. Also, staff units are often closer to formal centers of power and derive influence through association with legitimate power sources.

In the matrix structure, the situation is somewhat changed, however. Typically the environment is unstable, and innovation by the organization is valued highly. Greater tolerance for ambiguity is required by members of the organization. As pointed out earlier in this report, matrix organization requires dual authority. Since members of technical departments assigned to projects are influenced formally by the heads of their technical units and by project managers, matrix organizations also minimize distinctions between line and staff employees reducing that source of conflict.

In the matrix structure, when specialized (functional or technical) departments rely heavily for resources upon the project groups, then the power of the project balances the power of the technical units. That is, where most people in a technical unit are assigned to projects and where the technical unit therefore gains its income and legitimization through project work, then the resources gained through the project assignments balance the power through expertise coming from the technical units. Where, on the other hand, the technical groups are funded sufficiently on their own, then they might be expected to serve project groups less attentively.

A shift in this regard has apparently taken place in the Meteorological Satellite Program at Goddard. According to Dr. Clark, at one time most members of technical or functional departments were assigned to project work. Now 20% of members of technical departments are on a project, and 80% simply work for their functional unit. This shift might be expected to take place as economy takes priority over time schedules for project activities. Judging by interview data, the project managers are less able to bring in permanent members for the project and must rely more heavily upon negotiations with technical groups to obtain a service. That service is performed within the technical group rather than on a man-assignment basis to the project.

The coping mechanism of the project manager given this imbalance of power then becomes one of hiring project team members from outside Goddard or contracting outside of NASA. The latter strategy gives the project manager power (money) to control performance according to his needs.

The extent to which functional units uncontrolled by project client needs reinforce professional interest may also be illustrated here. One project manager described an incident in which he approached a technical unit in Goddard requesting a piece of equipment to be used on a series of satellites. The technical unit replied that they would be willing to make a single prototype since such an item had never been built before and represented a technical challenge. However, the department was reluctant to make the item in multiple units since such activity was merely a production job. Frustrated, the project manager turned to a supplier outside of Goddard for his equipment.

It would appear that another attempt to balance the power of projects with respect to technical units has occurred organizationally in Goddard by having a director of projects as a legitimate (responsibility and authority) scource of power equal to the power of the directors of functional units. The extent to which this has been operational is questionable, since program personnel never mention the director of projects when they describe the process by which project requirements were balanced with technical unit requirements.

It would seem that the emphasis in the Goddard Space Center and in its matrix organization has shifted to strong support for the technical or functional departments. As explained in Chapter 1, the result may be an increase in economy of operation but will be done at a cost of involvement in projects and emphasis upon meeting tight schedules for client needs.

Chapter 7

PROCESSES FOR COORDINATION AND CONTROL

The purpose of this chapter is to describe the various processes for coordination and control which are to be found in the Meteorological Satellite Program and in NASA's relations with clients and other agencies. In clarifying these mechanisms it is possible to indicate values and dysfunctions associated with each and to suggest their appropriate applications.

Within the past decade a number of studies (Burns and Stalker, 1961; Woodward, 1965; Hall, 1962; Lawrence and Lorsch, 1967) have indicated that where the organizational environment is stable and predictable, the traditional mechanistic or military model of organization is most appropriate. On the other hand, where the environment is characterized as having rapid changes in products and technologies, then flexible structures with less emphasis on channels, levels, and formal job definitions, and more emphasis on problem-solving teams should be used.

In a recent paper, Galbraith (1969) has suggested that the degree of information processing is a useful proxy for variability and that the amount of information to be processed is a function of (a) uncertainty concerning task requirements, (b) the number of decision-making elements (departments, occupations, products, clients) involved, and (c) the amount of connectedness or interdependence among these decision-making elements. Thus, if the task can be preplanned and if actual execution required little or no adjustment based on new information, the structure will be more mechanistic.

Further, if decision-making elements are independent and not interconnected, then information processing is relatively less and the structure will be simple and stable. The interdependence may vary in kind as well as degree. Some tasks may require element groups to draw from a common pool of money, personnel, or other resources. Some element groups will be related in a sequential task basis, with goods or information moving predictably from one element group to another. Finally, some tasks require an interactive and reciprocal relationship between element groups. It appears likely that as one moves through these three types he finds a decrease in mechanized relationships and an increase in informal group-oriented relationships.

We can explain much about structure, then, if we can determine the extent to which various element groups need to relate to each other and the way in which they do relate. The need to relate as has been suggested may be procedural or personal. Where groups draw from a common pool, then their relationship may be competitive for those resources until mechanisms are established to allocate resources according to some procedural mechanisms. For example, as Blake and Mouton have pointed out, if the parties do not see agreement as possible and yet must work together, then for important issues they will engage in win-lose battles and for less important issues they will resort to arbitration of the dispute by a third party. Minor issues under such conditions are resolved by leaving the resolution to the whims of fate.

On the other hand, where disagreement is present but the parties believe that agreement is possible, they will rely upon problem-solving conferences if the issues are important and will use compromise strategies where the issues are less important. Where the issues are unimportant then they are smoothed over and ignored.

Sequential tasks require agreement on the sequence, that is a division of the labor and the ordering of that division. Interactive tasks generally involve decision-making or problem-solving. Again, if the parties must deal with each other yet do not feel that agreement is possible, they must resort to power plays or arbitration. If they do feel that agreement is possible, they will rely upon problem-solving conferences to find mutually agreeable solutions or compromise to find a reasonably acceptable solution.

In any interactive situation between element groups there will also be a tendency to routinize the relationship. That is, to leave things in question, or to leave issues ambiguous is to encourage stress and confusion. So the parties will establish policies and procedures which make the issues themselves predictable and manageable,or policies and procedures which make predictable the way in which issues will be dealt with in the future.

Finally, where element groups disagree and have neither the expectation of agreement nor the mechanisms for resolving their disagreement, and where the element groups can operate separately, then they may be expected to withdraw from further interaction with each other.

To summarize, in discussing mechanisms for coordination and dealing with real or potential disagreement, we shall identify three strategies. The first, formalizing, is an attempt to routinize the content of relationships. The second, interacting, is an attempt to routinize the process of relationships. The third, isolating, is the separation of the parties, issues, and activities.

Where the parties do not believe that agreement is possible but must deal with each other, we would expect them to rely upon power conflicts or arbitration for resolution; where the parties do believe that agreement is possible we would expect them to rely upon problem-solving meetings and compromise. Where agreement is seen as impossible and one or both parties can withdraw, we would expect to find isolation of element groups.

Coordination Mechanisms in the Program

Role conflict and role ambiguity have similar effects in individuals and groups: felt pressure, anxiety, confusion. Not surprising, then, that the Meteorological Satellite Program evidences what might be called the doctrine of no surprises. Whether it is NASA-NOAA relationships or program-project relationships, one observes a pattern of "checking things out" informally before any document is tendered. For example, if a NASA representative sends a request for action to the Weather Bureau, a personal contact is likely to be made prior to sending it, inquiring whether such a request would be viewed favorably and making sure that the intent is clear. If the informal contact is cleared to the satisfaction of the sender and the receiver, then the formal document will be sent.

It is useful to speculate about the reasons for this "doctrine of no surprises" since it may well be endemic to matrix organizations or situations in which two element groups are relatively autonomous from each other. First, it seems to suggest an equality of power on the part of the parties. Where one is clearly subordinate to the other, the superordinate may more easily assume acceptance of its directives without question. Secondly, it demonstrates the intent of communication, both in terms of substantive material sent, and in terms of desire for mutual respect and openness. Third, it is concommitant with the degree of information processing required in organizations with changing environments. That is, such organizations have been shown to have more people employed in integrating capacities (Lawrence and Lorsch, 1967). Finally, it probably reflects a maturing of relationships in terms of conflict-resolution strategies. The parties apparently feel that agreement is possible and desirable, relying more upon problem-solving than upon power plays or arbitration.

The latter point is clearly consistent with our observations of conflict resolution strategies. At the program and the project level, we were interested in determining the extent to which program participants utilized resolution by (a) appeals to higher authority, (b) bargaining and negotiation, (c) mediation by outsiders, (d) problem-solving meetings, and (e) smoothing over real differences. Clearly, the greatest use is made of problem-solving meetings and, secondarily, of bargaining and compromise. Other methods are used infrequently, if at all. Given the history of conflict among element groups in the satellite program, the strategies now used suggest a desire and ability to reach agreement.

The doctrine of "no surprises" is to be found in the various mechanisms of coordination, to which we now turn.

Formalizing

If one differentiates task units in organizations, one can identify four principle types: the routine unit, the engineered unit, the craft unit, and the heuristic (or diagnostic) unit. The first two are highly formalized, requiring control by the system and a group of planners to develop the system. In the routine task unit, operations are highly specific and repetitive. In the engineered task unit, operations are also specific but are repeated as required. Routines are established indicating that if one does the job, it must be done as prescribed.

The craft and heuristic task groups, on the other hand, are person-controlled rather than system-controlled. A goal is specified and the members of the unit use their skills to meet process and task requirements.

In the usual bureaucratic structure, one finds task units ordered roughly from routine to heuristic as one moves upward in the administrative structure. One may also find these types if one moves across the organization structure as with repetitive task groups and staff or planning groups. The hierarchical ordering appears to be present in the NOAA structure since it is operational in nature but is not to be found in the matrix structure of the

Figure 5

Source and Type of Control by Task Unit

Unit Type	Control Applied to: Goal	Process	Task
Routine	AS	AS	AS
Engineered	AS	AS	TU
Craft	AS	TU	TU
Heuristic	TU	TU	TU

Code: AS — Control from Administrative System outside task unit.
TU — Control from Task Unit itself.

MS program or its constituent units. At the project level, it is difficult to routinize activities because they are seldom recycled and at the program level the issues change frequently.

The primary difference seems to be a sense of closure at the project level that is absent at the program level. For example, one individual in the program level commented on the sources of dissatisfaction in the program level: "I like working in the field better. One never finishes at headquarters. You can't see the results. There isn't enough time to dig into anything." On the other hand, at the project level project managers commented about the peak of morale at a successful launching followed by a decline for a period after that.

The usual formalizing methods, then, are altered in the matrix organization to be found here. We shall discuss three of these: hierarchy, rules and plans, and division of labor.

(a) Hierarchy—The usual notion of hierarchy is that routine work is programmed at lower levels leaving higher levels to deal with exceptions to routines, with balances of organization resources, and with long-range issues. To a great extent the hierarchy represents a ranking of legitimate power in the structure, legitimate power being the authority to exercise direction and to expect minimally defined performance.

If one takes the distinction between the program and the project office as two gross levels in the hierarchy, one should be able to distinguish differences expected and found in other organizations. Yet, this proves not to be the case. Differences depend much more upon expertise, personality, and a division of activities than upon authority. In fact, the program office defines its role as staff, which implies a lack of formal authority and resort to cooptation and persuasion as means of fulfilling expectations.

While this difference is common to matrix structures, it does seem to be exaggerated in NASA. Perhaps it grows from the tradition of the earlier National Advisory Committee on Aeronautics (NACA) which was a loose amalgam of research centers with minimal control at the top. The role of headquarters had been to insulate the research centers from intrusion by outsiders, to coordinate activities, and to obtain money. Technical responsibility was vested in the Goddard Space Flight Center itself.

(b) Division of Labor—For cohesion to take place between groups or individuals there must either be a homogeneity of values, personalities, work, and roles, or there must be a mutual need by the parties or groups, i.e. each must depend upon the other for resources that it does not have itself. The latter is clearly the case in the MS program. For example, comparing program managers and project managers, Mandeville (1969, p. 84, 86, 93, 94) found the most important activities for program managers, which were not shared with project managers, to be outside and buffering in their orientation: communication (e.g. "handle inquiries made personally by members of Congress or their staff"), budgeting (e.g. "prepare an annual budget"), and review (e.g. "analyze effectiveness of operation"). Similarly, judged as most time consuming were reporting (e.g. "submit regular progress reports to higher management or to the customer"), budgeting, and review.

In contrast, the project managers were inside- and operations-oriented: supervising (e.g. "review decisions that are made by subordinates"), expediting (e.g. "expedite completion of critical project tasks"), and gathering pertinent technical information (e.g. "keep informed about the latest research and development relevant to project activities"). Judged as most time-consuming project managers described trouble-shooting, supervision, project review, and reporting to higher levels.

Thus, unlike a conventional hierarchy, the division of labor in a matrix organization in the levels supplants an authority structure, and this division seems to be functional as long as the levels are equally dependent upon each other.

The cohesion of element groups based upon division of labor rather than upon homogeneity of values and programs may also be seen in the relationship between NASA and the Weather Bureau. As suggested earlier, for such arrangements to work effectively there must be a belief that the units can cooperate and resolve differences, and there must be a balance of power between the units. Where units do not believe that agreement is possible and where power is not balanced, one would expect the units to engage in win-lose disputes or resort to arbitration. The hierarchical arbitration mechanism is not possible in the case of NASA and the Weather Bureau because they are separate agencies, leaving the costly mechanism of dispute.

The exact nature of the relationship and the various historical disputes need not concern us here, yet it is of value to note that the exact resolution of a division of labor was at issue from 1960 when the Panel on Operational Meteorological Satellites was convened, through the Congressional program and budget hearings of 1961, through the 1962 NASA-Weather Bureau Agreement on the division of labor, and, finally, the 1964 interagency agreement. Both now appear to be equal partners with research and development work done in NASA and operational work done in the Weather Bureau. The latter's small size and relative political isolation is offset by its program funding, its control of communication through pooling user needs expressed by other agencies, and its demonstrated ability to withdraw support from NASA's activities.

(c) Rules and Procedures. The third method for formalizing relationships between units is to specify rules and procedures. Such mechanisms reduce or eliminate the need for communication or problem-solving and provide for coordinated activities throughout an organization. Once established, however, they make the system closed upon itself and enhance the danger of not adapting to the external environment. Rules become standing orders and by their very existence suggest that they will be repeated. Thus, they insure reliability of behavior but detract from the validity of the system as soon as conditions change.

The advantage of rules and procedures for insuring reliability (and, therefore, economy) in a system is also offset by its effects on the extent to which people identify with organization goals. When projects are well-funded, with extensive staff, and with an exciting goal which enhanced participant expectations, then motivation and morale are at a high level. There is some evidence now that by using project stages defined by strict procedures and documentation, the momentum and morale of projects has been reduced. In effect, procedures have depersonalized what was a highly personal group achievement.

As expected, we do not find the weather satellite system to be characterized primarily in terms of rules or procedures. Instead, problem-solving and task groups deal with issues as unique. The primary rule behavior seems to surround planning, budgeting, project proposals, and purchasing.

Interacting

As indicated earlier, interacting mechanisms formalize the process of relationships rather than their content. While hierarchy, division of labor, and rules are to be found as mechanisms for coordination and control, they are much less useful in matrix or project organizations. Rather than being enforced more rigidly and extensively as one moves down the organizational hierarchy—a characteristic of a bureaucratic structure—these formalizing mechanisms are distributed throughout the program and project level.

The nonhierarchical emphasis in the MS program, as is the case in other matrix structures, places much stress on integrating mechanisms, the principal ones being (a) coordinating committees, (b) liaison personnel, and (c) representatives in residence.

(a) Coordinating Committees—While coordinating committees will occasionally function as sources of negotiation, arbitration, or compromise, their primary responsibility is to act as a legitimate and known source of approval for agreements. It is here that the doctrine of no surprises functions most effectively. Following an informal exchange of information and opinion and an informal agreement, representatives make a formal presentation of request in the coordinating committee followed by a predictable formal acceptance.

The most important coordinating committee in the MS program is the Meteorological Satellite Program Review Board. The MSPRB was established in a 1964 agreement between the Weather Bureau and NASA. The agreement stated:

> A Meteorological Satellite Program Review Board is hereby established. The Board is composed of two members each from NASA and Doc - WB with the Associate Administrator for Space Science and Applications of NASA and the Chief of the Weather Bureau serving as co-chairmen. The Board will meet quarterly or at the request of either co-chairman to review the program and consider any substantive issues which may arise. It may make recommendations to the DOC - WB on the resolution of issues concerning the operational programs, and to NASA concerning the responsiveness of the NASA R&D program to the needs of NOMSS. Either chairman may refer any issue to the Associate Administrator of NASA and to the Assistant Secretary of Commerce for Science and Technology for resolution.

The structuring of the committee is of more than passing interest. Where two bodies, groups, or organizations differ in size or power, negotiations between the two may be somewhat equalized by having the same representation on coordinating committees. Were voting to occur in a combined membership of both organizations, one would always win.

The equality of relations in MSPRB is stressed by (a) equal representation, (b) rotating chairmen, and (c) opportunity to appeal to superiors in either system. The latter provides for a system of appeal which prevents buffering of information by committee representatives.

The MSPRB is much used and quite effective. It meets every six weeks to deal with an agenda which is agreed upon in advance. It is heavily attended, generally having twenty to thirty people present, apparently because of the presence of two principals —Dr. Naugle and Dr. White. According to Mr. Tepper, its main functions are "legitimation" of agreements and exchange of information.

(b) Liaison personnel—A second interacting device is the use of liaison personnel. Other writers (Lawrence and Lorsch, 1967; Galbraith, 1969) have pointed out that where the environment is unstable, adaptation and innovation are valued, and the needs for information processing are great, one expects to find integrators or integrating departments in the system. If the system attempts to maintain responsiveness without integrators, it must do so (a) through formal executive positions at a high level in the system, or (b) through delegated responsibility at lower levels.

Where executives attempt to do their own liaison work at top levels, they do so at a cost of regular task demands. Since the degree of routinized activities is greater in a matrix structure than it is in a bureaucratic hierarchy, the absence of liaison personnel at that level would be more costly in the former system than in the bureaucratic system. On the other hand, to push liaison activities to lower levels in the system is to increase the likelihood of suboptimization. Each project and each technical department has the interests of its own project or specialty in mind, making a circumspect view of the entire system less likely.

The ideal arrangement, then, is for the program office to have liaison or integrating personnel whose primary function is that of acting at the interface between organizational units to:

—pool task requirements from multiple sources

—initiate and receive communication on a daily basis with other units

—insure adherence to time and money constraints

—insure adherence to program constraints

—maintain a neutral party position at organizational interfaces.

Both the Weather Bureau and the MS program at NASA have such a liaison position. Interviews with the members of these two positions and with others about these two positions suggest their activities. First, they receive direction from many people. That is, they transmit or convey information from and to a variety of sources within and outside the program office, e.g. the liaison person in NASA receives direct supervision from five people. Second, as expected, they are process rather than content specialists. Both liaison people had some technical background, but both expressed a major interest in system accomplishment rather than technical accomplishment. Both saw organizational accomplishment and problem solving as major sources of personal job satisfaction, vis-à-vis money rewards, use of technical skills, or friendships.

Third, liaison personnel engage heavily in pooling program requirements from constituent groups and incorporating requirements in detailed plans. For example, the NOAA liaison person mentioned responsiveness to needs of nine different units within and outside of the Weather Bureau. These requirements were included into a five-year plan. At NASA, while a five-year plan is followed, detailed time and money planning is on a one-year basis.

Fourth, liaison personnel seem to evidence skills of problem-solving and conflict resolution. As such, they are seen as neutral parties who determine how to meet the needs of constituent groups rather than as protagonists for a single position of their own program office. They also engage in selling or persuasion to get constituent groups to cooperate:

> The goal of my position is to get a handle on the program, then to sell my management on the various needs. I help my management get the support of Bureau of the Budget and from Congress. Then, I sell the people who will implement the program, making sure that they meet user requirements. (Gärbasch)

Finally, most of the time of liaison personnel is spent on short-term tasks. Much like assistant-to positions in conventional organizations, the liaison person engages in a variety of nonrecurring short-term tasks rather than on project work or in tasks which would require work segments of more than two hours to perform.

Before leaving the discussion of liaison personnel, it should be emphasized that such roles are a function of the type of organization structure employed, not merely a function of organization size.

(c) Representatives in Residence—The third interaction mechanism to be seen in the MS program is temporary or permanent exchange of personnel. Since the matrix structure of the MS program cannot rely upon formal authority through channels for its operation, greater emphasis is placed upon personal interaction and problem-solving. Interaction is facilitated between two parties when each sees the other as "someone I can talk to" and "someone who understands my problems."

One finds occasions where permanent transfers of personnel from one unit to another makes interaction easier and reduces the likelihood of suboptimization. For example, Dr. Clark, director of the Goddard Space Flight Center, went to Goddard from NASA Headquarters. Thus, he has the perspective of both the program office and the project office. As will be pointed out elsewhere in this report, this perspective seems to balance requirements of the program and the project groups, while not pleasing projects themselves. His interest in program economy is quite consistent with the earlier discussion of values in the functional structure, though it does affect the freedom of project offices.

Other examples of permanent movement may be seen in Dr. Tepper's experience in the Weather Bureau for thirteen years before joining the MS program or in Dr. Townsend's activities as deputy director in NOAA after being a division head in NASA. Such experience might be expected to facilitate communication between NASA and NOAA and to increase headquarters' understanding communication between the two agencies.

A related strategy for improving coordination is the temporary assignment of personnel from one unit to another. For example, NOAA maintains its own personnel in residence at Goddard. They can insure that operational requirements are being maintained in project development and serve as liaison personnel at the project level. While we did not interview representatives in residence, we heard frequent reference to military or NOAA representatives in the project level at NASA. It is likely that they serve to integrate both technical and personal relations between diverse organization units.

The three interacting mechanisms described above may be expected where the content of relationships cannot be detailed. Instead, parts of the system are linked by formalized process mechanisms.

Isolation Mechanisms

Coordination within a system cannot always be accomplished by formalizing the content of relationships (formalizing strategies) or by formalizing the process of relationship (interacting strategies). In some cases, element groups in a system will simply try to minimize or eliminate coordination requirements by the withdrawal by one or both element groups or by attempting to make each group autonomous from the other.

We have seen elsewhere in this report how project managers will seek assignment of full-time technical people to their projects in order to make themselves autonomous from other projects or departments. For goal-oriented units to do this is to underutilize personnel and equipment and to increase the duplication of resources among the units. In much the same way there is a natural incentive for agencies to make themselves autonomous from each other where possible, even at a cost of duplication. Thus, even though NASA is concerned with research and development for the MS program, NOAA has its own people concerned with the design and development of satellites. Similarly, although the scientific input is presumably that of users outside of NASA, there is such talent within NASA and an expressed need for more.

Perhaps the most dramatic example of withdrawal occurred in 1963 when NOAA withdrew from the NIMBUS program. It is unlikely that NOAA could have developed its own satellite, but it is possible that the Department of Defense could have developed and orbited a satellite which would have met NOAA's needs. While the historical details of the dispute need not concern us here, the situation does demonstrate that when one or both parties in a relationship see the situation as unfair or unrewarding, they may withdraw and attempt to sever ties.

Both at the project level and at the interagency level the use of isolating and withdrawal strategies was most popular at a time when interest and money were focused on the weather satellite program. With the tightening of resources, isolation and withdrawal become academic considerations. Instead, the natural tendency is for an organization to draw toward its functional structure.

Chapter 8

THE PLANNING SEQUENCE IN THE METEOROLOGICAL SATELLITE PROGRAM

Rationale for Focusing on the Planning Cycle

Thus far we have largely focused on the structural configuration and program and project roles of NASA's Meteorological Satellite Program. However, by looking only at the structure and roles of NASA, it is difficult to understand the dynamics of the organization, in terms of the way plans or programs evolve and move through the structure. Therefore, in this chapter the interrelationships within the matrix structure will be illustrated by examining the process phases of the planning sequence. In particular, we are interested in the extent to which the planning cycle parallels Proposition 2 in our theoretical Chapter 2.

An important variable affecting the dynamics of the planning sequence is the extent to which an organization is an open or closed system. In an open system conscious attempts are made to integrate various constituencies during each planning phase. In a closed organization system, formalized procedures prescribe a particular reference group as the sole and dominant locus of influence at any phase of the planning sequence.

In the illustration below of the program development process followed in the Meteorological Satellite Program, the critical feature to note is how matrix management develops process guidelines at each phase of the planning sequence to specify the character of participation of multiple reference groups.[13]

Division of Labor Between Program and Project Staff

There is a significant division of labor in the planning process between the program office and the project office. The role of the program office concentrates on relationships with Congress, relationships with client organizations, and on securing approval of developmental programs within the NASA headquarters. Final decisions with respect to the selection of payload on a particular satellite, the level of funding, and the relationship

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[13] Material used to describe the NASA planning cycle was obtained from the following sources. A number of questions in the semistructured interviewing related to the issue of organizational planning. Each NASA administrator was asked to describe the nature of the planning process, the effectiveness of the process, the types of problems that were connected to planning sequences, and the ways in which various groups were involved in planning. In addition, the planning processes in NASA have been partially formalized by the initiation of specific guidelines dealing with a planning system called Phased Project Planning (hereafter abbreviated PPP). PPP has been prescribed as a policy within NASA (NASA Policy Documents 7121.1A). A detailed description of PPP is available in NASA Handbook 7121.2, August, 1968, and is available from the Superintendent of Documents. This guideline handbook describes PPP in greater detail than will be dealt with in this review of the planning sequence. Finally, an earlier description of PPP appeared as part of a discussion paper delivered to the Midwest Academy of Management in 1968 by Carl R. Prattish, entitled: "The Evolution of Program Management."

It is, of course, difficult to describe fully the fluid dynamics of planning within an agency. Although formal guidelines or bench marks such as PPP are promulgated, in reality phases overlap and processes are not as clearly defined as PPP might suggest.

of one project to another within the program, or one program to the other programs within the space science applications area, are the responsibility of the program manager. Thus, it is the headquarters program staff that is responsible for determining the rate of activity within different fields.

By contrast, the role of the project office relates much more to the determination and follow-through with respect to the technical characteristics of a particular project. It is the project office which is involved in the selection and monitoring of contractors, provides careful control over cost and schedule commitments, and must see that the project objectives are successfully operationalized within time and cost constraints. However, even given this division of labor, one of the characteristics of the NASA system is that (1) project staff freely enter into discussions with headquarters' personnel, and (2) program coordinators penetrate the activities of the project group.

Figure 6 presents a flow diagram which illustrates the manner in which a particular scientific satellite program is sequenced in terms of planning processes. Although there are differences between the planning process for operational satellites and that for scientific satellites (the latter being more complex), and while there are necessary differences between each project and program, in general the major features of the planning cycle summarized in Figure 6 were described consistently by both project and program managers.

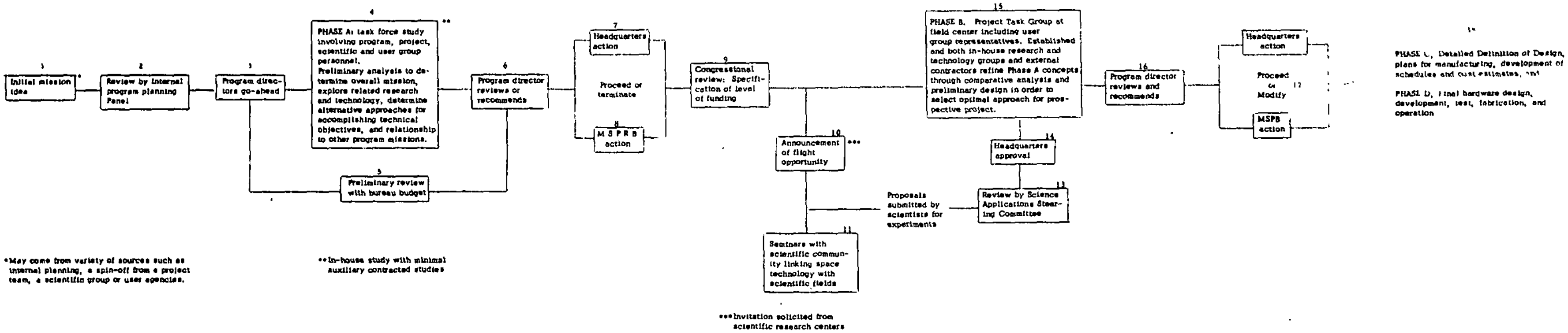

Figure 6 — NASA Project Planning Cycle

The Initiation of a Particular Project

Steps 1—3 in Figure 6 indicate (1) that conceptions of new projects might be initiated from a variety of sources, and (2) that any serious planning for a future project must be endorsed by headquarters early in the planning process because of the complexity and high costs of the technology. For example, the initial mission idea (Step 1 in the flow chart) may come from any of the following sources: 1) an internal planning group in the NASA headquarters; 2) a spin-off idea developed by a project team focused on earlier technology; 3) an idea or developmental area that has been under discussion by some scientific group—either domestic or international; 4) a project building on new demands, suggestions, or needs of user agencies. Typically, once the idea for a new project has been in circulation, a working paper is developed and the new project idea is reviewed by an internal program planning panel (Step 2). There are a variety of these panels, both within NASA and between NASA and user agencies. If the internal planning panel recommends a feasibility study be undertaken, the matter is referred to the program director for his approval (Step 3).

The Initial Feasibility Study

Steps 4, 5 and 6 in Figure 6 relate to the initial feasibility study which begins with a formal approval document authorized in Step 3 by the program director. At this point two activities tend to occur simultaneously, or tend to occur with a considerable degree of overlap. (1) At the program level, the program staff begins developing detailed statements concerning the project objectives (which are outlined for the Office of Space Science and Applications) with the major thrust of the project reviewed by the Bureau of the Budget. (2) At the project level, a task force under the guidance of the program office is formed to do a Phase A study. Phase A is normally not assigned to an established project team at one of the space flight centers, such as Goddard. Rather, it is a task force study which will involve: people from the program staff, selected members from an earlier project team, scientific and technical staff people from a space flight center, and representatives of the important potential user groups such as NOAA. In addition, contact and involvement of external scientific personnel at universities or research centers is normally a typical part of the Phase A study. The purpose of the Phase A study is (1) to undertake preliminary analysis to determine the overall mission characteristics of a project, (2) to explore research and technology which relates to the potential product, (3) to determine alternative approaches that are technologically feasible for accomplishing the objectives of the project, and (4) to determine the exact relationship of the project to other program missions. As much as possible, the Phase A task force group communicates with those personnel, both "in house" and external to NASA, who can lend insight and make contributions to problem-solving surrounding this general project definition. An important norm in NASA is that all parties having technical or working knowledge should have the opportunity to communicate and participate in the evolution of a new project. By the time the Phase A study is completed, some understanding of both the technological characteristics of the potential project, as well as probable funding implications, will be available for review in Step 6 by the program director. Results of the Phase A study are then passed on together with his own recommendations for formal management action by headquarters in steps 7 and 8.

Headquarters Action and Formal Authorization to Proceed

While the Phase A study should provide clear information with respect to the technological issues surrounding the study, there is still the responsibility on the part of the headquarters administrator to understand clearly the relationship of the particular project to other projects within the program and the generic focus of major program resource allocation within NASA. It is also true that there may be differences of opinion between NASA and the user agency. In the Meteorological Satellite Program, of course, the predominant user agency is NOAA within the Department of Commerce. As has already been discussed, there exists the Meteorological Satellite Program Review Board which would be involved in the review of the Phase A study. If both the NASA headquarters group and the Meteorological Satellite Review Board endorse the proposal, the project is taken by the program staff to Congress for review and the determination of specific levels of funding for the project (step 9).

It is important to note the character of the proposal when it is brought to Congress. A number of important preceding legitimatizing steps have already been undertaken before it reaches Congressional attention. Earlier, discussions with the Bureau of the Budget were undertaken by members of the program staff. The Meteorological Satellite Program Review Board provided a vehicle for arriving at joint interagency understandings, shared funding and endorsement of the central project objectives by both NASA and NOAA. The Phase A study provided detailed information with respect to the technical, engineering and scientific aspects of the proposed project. All appropriate parties were asked to participate in the Congressional hearings.

If approval is granted by Congress, hard funding will be allocated to the project. It is at this point when the project is approved and a specified level of funding determined, that the project is transferred to a specific project task group at the Goddard Space Flight Center.

Involvement of External Scientific Personnel

Steps 10 through 14 relate the sequences by which external scientific personnel are invited to become participants in the new project.

After funding is approved by Congress and the project becomes a firm reality, an "Announcement of Flight Opportunity" is released and sent to several thousand scientists, engineers, and research centers both in the United States and internationally. The Announcement for Flight Opportunity describes the basic character of the forthcoming project and invites scientists and researchers to prepare proposals for experiments as a means of becoming involved in the forthcoming scientific satellite.

It is important to notice that such an invitation is built on prior dialogue with the scientific community. In the early days of the Meteorological Satellite Program, because of the newness of space technology, scientists did not immediately respond to invitations for experimentation as a result of the Announcement of Flight Opportunity. For example, meteorologists were used to working with archive data, and the potentials for real-time data and experimentation based on real-time information which was made possible through space technology was outside the tradition of that particular scientific group. As a result, as indicated by Step 11, dialogue has taken place prior to Step 10. NASA has conducted seminars with various scientific groups—physicists, meteorologists, etc.—dealing with major scientific questions to which space technology can be related. In a sense, this has been an educational program to acquaint the scientific community with the potentials of space technology and to make them feel that their participation in the meteorological satellite program is desired. As a result, the Announcement for Flight Opportunities now goes to an audience which has already been introduced to the program and which, hopefully, may have been considering various types of scientific questions which could be adapted for experimentation to one of the scientific satellites.

As indicated by Step 12, proposals from individual scientists or groups of scientists are then received. Often as many as thirty such proposals are submitted by scientists external to NASA. These proposals are reviewed competitively, as indicated in Step 13, by the Science Applications Steering Committee.

Earlier, NASA had functionally based review groups who received particular experimental proposals in light of a particular scientific functional specialty. However, NASA found that a change to a more cosmopolitan review body results in an appraisal of the experiments without the suboptimization and tunnel vision that had been true of the earlier functional review group. Thus, the Science Applications Steering Committee is presently a cosmopolitan body made up of scientific members from various disciplines as well as multiple agency representatives. This committee, after reviewing the various proposals submitted, passes on recommendations to NASA Headquarters regarding which experiments should be included in the experimental satellite project.

Phase B Study—Project Definition

Simultaneous with these activities (Steps 10–14), the project task group at the space flight center will have been engaged in a Phase B study. This Phase B study (Step 15) integrates the contributions of in-house scientific and technological specialists from NASA, specialists from the user agency (NOAA), and members of the project group itself. The purpose of the Phase B study is to refine the preliminary concepts from Phase A by means of comparative analysis and preliminary design in order to select the optimal approach for the prospective forthcoming project. Phase B also makes use of external private industrial studies which are contracted for, in competition, by private sector firms. The output of the Phase B study is a preliminary system design, reliability assessments and quality requirements, which serves as the initial basis on which actual contracts will be let to prime contractors in later phases. As Steps 16 and 17 indicate, the results of the Phase B study are once again reviewed by the program director and passed on to headquarters in the meteorological satellite program review committee for official action.

Phases C and D follow a comparable sequence, and Figure 7 presents the details of Phases A, B, C, and D in somewhat greater elaboration.

Interorganizational Relationships within Phases

Although Figure 6 deals with planning phases, it is important to realize that many of the interfaces between NASA and other groups are contained within a single planning phase. The user group, in each instance, has representatives who are part of the project team at the space flight center. Normally three or four members of a project team are NOAA personnel.

Frequent problem-solving meetings of all parties (headquarters, program, project, and user agency) are the major mechanism for the resolution of differences except for those formal issues on which headquarters and MSPRB approvals are granted. At the working group level, very little distinction is made between scientists from NOAA, scientists from NASA, and

PHASED PROJECT PLANNING
PHASE RELATIONSHIPS

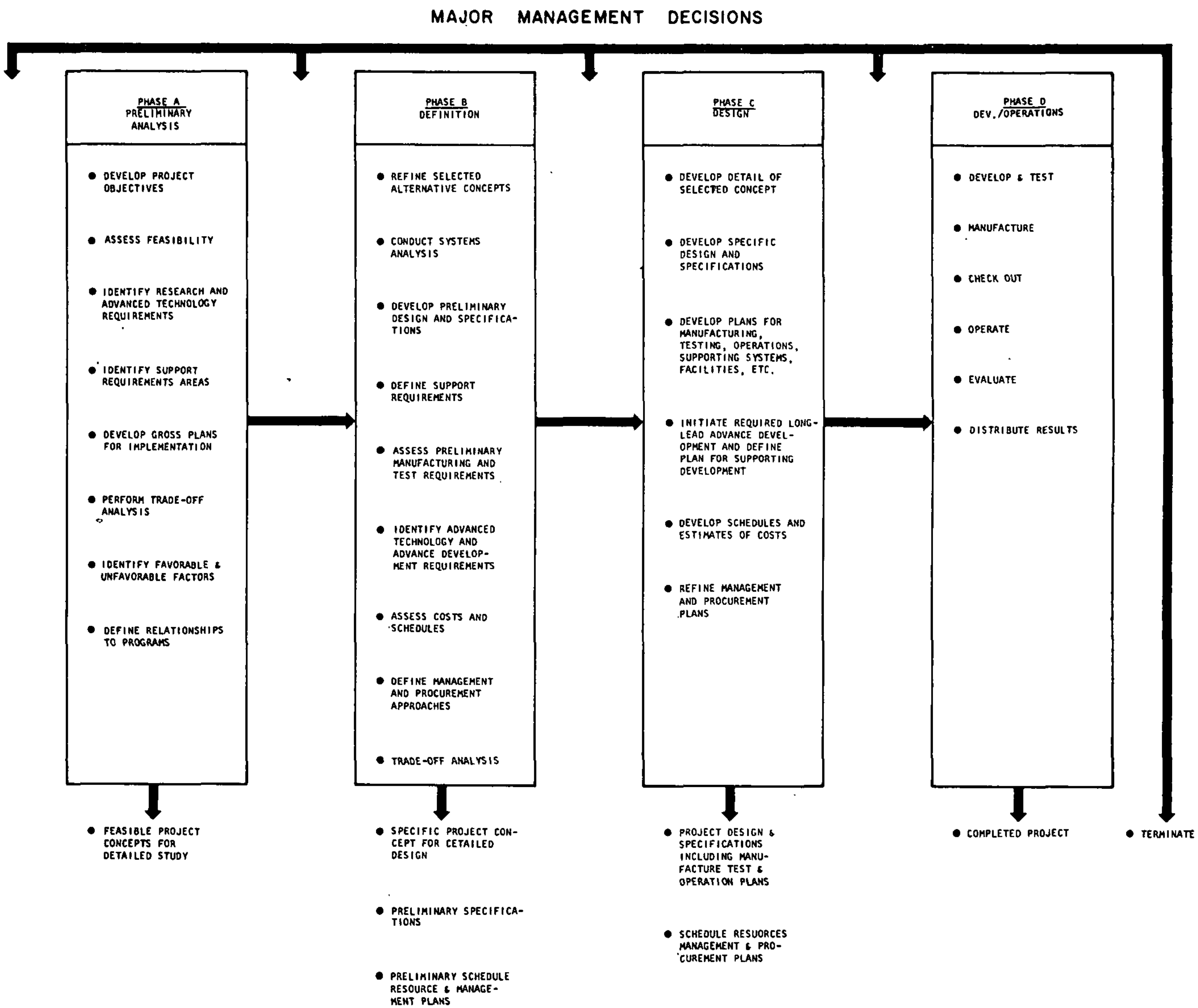

Figure 7

external scientists. The issue is the development of the most desirable method for accomplishing the mission objectives, and this task focus was described in interviews as the essential element in the relationship between all groups. Repeatedly scientists and project personnel stated the fact that jurisdictional and political issues were not the characteristic focus at the working level and that NOAA scientists and NASA scientists were scientists first.

However, not all issues can be resolved scientifically or technologically. Therefore the role of the Meteorological Satellite Review Board is strategic and crucial in resolving policy or allocational disputes.

Strengths of the Planning Sequence

A number of features of this particular planning sequence outlined in Figure 7 in our view contribute to the success of the Meteorological Satellite Program. These can be summarized in the following propositional form.

Proposition I. Division of labor between program and project staff strengthens the adequacy of both the technological and the budgetary interfaces.

It is very clear that communication with the Bureau of the Budget and with Congress is a very different matter than communication with scientists and engineers. One of the strengths of this particular planning process is the opportunity for program personnel to specialize in the more political interface with Congress and the Bureau of the Budget. Some of the notorious weaknesses of scientific and engineering personnel in dealing with legislative and budgetary bodies in other fields are renowned and do not need elaboration.

Proposition 2. The focus of program personnel on the basic mission objectives of the project, on consumer needs, and on the relationship of the project to the total program helps decision-makers to avoid projects deviating from mission objectives.

Many planning agencies have experienced the situation where as a project evolves, scientists or engineers begin to lose track of the original objectives or mission purpose and begin to "scientize" the project. One of the roles of the program staff is to ensure that both the objectives of the user groups, as agreed upon in the Meteorological Satellite Review Board, and the objectives of the project as it relates to the total set of NASA programs are honored. At any point in time, a program coordinator may plan a problem-solving meeting which reviews particular changes as they emerge technologically against the original objectives of the program and its time and cost schedules. This monitoring function is extremely important in that the scientists are tempted to suboptimize in terms of scientific excellence. For example, engineers will be concerned with engineering efficiency with little conscious concern for program objective or mission need.

What is not diagrammed in Figure 6 are the weekly meetings between program and project staff, the daily telephone calls between program and project staff, the formal monthly reviews, and the very formal yearly review at the headquarters level. This sytem of careful monitoring by headquarters staff of activities at the project level is probably more significant than the formal paper work support system. What is involved here is a very careful day-to-day awareness of the evolution of the project so that changes of technological developments which affect mission objectives, costs, and schedules are noted and can be dealt with consciously.

Proposition 3. The program planning cycle penetrates and integrates latent and not easily identified resources in each phase of program development. The composition of the project team within the Goddard Space Flight Center, which includes scientists from the user group, together with the normal matrix of both external contractors and internal scientific and technological personnel from Goddard, maximizes the technological insights of all reference groups.

Earlier we dealt with the strengths of the matrix structure, but these strengths are latent unless potential relationships become viable within the actual planning sequence for the project. The planning sequence in Figure 6 ensures that all the various constituencies are involved at different phases in the evolution of the project. Therefore, the latent strength of the matrix structure is activated as the planning sequence moves through its various phases.

Proposition 4. The planning cycle maximizes technological quality of a project and motivates participation of the external scientific community in educating scientific reference groups.

Both nationally and internationally (through GARP—Global Atmospheric Research Program) NASA has made conscious efforts to relate space technology to the scientific community. These efforts enhance the technological quality of the program. In doing so, NASA has not taken a passive role. As indicated in Step 11, it has initiated various week-long seminars dealing with selected topics so that the interrelationship of space technology to scientific questions can be understood more clearly by the scientific community. In addition, its policy of announcing flight opportunities and inviting experimentation operationalizes a conscious policy of NASA that the meteorological satellite should be an international facility.

In addition, NASA has learned that the review of proposals by single discipline oriented committee is not as functional as an interdisciplinary review body. Step 13 suggests NASA values multiple agency and multiple disciplinary resources as part of the process of reviewing individual proposals.

Proposition 5. Successful program development units use their own scientific and technological personnel to monitor contractors' performance.

One of NASA's strengths is that it does not simply turn over all responsibilities to a contractor without careful monitoring by its own scientific and technological personnel.

A frequent criticism of procurement policies of some government agencies is that the procuring agency does not have sufficient technological confidence to work closely with the contractor. NASA, however, has maintained in-house R&D competence which gives it confidence to perform four activities: (1) to know what to buy; (2) to know how to specify what they want to buy; (3) to monitor whether or not the contractor is actually providing what is originally specified; and (4) to know how to use what they buy. The Phase B study provides for this evolution in confidence on the part of the in-house project team so that what occurs in Phases C and D is, indeed, the purchase of technological instrumentation and resources from the private sector which is consistent with the mission objectives of NASA.

Difficulties with the Process

The above propositions summarize the critical strengths of the phased planning process and some of the dynamics of the planning process. However, there were complaints mentioned in interviewing with respect to the planning cycle which should be mentioned in closing.

The major complaint was that PPP has been too highly formalized. The cost of the formalization is predominantly one of time and documentation. If the cycles were truly discrete and if headquarters performed a formal review of Phase A before Phase B proceeded, and formally reviewed Phase B before Phase C proceeded, there would be a considerable amount of "down time" as perceived by the project personnel. Further, the elaborate procurement procedure entails a considerable amount of time when procuring a contract from the private sector. As a result, project managers feel the degree of rigidity in formal PPP procedures has decreased the speed and adaptability with which space technology can be applied to new problems.

The project managers have also complained that the formalization is "bogging them down in paper work." In essence, their disenchantment is not with the philosophy or spirit of PPP; rather with some of the requirements for documentation of individual phases of PPP.

It was not possible, based on our interview instruments, to determine the validity or to detail the reliability of these complaints. On the other hand, the pervasiveness of the comments made it clear that a planning cycle that becomes highly rigidified, relatively inflexible, and encrusted with a great deal of paper work may be self-defeating. The cycle, as we see it, is one in which provision is made for the movement of various reference groups into the planning process in an orderly and dynamic way, and therefore a process which would facilitate innovation. On the other hand, if there is a great deal of "down time," many delays and a great deal of unnecessary documentation, then the innovative thrust latently present in the planning cycle can be somewhat stultified.

In the last chapter of our report we will discuss some of the implications for this particular planning cycle for social system planning.

Chapter 9

IMPLICATIONS FOR OTHER PLANNING ORGANIZATIONS

It seems appropriate at the end of this manuscript which has (1) developed a theoretical perspective for a planning and development organization, and (2) presented a detailed case study of one of society's most sophisticated developmental organizations, to ask what the implications of this study are for other types of planning endeavors in our society. Urban and regional planning, health planning, environmental planning, social systems planning—all these planning endeavors are societally critical. Are there clues in the National Aeronautics and Space Administration's experience with the Meteorological Satellite Program that would be helpful to these other planning endeavors?

Figure 1 presents a summary of problems cited by Comprehensive Health Planning and Regional Medical Planning Organizations. Without being exhaustive, central dilemmas faced by these planning organizations seem to cluster on the following issues:

1. There is no clear-cut mandate defining the character of the planning organization and its relationship to existing operating institutions.
2. The character of planning itself is only vaguely understood.
3. The necessary staffing and organization patterns are, at best, dimly perceived.
4. The involvement of consumer and professional groups in the planning endeavor is fraught with difficulty.

Organizational Mandate

It does seem to us that some of the lessons of the Meteorological Satellite experience should be applicable to these planning situations. For example, the character of the organizational mandate for the Met Set program as a developmental organization was arrived at between NASA and the user agencies only with considerable difficulty. At the core of the present mandate is the notion that effective developmental structures should avoid creating manpower or facility redundance. Therefore, the program management structure for the Met Sat program is a truncated organization which substitutes part-time project resources obtained from functional and specialist units for self-possessed resources. The matrix of a program and project structure together with functional and specialist structures emphasizes the fact that in planning, development, and testing new technologies, the predominant mandate of the developmental organization is to work with and through existing functional, specialist and user groups.

In order to succeed as a truncated organization, the Meteorological Satellite Program had to clarify its mandate which legitimatized NASA as the developmental organization in such a manner as not to threaten NOAA as the operational organization. Further, coordination between the organizations was supported by policy review boards involving administrators at the highest levels of the involved organizations.

A key difficulty in social, health and regional planning observed by the authors is that a similar mandate often either does not exist or is not clearly understood. Consequently, there is the fear that the planning organization will in some way jeopardize or substitute for the existing organizations presently delivering services. Until these planning organizations are able to obtain an understanding between themselves as developmental programs and the operating organizations which provide the type of security that is presently represented in the agreement between NOAA and NASA, it is likely that these social planning organizations will experience the same troubled times that were present in the early days of the Meteorological Satellite Program.

The Development of Clear Planning Cycles

Much of the misunderstanding between scientific groups, professional groups, provider organizations, client groups, and planning agencies, however, relates not simply to the mandate of the planning agency, but also to the manner in which the agency develops its plans. There still exists in popular imagery that notion that someone isolated in his private office will write a plan or, alternatively, that a small inside clique will develop a plan which will some way jeopardize existing organizations, ignore existing scientific knowledge, treat the needs of clients and consumers cavalierly, or create a new organization which displaces present institutions. It is only the latter point (i. e., the avoidance of a duplicate institution) which is resolved by a mandate for developmental organization. To the extent that the developmental organization is seen clearly as a planning, development and testing vehicle rather than a competing agency in the delivery of services, the fear of displacement is lessened and the potential for collaboration is increased. However, the matter of cycling in important constituencies at critical phases of planning still remains.

In this respect, the phased planning cycle described in the Meteorological Satellite Case Study offers some important clues regarding pertinent bench marks for a complex developmental planning sequence. One of the remarkable strengths of the NASA program is the involvement of scientific groups, technical groups, and user organizations, in the identification of problems, and development of appropriate solutions. Until similar bench marks and involvement techniques evolve in social planning, it is unlikely that much trust will be accorded to planning agencies. This means that client organizations, scientific groups, professional groups, etc., all must be able to map critical evolutionary phases in major planning endeavors, identify appropriate techniques for their involvement at appropriate points in the process, and be able to identify decision-making structures that allow them to review major decisions. In this sense, a close scrutiny of the planning cycle at NASA and at the mechanisms for involvement of multiple groups at different phases of the planning cycle should be fruitful for social planners.

The success of the Met Sat program, however, is not simply based on the predictability of an orderly developmental planning cycle. There is also a philosophy of communication which stands behind the cycle. The principle of no surprises, and the close monitoring of each planning phase by the user organization means that cooperation and communication is not simply an intermittent event for purposes of cooptation, but is rather a continuous process which provides for honest confrontation of significant issues. It is out of this communication richness that trust emerges and fears begin to dissipate.

Since technical people involved in the developmental endeavor are often loathe to take time to maintain this type of critical communication, the role of the program coordinator staff is especially strategic.

Staffing

The pattern of a program manager who externally represents and internally coordinates a broad series of technical projects, of senior scientists who become project managers, and of project personnel who are assigned on a temporary basis to a particular technical endeavor is not unique to the National Aeronautics and Space Administration. What is unique is the addition to this matrix of the program management office. The NASA program coordinator (in their language, program manager) is perhaps the strategic glue in the system. Complicated matrix structures are only held together by information richness. The project manager, however, is likely to be primarily concerned with technical issues of the project, and may well be less sensitive to the intraorganizational power dynamics and interorganizational byplays, to say nothing of relationships with resource controllers. These relationships are the central province of the program coordinators. In our view, no parallel position exists in most social planning organizations. This facilitating, coordinating, communicating liaison role provided by the program coordinator is perhaps the critical lubrication in the complex matrix structure of the Met Sat program. Because the role of program coordinator is a staff role, it is easy to make the mistake of judging that the role is incidental to the project's success. Quite to the contrary—it seems to us that in an organizational sense, it is the essence of success holding together many of the tenuous relationships between headquarters staff, research groups, the client organizations, and the functional or specialist groups who must relate with the technical project team. Because the project director and his team will be essentially concerned with the technical achievement of the design objectives of a project, liaison and coordination will probably depend heavily on the program coordinator position. This underattended and often almost overlooked staff unit is as strategic to the success of a project as is the technical and administrative capacity of the project staff. NASA has achieved a synergistic division of attention and responsibility between program and project levels. Similar situations are not often found in social planning.

Conclusions

It is our feeling, then, that the meteorological satellite experience provides an example of critical organizational features which must underline large-scale developmental planning. Core features of the NASA design as exemplified by the meteorological satellite experience included:

1. A truncated program management organization which makes use of temporary resources from functional and specialist units.
2. A clear mandate which legitimatizes the program management organization as a vehicle for developmental planning.
3. A creative division of labor and responsibility between the program and project level, with institutional and managerial services performed in the office of the program manager, and technical administration as the major responsibility of the office of the project manager.
4. A proactive communication philosophy on part of the program office in relating timely information to headquarters staff, resource controllers and client organizations.
5. A style of planning that confronts problems by bringing together all relevant parties in a problem-solving context.
6. A planning cycle which assumes that client, professional, scientific, technical, and administrative groups are phased into decision-making at different, predictable, critical times in planning.

Interestingly enough, when we began our interviewing no one could answer the direct question: "What is the management system in the meteorological satellite program?" The purpose of this manuscript has been to share our perception of that system, and to put together our understanding of developmental program management of the Met Sat program, one of our society's most unique and successful experiments in complex planning can be studied by people engaged in social planning endeavors in other sectors of our society.

It is our hope that this manuscript will provide useful and critical insights as an appropriate spin-off of a space age adventure in planning.

Appendix A

QUESTIONNAIRE

100 ORGANIZATIONAL OR UNIT MISSION

101 How would you describe the goal or mission of
Your organization ( )
Your unit ( )

102 Are there any differences of opinion with respect to these goals or the means to achieve them?

Please summarize your answer to question 102 by circling a point on the following scale:

Significant differences of opinion	Very little opinion difference

/____/____/____/____/____/

103 What do you think are the weaknesses of the present program?

Please summarize your answer to question 103 by circling a point on the following scale:

These are major weaknesses	These are minor weaknesses

/____/____/____/____/____/

104 What changes do you recommend in the program?

200 RELATIONS WITH OTHER GROUPS

201 What groups does your [organization ( ) / unit ( )] have to please in order to be successful?

A____________________________________
B____________________________________
C____________________________________
D____________________________________
E____________________________________

202A Name of Group (refer to 201)________________________________

203A Please summarize your impression of this group's image of your organization (unit) by circling a point on the following scale:

Image very good   Image Relatively Bad

/________/________/________/________/________/

Explain:

204A What is the nature of this group's relation with your organization (unit)?

205A How are relations with this group maintained?

206A What are the recurring issues or differences of opinion between this group and your organization (unit)?

207A How are these differences resolved?

208A Do you have any suggestions for improving relations with this group?

202B Name of Group (refer to 201)________________________________

203B Please summarize your impression of this group's image of your organization (unit) by circling a point on the following scale:

Image very good   Image Relatively Bad

/________/________/________/________/________/

Explain:

204B What is the nature of this group's relation with your organization (unit)?

205B How are relations with this group maintained?

206B What are the recurring issues or differences of opinion between this group and your organization (unit)?

207B How are these differences resolved?

208B Do you have any suggestions for improving relations with this group?

202C Name of Group (refer to 201)____________________________

203C Please summarize your impression of this group's image of your organization (unit) by circling a point on the following scale:

Image very good — Image relatively bad

/______/______/______/______/______/

Explain:

204C What is the nature of this group's relation with your organization (unit)?

205C How are relations with this group maintained?

206C What are the recurring issues or differences of opinion between this group and your organization (unit)?

207C How are these differences resolved?

208C Do you have any suggestions for improving relations with this group?

202D Name of Group (refer to 201)____________________________

203D Please summarize your impression of this group's image of your organization (unit) by circling a point on the following scale:

Image very good | Image relatively bad

/ / / / / /

Explain:

204D What is the nature of this group's relation with your organization (unit)?

205D How are relations with this group maintained?

206D What are the recurring issues or differences of opinion between this group and your organization (unit)?

207D How are these differences resolved?

208D Do you have any suggestions for improving relations with this group?

209 Do you have an advisory or policy board committee? If so, what is its composition?

210 To what extent do members of your board (committee) legitimatize your organization (unit) to outside groups as opposed to simply representing their own reference groups to the board (committee)?

Please summarize your answer to question 210 by circling a point on the following scale:

Significantly help legitimatize our organization (unit) | Serve only as a representative of own group

/ / / / / /

300 ORGANIZATIONAL (UNIT) PLANNING

301 What is the planning process in your organization (unit)? Outline steps sequentially)

302 What types of problems are encountered in such a planning process?

Please summarize the significance of these problems by circling a point on the following scale:

Major problems — Minor problems

/______/______/______/______/______/

303 How successful is your program in effecting and legitimatizing new experiments away from traditional line programs?

Please summarize your answer to question 303 by circling a point on the following scale:

Very successful — Not successful

/______/______/______/______/______/

304 What kinds of problems do you face when you seek to transfer the learning from the experimental program back to traditional line programs?

Please summarize the significance of these problems by circling a point on the following scale:

Very serious problems encountered — Only modest difficulties encountered

/______/______/______/______/______/

305 How are clients or user groups involved in program planning?

306 Are there any difficulties with respect to client involvement?

Please summarize the significance of these difficulties by circling a point on the following scale:

Very serious difficulties — Only modest difficulties

/______/______/______/______/______/

307 Are outside technical experts, task specialists and resource people presently involved in program planning?

Please summarize the extent of involvement by circling a point on the following scale:

Great involvement of outside technical specialists	Outside specialists almost never involved

/______/______/______/______/______/

308 What type of technical knowledge not possessed by staff would be helpful if it were integrated into planning?

309 What difficulties do you have when you involve outside technical specialists in program planning?

Please summarize the significance of these problems by circling a point on the following scale:

Major problems	Minor problems

/______/______/______/______/______/

310 How is your organization's (unit's) total set of programs evaluated?

311 How adequate is this evaluation?

Please summarize your answer to question 311 by circling a point on the following scale:

Very adequate	Evaluation is inadequate

/______/______/______/______/______/

312 Please indicate the extent of planning efforts and time focused on the time cycles below:

Immediate crises:

Great extent very little

/______/______/______/______/______/

Short-run planning:

Great extent Very little

/______/______/______/______/______/

Intermediate-run planning:

Great extent Very little

/______/______/______/______/______/

Long-run planning:

Great extent Very little

/______/______/______/______/______/

313 What are the decision rules which determine which programs or proposals will receive funding?

400 ORGANIZATION (UNIT) STRUCTURE

401 Please list the key units and positions in your organization (unit).

402 Describe how work and decisions flow through this structure. Where does it enter? How is it processed? How does it leave?

403 What are the real problems of getting the job done in this system?

Please summarize the significance of these problems by circling a point on the following scale:

Major problems | Minor problems

/______/______/______/______/______/

404 How would you describe the character of the personnel in the unit (organization)? Technicians, specialists, generalists? (Identify each specialized group in terms of differentiated skills or competence.)

405 How are the various [(positions within the unit) / (units within the organization)] coordinated?

406 Is there any information which some [positions / units] are not receiving which they should receive in order to do a better job?

Please summarize your answer to question 406 by circling a point on the following scale:

Present communication is excellent | Present communication is poor

/______/______/______/______/______/

407 Which units in your organization (people in your unit)have the greatest power over decisions?

408 Do you think this balance of power ought to be changed in any way?

Please summarize your answer to question 408 by circling a point on the following scale:

Present power balance is excellent | Present power balance is poor

/______/______/______/______/______/

409 What are the issues or recurring sources of stress between units (people)?

Please summarize the significance of these stresses or issues by circling a point on the following scale:

Very serious stresses — Relatively minor stresses

/______/______/______/______/______/

410 When disagreement between units (people) arises, how is it resolved?

411 How frequently are the following conflict resolution strategies used:

Resort to a higher authority:

Very frequently — Infrequently

/______/______/______/______/______/

Bargaining and negotiation:

Very frequently — Infrequently

/______/______/______/______/______/

Mediation by outside experts:

Very frequently — Infrequently

/______/______/______/______/______/

Special problem-solving meetings:

Very frequently — Infrequently

/______/______/______/______/______/

Smoothing and ignoring the real differences:

Very frequently — Infrequently

/______/______/______/______/______/

412 How would you describe the morale of this organization (unit)?

Please summarize your answer to question 412 by circling a point on the following scale:

Morale is very high and positive	Morale is very low and negative

/______/______/______/______/______/

413 Would you describe your organization (unit) as a team, or as a group of loners, or as a group of cliques?

Please summarize your answer to question 413 by circling a point on the following scale:

Strong teamwork	Relatively separated as individual groups

/______/______/______/______/______/

414 How much confidence and trust do people have in each other?

Please summarize your answer to question 414 by circling a point on the following scale:

Open, friendly, trusting	Closed, competitive, hostile

/______/______/______/______/______/

415 Is there anything else about the organization (unit) you would like to see changed?

500 POSITION CHARACTERISTICS

501 How would you describe the duties of your particular position?

502 In terms of the tasks that you perform, which do you like most and which do you like least?

503 Briefly describe your education and career history.

504 How much freedom do you have to do things your own way?

Please circle the appropriate response on the scale below:

Great freedom ... Little freedom

/______/______/______/______/______/

Explain:

505 If you were hiring someone to take your place, what types of attributes or skills would you look for when you screened a candidate?

506 How is your work evaluated?

507 In what areas would you like additional education or training?

508 To what extent are the decisions you make each day similar to the decisions that you face on other days?

Please circle the appropriate response on the scale below:

Decisions very similar ... Decisions very dissimilar

/______/______/______/______/______/

Explain:

509 Could somebody be trained to make these decisions in a reasonable period of time?

510 In the course of doing your work, how often do you come across specific but important problems that you do not know how to go about solving?

Please circle the appropriate response on the scale below:

Very often   Very seldom

/______/______/______/______/______/

Explain:

511 What do you do in those cases where you encounter a problem that you do not know how to go about solving?

512 What types of mistakes do people in your type of work make?

513 What happens when such mistakes are made?

514 What kind of direction and supervision do you receive (from supervisor; by negotiated goal; by system)?

515 How adequate is this direction and supervision?

Please circle the appropriate response on the scale below:

Very adequate   Not adequate

/______/______/______/______/______/

Explain:

516 To what extent are there policies or rules which guide you in making decisions?

Please circle the appropriate response on the scale below:

Many policies and rules   Almost no policies and rules

/______/______/______/______/______/

Explain:

517 What types of stresses are you exposed to in your job?

518 How much influence do you have in areas important to your job?

519 How much influence do you think you should have?

Please circle the appropriate response on the scale below:

More influence | Less influence

/______/______/______/______/______/

Explain:

520 How much of your time is spent on the following types of tasks?

Tasks that can be completed in one hour:

Great deal | Very little

/______/______/______/______/______/

Explain:

Tasks that can be completed in two to four hours:

Great deal | Very little

/______/______/______/______/______/

Explain:

Tasks that can be completed in four to twenty hours:

Great deal | Very little

/______/______/______/______/______/

Explain:

521 To what extent are each of these a source of satisfaction to you in working in your position?

Salary/Financial benefits:

Very important source
of satisfaction   Unimportant source

/______/______/______/______/______/

Friendships and informal relations:

Very important source
of satisfaction   Unimportant source

/______/______/______/______/______/

Satisfaction with organization's accomplishments:

Very important source
of satisfaction   Unimportant source

/______/______/______/______/______/

Satisfactions from feeling you have solved difficult problems:

Very important source
of satisfaction   Unimportant source

/______/______/______/______/______/

Technical and/or professional satisfaction in doing your own job well and improving your skills:

Very important source
of satisfaction   Unimportant source

/______/______/______/______/______/

522 Is there anything about your present position you would like to see changed?

523 Think back over the past year. I would like to have you tell me something about your work which pleased you very much. And something about your work which made you feel bad.

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TORNADO FORECASTING

Hans Rosendal*

Tornadoes have always been a threat to inhabitants of the United States to the east of the Rocky Mountains. Our nation's early history contains several accounts of the ravages wrought by these storms and of lives lost during an epoch of a sparsely settled continent. The tornado which struck Charleston, South Carolina on September 10, 1811 was the first major tornado to strike a larger settlement and several hundred persons perished in this disaster. Likewise, terrible destruction was wrought at Natchez, Mississippi, on May 7, 1840, by a powerful tornado which, during its brief visit, took the lives of 316 people and injured hundreds more. These incidents and many others of lesser magnitude left a deep impression on the early residents and stimulated research into the problem by scientists of succeeding generations.

Over the relatively short span of time covering European settlement of North America, about 10,000 United States residents have lost their lives to tornadoes. The worst single disaster was the famed Great Tristate Tornado of March 18, 1925, which killed 689 persons in Missouri, Illinois and Indiana. With the increased population and the spread of suburbs and mobile home developments, the potential for future huge disasters looms large

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on the horizon. In addition, the subtle change of the earth's surface due to man's activity may affect the frequency and intensity of tornado formation in several ways, nearly all pointing toward an expected increase in tornado activity.

The tornado problem is mainly an American problem. The unique physical layout of North America with respect to sources of warm and moist air from the Gulf of Mexico and Caribbean Sea, and cold and dry air from the Canadian Arctic, plus the effect of terrain on the so-called low-level jet, polar jet and subtropical jet, all combine to produce the ingredients needed for tornado formation in the central United States more often than anywhere else in the world. Fortunately, the combination of meteorological parameters which produce the really severe mass outbreaks of huge tornadoes, such as occurred during the Palm Sunday outbreak of April 11, 1965, is rare and does not occur every year. On that April afternoon and evening, at least 37 separate tornadoes struck in the fairly densely populated countryside of Iowa, Wisconsin, Illinois, Indiana, Michigan, and Ohio killing 258 people, injuring 3148, and causing property damage estimated in excess of $250 million. No large cities or metropolitan areas were in the direct path of the Palm Sunday tornadoes. If any had been, the above figures would certainly have been much higher.

Early attempts to learn about the climatology of tornadoes were helped greatly by Lt. John P. Finley of the Signal Corps, who in 1881 published the Signal Office Professional Paper No. 7 entitled "The Character of Six Hundred

Tornadoes." From these data it was learned that tornadoes form within the circulation of a larger low pressure system in an area usually several hundred miles to the southwest of the center within the warm and moist sector of the storm. The destabilizing effect of solar heating of the surface seemed important since a great majority of the tornadoes were found to form during the late afternoon hours, though locations on the Gulf Coast were less influenced by this effect; many tornadoes were found to occur in this region during the very early morning hours. The seasonal march of the areas of occurrence northward during spring from a wintertime maximum near the Gulf to a late spring and early summer maximum over the plains states was also noted by the early investigators. Finley and others also elaborated on the reasons for the coincidence of large hail and unusually intense displays of lightning with tornado-producing thunderstorms.

Lt. Finley elaborated on the problem of issuing forecasts of tornadoes to the public in the August, 1890 issue of the American Meteorological Journal. Finley ended the fine article in which he summarized his work with tornadoes with the following conclusion:

"The writer is of the opinion that the forecasting of conditions favorable to the development of tornadoes and designating the quadrant of a state in which such conditions shall give rise to local signs that the inhabitants of that section can rely upon, is entirely practicable. By this admission he does not mean to convey the idea that the exact path of the funnel-shaped cloud can be indicated in the dispatch, for that would be impossible except by chance. The average width of the tornado's track is only a few hundred yards, and several of these storms may occur in the same county, with entirely independent paths of destruction and distinct cloud formation.

"It doubtless appears that the quadrant of a state, especially the larger ones, is a very extensive area to cover with a single tornado prediction, but the fact must not be overlooked, that where the conditions are favorable for tornadoes, local storms having various degrees of tornado violence, the development of which it is very important to herald, occur here and there over a large section of country. Therefore, the scheme of local storm predictions for state quadrants would seem to possess the elements of success, for, while the peculiar funnel-shaped cloud might not appear, the conditions are such that local storms of great violence would very likely occur, and destruction to life and property ensue. Although of course the area here indicated (statequadrants) is quite variable in extent, yet it possesses the decided advantages of definiteness, familiarity to the people who are interested, and brevity of expression in rendering a concise dispatch. The local signs of tornado development are certain, easily observed and well defined. With the people well informed concerning these indications, and there appears no reason why they should not be, the prediction of conditions favorable for local storms, issued from some central meteorological office, would, if successful, supplement the local signs with beneficial results. Failures in the official predictions would not only bring out more distinctly the importance and reliability of local signs, thus creating an interest in their careful observance, but would obviate the occurrence of serious results when wrong predictions were made, inasmuch as the people would test their trustworthiness by an appeal to the local signs."

Attempts to forecast tornadoes did not prove very fruitful, and the Weather Service actually discouraged any mention of tornadoes in forecasts, since the art of predicting their occurrence had given such poor results and the mere mention of the word tornado evoked fear in the populace. Basic research, nevertheless, continued on the problem. The advent of plentiful upper air data during and after World War II advanced research immensely. The concepts of the vertical stability of dry and moist air helped to explain the environment within which severe storms form and the rapid overturning of the atmosphere experienced near these thunderstorms. The destabilizing effect of a low-level jet feeding heat and moisture into the cyclone at low levels, and a strong upper jet acting as the outflow mechanism aloft while also helping to transport cold and dry air in over the region, were clues that meteorologists would look for when concerned with forecasting the occurrence of severe thunderstorm and tornado development.

The U. S. Air Force's Air Weather Service increased its interest in tornado forecasting after Tinker Field, Oklahoma, was struck twice within a week in late March 1948 with losses to aircraft and hangars mounting to more than $15 million. Lt. Col. Fawbush and Major R. C. Miller and their associates at Tinker Air Force Base devised in 1952, after several years of research, a workable method of forecasting tornadoes which has been improved from time to time as further investigations and experience accumulate. Prediction of the extreme turbulence in the neighborhood of severe thunderstorms with its implications for flight safety also attracted Air Force interest.

The National Weather Service cooperated with the Air Weather Service in this special attack on the tornado problem. A rash of severe tornadoes striking populated areas in 1953 helped focus national attention and support, and the Severe Local Storms Forecast Unit (SELS) was established in Suitland, Maryland to devote full time and energy to tornado forecasting. The SELS unit later moved to Kansas City and with the organization of ESSA in 1965 was included in the National Severe Storms Forecast Center (NSSFC). NSSFC routinely issues the now-familiar Tornado Watches when conditions are right for tornado development while local weather stations follow through with Tornado Warnings when tornadoes are confirmed in the area.

Our knowledge of the climatology of tornadoes has also improved over the years. The Weather Bureau Technical Paper No. 20, "Tornado Occurrences in the United States," published in 1952, has proven extremely informative and useful to forecasters. The Weather Bureau Research Papers No. 40 and 41 on the Dallas and Fargo tornadoes of 1957 also stimulated research and interest. Such allied discoveries by Tepper concerning the connection between barometric pressure jumps and tornado development, and by Vonnegut, Jones, and others with respect to the peculiar spherics emission by tornado thunderstorms are improving our ability to detect and track tornadoes. Spherics is another name for the annoying crackle of static experiences on an AM radio receiver during a thunderstorm. Research in this direction is in progress at the NOAA Environmental Research Laboratories at Boulder, Colorado, and at Norman, Oklahoma. Much individual research is also going on elsewhere, with important contributions in recent years coming particularly from Professor Fujita at the University of Chicago, Prof. Darkow at Missouri, Professors Johnson and Sechrist at the University of Wisconsin, and the late Professor Bates at St. Louis University. The personal efforts of the late Snowden D. Flora in writing the popular book Tornadoes of the United States also bears mention.

The forecast techniques applied at the NSSFC in predicting tornado or severe thunderstorm occurrences are based on surface and upper air data on the wind, pressure, moisture and temperature distribution horizontally as well as vertically. A day or two in advance the NSSFC can predict with good reliability which areas will be susceptible to tornado or severe thunderstorm formation. This is particularly true of the very destructive family-type outbreaks in the spring. Numerical weather-prediction charts supplied by the National Meteorological Center (NMC) in Suitland, Md., are an integral part of this forecast support system and give twenty-four-hour to seventy-two-hour prediction of the large-scale surface and upper air flow patterns. NSSFC forecasters use these charts in their issuance of the convective outlook which covers forecasts for a larger area more than twelve hours in advance. When it comes to issuance of tornado watches valid for the same afternoon and evening, special attention is paid to the most recent upper air and surface data. A typical tornado watch is issued about noon local time for the afternoon and early evening hours from 2:00 pm to 8:00 pm and covers an area about 150 miles wide and 300 miles long.

Radar has been used for many years as an important tool in detecting and tracking severe thunderstorms. Tall precipitation echoes can be tracked with a high degree of accuracy up to 150 miles away from the station. Radar meteorologists found at an early date that severe thunderstorms usually were oriented into squall lines or similar groupings associated with fronts or convergence lines in the flow pattern. Also noted was the good relationship between echo height and brightness and the severity and presence of hail. Any cell penetrating the tropopause automatically was suspect. Echoes moving into a diffluent flow pattern with the divergent movement of a few brighter cells to the right of the remainder also meant in many cases that a tornado-bearing cell was present. Nearby echoes with a hook-shaped appendix on their right rear flank or some which displayed an unusual hole in the echo were often recognized as tornado-bearing cells.

The meteorological satellite was relatively slow in being put to use in tornado research. The early TIROS series had few glimpses of tornado areas due to the constant orientation in space of these vehicles precluding their looking at the surface of the earth directly below more than a small percentage of the time. Also, the resolution of the vidicon cameras was relatively poor for picking up details. The later earth-oriented polar-orbiting ESSA and NOAA satellites gave once-daily coverage over the entire earth in early afternoon local time, so the interesting very rapid late afternoon and early evening growth in the huge cells which spawn tornadoes was not often monitored. Nevertheless, several views of the large cirrus canopies or blow-offs of the peculiar cells or groups of cells were obtained and pictures of the "square" or "parallelogram" clouds containing tornadoes underneath were investigated.

The launching of the ATS geosynchronous satellite viewing North America with a high-resolution spin-scan camera gave meteorologists their first chance to observe tornado development in a sequential fashion with the aid of pictures received fifteen to thirty minutes apart during daylight hours. These satellite pictures, because of cloud screens and insufficient resolution, do not show the actual tornado funnel. They do, though, reveal the unique appearance of the huge cumulonimbus clouds which have tornadoes associated with them. These clouds appear a magnitude larger than the ordinary thunderstorm clouds and their shapes have been variously described as "diamond," "oval," "square," or "cigar"-shaped. What the satellite sees are the huge cirrus plumes, also commonly called anvils or canopies, of these cells. The flat upper surface of these canopies will spread out and grow in size at a rapid rate proportional to the vertical motion experienced within the strong updraft in the cells during their formative stage. Therefore plume growth is a measure of the cells' vigor. The plumes or canopies seem to reach a steady-state size after a time as several towers of rising motion feed condensed moisture into them while sinking motion along the sides and ends of the plumes causes heating and evaporation of the cloud crystals or droplets. The tornadoes below often persist during this mature steady state of the thunderstorm conglomorate and therefore can be tracked as long as the canopy is visible, which may even be nearly an hour after local sunset. Later, infrared capability can help monitor these cells during hours of darkness. The infrared signature of these cells should be equally obvious because of the extreme height and low temperature of the cloud tops. The precise locations of the tornadoes under the canopies can only be estimated at this time, but the upwind end, near the origin of the plume, may be the logical place to expect to find the funnel. Protuberances through the canopies may also be associated with the funnel below. Again, more research is necessary to determine the location of the individual tornadoes.

Study of the satellite pictures taken on April 23, 1968 during a tornado outbreak in the Ohio valley has helped Professors Johnson and Sechrist at the University of Wisconsin formulate a new theory concerning the factors which initiate tornado development. It has been observed by many meteorologists over the years that tornadoes and severe thunderstorms form just east of the clear area which slices into the low pressure system from the southwest. The area of tornado formation is near the classical cold front which is the leading edge of dryer and cooler air, the line along which surface winds change (usually from southeasterly to southwesterly). Another cold front, ahead of the advancing cloudy, cold polar air coming down from the northwest, lags behind—perhaps another several hundred miles. Seen from space this intermediate air mass of drier, clear air would appear as a wedge or tongue curving into the center of the cyclone from the south or southwest. The huge cells with large blow-off plumes discussed in the previous paragraph would form along the eastern or southeastern flank of this clear tongue. Johnson and Sechrist in their research traced the air within this clear tongue back to a polar jet aloft curving southward and southeastward over the Rockies. This clear tongue therefore consisted of air from the middle and upper troposphere which was brought down to ground level, usually helped by the destabilizing effect of solar heating of the dry upper plains states. Johnson and Sechrist went on to show that the dynamic effect of a jet sinking down into the cyclone at low levels would be to destabilize the moist warm air pushed ahead of it and along its flank and set off convection. The strong subtropical jet would act as the mechanism sustaining this convection by removing the outflow aloft. Vince Oliver of the National Environmental Satellite Service has suggested that the subtropical jet also might be needed to supply the spin vorticity to twist the thunderstorm echoes. Many tornadoes have been shown to be associated with rotating thunderstorms. The clear tongue of an extratropical cyclone is one of the most striking aspects of the appearance of the storm as seen from space. Locating or pinpointing the area of tornado activity with respect to the clear tongue may therefore be of great value to the operational forecaster using these pictures. The problem of forecasting tornadoes within the circulation of a tropical cyclone or hurricane may also be alleviated if it is shown that hurricanes with clear tongues in them are also hurricanes with tornadoes.

Antecedent conditions outside the immediate area of suspected tornado formation have also been checked in great detail by Fujita, Vince Oliver and others. Clues as to the location and strength of the subtropical jet are looked for over the data-sparse tropical eastern Pacific and over Mexico. A cirrus veil accompanies this jet along part of its journey and cloudiness patterns including cirrus blow-offs of underlying convection over warm waters and mountain slopes give evidence of its location. The more sharply-curving polar jet likewise often has an accompanying cirrus veil to help delineate it.

The NSSFC in 1970 received access to ATS pictures on a real-time basis and currently is developing techniques for the operational use of these pictures. The 1970 tornado season was meager as such seasons go: very few tornado outbreaks occurred. The May 16, 1970 Lubbock tornadoes occurred before the NSSFC received operational use of the pictures. The Lubbock tornadoes also occurred very late in the day, and only the beginning of this intense activity was visible before nightfall. Fujita has taken the ATS pictures of the Lubbock case and produced movie loops of greatly magnified pictures which, because of the detail inherent in the spin-scan pictures, give forecasters many clues to look for in tornado development.

Real-time use of the ATS pictures for monitoring antecedent or incipient conditions and for observing formation and development of the tornado-bearing cells in conjunction with standard meteorological and radar data holds great promise for improving short-range tornado forecasting. Even though cumulonimbus clouds which produce tornadoes grow at tremendous speeds and the length of time between pictures becomes critical, the huge canopy-covered cells are, as far as is known, rather mature for thunderstorms by the time tornadoes form, and continue to exist, so some lead time for forecasting and warning purposes is still available. Of particular importance, therefore, in observing severe storm development is the frequent and rapid receipt of high-resolution pictures from the satellite. The geosynchronous satellite of the ATS type with the spin-scan camera has helped meteorologists approach this goal. Future manned orbiting observatories, either at geosynchronous altitude for continuous viewing, or in near-earth orbits for increased resolution, but only periodic observing, may help us further to approach these goals. The satellite thus promises to become an important link in the national severe storm warning system, a system which already has saved many lives since its initiation in the middle 1950's.

To get a better idea of the current operational use of satellites in tornado observing and forecasting at the National Severe Storms Forecast Center at Kansas City, a visit was made to this center on March 23-25, 1971, and questions were directed at several staff members who were most cooperative and helpful in showing the research and facilities connected with the usage of satellite data.

The NSSFC is under the direction of Allen D. Pearson and his principal assistant Joseph G. Galway. The center consists of three major forecast divisions which are supported by the National Communications Center. These three divisions are the Public Forecast Division, the Aviation Weather Forecast Division, and the Severe Local Storms Forecast Division. The SELS unit of the latter division has the responsibility for the issuance of severe weather watches to the general public and aviation interests for the contiguous United States. This unit maintains a continuous weather watch for thunderstorm activity and issues once daily an outlook for severe thunderstorm activity for the following 24-hour period. When conditions warrant, the unit will issue watches for specific areas and time periods. A severe thunderstorm is one in which any or all of the following phenomena occur: 1) hailstones of three-fourths inch diameter or larger, 2) surface wind gusts of fifty knots or greater, or 3) tornadoes. Adjacent to the SELS unit is located the Radar Analysis and Development Unit (RADU unit) which has as its duty the collection of hourly radar data from numerous radars across the country and display of a composite of these data on a map for

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transmission to users via facsimile or in message form over the national teletypewriter networks.

The use of real-time satellite data on an experimental basis within the NSSFC dates back only to 1970 when the center received a drop on the ATS-III satellite pictures transmitted from Suitland. Mr. William Williams is the meteorologist in charge of satellite operations. He is assisted by personnel for the operation of the receiving equipment and the photographic processing facilities. Pictures on the days of the visit were received at approximately twenty-five-minute intervals from 8:30 am CST to about 2:00 pm CST. On active days an extended cut-off time of 3:15 pm is allowed. (This early cut-off time may subsequently have been extended as NOAA obtained increased control over the ATS vehicle, since this is the usual time of the day when tornado development becomes active.) To increase the frequency of receipt of pictures, the ATS spin-scan camera can be programmed to photograph only the northern hemisphere rather than the whole disc of the earth.

On active thunderstorm days when conventional meteorological data tell the forecasters on duty that tornado development threatens, these pictures are assembled into movie loops for detailed study of the development of severe thunderstorms. Pictures are also printed in enlargements covering the United States portion with a grid overlay for easy identification of suspect areas. Landmarks used are Lake Okeechobee, Yucatan, Baja California, White Sands, the Black Hills, etc. The ATS-III pictures as yet are only received on weekdays. Forecasters therefore were unable to follow the large, severe tornado outbreak across the southern states on Sunday, February 21, 1971, when more than 100 people lost their lives and in excess of 1,000 received injuries from a rash of tornadoes which devastated many rural communities in Mississippi.

In summary, meteorologists at the NSSFC rely on conventional data transmitted over the National Facsimile Network and teletypewriter circuits from the National Meteorological Center (NMC) for forecast guidance to determine conditions conducive to severe thunderstorm formation. Part of these conventional data have been improved because of observations from the meteorological satellites. The twenty-four-hour to seventy-two-hour barotropic or baroclinic numerical forecast charts are particularly valued and studied by the NSSFC forecasters. Synoptic weather patterns conducive to severe thunderstorm or tornado formation are readily recognized. Such conditions usually involve a deep and wide eastward-progressing upper trough traversing North America with associated strong upper jets and warm, moist air at low levels to the southeast of the surface low pressure system.

On mornings of expected tornado outbreaks, very detailed analyses of the large-scale horizontal temperature pressure, moisture and wind distribution at the surface and aloft are carried out. Individual balloon soundings of the vertical distribution of these same parameters are also analyzed in detail to delineate the areas for which watches may have to be issued. Additional upper air balloon soundings or reports from pilots may be requested. The NSSFC has adopted computer technology to a high degree for the abundant data-processing and plotting work. The region below a strongly diffluent flow pattern in which the subtropical jet curves eastward and the polar jet northward above the surface warm front is usually included in a tornado watch area. The timing of the issuance of the watch generally coincides with the climatologically most likely time of day for tornado development, namely the afternoon and early evening hours between 2:00 pm and 8:00 pm local time. If severe activity persists past 8:00 pm, the watch areas may be extended in time and space.

It is during these late afternoon and early evening hours until sunlight disappears from the tops of the tallest thunderheads in the area of concern that meteorologists search each successive satellite picture for signs of tornado or severe storm development. Conventional meteorological data and reports from radar stations, pilots and the public in the area of activity are used in conjunction with the satellite pictures. If and when a damaging storm or tornado is confirmed, a tornado warning is issued for areas downstream, and neighboring thunderstorm cells, particularly to the south and east, are watched very closely for signs of tornado formation.

The operational use of satellites in tornado or severe thunderstorm detection or tracking is still in its infancy. Enough tornado cases have been studied in retrospect with satellite pictures at hand to realize the promising future that satellites have in this vital observing and warning mission. There are a number of small, erratic, and less damaging tornadoes with short tracks which probably will not be detectable from satellites. On the other hand, the familiar cloud patterns of the large family-type outbreaks, which are so damaging to large areas and which cause the most fatalities, should be readily recognizable, especially as new techniques are developed and as nighttime infrared capabilities are added. In addition, a continued gain in theoretical knowledge and insight into the severe thunderstorm problem will be realized as researchers become able to compare and utilize satellite data together with conventional data in more and more cases.

APPENDIX

SOUTHERN CORN LEAF BLIGHT ADDENDUM TO THE CASE STUDY: IMPACT ON CORN PRODUCTION FROM RECENT ADVANCES IN SATELLITE METEOROLOGY

R. H. Andrew*

Southern Corn Leaf Blight, a corn disease previously of minor importance and confined to the southern half of the Corn Belt, suddenly in the late summer of 1970 emerged as a serious malady. Primary cause is a new race of the fungus Helminthosporium maydis called the T-strain which produces a new crop of spores within a seven-day period. The disease has caused serious loss in southern states. With unusually warm, wet weather in the Midwest in 1970, it progressed northward rapidly and was detected in Wisconsin in August.

Because of the close relationship of weather to development of this disease, an addendum to the case study of corn as related to satellite meteorology was pertinent. To this end representative producers and agricultural extension and research personnel in the blighted area were contacted to document the economic impact of improved forecasting on chemical control, sanitation procedures, production plans, alternate uses and harvest of the corn crop.

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Conferences were held with the following representative individuals and firms, among others, during January of 1971:

T. F. Toohey, Cotton Producers Association (CPA), Atlanta, Ga.

Dr. Norman E. McGlohon, Head, Extension Plant Pathology, Univ. of Ga., Athens

Dr. D. H. Teem, Extension Agronomist, Dept. Agronomy and Soils, Auburn Univ., Auburn, Ala.

Dr. Luther Farrar, Extension Pathologist, Botany and Plant Pathology, Auburn, Ala.

Dr. Gene E. Scott, Agronomy, Miss. State Univ., Starkeville, Miss.

Dr. M. C. Futrell, Plant Pathology and Weed Science, Starkeville, Miss.

Mr. W. F. Moore, Plant Pathology and Weed Science, Starkeville, Miss.

Weather as Related to Movement of Inoculum and Geographic Distribution of the Disease in 1970

The origin of the 1970 outbreak in the United States apparently was in the Belle Glade, Florida area where Southern Corn Leaf Blight reached epiphytotic proportions during late February and early March. Inoculum from diseased fields in the Belle Glade area was carried northward by winds from the south and deposited throughout Florida, southern Georgia, and the coastal areas of Alabama, Mississippi, Louisiana, and Texas.

Between June 13 and July 7, spread of inoculum apparently began to form two definite paths. One path moved northward up the Mississippi

River and surrounding areas on into southern Minnesota and Wisconsin. The second path moved through coastal Georgia, South Carolina, and the coastal areas of southeast North Carolina where the disease was found on June 25. During this period, June 13 to the first part of July, a lack of moisture slowed development of the disease through Alabama and Georgia.

Wisconsin first reported Southern Corn Leaf Blight on July 7 in the southern part of the state. The initial report of this disease in Michigan was from the western and central parts where it was observed before it was reported in northern Indiana, indicating the inoculum had moved from southern Wisconsin across Lake Michigan.

Georgia reported a rate of movement of the disease of about twenty miles per day. Spread was temporarily halted in some cases by natural barriers. Field observations indicated, in some cases, the movement of inoculum was slowed by forests and mountain ranges. Blight was observed on the Georgia side of the Blue Ridge Mountains two weeks before it was observed on the Tennessee side. By August 28, blight had been reported throughout the eastern part of the United States, and by September 20 it was as far westward as north central Kansas.

The progressive state-by-state spread from Florida into southern Canada indicates the possibility that Race T may not overwinter in the area north of southern Illinois. Field observations indicated very little moisture was necessary for disease development. In many areas, corn which was suffering from the lack of moisture had severe Southern Corn Leaf Blight.

Dew apparently furnishes sufficient moisture for sporulation and infection to occur. In drought areas with heavy dew corn was severely spotted, but in other drought areas without dew the corn had few if any spots. The amount of dew on the foliage and the length of time it was present apparently was a contributing factor in the occurrence of the disease in a few areas.

Air movement within the corn fields influenced the degree of early infection. High plant populations and the presence of weeds apparently increased severity.

The rapid spread of inoculum and the subsequent serious development of the disease in 1970 was brought about by the presence of favorable environmental conditions, widespread inoculum dissemination and the very intensive acreage planted to corn hybrids containing TMS cytoplasm. Due to the high inoculum potential if capable of overwintering, it is possible, given favorable environmental conditions, that future 1971 losses may involve all acreage planted to corn containing TMS cytoplasm. By planting Texas male sterile seed, experience in 1970 indicates a probable crop failure, and by planting blended seed, a crop failure to the extent of the blend. There should be no substitute for use of F_1 seed produced by normal cytoplasm (hand detasseled) as long as seed is available. Some farmers will probably plant F_2 (second generation) seed of the tolerant hybrids which they produced this year. According to research, yield reductions of 15 to 25 percent can be expected from use of this seed. In addition to yield losses from F_2 seed, there will probably be a reduction in quality. This yield reduction would be much larger from single crosses.

Expected 1971 Supply of Seed Corn

Companies normally handling about 80% of the nation's seed corn production indicate approximately 818 million pounds of seed available for planting in 1971. The current expected supply consists of 22% normal cytoplasm (detasseled) seed, 40% T-cytoplasm seed, and 38% blend seed. Most corn produced from T-cytoplasm seed proved susceptible to Race T of Southern Corn Leaf Blight during the 1970 growing season. Planned 1970-71 winter production of seed makes up about 3% or 27 million pounds of the total supply. Production from this source has not yet been realized.

Plans for 1971

Research and extension underway in Georgia, Alabama, and Mississippi to ameliorate Southern Corn Leaf Blight in 1971:

1. Determination of disease reaction on commercial hybrids.
2. Use of feeding trials to check for mammalian toxicity.
   a. Negative results have been obtained on large animals.
   b. Negative results also with mice and guinea pigs, but these tests are being continued.
3. In greenhouse tests, corn inbreds are being screened for resistance both in T and N cytoplasm.

4. Seed treatment chemicals are being screened to see if they will control internal infection in the seed.
5. Determination of the geography of fungus overwintering.
6. Screening inbred lines and hybrids for resistance to this disease under field conditions both with and without artificial inoculation.
7. Growing different dates-of-planting tests to study reaction to this disease when inoculated at different stages of growth.
8. Detailed plans to trace the epidemic and prepare distribution maps of the disease in 1971.

It is proposed that the USDA set up a National Corn Blight Information Center for the 1971 production season:

a. to provide a national center for gathering and dissemination of information related to blight on the 1971 corn crop.
b. to assist in providing consistent and responsible information on a timely basis.
c. to help provide producers with information useful in making decisions pertaining to production, harvesting, and storage of the 1971 corn crop.
d. to keep the Department informed and to provide a framework for national leadership on problems associated with corn blight.

Corn Seed Summary (November, 1970)*

Maturity Zone	Expected seed corn supply (80%) for 1971 seeding by method of hybridization		
	N-cytoplasm	T-cytoplasm	Blend
		(1,000 pounds)	
DEEP SOUTH:			
Ga., Ala., La., Miss., Fla., East Texas	25,320	5,095	4,811
MID-SOUTH:			
Mo., Ky., Tenn., Va., N.C., S.C.	23,158	17,828	49,488
EASTERN:			
Pa., N.Y., New England	5,144	11,241	19,537
EASTERN and CENTRAL CORN BELT:			
Ill., Ind., Ohio, Eastern-Central Iowa	94,308	105,823	152,718
WESTERN CORN BELT:			
Western Iowa, Nebr., Kans., S.D.	9,993	119,893	44,287
NORTHERN STATES:			
Mich., Minn., Wis., N.D.	25,543	66,871	36,520
Total	183,466	326,751	307,361

*USDA Crop Reporting Board, Washington, D.C. 20250