ORGANIZATIONAL RESPONSE TO COMPLEXITY: RESEARCH AND DEVELOPMENT AS ORGANIZED INQUIRY AND ACTION -- PART I

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January, 1971

Working Paper No. 141

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PREFACE

This paper is essentially the theoretical portion of a larger monograph which reports the results of the research introduced in Chapter Four. Part I is a general theoretical perspective within which Research and Development organizations are viewed. We see them as potential pictures of many complex organizations in the future as more of them address the conditions challenging R and D laboratories. The general argument is outlined in Chapter One. Chapters Two and Three attempt to integrate several theoretical perspectives in modern organizational theory as a conceptual device to understand the structure, processes, and role constellations and interaction in organizations confronting high degrees of internal complexity and uncertain environments. Chapter Four is an introduction to the field research upon which the rest of the monograph, Part II, is based. The first three and a half chapters may be seen as an integrated whole -- the conceptual basis for the study.

As an extension and revision of Internal Working Papers 108, 109, and 111, of the Space Sciences Laboratory, Social Science Project, University of California, Berkeley, this project has been supported by its General Grant #NGL 05-003-012, National Aeronautics and Space Administration. The field study upon which Part II is based was supported by the Air Force Office of Scientific Research, Contract No. 49(638)-1028 under a sub-contract with Stanford Research Institute.

Other assistance was given by the Institute of Governmental Studies on this campus. This assistance is gratefully acknowledged, with particular gratitude to the staff in the Institute of Urban and Regional Development.

CHAPTER I

UNCERTAINTY, SOCIAL COMPLEXITY AND PROFESSIONALIZATION: THE CONTEXT OF ORGANIZED INQUIRY AND ACTION

Inquiry follows bewilderment: action is prompted by barriers. Bewilderment and barriers in large quantity stimulate organized inquiry and action. Each of us experiences existence as alternatively expected or bewildering, explicable and puzzling. Common sense understanding of the immediate "here and now" has solidity to it; lawn mowers do cut grass, police do issue citations for running stop lights, and taxes must be paid.[1] There is a certitude in the here and now. Bewilderment arises from the flow of activities of somewhat anonymous persons and groups beyond our immediate circle of experience. We notice such groups only when they become barriers to our freedom or unexpected allies. Local school boards sometimes act in unexpected ways; neighbors cannot always be counted on for assistance when trouble is upon us; and the actions of local politicians or men of superior organizational status often puzzle and bring consternation. When these impersonal "they" take on the typification of corporation, social class, government or military, our sense of predictability declines still further. Can we foretell the actions of Congress, a military retreat or invasion in the face of hostile forces, or the gyrations of a troubled economic sector? Most removed from comfortable understanding are the curious patterns of diplomatic maneuver, political revolution in distant states, and the global flow of international trade.

When barriers are encountered, action is stimulated. In many situations, the actions have been rationalized, given order in the technologies of modern life. These social and physical activities are the tools of action; the combinations of machine and process we have learned can multiply human effort in surmounting barriers. These tools reside mainly in persons, groups, and organizations outside ourselves, beyond our individual or family capacities. For most of us technologies remain an array of minor wonders, received with mixed awe and unease. These things we do not try to understand. Rather we delegate the responsibility of understanding to the expert, engineer, lawyer, physician, warily trusting in their technical skill.

When those upon whom we depend remain in stable relationship to us and to each other, we can find a way to understand them, give them rough predictability. The certainty of day-to-day and intermediate events is high, if not explained: common sense cause/effect beliefs reduce our puzzlement.[2] As student, father, soldier, worker, citizen, we apply our cause/effect beliefs to the world as we experience it. Beliefs about "how things work" filter out extraneous events and give order to experience. Such beliefs provide some rough predictability to our actions and those that others do to us.

A good fit between the present situation and those upon which current cause/effect notions were founded and refined, brings a perceived sense of order and reasonableness. If, however, the pattern of relationships in our environment changes, our connections to it vary in intensity, or multiply rapidly, cause/effect beliefs shaped in past and different times are due for shock. Persons applying outdated categories

to an altered present are likely to be increasingly surprised by what subsequently happens around them. Whether a person acts for himself or as a member of an organization, if his actions are based on ill-fitting categories the surprises can be personal and/or organizational disasters. This is the case in family decisions, policies of commercial firms, political decisions, military actions, research projects, or radical movements. In each of these settings, actions are based on assumed causal relations. To the degree these no longer roughly approximate reality, intended results are not likely. As common sense predictions fail in organizational decisions, the sense of doubt and uncertainty rises. Dealing with those outsiders upon whom the organization depends becomes much more problematic. When doubts about cause/effect beliefs become evident, they are likely to require renovation if our sense of uncertainty is to be reduced and our actions to produce fewer surprises.

Recently there has been a growing suspicion that the categories of organizational theory do not take into account new and emerging sources of uncertainty. In one emphasis, the organization's external environment is nominated as an increasing source of contingency for organizational action, and executive uncertainty.[3] Traditional conceptions of organization have great difficulty in handling qualitative changes in organizational environment. Renovation is in order. Broadly, the conditions prompting renovation are: (1) the increasing interdependence that formal organizations have upon their immediate environments, and (2) the increased rate of change in the number and stability of interdependent connections among formal organizations.

As interdependent relationships increase in number and rate of change, the capacity of common or uncommon sense conceptions to

comprehend them declines. Management and policy processes, apparently useful in the past for control, falter as conditions to which they are applied no longer meet the assumptions of traditional measures. To the degree this is the case for contemporary organizations, the importance of increased environmental dependence and perceived uncertainly is likely to mount. "Uncertainty appears as the fundamental problem for complex organizations, and coping with uncertainty [becomes recognized] as the essence of the administrative process."[4]

The foregoing have been the general underlying assumptions of this study. Our perspective will now be limited to that of the organizational members. This chapter is a discussion of uncertainty and contingency, the sources of organizational uncertainty, and professionalization as a central response to that uncertainty.

Contingency, Uncertainty and Alternative Responses

The behavior of persons faced with contingent, ambiguous conditions has been important for a number of studies in decision-making, economic behavior, psychological studies and, recently, theory construction in organizational studies. In many cases, assumptions about the intolerance for ambiguity have been significant premises for consequent development, yet there has been rather meager explication of their meaning.[5]

Uncertainty, for our purposes, is the feeling state of persons which is characterized by doubt, hesitancy and ambiguity with regard to the outcomes of their actions or the meaning of events in their environment. This use of the concept combines the familiar economic denotation defining uncertainty as "any lack of sure knowledge about the course of

past, present, future or hypothetical events,"[6] with the feeling states of persons recognizing such absence. While a person may perceive that he has little reliable information about some past or present event, it may have little or no significance for him, therefore raising no feelings of doubt. Neither would it necessarily prompt any search to discover information that would repair that lack. We are interested in those feelings of subjective uncertainty arising from perceiving an ambiguous, disordered situation which has at least minimal significance to the person. If events associated with this uncertainty are important to the person, group or organization, uncertainty results in increased anxiety and attention to its alleged source.

States of uncertainty are associated with inadequacy or absence of cause/effect beliefs "accounting for" events in a person's experience or environment. The more generalized the disagreement about or absence of credible cause/effect beliefs, the greater the doubt, ambiguity and the less likely a sense of predictability.[7] The degree of contingency perceived in the person's environment is also a source of uncertainty. Persons, groups, or organizations experience contingency in their environments when many outcomes are partially determined by actions of others in that environment. The greater the extent this determination is associated with "outsiders," the greater the perceived contingency or dependency of the units on elements in its environment. It is reasonable to expect that if cause/effect belief remains crystalized, as degrees of contingency increase, members and leaders of organizations will have increased difficulty comprehending them.

A basic postulate of this study is that, holding constant the cause/effect beliefs of persons, the greater the perceived contingency

of the environment, the greater the level of individual or organization uncertainty. Figure I illustrates the relationship between degree of objective environmental contingency, the degree of consensus about cause/effect beliefs, and subjective feelings of uncertainty.

Figure I

Environmental Objective Contingency

Agreement about cause/effect beliefs	High	Low
High	Moderate Uncertainty	Low Uncertainty
Low	Greatest Uncertainty	High Uncertainty

Organizations, as a molar unit of analysis, confront these generalized sources of uncertainty continually. If, however, we view complex organizations from the perspective of the controlling "dominant coalition,"[8] composed of elite members able to reduce collective uncertainty, their decision environment includes both external and internal aspects of the organization as a source contingency. The internal structure and processes of their <u>own</u> organization are clearly part of an elites environment, much more immediate and close linked than the "outside" of the organization. Patterns of internal interdependencies are influenced by whatever technologies are essential to what the organization does. They become internal constraints or opportunities for members of the dominant coalition in confronting external uncertainties. Of course, internal contingencies do not become uncertainties unless the

dominant coalition's collective understanding declines. In sum, there are several general sources of uncertainty: the cause/effect beliefs of members of the organization, the contingent character of the organization's external environment, and the internal interdependencies of organizational components.

Alternative Responses to Uncertainty

Everyone and every organization confronts many kinds of uncertainties; for most of the time they are bearable. There is, however, some level of uncertainty which is not, at least if some relatively unaltered state of the personality or organizational structures is to be maintained.[9] When that level or threshold of uncertainty is reached, then passed, feelings of discomfort increase. At some point they reach sufficient intensity that persons and dominant coalitions suffer fears for survival. Long before this point is reached searches begin to reduce the uncertainty of important relationships.

We must add that the reduction of uncertainty (some would say tension) is not necessarily a linear phenomenon.[10] Neither persons nor organizations necessarily attempt to extinguish uncertainty altogether. At low level of uncertainty or absence of tension important relationships are quite predictable and unchanging. This state of organizational boredom seems to prompt active attempts to increase the degree of stimulation, surprise and uncertainty. Search for uncertainty is probably associated with the capacity for risk-taking and very stable situations. But stability does not characterize the state of most contemporary organizations. Rather, organizations everywhere are experiencing considerable destabilizing pressure and many surprising conditions. If

uncertainty is sought there is no end of situations available to satisfy this search. It is quite the other way around -- how do persons and organizations respond to relatively high levels of perceived contingency, inadequate cause/effect beliefs, hence uncertainty in a turbulent environment?

Three responses may appear in solo or ensemble. One response is straightforward withdrawal: removing the source of contingency, severing ties with those depended upon and often retreating to another environment (sometimes fantasy). It is a disconnection from the problem arena, though the problem may not evaporate even if it is no longer recognized. Extreme manifestations of this response are seen in psychotic withdrawal in the face of intolerable uncertainty and the "double-bind."[11] It is also evident in the rise of protective isolationism, when nations sever their connections with other nations and look exclusively inward. In a sense, this response is a self-imposed loss of consciousness, narrowing one's vision of circumstances, or leaving the field of contention. Clearly, this may be a disastrous response since the contingencies do not objectively wither away when they are out of mind.

A second response is essentially ideological. Rather than withdrawing from the field, one engages with it on the basis of a cause/effect belief system which "explains" past uncertainties. Often such explanations are accompanied by programs of action to change the objective situation so it will coincide with the images of a "good" family, group, organizational structure or nation. The Marxian revolution is a clear example of such a response, similar in effect to the early Christian era and in a less dramatic way with the New Left and other youth movements of the present. Extreme right wing programs also appear

ready to alter political and social conditions so that social life will once again be "explained" by their ideology. The New Left and other convulsions among the young may be viewed as an attempt to build a new ideology with quite different action alternatives to achieve a more "sensible" pattern of experience.[12]

A third response to uncertainty, one that is central to this study, is an organizational response. This is an intermediate strategy, based on constructing cooperative systems in order to increase the collective predictability.[13] It is argued that gathering a number of persons in cooperative efforts increases the range of skills available to "comprehend" the environment thus reducing the number of collective surprises. The capacity of the organization to store resources with which to cope with the consequences of unexpected events is also increased. In this, as in other sections of this chapter, we are following J.D. Thompson's view of complex organization "as open systems, hence indeterminent and subject to uncertainty, but at the same time subject to the criteria of rationality [goal seeking] and hence needing determinateness and certainty."[14] Both individual members and the collectivity are subject to uncertainty from the environment and to a lesser degree from the internal processes of the organization. In order to achieve a sense of internal continuity, and hence relative certainty, knowledge about both these processes and the effects of environmental elements is required. To the degree these are known, resources can be used to deal with them in desirable ways. To the extent they are not known, but expected, strategies for reducing their effects when they do occur are subject to design and planning.

This study deals with the organizational response to uncertainty. Its primary focus is a special type of organization explicitly confronting both changes in internal technologies and a relatively fluid organizational environment. In a sense, the research and development organization is an organization instituted on the basis of permanent change. It is designed for inquiry and action in the face of deliberate internal technological changes, hence increased internal contingency. It confronts an environment altered at least partially due to its own outputs, products of research and action, hence increasing external contingency. The manner in which the three research and development organizations in this study have responded, in structure and process, internal role relationships and organizational norms, can be a window to the future of organizations. There is little doubt that the conditions of rapid internal and external change will become the general condition for many other organizations in our society. These are the structural fruits of uncontrolled technical and political development.

Environmental Sources of Uncertainty: Complexity and Turbulence

Conceptions of environment implicitly include the notion of boundary, the "dividing line" between inside and out, interior and exterior. By definition, organizational members perceive outsiders differently than themselves. The stranger or outsider is generally viewed as a competitor and possibly hostile: insiders are assumed to be loyal and friendly -- until either assumption is proved false. For our purposes two environmental boundaries are important. The first separates the organization as a whole from its external environment. Outside are the institutions and groups upon which the organization depends, composing

the more generalized social, political and economic setting. The second boundary separates management or the dominant coalition from the internal environment of organizational structures and processes, intended for their orchestration. For the dominant coalition two sources of uncertainty are the external environment outside the permeable boundaries of the organization's formal skin, and the internal relationships "between" that skin and the lines enclosing the coalition.

External Sources of Uncertainty

The character of the external environment can dramatically affect the sense of uncertainty and unpredictability perceived by organizational members. Three aspects are of particular importance: first, the extent of interdependent connections between the focal organization and elements in its environment; second, the direct connections among those "outside" organizations; and third, the rate of change or stability of the connections between and among them all.[15]

External environment as an uncertainty source is based on two assumptions: (1) that the relationship between an organization and its environment is one of resource exchange, and (2) that the degree of connectedness among organizations is a telling condition in determining the degree of constraint or contingency of that environment. Organizations must acquire resources from outsiders: funds, personnel, material and sometimes ideas. All organizations are, therefore, involved in a network of resource dependencies with other providing organizations. This is also the case for the consumption of the "products" of the organization.[16]

Resources can be roughly divided into those required for continuous, day-to-day operations and those associated with the less immediate conditions of political legitimacy and consumer credibility. The former, primary resources, include relatively continuous flows of funds, personnel, and materials. The particular character of these resources are largely determined by what the dominant coalition perceives as necessary for immediate operations. This, in turn, is based on their cause/effect beliefs about the necessary means to accomplish the technical goals of the organization. These beliefs provide the criteria for judging with whom the organization establishes dependency connection. These organizations become its "task environment."[17]

Resources associated with political legitimacy and consumer credibility, secondary resources, are of considerable importance to the dominant coalition. Quality control, public relations, and rapid response to public and/or consumer demand, for example, are intended to maintain or increase the general legitimacy of the organization's life.[18] The success of such activities has a strong effect, for example, on annual contract negotiations with government and labor unions. In another way, the uncertain cycles of appropriations activities in Congress represent aspects of this kind of dependency. Changes in organizational reputation among consumers or shifts in the share of product markets also become sources of uncertainty.

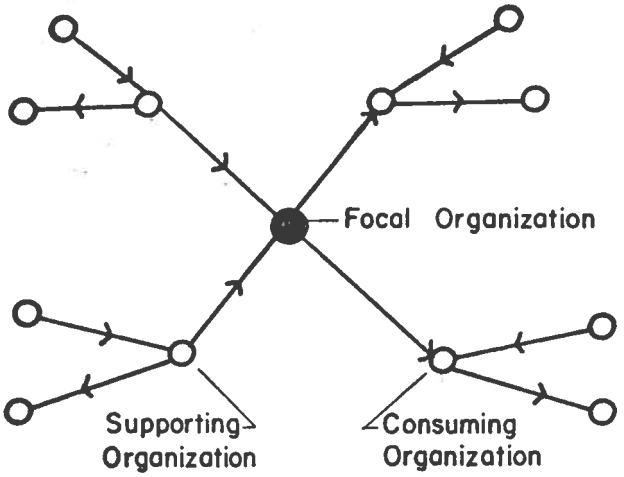
Both primary and secondary resources are exhanged within networks of organizations extending far beyond the immediate set of suppliers a particular organization might depend upon. The extent, indirect connectedness and stability of connections among these exchange conduits each contribute to the objective contingency for a particular focal

organization. As the number of direct links to organizations providing primary and secondary resources increases, so does the likelihood of perceived contingency, i.e., more outside units must be taken into account. If the organization's collective cause/effect beliefs are not able to account for this increase, uncertainty is also likely to increase. Incidentally, the dependency upon any single organization decreases as the number of connections to the environment increases.

Direct dependent connections to outside organizations are compounded by indirect dependency connections among supporting organizations. As networks of direct and indirect dependencies expand, they become the roots of considerable uncertainty for an organization. Figure II schematically compares a simple hierarchical situation and one in which a skein of connections is present. It should be clear that the information necessary to comprehend the complex situation is considerably greater and probably more problematic than the hierarchic one.[18] In the latter case, there are only a few direct linkages, either direct or indirect. However, the connections in the complex case are more numerous, less linear, and hence more difficult to predict.

It is obvious that in highly industrialized societies, very few organizations of scale fit the simple hierarchic situation. Generally the relationships between focal organizations and resource supporters are much more numerous and tend to increase as a culture becomes more differentiated. It is probable that the dominant coalition will experience markedly increasing difficulty in comprehending what these linkages are and how organizational action will affect them as their number increases. This suggests that all large organizations face highly

SIMPLE HIERARCHY SET



COMPLEX
OVERLAPPING SET

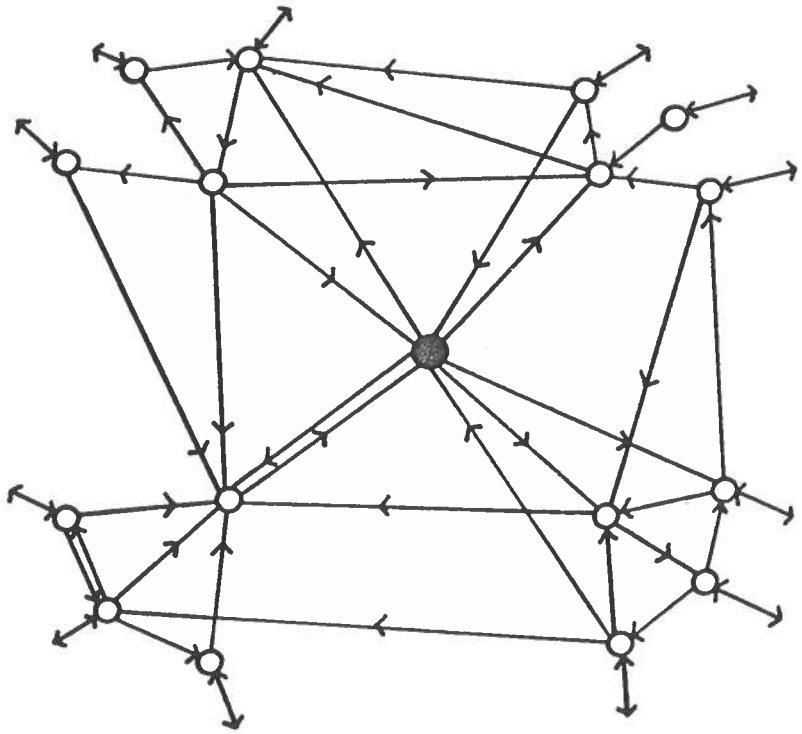


Figure II. SIMPLE - COMPLEX ORGANIZATIONAL SETS

contingent, uncertain, environments, even if the relationships between the organization's resource set were to remain relatively stable.

Change and Uncertainty

Stability, however, is not the lot of modern organizations. The connective relationships between organizations change in number and degree of dependency often quite rapidly. High rates of change also contribute markedly to the perceived uncertainty of the environment. This makes it more difficult to construct and test cause/effect beliefs about the character and behavior of dependency relationship and the consequences of their change. If modifications of cause/effect beliefs proceed more slowly than the changes in the environment, uncertainty is greatly heightened.

Figure III represents the combination of the three variables we have discussed thus far. Though there is not sufficient empirical evidence available to be conclusive, rapid rates of change in dependency relationships appear to have the greatest weight in increasing contingency, followed by increases in direct linkages and, then, indirect connections. The numbers in the cells represent the increase in contingency likely to be perceived by members of an organization, especially those of the dominant coalition.

If cause/effect beliefs remain relatively constant, the more rapid the rate of change, the greater the number of direct and indirect dependency relationships with organizations in the environment, the greater the sense of uncertainty within the organization.

Figure III

		Rate of Change: Stable — Direct Connections: Few	Rate of Change: Stable — Direct Connections: Many	Rate of Change: Rapid — Direct Connections: Few	Rate of Change: Rapid — Direct Connections: Many
Indirect Connections	Few	1	3	5	7
	Many	2	4	6	8

Internal Sources of Contingency: Structure and Technology

For an organization as a whole, the external environment is a continuous source of major contingencies and uncertainty. However, the internal processes and structure devised to cope with uncertainty and provide continuity of operations also take their place as sources of uncertainty. This section is written from the perspective of the "dominant coalition," generally "the management." Much of what is discussed can be said for other members of the organization as well as they carry on directive and/or problem-solving roles.

One important source of internal contingency is the organization's technology, that is, the combination of physical manipulation of the "objects worked upon" and the coordinative activities believed necessary to produce an organizational desired outcome.[20]

The process is carried out by persons working upon materials (increasingly in the form of machines) or upon other persons. Workers are organized in work and coordinative roles each acting out a cluster

of activities which together are believed to "produce" a desired outcome, product, or effect for which outsiders will exchange resources. Management contingencies arise from the social organization of technologies in much the same way as from external environment. As the relationships between organizational positions and roles become more interdependent and connected, the number of people and groups who can affect outcomes increase. If these internal social relationships are stable and relatively simple they can be comprehended fairly easily and the sense of contingency, hence uncertainty, is likely to be low. However, improvements in processes and/or machines may occur, often at accelerating speeds. This often requires changing role specifications and adding new roles. The more new roles are added, the more the internal contingencies.

As the internal contingency and interdependency of the "technical core" increases, the cause/effect beliefs held by the dominant coalition are likely to be less useful in understanding internal dynamics . . . unless these beliefs incorporate the probability of these changes. If they do not, and few do, the sense of uncertainty is likely to increase. The recent enthusiams among modern managers, both private and public, for systems analysts, computerized information systems, and human relations specialists may be seen as an attempt to provide better information and modified cause/effect beliefs to reduce the uncertainty of internal environments. Insofar as these efforts do not alter causal knowledge about internal operations rapidly enough or alter it in spurious directions, uncertainty is not likely to be dissipated.

Another major source of increased internal contingency is the management infrastructure built up around the technical core to shield it from external disruptions.[21] One of the apparently crucial

characteristics of technical systems is the requirement for relative stability of proximate organizational structure. Organizations develop a layer of service and buffering infrastructure intended to reduce the uncertainty of inputs and demands on the technical or producing core. As sectors of the task environment increase in objective contingency, and possible uncertainty, attention is paid to dealing with the organizations in it. The more differentiated and extensive the salient sectors of the task environment, the more likely a parallel differentiation within the organization. Groups specializing in gathering and stockpiling resources, searching the environment for potential problems, and attending to numerous liaison activities, include legal offices, personnel groups, budget and planning offices, sales and public information activities. As these groups become clearly distinct and interdependent, they also add to the contingent character of the infrastructure surrounding the dominant coalition. Management has considerably more formal control over these groups; but this does not necessarily mean operative control. This requires an adequate cause/effect system predicting roughly how this infrastructure is likely to respond to decisions.

As the connections between the technical core and managerial infrastructure increase, they begin to exceed the capacity of any small group or person to comprehend them.[22] This is so, even if the development is relatively stable and leisurely. If, however, rapid changes in the growth of internal complexity occur, this adds greatly to the uncertainty of operations. Figure IV represents the relationships between these three variables in terms of increasing internal contingency. As in the relationships between change and external environmental connectedness, rate of change is assumed to be of greatest moment, followed by the complexity of the technical core and the management infrastructure.

Figure IV

		Rate of Change			
		Stable		Rapid	
		Technical Core		Technical Core	
		Simple	Complex	Simple	Complex
Managerial Infra-structure	Simple	1	3	5	7
	Complex	2	4	6	8

Complexity, Uncertainty and the Organizational Problem of Knowing

In this chapter so far, we have outlined our view of individual responses to ambiguity and the sources of organizational uncertainty. This has been based on the growth of an organization's resources dependencies upon its environment, and the increases in the number and differentiation of roles within the organization. For summary purposes, let us gather the concepts of connectedness or interdependence, and differentiation of roles and groups in a simplicity-complexity continuum. This is used to construct a summary notion of organizational structure and a point of departure for a discussion of the problem of knowing.

Increases in the number of elements, their differentiation and interdependence is, by definition, an increase in the complexity of the system.[23] Differentiation of social systems has been discussed by a number of sociologists, political scientists, and some economists, as a dependent condition or variable; that is, what seems to account for

the differentiation of various social systems.[24] We shall not repeat their arguments here, rather we view complexity as an antecedent condition, or independent variable, stimulating a variety of structural and behavioral responses from organizational members.

Our argument is that the more complex an organization's environments, the more their perceived contingency. Cause/effect beliefs which do not take increased contingency into account are liable to become less correlative with the actual structure and dynamics occasioned by increases in connectedness and change. Thus, the overall sense of uncertainty is also likely to escalate. When this becomes tension-inducing enough, attempts to reduce uncertainty are likely. These may be directed toward: (a) modifying the external and internal structure of salient environments so they are more nearly in accord with relatively stable conceptions of organizational dynamics, and/or (b) modifying conceptions of organizational dynamics to take into account significant shifts in the character of various environments.

Strategies used to alter both the internal and external environments, or at least make them more predictable, have been ably summarized by Thompson.[25] Internal strategies used in attempts to reduce uncertainty include the development of buffering units between the environment and the technical core, smoothing or leveling input and output transactions, and attempts to forecast or anticipate, then adapt to environmental change. When internal strategies are not sufficient to quell uncertainties and lower dependencies, organizations may pursue strategies which will decrease their dependence upon significant external elements resorting to contracting, co-opting or coalescing with them.

The other major response to high levels of uncertainty, i.e., conceptual reformation, has begun in some academic circles.[26] There is some indication of conceptual change within large organizations, but it is not clear how self-conscious this has become. An emphasis on planning with the consequent influx of professionals into large organizations, suggests an increased likelihood systematic reformation may occur.

In the face of greatly complicated environmental situations, most conceptions of formal organizations are based on the implicit assumption that external and internal environments require organizational structures which are relatively simple hierarchies, or ought to be. These conceptions are logically simple hierarchies themselves, probably reflecting the logical limitations of the human being. Moreover, there is an assumption in almost all older and some current theoretical formulations that organizational change should be reduced, even at considerable cost. The tendency to seek simplicity and stability rather than complexity and rapid change, is consistent, of course, with penchants to reduce uncertainty. Thus, the common sense knowledge of executives and the supporting uncommon sense of theorists re-enforce both the cognitive and normative emphasis upon simple organizational hierarchies. Hierarchy, in this sense, means that the elements of an organization (and perhaps its external environment) are arranged in "a system that is composed of interrelated subsystems, each of the latter being, in turn, hierarchic in structure until we reach some lowest level of elementary subsystem."[27]

This definition of hierarchy provides a basis for constructing a means of describing the degree of internal connectedness among

elementary units or subsystems. Beginning with a simple hierarchy, as illustrated in Figure IIa above (p. 14), in the language of set theory, such a hierarchy if it maintains this present superior-subordinate form can be described as a "tree," no matter how many elements it has. Other more complicated, interdependent structures are termed "semilattice," the most extreme of which is a full matrix.

The "tree" in Figure IIa (p. 14) is formally described as follows: a collection of elements forms a tree, or simple hierarchy, if and only if, all elements in the collection are directly or indirectly connected to a single superordinate element, and elements are only directly or indirectly connected with each other through a common superordinate element. The more complicated structure (Figure IIb) is an example of the overlapping set structure of the "semilattice." Formally, a collection of elements forms a semilattice, if and only if, the elements in the collection may be connected directly to any other element and no single element is in superordinate relationship to all other elements.[28] A special case of semilattice is the full matrix in which each element is connected to all other elements.

The important difference between trees and semilattices is, that semilattices have overlapping sets of relationship and trees do not. In organizational terms, this means that in semilattice structures communication and authority relationships violate the single superordinate principle systematically and run counter to most of the implicit assumptions of chain of command, span of control and formal, simple hierarchical concepts of centralized decision-making. Traditional concepts of organizational structure tend to assume the <u>desirability</u> of developing mutually exclusive groups only related to each other through

a common superordinate person or group and communication node. There is, however, no reason to suppose that either contemporary social environments or internal relationships between organizational groups ape our simplifying assumed conceptions of them. On the contrary, there is sufficient evidence, mostly in studies of informal social and communications nets, to suggest that the opposite is the case; that modern organizations are densely packed with overlapping sets of relationships so numerous as to defy description. As we noted above, these appear to be prompted by extensive technological imperatives and increased unpredictability of the formal, stable structures in coping with changing technical and environmental contingencies.

For an administrative culture captive of Weberian hierarchies and the chains of command of Gulick and Urwick, and only recently come to the seductions of systems analysts, a recognition of complexity is distressing. Seriously considering objective complexity-contingency as a major uncontrollable, perhaps undesirable, condition of organizational action, means that many of the familiar precepts of administrative structure and processes become inappropriate. But the difficulties of finding alternative conceptions are severe ones. "In a single mental act you can . . . visualize a tree. You cannot bring the semilattice structure into a visualized form for a single mental act."[29]

The mind's basic intolerance of ambiguity and overlap is central in subduing confusion and uncertainty.[30] Semilattice structure of environments are perceived more easily in the form of trees, though they still remain a complex of overlapping relationships. And properly so, <u>if</u> these simplifications are based upon the recognition that they parse out only pieces of a more connected reality . . . that they are

not the only, or perhaps the most important, piece of reality to the organization. To the degree our conceptions are necessarily tree-like, they are subject to error and modification in the face of galloping surprises.

Experiences of a great many organizations, private and public, in the recent past teach the lesson that neither external nor internal organization environments are made of trees and probably never were. The semilattice complexity of contemporary external environment, however, seems somehow more closely connected, more tightly knit, and the consequences of holding tree assuming conceptions produce more surprises. Closely following is a sense of complex internal environments as well, though we have even less well formulated notions about this cluster of relationships. Managers are confronting complex external and internal organizational environments. They are differentiated into many relatively cohesive groups and organizations, and woven together with tightening bonds of reciprocal interdependence. Much of these environments form apparently incomprehensive skeins of semilattice structures. Familiar managerial conceptions are under assault and events happen more rapidly than can be known.

All three sources of uncertainty call for considerable effort in reducing them. They require greater investments in intelligence gathering, search and reconnaissance, and the development of organizational capacities to comprehend changing environments and to begin conceptual reformation. In each instance, this means involving various types of experts and professionals in searching for, collating, and interpreting information in comprehensible forms. One interpretation of the substantial growth of professionals in complex organizations is

as a means of reducing uncertainty. In an era of turbulence and technical complexity, this suggests that organizations will become increasingly professionalizationed. It also suggests that there will be increased emphasis upon organized inquiry and conceptual reformation as a requisite for action.

Organizational Professionalization: Response to Uncertainty

The following section discusses organizational professionalization as one of several strategies to reduce organizational uncertainty. Organizational professionalization refers to the successive introduction of various types of professionals into the organization. The larger the proportion of professional members employed by the organization, the more professionalized it is. The discussion includes a brief examination of the meaning of professional and professionalism, the professional as a source of uncertainty reduction, and a typology of professionals providing organizational intelligence.

Professionals and Professionalism

Over the past four decades there has been considerable theoretical and empirical examination of the professional phenomenon.[31] Early discussions by Carr-Saunders and Wilson were devoted to the evolution of occupations becoming professions. Later, a host of studies explored the lives of men in specific professionalized occupations, and the interdependence of professional groups and large complex public and private organizations.[32]

A good deal of effort has been spent in arguing for specific meanings of terms associated with these phenomena, and is nicely

summarized in the Vollmer and Mills volume. We shall be following their distinctions.[33]

The concept of profession denotes only an abstract model of occupational organization defined as "a vocation whose practice is founded upon an understanding of the theoretical structure of some department of learning and upon the abilities accompanying such understanding. . . . The practices of the profession are modified by knowledge of a generalized nature and by the accumulated wisdom and experience of mankind which serves to correct the errors of specialism. The profession, serving the vital needs of man, considers its first ethical imperative to be altruistic service to the client."[34] Professionalism refers to an ideology and associated activities of groups whose members aspire to achieve or maintain professional status. Enunciating professional ideology does not necessarily define a professional group, though it may be a requisite for becoming one. Professionalization, then, is the process whereby groups take on the characteristics of profession -- where they meet the criteria of profession. As a process, professionalization may be observed in many occupations, even though some groups have only small advance on meeting all the criteria. Those persons "who are considered by the colleagues to be members of professional groups" are labeled professionals.[35] They are a part of occupational groups having a high degree of the following characteristics:

(a) Skill and training, acquired on the basis of specialized technique supported by a body of theory, i.e., conceptions and cause/effect beliefs "explaining" some aspect of physical or social reality, and asserted to be the predominant possession of the group.

(b) A system of occupational norms assuring solidarity, and quality and continuity of cause/effect beliefs; articulated in codes of ethics re-enforced by community acceptance; and at least a minimum system of collegial social control, e.g., quality control through licensing, degree standards, etc.

(c) Support by career options within a body of colleagues manifested by salary and/or fee norms and roles embedded in an infrastructure providing technical resources.

(d) A less agreed upon characteristic is formal allegiance to service motivations at least equal to instrumental economic motives.[36] What is important here is the adherence to the occupation as an intrinsic value rather than primarily an instrumental one used in pursuit of some other ends. Intrinsic values of the profession are often put in tension with demands from supporting organizations seeking to use the professional's skill for organizational purposes rather than client or intrinsic benefits.[37]

In this section the task is not to weed out the thickets of terminological debate and explorations of professionalization. It is a vast literature dealing with professionalization, the characteristics of professional groups, and the socialization of persons into formal professional status.. Our concerns are the qualities such processes bestow upon professionals that prompt others to seek them out as means of reducing uncertainty.

The following consequences of professionalization are the most telling as attributes which dispell uncertainty. First the rigors of professional education results in a relatively well articulated system, which is often internally consistent and generally captive of a technical

language available only to other professionals. Such a situation makes weaknesses of a theory invisible to outsiders and largely unassailable by managers who are not professionally trained.

Second, a professional in good standing (i.e., one who is thought well of by professionals of similar stripe) is supported in his professing of cause/effect beliefs and implied action by others holding similar views. His authority is validated by those who could effectively refute it. The community-at-large, having no alternative explanation for the same phenomenon, is also likely to sanction professional authority.[38] Furthermore, professionals generally give explicit attention to maintaining the quality and exclusiveness of their skills in interpreting a particular cause/effect belief system. Insofar as they are successful, this enhances their monopoly of skill held by their profession.

Finally, uncertainty reduction capacities of professionals are directly related to how intensely potential clients perceive their own need for specific expertise. If they have learned, or are taught by professionals, the utility of "professional assistance," then the salience of cause/effect beliefs and the professional group's monopoly in interpreting them is very conducive to uncertainty reduction.

For increasing numbers of people uncertainty caused by eroding cause/effect beliefs is reduced not by marked improvement of their own beliefs and comprehension, but by the <u>delegation of interpretation</u> to experts. Trust between the professional and his client is crucial. Uncertainty reduction through technical trust is a frequent device in many organizational situations. We trust to the professional the distillation of information and its interpretation so that "sensible" action can be taken. Clearly, this is, in a direct sense, the informal delegation of authority to men of presumed knowledge.

The Professional as Information Coder

Intuitively all of us recognize that our capacities to assimilate information are limited. Apparently our "channel capacities" to receive and discriminate among large numbers of stimuli are quite limited. It stumbles along at the rate of some seven bits of information at a time, i.e., the number of alternative stimuli among which choice or discrimination can be made.[39] Imposed on both span of absolute judgment and immediate memory, this limit results in "severe restriction on the amount of information we are able to receive, process or remember."[40]

Information bottlenecks bounded by these restrictions can be expanded by simultaneously organizing stimuli along several dimensions, and successively into sequences of information "chunks" or clusters. Clustering or chunking is recoding information under a symbol denoting groups of similar events or stimuli. Anytime a term is used to name a group of events, e.g., role expectations summarizing various expectations held about a particular role occupant, recoding is taking place. Codes can include both rules for sorting data and those specifying the relationships between elements within the code.[41]

All organizational members are, of course, subject to similar channel capacity restrictions. Therefore, our fundamental need to reduce ambiguity and develop understandable cognition on the face of numerous stimuli confronts all members with potential information overload and confusion.[42] There is a need to somehow reduce the organizationally bounded stimulus field down to some kind of comprehensible level. Overload is reduced through recoding information into simplified sets of words which gather many "events" under an abstract symbol, e.g., chain of command, goal attainment, executive responsibility. In these terms,

bits of unitary data in quite elemental forms are gathered under a symbol; this symbol then implied these bits. First level summary symbols of similar meaning are then gathered under more abstracted terms, and so on in hierarchic fashion. If the overall code is well known, uttering the final term, i.e., the most symbolically abstract and superordinate, will evoke all the lesser order information, including the relationships between sub-components. This is the process of "unpacking" or explicating the meaning of many information chunks.[43] Simple coding schemes of fairly low internal complexity are the common plight of us all. More complex coding schemes, cause/effect beliefs, theories and methodologies, are hard won requiring considerable effort to learn and make ready for use. They generally are possible only with sharp limits in the scope of the phenomenon. The more complex the interstices of a theory (code), the more information is packed into its summary terms -- sometimes referred to as "law-like relationships."

When organizational members have purchase on complex cause/effect beliefs (codes) that purport to describe environments which are relatively stable, feelings of uncertainty decline. However, there are often periods in which considerable new and unfamiliar information is entering an organization. When this happens, it is likely that appropriate codes are not available and new information will either be ignored and/or overload will occur. This is another way of saying that the cause/effect beliefs of members do not provide a set of codes to order incoming information and make it comprehensible.

Long periods of education in the theories and methods of a discipline furnish a number of codes useable in sorting and storing information applicable to particular problems. Concepts and theories

"explaining" the behavior of markets, the dynamics of man-machine systems, legal processes and the behavior of courts, or the mechanics of deep space trajectories are intricate codes sorting primary data and ordering cause/effect reasoning to comprehend massive amounts of information. Education, including graduate work, is at least a period of intensive code learning, during which rules of encoding are internalized, criteria for noticing relevant data formulated, and skills in interpretive unpacking burnished.

As reducers of uncertainty, professionals are skilled in recoding information into efficient packets ready for unpacking when the situation calls for it. They are used to provide refined and efficient coding schemes so that organizations can benefit from these human information processing and relating devices. Theoretical codes, organized to reveal hidden relationships, have been written on the neural networks of the brain during the long years of apprenticeship. Theories and methods enclosing a particular segment of the world have been "memorized." They are ready to pack and unpack information in the process of reducing the uncertainty of the client-manager. This is the basis for professional influence, generally limited to the questions about which they are thought effective in reducing uncertainty. Professionals are human devices, predictably able to use their cause/effect beliefs to lower a manager's sense of doubt about some aspect of a contingent environment.[44] At minimum, many professionals can do this; as we shall see, they are also a source of uncertainty as well.

Professionals as "Organizational Intelligence Agents"

It is obvious that the contingencies faced by organizations, which, we have argued, prompt an increased flow of professionals into

organizations, are not evenly distributed through their internal or external environments. Information and intelligence requirements fluctuate according to the uneven patterns of change within and outside organizations. Emphasis on uncertainty reduction capabilities is likely to fluctuate as well. Organizations develop information gathering or intelligence capacities in areas which, from the dominant coalition's view, are becoming importantly uncertain. If intelligence capabilities are increasing, they are most likely to be in those areas from which new or growing levels of uncertainty are expected and which do not already have adequate intelligence. March and Simon's notion of uncertainty absorption is useful here. It suggests that as information is exchanged within an organization, persons distill, filter and recode information, they communicate to others in a way which reduces the level of the receiver's uncertainty about the substance of the information.[45]

This process operates for information regarding internal technical processes, the coordination of these processes, and various elements in the task environment. The more complex and unstable these sources of contingency are, the more complex the codes (cause/effect belief system) applied to them are likely to be. The more complex the codes, the more likely long periods of experience or education will be required to learn them. As learning time increases, the more likely the role or occupation dealing with a department of knowledge will become professionalized. For example, as an organization's task environment becomes more uncertain, resources will likely be devoted to coping with it. These resources will be spent partially on employing specialists (sometimes professionals) who are believed competent to reduce specific uncertainties. Therefore, different types of professionals are likely to be related to the several sources of

uncertainty, i.e., technology, internal structure and processes, and boundary spanning activities related to the external environment. Wilensky has roughly mapped several types of intelligence professionals in complex organizations in terms of the sources of uncertainty and the requisite skills needed to cope with them.[46]

Arenas of needed surveillance are separated between external and internal environments. Then the means of coping with them are divided between those based on ideological and political knowledge and those based on technical, economic, legal or scientific knowledge. From these two variables, a typology of "men of knowledge" is drawn. The "contact man" and "internal communicatcns specialists" both provide political and ideological information; the former about the external world of government, unions, and competitors, and the latter about internal politics, informal communication nets and coalitions. They are valued for their skills in shaping thoughts, feelings and activities through persuasion and manipulation. Another type is also noted, the "facts and figures man valued for his skill with data, records, and argument, and producing simple answers to complex technical problems. . . ."[47] He supplies technical, economic, legal or scientific information used to build a case in fending off attacking outsiders or members, as well as competitors.

While he does not do so, Wilensky's "facts and figures men" can be distinguished, for our purposes, in terms of the predominant focus of their activities, internal or external. External boundary spanners or task environment professionals, gather and digest information about markets, courts and legal processes, systematic sampling of opinion, technical breakthroughs and the like from the communities

beyond the organization. Found in legal offices, offices of market research and planning, these men support the institutional activities of the dominant coalition. Facts and figures men whose domain is the internal technology and structure of coordination within the organization, are the technical professionals. They provide information on technical processing patterns of internal control, development of managerial infrastructure, and support the internal management and technical functions of the organization. Directors of research, scientists and engineers, systems analysts, computer specialists all cluster here. Insofar as personnel and administrative specialists base their activities on scientific conceptions of interpersonal behavior and economic theories, they can also be classified as technical professionals.

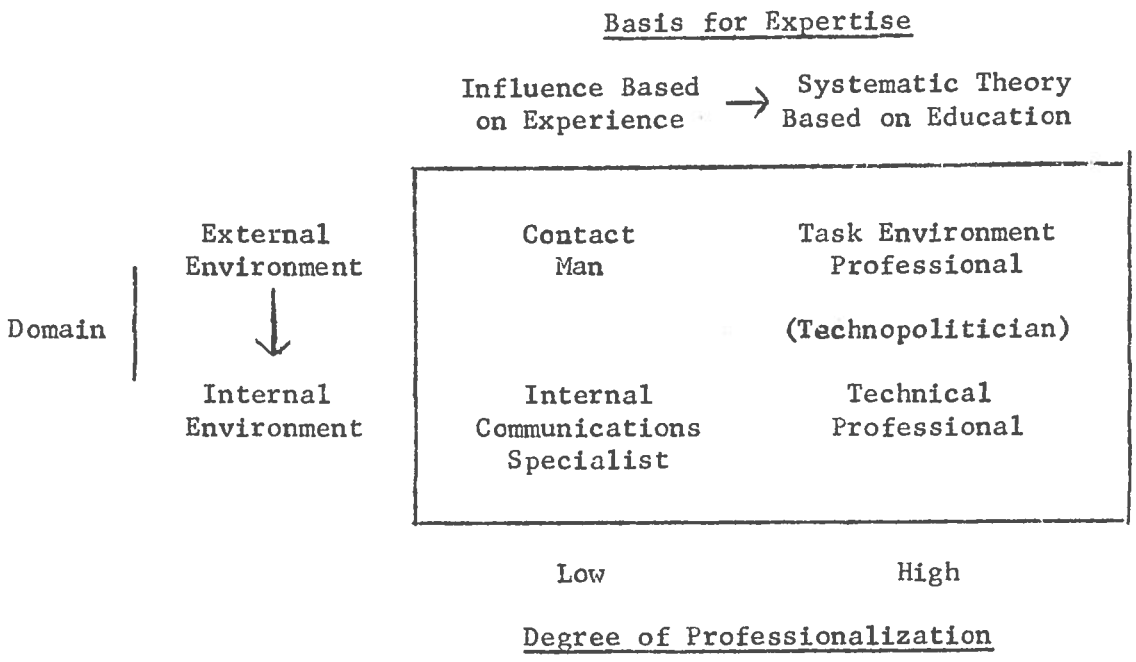
When faced with uncertainty, managers employ these experts they believe have the skills appropriate to deal with it. The more confidence the dominant coalition has in political and/or ideological information, the more likely contact men and internal communications specialists will be utilized. However, the more the coalition "sees its external and internal environment as rationalized -- that is, as subject to discernible, predictable uniformities in relationships among significant objects -- ,"[48] the more likely resources will be spent on task environment and technical professionals.

Another implicit dimension in the distinctions among experts is the kind of backgrounds required to develop a particular skill. Contact men and internal communications specialists derive theirs primarily from personal experience in the arenas they survey. This is necessary to develop the associations and personal relationships with important actors in politics or in internal groups that is the

basis for intuitive understanding and trusted communications. On the other hand, all facts and figures men base their knowledge on extensive formal education founded on rigorously articulated technical cause/effect beliefs about their domains. It is our assumption that the more years of formal education devoted to these specialties, the more likely the expert is to take on the characteristics of a professional discussed above. Figure V summarizes the several dimensions.

FIGURE V

Typology of Organizational Experts



Finally, when "there is an urgent demand for broad policy advice on issues of politics and administration that relies heavily on technical intelligence . . . administrative leaders [will seek] a new breed of expert who can interpret the work of separate disciplines" and combine the functions and characteristics of all other types of experts.[49] This composite expert, the technopolitician, would be sought when:

(1) the contingency seems to spring from numerous elements within and without an organization, and (2) the dominant coalition believes that systematic, technical knowledge is available to integrate both political and technical information.

We have already discussed the effects of increasing complexity in an organization's environment. It is apparent that this source of objective contingency confronts many groups and organizations. It is also apparent that many professionals are ready to persuade us that they now know -- in the systematic, scientific sense -- much about the cause/effect relationships of both external environments and internal social dynamics of organizations. In the face of uncertainty, there is a marked tendency in management ideology and practice to turn to men who profess knowledge and in this way open the doors of decision processes to professionals. This seems to be true regardless of the controversies within professional circles about the actual quality of their craft. To the degree task environment and technical professionals' cause/effect beliefs, data skills, etc., are modestly adequate to the reality they face, overall uncertainty can be reduced. However, as their numbers increase, the areas of decision delegated to them also expand. Dominant coalition dependence upon professionals increases accordingly. If an area is delegated to professionals who hold a relative monopoly over relevant skills, then the professionals themselves very likely become a new constraint upon management.

Professionals are far more than finely tuned information recoders and unpackers, though many are at least that. Bonds of association and occupational loyalty knit professionals together in networks spilling far beyond the organization. Professional activities are intrinsically

valued, often subordinating instrumental organizational values. Insofar as the conditions of professional employment are counter to traditional authority and status structures in complex organizations, professionals are likely to bring pressures for change.[50] As the coalition's dependence on professionals grows and more of them become integral parts of the organization, they become a general source of contingency -- as well as agents of uncertainty reduction.

Displacement of uncertainty or trade-off between reduced technical uncertainty and increased "professional egg-head" uncertainty, has generally been greatly in favor of reduced technical uncertainty. However, the change occasioned by this displacement has meant strains toward altering organizational form, and authority and role relationships. In many organizations what has emerged is a semi-collegial authority structure paralleling the traditional bureaucratic ones. They operate in sub-groups dominated by professionals and in ways still not very comprehensible to most managers. As the proportion of professionals increases, organizations are likely to go through a process of professionalization, taking on quite different forms from nonprofessionalized organizations.

Patterns of Organizational Professionalization

Organizations may be grouped according to the proportion of members who are professionals and the degree to which they are professionalized.[51] Many organizations have very few professional employees, others are predominantly filled with technical and task environmental professionals. By dint of education and experience some experts are highly qualified, meeting all the criteria previously noted. Others, however, while they ascribe to the ideology of professionalism, fail

to meet those criteria. These two dimensions bracket almost all large modern organizations, for there are very few organizations of scale that do not have their professional contingent. Figure VI schematically depicts these relationships.

FIGURE VI

Degrees of Organizational Professionalization

Degree Occupation is Professionalized	Proportion of Professionals in the Organization: Low	Proportion of Professionals in the Organization: High
Low	A	B
High	C	D

A good many organizations have only a low proportion of professionals. Those they do employ are not far along the path of occupational professionalization. Most factories, construction and craft industries, small and moderate-sized city governments, and state legislatures all are included (Type A). Other organizations, such as social welfare agencies, primary and secondary schools, some custodial institutions, and churches, have relatively high proportions of semi-professional members (Type B). Classifying organizations in this way assumes that clients, students, and practitioners are not included in the organization. Rather, in technological terms, they are the "objects worked upon," and tend to have only modest individual involvement in decision processes and impact on the organization.[52] They are not normally employed by the organization, often paying some sort of fee for their

temporary inclusion. The professionals also fall short of meeting the criteria noted above, though they espouse the values of professionalism and may have relatively advanced educations.

Type C represents organizations with a small proportion of highly trained professionals, such as medical doctors, lawyers, economists, or scientists. Generally grouped in segregated staff positions, these men have a clear identity as professionals. They are "licensed," have gone through extensive educational extrusion, and have formed relatively strong formal associations. Labor unions, political parties with small, sophisticated staff strategists, large private voluntary organizations, such as establishment churches and charitable organizations, and large government service and military agencies with planning and analysis offices are examples.

In some cases, when these planning and staff functions are carried out by large numbers of people in semi-autonomous organizations, such as some intelligence agencies and corporate consulting services, they fall into Type D. These organizations are relatively new and, like universities, have a large proportion of highly skilled professionals. Most of them were established during and after World War II and are predominantly related to government operations, either integrally or as contractors. In addition to universities, these organizations include autonomous or semi-autonomous Research and Development groups, large research hospitals,government and private agencies planning and supporting scientific research, such as NSF and Ford Foundation, high level planners like the U.S. Bureau of the Budget, and Council of Economic Advisers, and some management consultant and law firms. They are all organized for inquiry, and some for action. They represent

organized attempts to deal with quite complex environments, some external, such as law firms and strategic planning staffs; some internal, such as the BOB, universities and R&D laboratories. In all cases, they are increasingly specialized internally: the larger ones develop specialities for internal coordination and surveillance. In many instances they are organized to inquire into the nature of physical and/or social reality, and then translate this knowledge into policy and prototypes. Three such organizations of inquiry and action are the objects of this study.

Research and Development Laboratories are one of a small number of organizational types quite consciously contending with both changing internal complexity and uncertain external environments. These conditions are very likely to infect the context of all organizational life as the texture of contemporary society becomes more complex. As connectedness and change engulf more types of complex organizations, it is quite likely that many of them will follow the research laboratory in becoming intensively professionalized. In this sense, the Research and Development Laboratory can be a window into the future of emerging organizational forms. Their problems and solutions are likely candidates for transfer to public bureaucracies, private industry, and organizations of healing and personal service. From their experience, lessons may also be learned about the adequacy of traditional and present day conceptions of complex organization. How adequate are current alternative cause/effect beliefs when professional staff is transformed into the operational line; when the familiar administrative line becomes supporting staff; when former line workers support former staff? What has occurred in this structure of "inverted roles" and processes confronting uncertainty?

Summary

In this chapter the conditions associated with increasing organizational uncertainty have been suggested. They include increased interdependence within and among organizations, increased changefulness in their relationships, and a consequent decline in the quality of the cause/effect beliefs members employ to order their organizational worlds. When organizational decisions and actions are based on such conceptions, they are likely to produce unsettling surprises. Should this happen frequently, experts will be sought who can provide information and understanding to reduce surprise and uncertainty. This begins the process of organizational professionalization. At high levels of professionalization, an organization becomes the site for sustained organized inquiry and action. Such inquiry becomes necessary for effective action in the face of increasing interdependence and change.

Research and Development organizations confront these conditions more frequently than almost any other type of complex organization. They have responded with a highly professionalized membership and a pattern of internal dynamics substantially different from more traditional organizations. Chapters Two and Three are a discussion of R and D organizations which attempts to describe them using the middle-range conceptions of structure-process theory, and then to develop a way of relating the key roles within them. This becomes a basis for a comparative examination of three Research and Development Laboratories and their responses to different environments.

FOOTNOTES, CHAPTER ONE

I am pleased to acknowledge the helpfulness of James Wood and Judith May in revisions of this chapter.

1. See P.L. Berger and T. Luckman, The Social Construction of Reality (Garden City, N.J.: Doubleday, 1966), esp. ch. 1 for a useful discussion of this perspective.

2. See J.D. Thompson, Organizations in Action (New York: McGraw-Hill, 1967), for use of the concept of cause/effect beliefs in the development of organizational structure and decision strategies. Cf. M Rokeach, Beliefs, Attitudes and Values (San Francisco: Jossey-Bass, 1968), p. 123.

3. Ibid.; and S. Terreberry, "The Evolution of Organizational Environment," Administrative Science Quarterly, 12 (March, 1968), pp. 540-613.

4. Thompson, op. cit., p. 59.

5. For example, J.G. March and H.A. Simon, Organizations (New York: Wiley, 1958), p. 113, 165; R.M. Cyert and J.G. March, The Behavioral Theory of the Firm (Englewood Cliffs, N.J.: Prentice-Hall, 1963); J.E. McNulty, Some Economic Aspects of Business (Philadelphia: University of Pennsylvania Press, 1964), esp. ch. V; A Downs, An Economic Theory of Democracy (New York: Harpers, 1963); K. Arrow, Social Choice and Individual Values (New York: Wiley, 1951); W.R. Garner, Uncertainty and Structure as Psychological Concepts (New York: Wiley, 1962); D. Berlyne, "Uncertainty and Conflict: A Point of Contact Between Information Theory and Behavior Theory Concepts," Psychological Review, 64 (November 1957), pp. 329-339; and H.M. Schroder, et al., Human Information Processing (New York: Holt, Rinehart and Winston, 1967); and F. Attneave, Applications of Information Theory to Psychology (New York: Holt, Rinehart and Winston, 1959), ch. 2. All of these works ground their use of uncertainty on its meaning in information theory. For a more sociological use of this concept, see R.C. Fox, "Training for Uncertainty," in R.K. Merton, et al., eds., The Student Physician (Cambridge: Harvard University Press, 1957), pp. 207-221; and R. Darhendorf, Essays in the Theory of Society (Stanford: Stanford University Press, 1968), ch. 9, "Uncertainty, Science and Democracy," esp. pp. 236-240; and Thompson, op. cit.

   For discussions of intolerance for ambiguity and need for cognition, see E. Frenkel-Brunswick, "Intolerance for Ambiguity as an Emotional and Perceptual Variable," Journal of Personality, 18 (1949),

pp. 108-143; A. Cohen, E. Stotland, and D. Wolfe, "An Experimental Investigation of Need for Cognition," Journal of Abnormal and Social Psychology, 51 (1955), pp. 291-294; and R.L. Kahn, et. al., Organizational Stress: Studies in Role Conflict and Ambiguity (New York: Wiley, 1964), esp. pp. 21-24, 86-88 for a summary discussion.

6. Downs, op. cit., p. 77; cf. March and Simon, op. cit., p. 112, and the definition of uncertainty from information theory, Garner, op. cit., p. 3.

7. Thompson, op. cit., p. 159.

8. Thompson, ibid.

9. Cohen, op. cit.

10. See D.E. Berlyne, Conflict, Arousal and Curiousity (New York: McGraw-Hill, 1960); and Schroder, op. cit., ch. 3, esp. p. 34f. The best discussion of the nonlinearity of tension reduction I have seen is in P.W. Sperlich, Conflict and Harmony in Human Affairs: Cross-Pressures and Political Behavior (Chicago: Rand McNally, 1971).

11. For an especially vivid description of this process see R. Laing, The Politics of Experience (New York: Ballantine Books, 1967).

12. Dogmatic, rigid reactions are found in both political conservatives and radicals and differ markedly from the more flexible and "open minded" approaches probably more appropriate to dynamic and changeful situations. Discussion of these types of responses in Rokeach, op. cit., parallel our use here. See also M. Rokeach, The Open and Closed Mind (New York: Basic Books, 1960). These studies include good summaries of the literature. See also Schroder, op. cit., on the conditions of cognitive structure appropriate to complex environments.

13. See particularly the work of H.A. Simon, J.G. March, and R.M. Cyert. For example H.A. Simon, Administrative Behavior, rev. ed., (New York: MacMillan, 1957); March and Simon, op. cit., and Cyert and March, op. cit.

14. Thompson, op. cit., p. 10.

15. Terreberry, op. cit.; W. Dill, "Environment as an Influence on Managerial Autonomy," Administrative Science Quarterly, 2 (March, 1958), pp. 409-443, and "Impact of Environment on Organizational Development," in S. Malick and F.H. Van Ness, eds., Issues in Administrative Behavior (Englewood Cliffs, N.J.: Prentice-Hall, 1962), pp. 94-109; M. Aiken and J. Hage, "Organizational Interdependence and Intraorganizational Structure," American Sociological Review, 33 (December, 1968), pp. 912-930; F. Emery and E. Trist, "The Causal Texture of Organizational Environments," Human Relations, 18 (February, 1965), pp.21-32; E. Yuchtman and S. Seashore, "A System Resource Approach to Organizational Effectiveness," American Sociological Review, 32 (March, 1967), pp.891-903; W. M. Evan, "The Organizational Set:Toward a Theory of Interorganizational Relations, in

J.D. Thompson, ed., Approaches to Organizational Design (Pittsburgh: University of Pittsburgh Press, 1966). See also A.L. Stinchcombe, "Social Structure and Organizations," in J.G. March, ed., Handbook of Organizations (New York: Rand McNally, 1965), pp. 142-193.

16. For an extended discussion of research organizations as functional systems, see Ch. Two below. Also S. Levine and P. White, "Exchange as a Conceptual Framework for the Study of Interorganizational Relationships," Administrative Science Quarterly, 5 (March, 1961), pp. 583-601; and D. Katz and R. Kahn, The Social Psychology of Organizations (New York: Wiley, 1966).

17. Thompson, Organizations . . ., op. cit., introduction by W.R. Dill, "Environment as an Influence on Managerial Autonomy," op. cit.

The primary resource dependencies an organization holds for another organization are the basis for establishing a pattern of "primary power" over the receiving organization. The magnitude of this power (which may be most meager) is a function of the degree of monopoly the providing organization has over the resource, the perceived need of obtaining the resource, and the cost to the receiving organization of obtaining it. Clearly the more the monopoly over the resource, and the more the perceived need for it, the more the dependency of the receiving organization upon the supporting organization. However, if the cost of obtaining the resource becomes too high for the receiving organization, it is likely to redefine its needs or in some other way attempt to reduce its dependency on the supporting organization. See Thompson, Organizations . . ., op. cit., p. 30f; and T.R. La Porte, "The Recovery of Relevance in the Study of Public Organizations," in F. Marini, ed., Toward a New Public Administration (San Francisco: Chandler Press, 1971), ch. 1; and P. Blau, Exchange and Power in Social Life (New York: Wiley, 1964). Cf. J.G. March, "The Power of Power," in D. Easton, ed., Varieties of Political Theory (Englewood Cliffs, N.J.: Prentice-Hall, 1966), pp. 39-70; and R.L. Kahn and E. Boulding, eds., Power and Conflict in Organizations (New York: Basic Books, 1964).

18. Throughout this book several distinctions are made regarding various types of activities and their associated subsystems. We follow those made by Thompson, op. cit., p. 10f, and Katz and Kahn, op. cit., ch. 4; both are inspired by Talcott Parsons. At the core of any organization are groups working directly on the "product" or expected outcome of organizational energies, i.e., the technical core or production subsystem. Supporting, servicing and coordinating core activities is the mangerial subsystem composed of maintenance, procurement and mediating activities necessary to absorb and dampen unexpected demands and conflict within the organization. Finally, the institutional subsystem provides a basis for relating internal activities to the broader community within which the organization exists. At this level broad problems of external relations are dealt with, generally in the group holding "central authority." A fourth subsystem is sometimes noted, e.g., Katz and Kahn, op. cit., which carries on intelligence gathering, research

and development, and planning. We have divided these adaptive functions between the institutional and managerial levels.

19. See especially, Schroder, op. cit.

20. Various typologies of organizational technology have been noted by Harvey. They range from Thompson's degrees of interdependence between persons or groups involved, to Perrow's degree of ambiguity in the process and hardness or softness of the objects worked upon. Thompson, Organizations . . ., op. cit., p. 14ff; C. Perrow, "A Framework for the Comparative Analysis of Organizations," American Sociological Review, 32 (April, 1967), pp. 194-208; E. Harvey, "Technology and the Structure of Organizations," American Sociological Review, 33 (April, 1968), pp. 247-259; and J. Woodward, Industrial Organization: Theory and Practice (London: Oxford University, 1965).

21. This follows Thompson's contribution to resolving the dilemma in organization theory between structures that resist change and those that are continually changeful. Thompson, Organizations . . ., op. cit., ch. 1.

22. Cf. Schroder, op. cit.: see also W.H. Starbuck, "Organizational Growth and Development," in March, Handbook, op. cit., pp. 495-505.

23. See T. R. LaPorte, "Organized Social Complexity: An Introduction and Explication," in T. R. LaPorte, ed., Organized Social Complexity: Challenge to Politics and Policy, a series of papers examining the consequences of increased social complexity for understanding political action and policy studies; and R. Brunner and G. Brewer, Organized Complexity: Empirical Theories of Political Development (New York: Free Press, 1971) for the methodological implications of the phenomenon.

24. This notion has its roots in the work of H. Spencer, The Principles of Sociology (N.Y.C.: D. Appleton, 1893-99, 3rd. vol.), and E. Durkheim, The Division of Labor in Society, trans. G. Simpson (Glencoe, Ill.: Free Press, 1933), and elaborated by T. Parsons, The Social System (Glencoe: Free Press, 1951); T. Parsons and E.A. Shiks, Toward a General Theory of Action (New Haven: Yale University Press, 1954); and N. Smelser, Social Change in the Industrial Revolution (Chicago: University of Chicago Press, 1959), and Theory of Collective Behavior (N.Y.: Free Press of Glencoe, 1963). See also S.N. Eisenstadt, "Social Change, Differentiation, and Evolution," American Sociological Review, 29 (June, 1964), pp. 375-85. For social psychological variations on this development see T. Parsons, R.R. Bales, et al., Family: Socialization and Interaction Process (Glencoe, Ill.: Free Press, 1960); and R.F. Bales, T. Parsons, and E.A. Shiks, Working Papers in the Theory of Action (Glencoe, Ill.: The Free Press, 1953). Discussions of differentiation in political science are mainly derived from the sociological literature above. See M. Landau, "On the Use of Functional Analysis in American Political Science," Social Research,

35 (Spring, 1968), pp. 48-75; D. Easton, The Political System (New York: Knopf, 1953); F. Riggs, Administration in Developing Countries (Boston: Houghton-Mifflin, 1964); L. Pye, "The Concept of Political Development," Annals, 358 (March, 1965), pp. 1-13, and Aspects of Political Development (Boston: Little, Brown, 1966); G.A. Almond and G.B. Powell, Comparative Politics (Boston: Little, Brown, 1966); and R.S. Milne, "Differentiation and Administrative Development," Journal of Comparative Administration 1 (August, 1969), pp. 211-248. Thus far only little attention has been paid by organizational theorists to this concept, as such, although a good deal of work has been done on specialization. Cf. P.R. Lawrence and J. W. Lorsch, "Differentiation and Integration in Complex Organizations," Administrative Science Quarterly, 11 (June, 1967), pp. 1-47. Although they do not use the term, as such, economists have dealt with the phenomenon of differentiation under the headings of division of labor, specialization, and technological progress, based initially on the work of Adam Smith. Cf. Adam Smith, An Inquiry Into the Nature and Causes of The Wealth of Nations, E. Cannon, ed., (N.Y.: Modern Library, 1937); Bert Hoselitz, ed., Theories of Economic Growth (Glencoe, Ill.: The Free Press, 1960); B.F. Hoselitz and W.E. Moore, eds., Industrialization and Society (UNESCO: Mouton, 1963); Albert O. Hirschman, The Strategy of Economic Development (New Haven: Yale University Press, 1958); and W.W. Rustow, ed., The Economics of Take-Off into Sustained Growth (New York: St. Martin's Press, 1963).

25. Thompson, Organizations . . ., op. cit., ch. 2 and 3. See also J.K. Galbraith, The New Industrial State (Boston: Houghton Mifflin, 1962).

26. These come in various forms from Thompson's and Katz and Kahn's work cited above; W.G. Bennis, "Changing Organizations," Journal of Applied Behavior Research, 2 (August, 1966), pp. 247-263, and W.G. Bennis and P.E. Slater, The Temporary Society (New York: Harper, Row, 1968); H.A. Shepard, "Changing Interpersonal and Intergroup Relationships in Organizations," in March, Handbook, op.cit., pp. 1115-1144; C. Argyris, Integrating the Individual and the Organization (New York: Wiley, 1964); O. White, "The Dialictical Organization," Public Administration Review (Jan./Feb., 1968), pp. 32-42. There is also another kind of reformation emanating from the experience of the large research based weapons systems organizations summarized in D.I. Cleland and W.R. King, eds., Systems, Organizations, Analysis, Management: A Book of Readings (New York: McGraw-Hill, 1969), and R. Johnson, F. Kast and J. Rosenzweig, The Theory and Management of Systems (New York: McGraw-Hill, 1963). The former group is rooted primarily in social-psychological traditions, while the latter firmly in industrial management and systems analysis.

27. H.A. Simon, "The Architecture of Complexity," Proceedings of the American Philosophical Society, 106 (December 1962), p. 367, reprinted in H.A. Simon, The Sciences of the Artificial (Cambridge: M.I.T. Press, 1969), pp. 84-118.

28. Compare the following definitions from C. Alexander, "A City is Not a Tree," Architectural Forum, 122 (April and May, 1965), pp. 58-61, 58-62. "A collection of sets forms a tree, if and only if, for any two sets belonging to the same collection, either one is wholly contained in the other, or else they are wholly disjointed." "A collection of sets forms a semilattice, if and only if, when two overlapping sets belong to the same collection, then the set of elements common to both belong to the collection." See also M.F. Freedell, "Organizations as Semilattices," American Sociological Review, 32 (February, 1967), pp. 46-54 for a socio-mathematics discussion of trees and semilattices applied to organizational descriptions.

29. Alexander, op. cit., May issue, p. 60.

30. See note 5 above.

31. See the summary of this literature in H.M. Vollmer and D.L. Mills, eds., Professionalization (Englewood Cliffs, N.J.: Prentice-Hall, 1966), ch. I, pp. 1-45; and J. Ben-David, "Professions in the Class System of Present-Day Societies," Current Sociology, XII (No. 3, 1963-64).

32. The Professions (Oxford: Claredon Press, 1933); Vollmer and Mills, op. cit., ch. 3, 8, 9; C. Gilb, Hidden Hierarchies: The Professions and Government (New York: Harper and Row, 1966); K.S. Lynn, ed., The Professions in America (Boston: Houghton Mifflin, 1965); M. Abrahamson, ed., The Profession in the Organization (New York: Rand-McNally, 1967); and N. Storer, The Social System of Science (New York: Holt, Rinehart and Winston, 1966).

33. Vollmer and Mills, op. cit., p. viif.

34. M.D. Cogan, "Toward a Definition of Profession," Harvard Educational Review, 23 (Winter, 1953), p. 49.

35. Vollmer and Mills, op. cit., p. viii.

36. See the discussion by T. Parsons, "The Professions and Social Structure," Social Forces, 17 (May 1939), pp. 457-467.

37. P. Blau and W.R. Scott, Formal Organization (San Francisco: Chandler Press, 1962), pp. 60-74; and Note 50 below.

38. See Blau, Exchange and Power . . ., op. cit., ch. 4, for a discussion of the importance of third party support in authority relationships.

39. G.A. Miller, "The Magical Number Seven Plus or Minus Two: Some Limits on our Capacity for Processing Information," Psychological Review, 63 (March, 1956), pp. 81-97; Attneave, op. cit., pp. 67-80; Garner, op. cit., ch. 3; and Schroder, op. cit.

40. Miller, op. cit., p. 95.

41. Miller, op. cit.; and Simon, "Architecture of Complexity," op. cit.

42. Cohen, Stotland, and Wolfe, op. cit.

43. Miller, op. cit., p. 95.

44. See H.A. Simon, "The Changing Theory and Practice of Public Administration," in I. de S. Pool, ed., Contemporary Political Science: Toward Empirical Theory (New York: McGraw-Hill, 1967), ch. 4, in this regard.

45. March and Simon, op. cit., p. 165.

46. H.L. Wilensky, Organizational Intelligence (New York: Basic Books, 1967), esp. ch. 2.

47. Ibid., p. 14.

48. Ibid.

49. Ibid., p. 49.

50. See Note 31 above and Ch. 2, Note 37. Particularly interesting in this regard is W. Kornhauser, Scientists in Industry (Berkeley: University of California Press, 1962).

51. See A.J. Reiss, Jr., "Occupational Mobility of Professional Workers," American Sociological Review, 20 (December 1955), pp. 693-700; and H.L. Wilensky, "The Professionalization of Everybody?" American Journal of Sociology, LXX (September 1964), pp. 137-158.

52. Perrow, op. cit.

CHAPTER II

ORGANIZATIONS OF INQUIRY AND ACTION: A STRUCTURE-PROCESS VIEW[1]

During the past two decades the number and size of complex research organizations has increased substantially, stimulated by the vast expenditures of a Federal government seeking technical innovation. Congress and the Federal Executive, spurred on by exhortation from the scientific community, demonstrated wide-eyed faith in the potential benefits of technical-scientific progress by providing abundant resources. Weapons and nuclear development, space exploration, and research in many health fields all profited greatly, and this beneficience spilled over into the cups of basic research as well.[2] Strong stimulants encouraged the growth of research and development capacities reaching far beyond the intramural capabilities of the traditional university organization. Many major universities added vigorous semi-autonomous research facilities, such as the Lawrence Radiation Laboratory at Berkeley. Similar opportunities spawned a number of university-affiliated or independent organizations engaging in government and industrial research. The Atomic Energy Commission's contract laboratories at Oak Ridge and Los Alamos, Lincoln and Argonne Labs, RAND, Jet Propulsion Laboratory, Stanford Research, and Battelle Memorial Institutes, and the growth of government and military "in-house" laboratories are illustrative. The Bell Labs is one of the very few major laboratories begun before the

Second World War. All the other examples have essentially post-war histories.

In a sense, the proliferation of research and development organizations is a macroscopic parallel to the professionalization of organizations discussed in Chapter One. National leaders were convinced that aspects of political and military contingency-uncertainty could be reduced by harnessing men of technical knowledge. In this process, unprecedented sums were spent from the public purse to bring forth whole organizations charged with the mission to inquire, reflect and produce uncertainty reducing devices, policies and intelligence.[3]

Public concern and hope has always accompanied these emerging organizations of scientific inquiry and action. It provides a central element in their external environment. Public concern transmitted through Congress and budget review processes, prompt demands for responsible control and accountability. Corporate and Federal research sponsors try to apply management techniques in often bewildered efforts to direct technical work. Scientists and engineers, in turn, often respond as irritable wise men, demanding technical and professional autonomy. Their managers, caught in the cross fire, fume about constraints and shifting resources, and seek patterns of organizational structure and personal accomodation which will mesh the values and goals of technical and the persistent pressures of watching sponsors.

It is obvious that research organizations are embedded in a social environment which includes the employing institution, the agencies or organizations furnishing resources, and a broad scientific community. Sponsors or underwriters of research and development seek assurances that funds will be used to forward their economic, academic

or economic goals. Research institutions seek to assure their continued growth and survival. And scientists and engineers seek to uphold the rigor and progress of scientific discoveries and their respective professions. In an organization, men holding these respective views generally assume that each may be pursued to the advantage of its advocate, without undue damage to the interests of the other. However, the exigencies of politics and the market often intrude to create strains and tension between representatives of sponsor, management, and technical professionals.[4] This chapter discusses the environment of organized research and the consequent bases for tension, altered authority relationships, and organizational structure.

The Environment of Organized Research

Research sponsor, the mediating parent's administrative organization, and the indirect influence of the scientific community, each is a source of contingency-uncertainty for members of research organizations. Their influence can reach deep into the working levels of the laboratory and shape the demands and expectations of both technical professional and the dominant coalition.[5]

Research Sponsors

The vehicle of contingency ridden by both sponsors and parents are resources and legitimacy, i.e., funds and authorization to spend them. Researchers require funds; supporters require the assurance of apparent control. Funds are claimed and the conditions of claim settlement become contingency made manifest.

The transfer of funds for technical work from government and industry to research labs has been accompanied by a parallel interest

in achieving research sponsor goals. Recurring Congressional and Executive examinations of research management and the rash of conferences, institutes and studies dealing with the "problem," reflect the intensity of this concern.[6] Problems of "research effectiveness," "planning for research," and "utilizing research for product development," while only dimly understood, are intensely interesting to managers. Clearly, these "problems of research" are not technical: they are administrative and managerial. These are not the problems scientists would define as research problems; rather these situations are problematic due to the political and commercial objectives of the research sponsors.

On the Federal level, is a continuing debate over the degree to which research should be controlled and/or centralized in coordinating efforts. Many public officials feel increased coordination and direction is warranted through some unification of scientific-technical effort in a central scientific agency.[7] Countering this, many scientists have criticized further government control, whether it is by lay boards or consolidation of federal agencies. They fear this would warp the development of unknown scientific advances.[8] These two beliefs were the basis for the extended and intense debate that has continued to the present over the relationship of the National Science Foundation to the Executive Office.[9]

In less documented form, this debate has been repeated within major industrial and governmental research organizations. Control by non-scientist executives over scientific direction and work is the issue. Executives in both industry and government seek assurance, through controls, that technical products will meet organizational needs. Scientists fear these controls will jeopardize the rigor and integrity of the scientific enterprise.[10]

Parent Organizations

Most research organizations or groups do not interact directly with their sponsors, but are part of a larger organizational context. Generally, some kind of parent organization, such as a large corporation, university administration, or government agency, provides administrative service and management direction functions. Management groups, closely tied to the dominant coalition of the parent organization, have important direct influence upon the requirements research managers must meet and those they place on technical persons. Many of these influences can be traced to the so-called bureaucratic characteristics of complex organizations. Critical characteristics of the parent which affect the offspring are: formal organization, goal structure, large size, authority relationships, and the procedures for control and coordination.[11]

The goals structure of complex organizations links middle-level and short-range objectives with longer range organizational goals.[12] General goals and shorter range objectives are the basis for many of the requirements that are placed upon scientists and engineers. A perceived inconsistency between the organization's goals structure and professional values can be expected to lead to the estrangement of professionally committed scientists and managers.

Size is one predictor of the degree to which structural differentiation occurs, and that hierarchical authority, division of labor, and procedures or rules governing personnel actions will become, or are, formalized. The larger an organization is, the more likely research and development activities will be formally recognized as a functional activity apart from other organizational functions, such as production or general administrative services. As an organization grows

larger and more bureaucratized, formal distinctions are likely to be drawn between pure research activities, on one hand, and advanced engineering or development, on the other. This appears to be common to all types of research institutions, academic, governmental and industrial.[13]

Increasing size and complexity of organizations also increases the likelihood that managers will depend on hierarchical authority relationships and formal procedures, rather than informal or collegial relationships. This includes designation of levels of responsibility and channels of decision-making, and greater dependence upon procedures or rules for control and coordination of purposes. The resulting paperwork or "red tape" is often a major frustration to everyone. These include such procedures as budgetary reporting, equipment procurement, and personnel records.

It is an empirical question whether hierarchical authority relationships and formal procedures are effective controls as the system grows increasingly complex. The point is not that managerial hierarchy is effective, but that managers attempt to use hierarchical structures to control. There is empirical evidence and some conceptual formulations which suggest both that hierarchies increase with complexity and that they decrease with complexity. Weber's classic formulation suggesting they increase is supported by several studies.[14] There are, however, a number of studies which suggest just the opposite, i.e., that with increased differentiation and complexity hierarchical authority relationships decrease.[15]

It is probable that all these studies represent organizational reality at the time they were conducted. Their differences are resolved

if the relationship between complexity and hierarchy is conceived of in curvilinear terms rather than as a unilinear dimension. That is, as complexity increases in initial or beginning periods, managers can meet the assumptions of adequate information about the activities within the organization and can safely act in a relatively directive manner. As complexity increases, managers' abilities to gather and interpret information declines. There they begin to depend on knowledgeable subordinates for that information, and directive authority patterns begin to break down.[16] As that occurs, collegial or non-hierarchical authroity structures begin to emerge despite the wishes of managers. Essentially they are caught in the web of dependence upon formal subordinates, and their relationships with them tend to be characterized by diminishing status distance, and more continuous consultation.[17] The crucial intervening variables are probably the degree of conceptual refinements available to organize and give meaning to information, and the adequacy of information technology.

Demands of sponsors and "parental" characteristics account for many direct and second order contingencies though they do not complete the pattern. Research organizations are also subject, to the more distant, pervasive constraints the scientific community exerts on its members.

Professional Communities

One slice into the literature of the professions reveals a picture of professional communities, though internally varigated, standing solidly together in the face of outsiders who would compromise professional values.[18] Professional communities cut across the

organizations that employ professionals, and furnish an association of respected persons re-enforcing professional norms and allocating symbolic rewards which demand loyalty above occupation work place.[19] As such a counter-reference group to organizational demands, these communities are salient aspects of a research organization's external environment.

Sponsors and parent organizations have direct and legal connections to laboratories; professional communities do not. Their constraining characteristics are indirect and enter the laboratory in the form of attitudes technical professionals hold about what is important in their work, the ways it should be done, what is "successful performance" and the rewards appropriate to it, and the conditions necessary for good science or engineering.

Professional associations, such as the American Association for the Advancement of Science, the American Physical Society, the American Chemical Society, and the American Institute of Electrical Engineers, provide a continuing body of men and women committed to maintaining quality of intellect, competence in practice, and adherence to professional norms. Within these "invisible colleges," the commodity of "competent evaluation" by others for creative work is exchanged and the norms of science supporting this exchange are encouraged.[20] Primarily through the processes of intensive education and socialization in graduate work, neophyte professionals learn to place a high value on: objectivity and generalization; organized skepticism and communality; and emotional neutrality and disinterestedness. (See Figure VII for the relationship among these values.)

FIGURE VII

	POINT OF REFERENCE:		
FOCUS OF NORM:	The body of scientific knowledge	Interaction among scientists	The scientist's psychological state
Orientation	Objectivity	Organized scepticism	Emotional neutrality
Action	Generalization	Communality	Disinterestedness

Source: N. Storer, The Social System of Science, p. 84.

If professional socialization and re-enforcement by professional communities are effective these values will be central to technical professionals' evaluation of and response to organizational demands. At present, these values seem quite central to many professionals. One of the striking characteristics of developing occupational structures in highly industrialized societies is the vitality and prestige attached to professionalism.[21] This is very evident in both scientific and engineering fields. In many cases, loyalty to the profession heavily outweighs commitments to the employing organization. Tension between professional and organizational values is not inevitable though most students of bureaucracy and professions document many instances where it did exist.[22]

We expect that the professional community is an organizational constraint only to the degree the organization is less committed to professional values and work situations that its own professionals. Organizations vary markedly in this regard. Universities, for example,

seem not to view professional communities as a contingency at all: rather as key allies in maintaining public resource flows and academic freedom. This is much less the case for industrial firms with R and D groups.[23] Midway are organizations, such as non-profit labs, struggling to gain professional recognition and find support without the added public incentive of teaching and educational responsibilities.

Summing up, professional communities strongly support rigorous socialization in formal education and maintain vigorous associations into which young professionals are recruited. These communities can become significant sources of contingency for research laboratories. They may call into question the quality of work and facilities in the lab, set informal standards and make professional recruiting more difficult. Furthermore, the more the dominant values of the organization diverge from professional ones, the more intense the conflicts between professionals and the dominant coalition are likely to become. Technical professionals strongly identified with professional groups, are likely to resist bureaucratic rules and supervision, reject bureaucratic standards, and have only conditional loyalty to the organization.[24]

A research organization's environment, then, is studded with sponsors, bounded by the constraints of the parent organization and given texture by the quality and values of a broad scientific community. These elements form a matrix of demands and conditions which constrain the variations of organizational form and processes an organization can take. They also become the underlying contingencies within which managers must contend. Demands from the supporting sectors of the task environment may be contradictory and difficult to reconcile in the face of scientific professional values. Institutional goals emphasizing

profit-making, for example, often clash with scientists' intention to defining their activities in professional terms.

The constraints of the surrounding institutional and professional environment gives shape to the particular internal structure and processes an organization constructs to cope with both environmental and technical requirements. Following is a description of research organizations as a system of processes carried on by members acting in structured, relatively regular ways. Through these processes and structures, inquiry and action are brought into being.

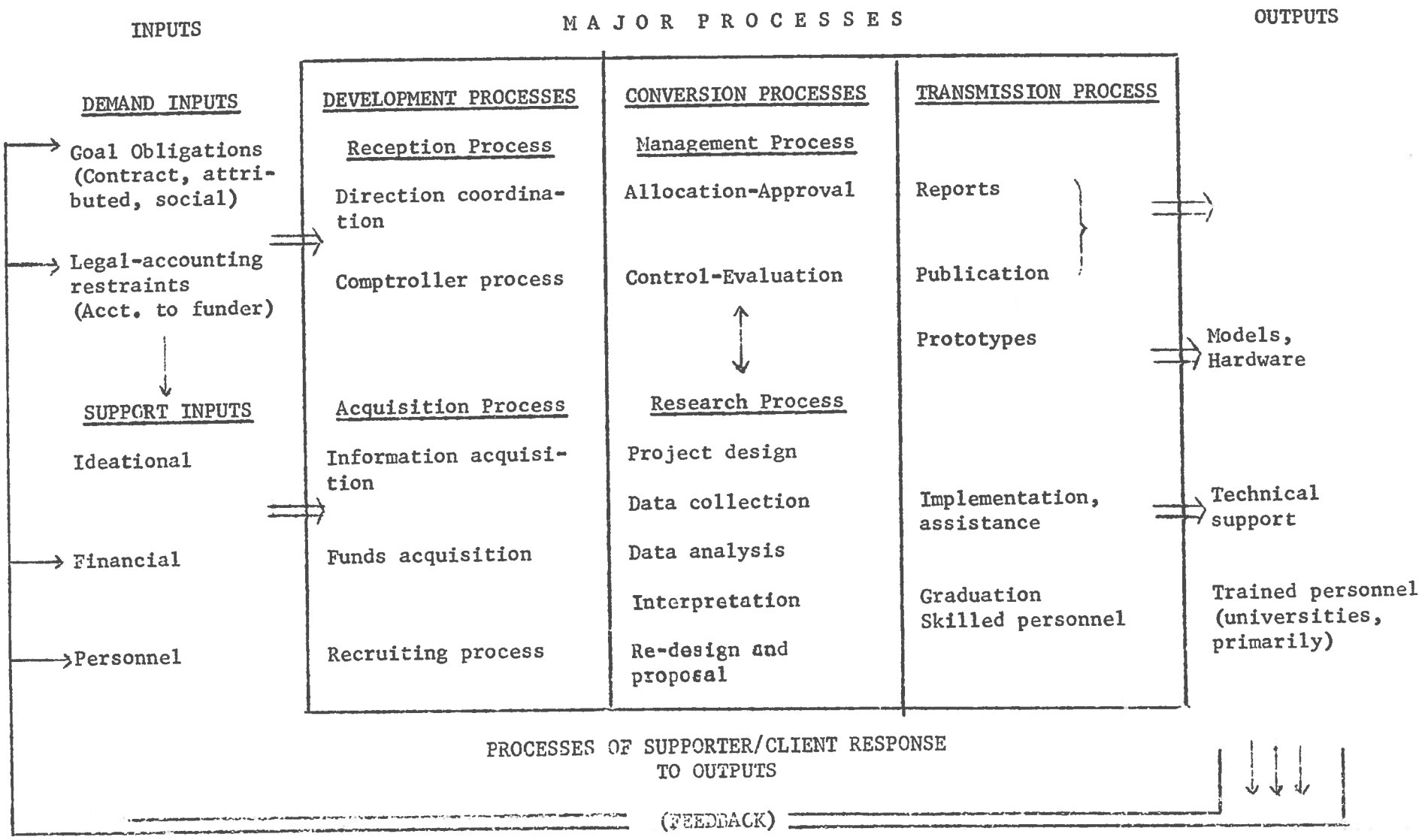
The Processes and Structure of Research Organizations

Several processes connect research organizations to their external environment; others define the internal dynamics of research and development. Described in familiar input-output terms, these processes of production and coordination transform or convert input resources into the "products" of research. Figure VIII schematically represents those processes in research organizations.[25]

There are two major classes of inputs into complex organizations: demands and resource supports. Every organization is confronted with demands it must meet at some minimum level in order to stimulate enough resource inputs to survive. However, mere survival is almost never a satisfactory condition. Rather, the maintenance of an organization's relative position of influence or prestige and the protection of its internal social character is what is at stake. This requires a higher level of resources than would be necessary for simple survival. These demands originate from the sponsors of the organization and reflects their expectations for output. They also come from the community at

FIGURE VIII

Research Organization



large in the form of generalized expectations that the research organization should do good research. When it is, the public affirms the organization's legimacy and provides positive sanctions.. These demands come in the form of expected goal obligation and resource accountability, and are a condition attached to supplying resources to the organization.

Goal obligations are formalized in the research contract terms, legal charters, etc., which are the basis for the mission of the organization. They set the general criteria for sponsor evaluation of the research performed. This is also the case for the resource accountability demand, i.e., the legal accounting demand. More fiduciary in nature than goal obligations, they stipulate criteria to be used in accounting for funds, the internal allocation of resources, etc. In Federally supported research organizations, these accountability demands originating in Congress and the Executive are enforced by the General Accounting Office and the Bureau of the Budget.

The other major class of inputs, resource supports, are the "raw materials" for conversion to outputs and are required for the maintenance of the organization. In research organizations there are three major resource supports. The most characteristic of research or inquiring organizations are ideational resources, that is, ideas, concepts, problems for research and technical information which is the stuff of technical innovation. The second and third are characteristic of all complex organizations, that is, physical and/or financial resources to provide the necessary materials for research, and personnel resources to accomplish research and administrative activities. In the last instance, primary emphasis is placed upon scientific and technical personnel as the most important human resource required for technical

innovation. The combination of demand and support inputs, then: provides the major priorities for the organization's direction and internal constraints; funds to maintain adequate facilities; information on current scientific developments in relevant fields; and personnel capable of creatively utilizing that information and coordinating supporting services.

The outputs of research organizations are the embodiments of the goal obligations, restricted by accounting demands, constructed out of supporting resources and made "visible" in three major forms. The first, paralleling the ideational inputs, are those new ideas, concepts and findings transmitted to the technical community through publications and reports. Models or prototypes are also organizational outputs and are physical representations of many scientific and technical concepts. A third output, technical support, provides services to non-research groups that are faced with technical problems beyond their own internal capacities.

A fourth output is less evident; this is an addition to the pool of trained researchers and technical analysts. While this seems to happen in most research organizations, only the universities have this as one of their goal obligations and attempt systematically to provide technically trained personnel as an output. In effect, the university is the major support source of the required personnel inputs to non-academic research organizations.

All complex organizations develop internal structures and processes "spanning" its boundaries, reaching out into the surrounding external environment to stimulate resource support inputs and coordinate demands focused on the organization.[26] The greater the contingency in

resource acquisition, the more likely specialized units, e.g., personnel office, public relations, will be assigned surveillance responsibilities over a portion of the outside environment. Thus, there are identifiable groups in research organizations that deal primarily with the problems of acquiring funds, recruiting technical personnel and keeping available technical information as current as possible. There are also units of the organization that attempt to absorb demands for accurate accounting and fiscal management. Finally, top management is generally that part of the organization which attempts to coordinate goal obligation demands.

Acquisition of resource supports and reception of demands alone is not sufficient to stimulate outputs. Processes that convert "raw materials" into outputs are also required and have their structural embodiment. Figure VIII outlines two intermediate processes between the reception and acquisition of inputs and the transmission of outputs. Both the management and research processes are necessary for effective conversion. Management processes includes the allocation and control of resources and the approval and evaluation of the research. They enable the research to rise above the individual level and become a group or corporate effort.

The research process outlined in Figure VIII follows, in some sense, the idealized sequence of scientific method. That is, it includes project design, data collection and analysis, interpretation, and, finally, redesign of the research and proposal of a new study. Phases of the research process can be analytically discussed in this way, but it should be recognized that in fact the various steps may occur simultaneously, may be skipped, or perhaps ignored in some formal sense.

However, as in the logic of decision-making, these steps are expected to occur in a classic research project. They are often criteria by which the supporters of research evaluate the research group. It is an empirical question to what degree these steps actually describe what goes on in the research process.

In a fundamental way, the research process and its attendant structure is the "technical core" of the organization. It is the combination of human and non-human resources which, in motion, is inquiry. Specialized into relatively homogeneous sub-groups, differentiated and linked together by coordinating groups, research units carry on the complex activities required for effective inquiry and action. Typified by J. D. Thompson, as reciprocally interdependent, research organizations probably have the most complex, overlapping internal structure of modern organizations.[27] Groups depend upon each other in direct and reciprocal ways, more immediate than the serial interdependence of an assembly line, and more difficult to direct.

Buffering the technical research core from the external environment and reducing the uncertainty inducing effects of change is the managerial sector of the organization. Composed of some boundary spanning units and a number of internal communication and coordination groups, this managerial infrastructure mediates between the environment and the technical core. It also adds to the overall complexity of the organization with both pooled and serial interdependent units, stratified in rough hierarchies of decision-making.[28]

Linking the "private" research knowledge of the laboratory to the scientific community and meeting the goal obligations of the funder involves the processes of transmission. They include publishing articles and books, constructing prototypes and hardwares, i.e. models

of technical devices, and assisting in the application of research findings to specific problems. In the case of the university, transmission also includes teaching.

Finally, there are processes which enable the organization to sense the effects of its outputs on the sponsor and users of their work. This is then "fedback" to various sections of the organization, e.g., higher management and the working level of scientists. The feedback occurs through a number of procedures, ranging from the rather formal organizational evaluation in tracking their products, to the much more informal give and take between scientists and engineers at professional meetings. Depending on the quality of the information gathered through these activities, managers and technical professionals are often able to make changes in the internal processes and structure that result in supportive feedback, increased possibility of resource supports, and more latitude in defining goal obligations.

Joined together under an overarching coalition of senior managers, these various units are clustered in major functional subsectors and form the overall structure of a research organization. This structure is generally exceedingly complex, reflecting the internal complexity of highly sophisticated technical processes undergoing continual change. If the external environment is also highly differentiated and complex (see Ch. One), managerial and institutional infrastructure parallels that complexity. The more dynamic the external environment, the more difficulty boundary-spanning groups have in adapting to it. When they are also reciprocally interdependent with technical core units, the "resulting set of constraints and contigencies (may) exceed the organization's capacity to adapt and coordinate."[29]

This puts considerable strain on traditional forms of organizational processes and accounts for much of the structural innovation seen in research laboratories which will be discussed in Chapter IV.

When the management and research processes are translated into positions, roles and duties, the patterned structure of the research organization is thereby defined and becomes the basis for the structural characteristics of the organization. A summary of these characteristics include: allocation of work to those competent to do it; a loose hierarchical pattern of authority relations; organizational relationships formalized generally as depicted in organization charts; standard operating and control procedures meant to stabilize ways of communicating goals and seeing that they are accomplished; procedures for personnel promotion in career patterns; and, finally, a number of accepted norms which are not formally stated, but are the basis for many of the expectations members have for each other.[30]

These are the usual characteristics of large complex organizations generally called bureaucracies, and many seem to persist in research organizations as well. They are a kind of minimum requisite for the administrative support of research and development. The relationship between process and structure is important in fulfilling the organization's goals and has precipitated many questions concerning the "proper" way to organize research, the degree to which research direction should be centralized, and the "right" proportion of scientists to engineers in research teams. Generally, the discussion of "proper" structure and process are biased toward the management orientation of coordination and control. A resolution to many of the "problems" voiced in research organizations, however, awaits a more balanced

perspective. One that includes the expectations of technical personnel and their relationship to the research process. Different roles or positions in the organization often generate variant interests which become the bases for different notions of proper organization. In the next section we move to a general discussion of roles and their relations in these organizations.

Major Organizational Roles

Persons who act out the processes of organized inquiry and action do so within a matrix of sponsor and institutional expectations, and the indirect demands of professional associations. These form one side of an interaction process; the other side is those expectations born out of the logics of the research and development processes. Each side of this exchange limits the other: environmental expectations form broad constraints on the character and direction of research; and the technical logics of research and development place limits on what can be done and how it can be accomplished. These expectations are the bases for a system of interpersonal relationships that is the process of inquiry. Processes of research and supporting administrative activities must be divided among persons who will act them out in patterns of mutual interaction. These divisions, or organizational roles, are formal positions occupied by persons expecting to carry out clusters of activities. In concert they span those actions necessary for organized inquiry, or the role system of organized research.[31]

Major organizational roles paralled the types of activities characterized by the processes of organizational research (see Figure VIII).[32] The core work of the research process is, of course, carried on

by scientists and engineers, assisted by a cadre of technicians. Acting as immediate coordinators and buffers are technical managers, who are the supervisors for technical groups actually doing the work. These men are often aided by group administrators, who handle much of the administrative work at the group level leaving technical coordination or technical managers. Clustered around the technical core are a number of administrative units, i.e., support administrators. They are removed from technical groups and carry out a number of administrative functions, such as budget control and review, accounting, recruitment and personnel matters, payroll, reproducing facilities, and other housekeeping and maintenance chores. At the "apex" of the organization is the dominant coalition of laboratory executives, several steps removed from the actual research process, these men coordinate the work of resources acquisition and reconcile the demand from sponsors and parent organizations. These roles may be grouped according to the predominant focus of their activity, technical managers and their group administrators deal almost exclusively with internal managerial problems. On the other hand, support administrators and executives are much occupied by relations with outside demands, etc., or institutional concerns. Schematically, Figure IX presents the distinctions of managerial and administrative roles.

A similar distinction can be made between technical professionals who are engaged in either of the two major processes of inquiry or action. (See Figure X.) Inquiry, in this sense, is synonymous with basic or fundamental research. This is research intended to contribute to the store of scientific or engineering knowledge, without particular regard for its practical applications. The action phase combines

development and/or advanced design activities, in which primary attention is paid to utilizing scientific and technological knowledge for the solution to problems defined by sponsor or parent organization. Obviously, these two activities are closely related to each other in many R and D labs: new development alternatives are stimulated by advances in scientific knowledge; likewise, applied problems in turn unearth scientific problems for which basic research is required. However, they are sufficiently distinctive to warrant at least informal separation in laboratories and to prompt significantly different attitudes about organizational matter. (See Chapter VI.)

FIGURE IX

Type of Organizational Activity

	Institutional	Managerial
Research Management	Laboratory Executives	Technical Managers
Supporting Administration	Support Administrators	Group Administrators

FIGURE X

Type of Technical Professional

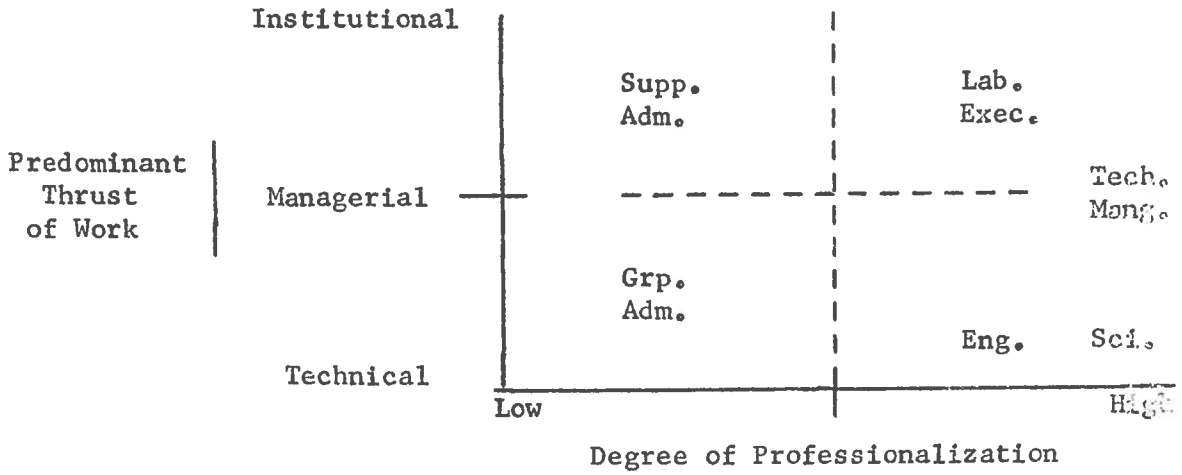
		Scientist	Engineer
Orientation Toward Technical Work	Basic		
	Applied		

Notes on the Professionalization of Laboratory Roles

Referring to the discussion of professionalization in Chapter One, we can describe the major roles of research organizations in terms of the degree to which each of them are professionalized. Figure XI is a rough approximation of what they are likely to be along the dimensions of professionalization and the technical-managerial-institutional thrust of their activities. (See Note 19, Ch. 1.)

FIGURE XI

The Professionalization of Major Laboratory Roles



Laboratories have a good deal of help in developing special competence in two roles from agencies outside the lab. Both scientists and engineers go through intensive socialization in the process of becoming professionals which releases the lab from this requirement.[33] They come "ready-mixed" from colleges and universities primed to train men in those roles. The laboratory's responsibility is to "mold and finish" them for the specific task. This is not the case for either

administrators or technical managers. There are almost no programs for the training of research managers, particularly for those directing basic research work. Only recently have schools of business begun tentative programs which could train a man in administrative skills needed in group or support administration.

Most of the major roles in research organizations are far along the path toward professionalization. Clearly, highly educated scientists and engineers fall into this category; so do most technical managers and laboratory executives. Having come from the ranks of bench scientists and engineers themselves, they have long histories as technical professionals. Their shift of roles does, however, place them outside many of the regular activities of professionals. In a much more limited sense, research administrators as a group take on some characteristics of professionals and, along with managers, tend to key their behavior to organizational objectives.

Both managers and technical professionals, then, share some of the same professional characteristics.[34] They make decisions based on generalized or "universal" criteria which are independent of specific cases, and generally founded on long training in technical fields. They possess a certain area of expertness in their respective areas and are appointed to their positions because of past "achievement" or performance and competence. There are, however, some important differences which can lead to disruptive relations between them.

Managerial and administrative roles often differ from scientific and engineering ones in goal orientation, source of organizational authority, the basis of decision-making, and, of course, role content -- the things they do.[35] Managers and their administrators, whether on

the research levels or on the higher corporate levels, are bound by their organizational superiors to the goals of the organization; their foremost responsibility is to present and promote those goals. When organizational goals run counter to professional technical goals, as they sometimes do, managers are expected to place organizational objectives first. We can expect the intensity of goal commitment of managers to vary, depending on the proximity of the manager to scientists. Technical managers, men who are closely connected with research, tend to perceive technical goals as most legitimate. Laboratory executives, generally removed from scientists and engineers, almost always place scientific or technical goals in subordinate position to organizational goals. Scientists, particularly, almost always reverse that order, putting technical objectives first, only under strenuous pressure bending to allow organizational goals to dominate. Engineers tend to fall in an intermediate position, often deferring to organizational values.

In the organizational setting, the basis for authority also differs between technical professionals and their managers. Scientists and highly trained engineers derive their authority from specialized technical competence, often reinforced by organizational position. Managers' authority, on the other hand, rests primarily in the positions they occupy with occasional technical reinforcement. Managers' formal positions give them access and legitimacy in the use of formal sanctions, budgetary controls, etc. These means of formal authority are often technically reinforced, at least for the technical manager, by a past excellence in science or a history of technical work. Managerial decision-making is bounded by the directives from superiors in the

organization, and often in the case of the science manager, the canons of science as well. Finally, managers' duties include activities designed to control the actions of subordinates in achieving organizational goals. Control devices are sometimes used in a directive fashion and may not attain the collegial relationship that is the modus operandi of scientific peers.

These major roles and their permutations make up much of the research and development organization. They give research organizations their particular style and color, and interaction among and between them furnishes the dynamics and drama of inquiry and action.

Summary

The prominent features of research and development laboratories' environments are the agencies providing major financial resources, the labs' parent organizations, and various scientific and technical professional communities. In combination, they shape the character of the demands made of laboratories and the resource available to meet them. Laboratories can be described in terms of the processes of resource acquisition, product transmission, and the internal conversion of "raw materials" into those products. Central to laboratory operations are the research processes manned by scientists and engineers, and the administrative processes carried on by managers and administrators. Persons who occupy each of these roles have characteristic obligations and expectations about what they are to do and how they are to do it. Their interaction is the heart of the internal dynamics of organized inquiry and action. In Chapter Three a more detailed discussion of role relations is presented.

FOOTNOTES, CHAPTER TWO

1. This chapter is a revision and expansion of a paper presented to the Conference on Science and Contemporary Problems, Institute of Nuclear Studies, Oak Ridge, Tennessee, June, 1964, and Internal Working Paper No. 75, Space Sciences Laboratory, Social Sciences Project, University of California, Berkeley, November 1967. Special appreciation goes to James L. Laing, Carnegie Institute of Technology for his lucid comments on early versions when we were both at Stanford University, and Walter O. Weyrauch, University of Florida, for his helpful comments in latter stages.

2. See M.D. Reagan, Science and the Federal Patron (New York: Oxford University Press, 1969), ch. 1; and C. Kaysen, The Higher Learning, the University and the Public (Princeton: Princeton University Press, 1969), ch. 1, for recent reflections on this process. Also see summaries in House Committee on Science and Astronautics, Science, Research and Development Subcommittee, Hearings, 1970 National Science Foundation Authorization, Vol. II, 91st Congress, 1st Session, 1969, pp. 35-70; National Science Foundation, Surveys of Science Resources Series, Basic Research, Applied Research and Development, 1962 and 1965 (NSF 65-18 and NSF 67-12, respectively); and Federal Funds for Research, Development and Other Activities, Fiscal Years 1965, 1966, 1967, Vol. XV (NSF 66-25). The latter reference has the more complete summary statistics.

3. While reducing some uncertainty about whether the U.S. would have nuclear weapons and space capabilities, science has, on the whole, subjected us to uncertainty displacement. It has been a spectacular failure in reducing second order uncertainty, and perhaps has increased it.

4. Examples of this are evident in the writings on the broad problems of government support of research. See D.K. Price, Government and Science (New York: New York University Press, 1954); J.S. Dupre and S.A. Lakoff, Science and the Nation: Policy and Politics (Englewood Cliffs, N.J.: Prentice-Hall, 1962); V.K. Heyman, "Government by Contract: Boom or Bust," Public Administration Review, 31 (Spring, 1961), pp. 59-64; C.V. Kidd, American Universities and Federal Research (Cambridge: Harvard University Press, 1959); and The President's Science Advisory Committee, Scientific Progress: The Universities and the Federal Government (Washington, GPO, 1960); R. Gilpin and C. Wright, eds., Science and National Policy-Making (New York: Columbia University Press, 1964); and S.A. Lakoff, ed., Knowledge and Power: Essays in Science and Government (New York: Free Press, 1966). For a shrill discussion of the same effects see H.L. Nieburg, In the Name of Science (Chicago: Quadrangle Press, 1966).

5. See H.A. Simon, The Sciences of the Artificial (Cambridge: M.I.T. Press, 1969), pp. 1-13, for a theoretical discussion of the molding effects of environment; and Chapter I, Note 15.

6. Congressional attention can be seen in the numerous reports, etc., issued concerning these matters. As an example, see from the Senate Committee on Government Operations, Senate Report No. 16, Establishment of a Commission on Science and Technology, 1964; from the House Select Committee on Government Research, House Report 1942, Contract Policies and Procedures for Research and Development, 1964; and House Report 1729, Study No. 1, Administration of Research and Development Grants, report under authority of House Res. 504, 1964. Executive concern is most characteristically represented by studies such as The Administration of Government Sponsored Research at Universities, Bureau of the Budget, Executive Office of the President, GPO, 1966. Other evidence may be seen in the numerous proceedings of conferences, etc., held by government agencies focused on these problems.

7. H. Humphrey, "The Need for a Department of Science," The Annals of the A.A.P.S.S., 327 (January, 1960). See also B. de Jouvenal, "The Political Consequences of the Rise of Science," Bulletin of the Atomic Scientists, XIX (December, 1963), pp. 2-83; and Dupre and Lakoff, op. cit.; Price, op. cit.; and R. Barber, The Politics of Research (Washington: Public Affairs Press, 1966); and A. Etzioni, "On the National Guidance of Science," Administrative Science Quarterly, 10 (March 1966), pp. 466-487. See also House Committee on Science and Astronautics, Subcommittee on Science, Research and Development, Proceedings, Technology Assessment Seminar, Sept. 1967, esp. Summary Index, pp. 167-173; and National Academy of Science, Technology: Process of Assessment and Choice, Report to House Committee on Science and Astronautics, July 1969, esp. Ch. 1.

8. See, for example, Kidd, op. cit.; C.W. Bray, "The Effects of Government Research Contracts on Psychology," American Psychologist, 7 (December, 1952), pp. 710-713; R.D. Reid, "Freedom and Financing in Research," American Scientist, 41 (April, 1953), pp. 286-292; W.G. Bennis, "The Effect of Academic Goods on Their Market," American Journal of Sociology, 62 (July 1956), pp. 28-33; N. Colvard, "Foundations and Professions: The Organizational Defense of Autonomy," Administrative Science Quarterly, 6 (September 1961), pp. 167-184. See also B.L. Johnson, "The Changing Role of Scientists in International Affairs," American Scientist, 52 (June 1964), pp. 138-145; J. Shannon, "Science and Federal Programs: The Continuing Dialogue," Science, 144 (May 22, 1964), pp. 976-978; and L.A. Dubridge, "Policy and the Scientists," Foreign Affairs, 41 (April 1963), pp. 571-588.

9. This debate is chronicled and interpreted in J.L. Penick, et al., eds., The Politics of American Science: 1939 to the Present (Chicago: Rand McNally, 1965), esp. Part II; Price, Government and Science,

op. cit.; and A.H. Dupree, "Central Scientific Organization in the United States Government," Minerva, I (Summer 1963), pp. 453-469; and A.H. Dupree, "Centralization of Federal Science Activities in an Age of Academic Unrest," statement before Subcommittee on Science, Research and Development, House Comm. on Science and Astronautics, July 24, 1969.

10. See W. Kornhauser, Scientists in Industry: Conflict and Accommodation (Berkeley: University of California Press, 1962), esp. pp. 50-56, for a summary of this debate. The best statement from the scientific community regarding this problem is found in "The Integrity of Science," A Report for the American Association for the Advancement of Science, Committee on Science in the Promotion of Human Affairs, in G. Holton, ed., Science and Culture (Boston: Houghton Mifflin and the American Academy of Science, 1965), pp. 291-332.

11. For discussions of bureaucratic characteristics see P. Blau, Bureaucracy in Modern Society (New York: Random House, 1956); P. Blau and W.R. Scott, Formal Organization (San Francisco: Chandler Publishing Co., 1962); P. Brown, "Bureaucracy in a Government Laboratory," Social Forces, 32 (March, 1954), pp. 259-268; S.N. Eisenstadt, "Bureaucracy and Bureaucratization: A Trend Report," Current Sociology, No. 2 (1958), pp. 99-163; A Etzioni, A Comparative Analysis of Complex Organizations (Glencoe: Free Press, 1961); J.G. March and H.A. Simon, Organizations (New York: John Wiley and Sons, 1958); S. Marcson, The Scientist in American Industry (New York: Harper, 1960); V.A. Thompson, Modern Organization (New York: Alfred A. Knopf, 1961); and M. Weber, From Max Weber: Essays in Sociology, H. Gerth and C.W. Mills, eds. and trans. (New York: Oxford University Press, 1946).

12. March and Simon, op. cit. C.I. Barnard, The Functions of the Executive (Cambridge: Harvard University Press, 1938), especially Part IV; H.A. Simon, Administrative Behavior, 2nd ed. (New York: Macmillan Co., 1957); T. Parsons, "Suggestions for a Sociological Approach to the Theory of Organization," Administrative Science Quarterly, I (June 1956), pp. 63-85; E. Litchfield, "Notes on a General Theory of Administration," Ibid.; J.D. Thompson, et al., Comparative Studies in Administration (Pittsburgh, Pa.: University of Pittsburgh Press, 1959); and B.V. Dean, "Applications of Operations Research to Managerial Decision-Making," Administrative Science Quarterly, 3 (December 1958), pp. 412-416; A. Etzioni, op. cit., ch. IV; Eisenstadt, op. cit., the series of articles in A. Etzioni, Complex Organizations: A Sociological Reader (New York: Holt, Rinehart and Winston, 1962), ch. 3; and H.A. Simon, "On the Concept of Organizational Goal," Administrative Science Quarterly, 9 (June 1964), pp. 1-22.

13. See, for example, E. Haas and L. Callen, "Administrative Practices in University Departments," Administrative Science Quarterly, 8 (June 1963), pp. 44-60; J.P. Gibbs and H.L. Browning, "The Division of Labor, Technology and Organizations of Production in Twelve

Countries," American Sociological Review, 31 (February 1966), pp. 81-92; P. Blau, et al., "The Structure of Small Bureaucracies," American Sociological Review, 31 (April 1966), pp. 179-191; and Kornhauser, op. cit., pp. 33-42.

14. W.A. Flushing, "Organizational Rules and Surveillance: Propositions in Comparative Organizational Analysis," Administrative Science Quarterly, 10 (March 1966), pp. 423-443.

15. See V.A. Thompson, Modern Organizations, op. cit.; M. Zald, "Organizational Control Structures in Five Correctional Institutions," American Journal of Sociology, 68 (November 1962), pp. 335-345; B. Walter, "Internal Control Relations in Administrative Hierarchies," Administrative Science Quarterly, 11 (September 1966), pp. 179-206; and a summary of other studies in J. Hage, "An Axiomatic Theory of Organizations," Administrative Science Quarterly, 10 (December 1965), pp. 289-320. See also J.D. Thompson, Organizations in Action (New York: McGraw-Hill, 1967).

16. See general discussion of delegation of uncertainty in Chapter One.

17. See T. Caplow, Principles of Organization (New York: Harcourt, Brace, 1964), Ch. 3, for an extensive analysis of relationship of status, interaction, achievement, etc.

18. For three good summaries of this literature see Kornhauser, op. cit.; N. Storer, The Social System of Science (New York: Holt, Rinehart and Winston, 1966); and H.M. Vollmer and D.L. Mills, eds., Professionalization (Englewood Cliffs, N.J.: Prentice-Hall, 1966).

19. Etzioni, A Comparative Analysis . . ., op. cit., ch. 2, for a discussion of symbolic rewards as a basis for compliance. Research organizations are specifically noted as examples of normative compliance systems.

20. Storer, op. cit., pp. 76-86, for a discussion of scientific norms and the conditions of exchanging this commodity.

21. Vollmer and Mills, op. cit., ch. 10; and H.L. Wilensky, "The Professionalization of Everyone?" American Journal of Sociology, LXX (November, 1964), pp. 137-158.

22. Notes 19 and 37. See also Marcson, op. cit.; M. Abrahamson, ed., The Professional in the Organization (Chicago: Rand McNally, 1967); W. Hirsch, Scientists in American Society (New York: Random House, 1968); D.C. Pelz and F.M. Andrews, Scientists in Organizations (New York: Wiley, 1966); and J.J. Beer and W.L. Lewis, "Aspects of the Professionalization of Scientists," Daedalus, 92 (Fall 1963), pp. 764-784.

23. Kornhauser, op. cit., chs. 3-5.

24. W.R. Scott, "Professionals in Bureaucracies -- Areas of Conflict," in Vollmer and Mills, op. cit., pp. 265-275.

25. The schema and its interpretation are based on a composite of several statements of structural-functional or structure-process analysis. While these concepts have been developed to aid in explaining social and political systems, we have attempted to reduce the level of generalization and apply them to organizational analysis. This avoids some of the logical problems of structure-process analysis on the societal level, for we take the formal goals of the organization as the basic logical root, deriving processes from them, rather than the global and amorphous "goal" of system survival or maintenance. For discussions of this type of analysis see D. Katz and R. Kahn, The Social Psychology of Organization (New York: Wiley, 1960); Blau and Scott, op. cit.; R. Merton, "Manifest and Latent Functions," in Social Structure and Social Theory (Glencoe, Ill.: Rev. Ed., 1957); A.W. Gouldner, "Reciprocity and Autonomy in Functional Theory," and C.G. Hempel, "The Logic of Functional Analysis," in L. Gross, ed., Symposium on Sociological Theory (Evanston, Ill.: Peterson, Row, 1959), pp. 241-270 and 271-307; M.J. Levy, Jr., The Structure of Society (Princeton: Princeton University Press, 1952). For a discussion of this type of analysis in political science see D. Easton, A Systems Analysis of Political Life (New York: Wiley, 1965), and G. Almond and G.B. Powell, Jr., Comparative Politics: A Developmental Approach (Boston: Little, Brown, 1966). See also H.M. Vollmer, A Preliminary Investigation and Analysis of the Role of Scientists in Research Organizations (Menlo Park, Stanford Research Institute, 1962), and "Structural-Functional Analysis as a Method," in R.V. Bowers, ed., Studies on Behavior in Organizations: A Research Symposium (Athens, Georgia: University of Georgia Press, 1966), pp. 45-63. For a cogent discussion of the assumption that must be met in the use of this perspective, see A.J. Gregor, "Political Science and the Uses of Functional Analysis," American Political Science Review, 62 (June 1968), pp. 425-439, and M. Landau, "On the Uses of Functional Analysis in Political Science," Social Research, 35 (Spring 1968), pp. 48-75.

26. See particularly the discussion of boundary-spanning structures in Thompson, Organizations . . ., op. cit., pp. 70-73.

27. Ibid., pp. 51-55.

28. Ibid., pp. 55-61. See also T.R. La Porte, "Conditions of Strain and Accommodations in Industrial Research Organizations," Administrative Science Quarterly, 10 (June 1965), pp. 36-38.

29. Thompson, Ibid., p. 76.

30. For a discussion of these characteristics see particularly Blau and Scott, op. cit.; and R.H. Hall, "The Concept of Bureaucracy," American Sociological Review, 69 (July 1963), pp. 32-40. The voluminous literature on formal-informal organization is also relevant here; see particularly M. Evans, "Superior-Subordinate

Conflict in Research Organizations," Administrative Science Quarterly, 10 (June 1965), pp. 52-64.

31. See Chapter III for a more detailed discussion. General material in role theory includes N. Gross, et al., Explorations in Role Analysis (New York: Wiley, 1958); R. Merton, "The Role-Set: Problems in Sociological Theory," Journal of British Sociology, 8 (June 1957), pp. 106-200; B.J. Biddle and E.J. Thomas, eds., Role Theory: Concepts and Research (New York: Wiley, 1966), esp. ch. 1-3; R.L. Kahn, et al., Organizational Stress (New York: Wiley, 1964), ch. 2; E.G. Palola, "Organization Types and Role Strains: An Experimental Study of Complex Organization," Sociology and Social Research, 51 (January 1967), pp. 171-184; and R. Darhendorf, Essays in the Theory of Society (Stanford: Stanford University Press, 1968), ch. 2, "Homo Sociologicus."

32. For discussion of the roles of manager and scientist, see N. Kaplan, "The Role of the Research Administrator," Administrative Science Quarterly, 4 (June 1959), pp. 20-42; E.J. Jones, The Administrative Man in a Research and Development Environment (Unpublished D.P.A. Dissertation, University of Southern California, 1961); D. Marvick, Career Perspectives in a Bureaucratic Setting (Ann Arbor: Michigan Governmental Studies, Michigan University Press, 1954); B. Barber and W. Hirsch, eds., The Sociology of Science (Glencoe: Free Press, 1962), esp. Parts 3 and 4; B. Glass, "The Academic Scientists, 1940-1960," Science, 132 (September 1960), pp. 598-603; E.S. Uyeki and F.B. Cliffe, "The Federal Scientist-Manager," Science, 139 (March 1963), pp. ; and R.M. Hower and C.D. Orth, 3rd., Managers and Scientists: Some Problems in Industrial Research Organization (Boston: Division of Research, Graduate School of Business, Harvard University, 1963), esp. ch. 3, 19.

33. See A. Etzioni, A Comparative Analysis . . ., op. cit., for a general discussion of the relationship. See also W.R. Scott, op. cit.

34. Blau and Scott, op. cit., ch. 2.

35. See P. Brown, op. cit.; A. de Grazia, "A Concept of Scientists and Their Organization," American Behavioral Scientist, VI, (December 1962), pp. 30-34; Kornhauser, op. cit.; Marcson, op. cit.; Opinion Research Corporation, The Scientific Mind and the Management Mind (Princeton, N.J.: Opinion Research Corporation, 1954); H.A. Shepard, "Nine Dilemmas in Industrial Research," Administrative Science Quarterly, I (December 1956), pp. 295-309. B.G. Glaser, "Attraction, Autonomy, and Reciprocity in Scientist-Supervisor Relationships," Administrative Science Quarterly, 8 (December 1963), pp. 370-398; B.G. Glaser, "Differential Association and the Institutional Motivation of Scientists," Administrative Science Quarterly, 10 (June 1965), pp. 82-97. See also T.R. La Porte, op. cit.; H.M. Vollmer, et al., Adaptations of Scientists in Five Organizations: A Comparative Analysis, 2 vols. (Menlo Park, California, Stanford Research Institute, May 1964, R&D Series).

CHAPTER III

FROM STRUCTURE-PROCESS TO ROLE EXCHANGE SYSTEMS

Thus far our discussion has been largely at a abstract, macroscopic level dealing in broad generalities. Such a view may be intuitively interesting, satisfying or distressing. However, at this level alone, the match of our own cause/effect beliefs with empirical reality cannot rise above the floor of personal or unsystematic vicarious experience.

This chapter is a transition from abstract and general conceptions to those more operational in form. Rooted fundamentally in role analysis, we shall translate the symbols of structure-process into the major roles and relations between persons who occupy them, their perceptions of interdependence and expectations, and the strategies they employ in acting out the multitude of regularized behaviors which is structure and process. We began this translation in the closing sections of Chapter Two. Our task here will be to recapitulate the general argument, then refine the notions of role and their relationships in research and development laboratories. Closing the chapter will be an outline of major research questions.

From Uncertainty to Complex Organization

Underlying this study is the postulate that man, alone and in groups, has strong tendencies to reduce uncertain feelings about what is and what will occur. Contingent environs combine with cause/effect

beliefs ill-fitting to the contours of experience as roots of uncertainty. For persons, complexity and turbulence around them is the origin of much uncertainty. From the vantage of dominant coalitions, external dependencies, connectedness, and change are joined by the internal relationships of those they direct as a significant element of contingency.

Flight from fast-pursuing doubts turns men to organize, to blend their efforts and collective knowledge in structures shielding from the consequences of surprise. And still surprised, add others promising some new measure of certainty, till each seen source is coupled with some interior expert charged with taming it. Those men of knowledge, schooled by experience or years of formal tooling, hold in their heads those codes of cause/effect that others turn to trust. Complex codes, to sort noteworthy data and tell the meaning of it, to drive doubt back a bit for coalition members. These experts and professionals sweep into organizations viewed with hope, at first, to settle questions and uncertainties before decisions need be made.

Analytically breaking into the empirical cycle of stimulus-response, then response-as-stimulus, and further response we begin with environment. When the external environment (Ex) and technologically induced internal environments (T) vary in complexity and rate of change, so vary the sense of certainty held by coalition members (U).[1]

$$(Ex + T)_i \longrightarrow U_j \qquad (I)$$

Uncertainty for coalition members, when increased as (a) cause/effect beliefs become productive of surprises, and (b) information is perceived to be inadequate, prompts them to seek knowledgeable persons to aid in reducing it. Experts/professionals (p) are brought into the organization in proportion to the range of perceived contingencies in

both environments (Ex and $T)_i$. As the complexity and rate of change of Ex and T increase, the greater the organizational professionalization $(Op)_k$, i.e., the proportion of experts/professionals relative to all members, and the level of their professional skill increases.

$$(Ex + T)_i \Longrightarrow U_j \Longrightarrow (Op)_k \qquad \text{(II)}$$

Increasing organizational professionalization tends to increase the informational interdependence among professionals as problem solving begins to require information from more than one expert. Therefore, as the interdependence among professionals grows, control and coordination procedures which assume simple command and information exchanges, i.e., bureaucratic hierarchies, decline in usefulness and/or produce increasing numbers of unpleasant surprises. Thus, as professionalization increases, the interdependence within formal structure $(S)_m$ will increase. This is likely to be evident in strengthening already existing informal relationships and/or construction of new formal relations.

$$(Ex + T)_i \Longrightarrow U_j \Longrightarrow (Op)_k \Longrightarrow S_m \qquad \text{(III)}$$

Then the new structural relationships become an aspect of the internal complexity $(T)_i$ of the organization in the next round of stimulus-response. If a time dimension (t) is placed in the formula with S_m, it is modified to read:

$$(Ex + S_t T)_i \longrightarrow U_j \longrightarrow (Op)_k \longrightarrow S_{(t+1)m} \qquad \text{(IV)}$$

If these symbols were put in words, the formula would read:

External and Internal Complexity	leads to	Coalition Uncertainty	leads to	Organizational Professionalization	leads to	Interdependent Internal Structure

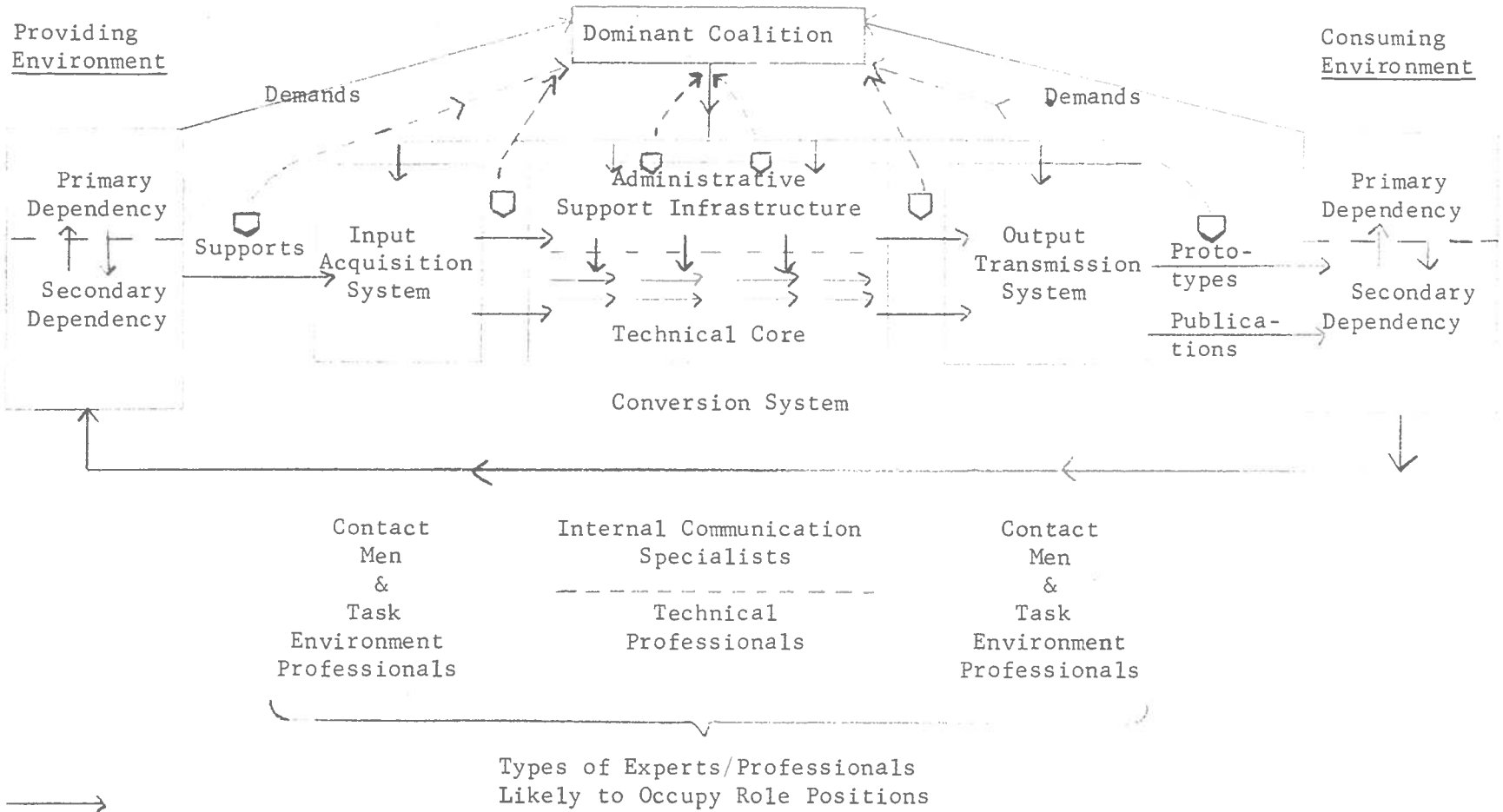
Moving one step closer to research and development, some of the notions above can be melded with the structure-process discussion in Chapter Two. In Figure XII, the language of the general argument is mixed with the structure-process view in the schematic relationships of various activities and the environment. Also included in Figure XII are the probable types of organizational experts/professionals likely to be located in units carrying on various processes. The dominant coalition receives demand inputs from outside organizations in the providing and consuming external environment, and directs and monitors activities within the organization. Contact men and task environment professionals attend to problems of resource acquisition and output transmission, while internal communication specialists and technical professionals act out the processes of converting administrative and technical resources to transmittable "products."

The overall complexity of the organization, i.e., the differentiated and interdependent character of formal structure, is a function of the mix of professionals employed, and the specialization of administrative groups intended as buffers from external contingencies. As we have suggested, the greater the range of perceived sources of contingency/uncertainty, the more likely a highly differentiated, interdependent structure.

Finally this general scheme can be applied to specific laboratory in terms of the roles developed to act out research processes. These roles symbolize the complex behaviors and expectations which complete the processes of inquiry and action. Expectations define the more or less regular patterns of interaction, legitimate dependent relationships, and direction of communication, prompt the behavior we

FIGURE XII

General System and Role Relationships



recognize as organizational structure. The next section is a more detailed discussion of research organization as a role system.

From Complex Organization to Role Relationships:
Research Organizations as Role Systems

While organizational systems can be described at the gross level of structure-process, persons experience their organizational worlds more concretely as a pattern of interaction with other persons who occupy formal positions and carry out a multitude of activities which define the work process.

Organizational job titles, names given to social positions in organizations, denote a range of expected activities, attitudes and normative imperatives to be followed by anyone taking on that position. Terms such as laboratory director, senior research scientist, personnel administrator III, are densely packed summary symbols which can be "unpacked" to provide cues to what action a role occupant should take; or what values he should use in judging the behavior of others he depends upon and those who depend on him. Research scientists, for example, expect that they will define the details of how they will solve technical problems, and that clerical work is not their responsibility. Personnel administrators neither expect to define technical problems nor to shun clerical work. Others who work with persons occupying these positions are very likely to share these expectations about scientists and administrators.

Describing organizational structure in terms of the various positions making it up, then attending to the range of expectations persons have in these positions, allows the researcher to dip below the aggregate level of structural language to examine the behavior and

attitudes of the people who compose it. Formalized in the language of role analysis, these conceptions are the basis for empirical research in organizational life. The elements and central relationships of this language are summarized below.[2]

The four basic elements are position, expectation, role and sanction.[3] Position refers to the "location of an actor or class of actors in a system of social relationships." For example, a research manager is located in the social group which constitutes the research laboratory. A position is the basic element in a network of relationships at the center of group or corporate life. Second, expectations are evaluative standards applied to someone occupying a position, e.g., research scientist. It is a normative statement about how occupants should or ought to behave.

The third element, role, "is a set of expectations applied to the [occupant] of a particular position." This is distinguished from role behavior which is those actions or activities associated with a particular position. Expectations arise from the individual's notion of what he should do, i.e., his role orientation, and the expectations of others in his group or organization. For example, scientists have a specific orientation, as professionals, which they bring to the organization. Likewise, managers have expectations for scientists' activities. The sum of these expectations provides cues for a person in a particular position. Finally, there is an element which deals with the control of role behavior, i.e., sanctions. They are the recognized degrees of reward or inducement and punishment associated with a particular role behavior or activity, e.g., publishing many competent research reports. Reward for adequate performance or punishment for below-average

performance are both included assuring activities that are at least partially consistent with expectations for that position.

But a role never stands alone, by definition. It is always in relation to other roles. This reciprocal nature of roles is the basis for another set of concepts in role analysis. They are: role system, role set, and role consensus-conflict. Any social group, from a family to a large corporation, can be seen as a series or system of positions occupied by people each having expectations for themselves and others, who strive to satisfy their own expectations as well as the goals of the group.

Thus we can conceive of research and development organizations as role systems, composed of a variety of roles in the reciprocal relationships implied by the logic of inquiry and action. The functions of each role are complementary to others in the organization, and together perform the complex sets of activities required in order to carry out experiments, search literatures, develop prototypes, test them for reliability and accuracy, etc.

To be effective, such role systems of research must provide coordinative roles as well as primary task roles. This brings us close to the rough typology of roles we discussed in Chapters I and II. Many organizational roles are devoted primarily to accomplishing the major mission of the organization, i.e., technical professionals, such as scientists and engineers. There are also roles mainly concerned with coordination, direction and group maintenance, i.e., laboratory executives, research managers, and support and group administrators.

When these roles are combined in approximate functional relationships depicted in Chapter II, the complicated set of role relationships

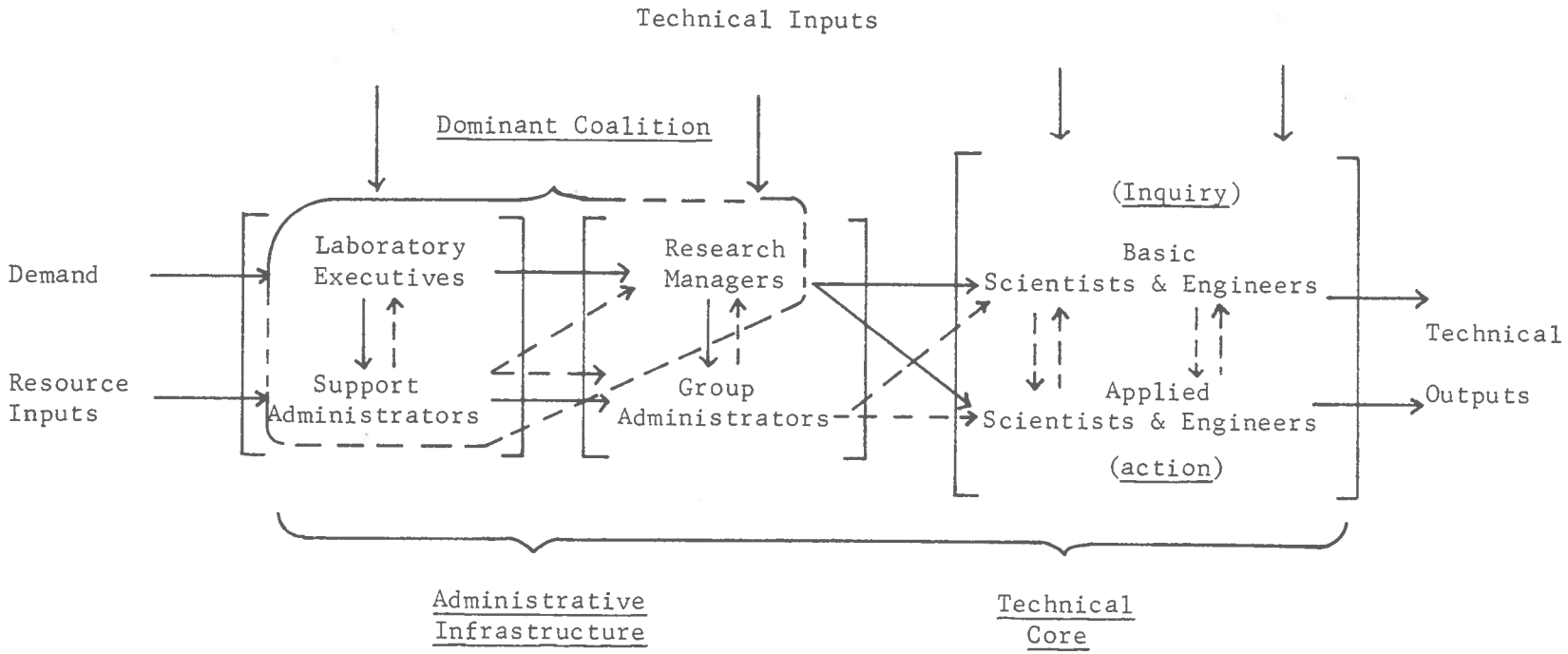
outlined in Figure XIII emerges. How the person occupying each role understands his or her set of expectations and obligations and those of others about him explains in large measure the degree of strain or tension within the organization, the kinds of issues likely to be most important, and the level of satisfaction within the laboratory.

The concept of role-set shifts the perspective from the whole system or group to a person inside it. Other perceived roles are spread out in array around each person, having various degrees of significance to him. This complement of role relationships is termed an individual's role-set. In part, the people in a role-set act as role definers, providing cues for a clearer role definition.

In general, these cues are the basis for the degree of consensus or disagreement evident in all organizations. Interaction is predicated on them; inducement/contribution exchanges are carried on in rough accord with them. If all organizational members are clear about what their own role behaviors and attitude imperatives are, accept them, and know unambiguously what the accepted role behaviors of others are, there is high role consensus within the organization. If, for example, all members take their cues from either a well-defined set of organizational goals or professional values, agreement is likely to be relatively high and tension between members will be modest. However, consensus of this order is rarely the case. Mixed organizational and research values shape goals and prompt contradictory demands that stimulate cross pressures on both technical professionals and managers/administrators. Role conflict or strain can be expected when contradictory expectations are experienced by professionals or managers. The degree of strain or

FIGURE XIII

Role Relationships Within R & D Labs



Input/Output Flows and Directives

Service and Consultation Directives

Semi-permeable boundary of coalition

conflict, of course, is reduced when organizational and professional values are similar.

Role strain occurs when a role occupant has "difficulty in meeting role demands."[4] It is primarily an intra-personal state resulting from a situation in which the occupant is confronted with a dual or multiple sets of obligations attached to his role. A scientist, for example, would experience strain when he feels both professional and organization demands are legitimate and they turn out to be contradictory. Role conflict on the other hand, refers to a struggle between the incumbants of two or more different roles: the emphasis is inter-personal. Some members may expect things that others feel are not warranted. When an engineer, for example, demands an equal part in making technical decisions involving scientists, he is due for a fight. A research manager may find that scientists expect him to "protect" them from the demands of upper management. His superior may expect him to enforce company policies even to the displeasure of the technical staff. If our manager feels both scientists' and managements' demands are legitimate, he will likely experience considerable role strain. If he judged one or the other demand to be unwarrantly, role conflict is likely to result.

The relationship between expectation and behavior among different roles becomes the central model of interaction between various roles in an organization. This basic paradigm is developed below, using the manager and professional roles illustratively.

Role Relations: Basic Paradigm

Interaction between persons who occupy different roles in an organization is an intricate set of action and reaction, intended and

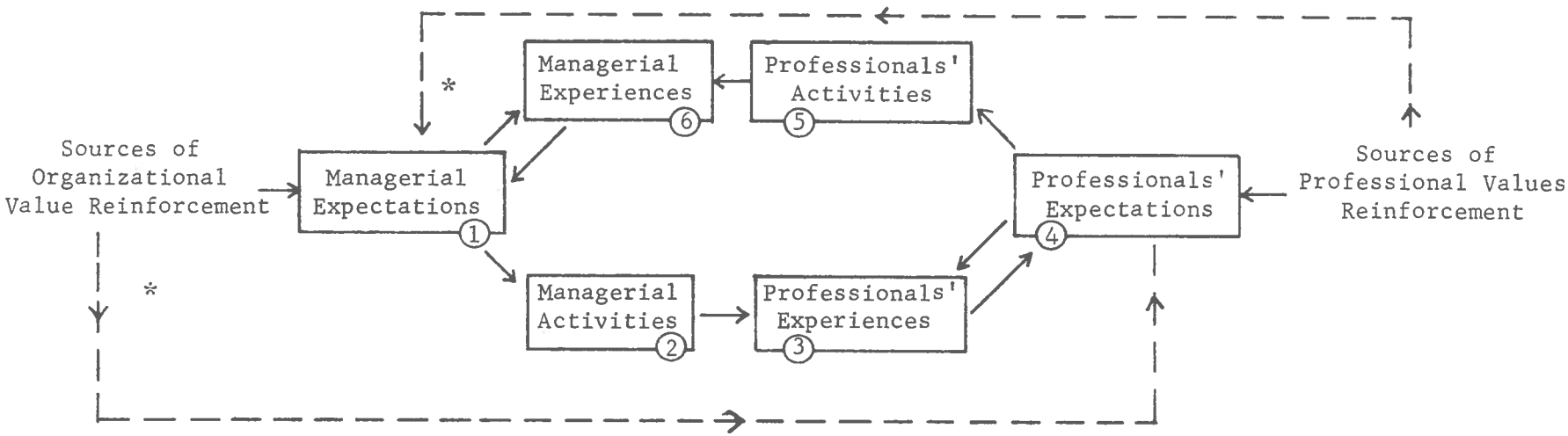
perceived meaning, expectations and experiences. A person acts, intending certain meaning to be communicated and expecting certain actions from others to follow. In turn, these actions are experienced and given meaning by the receiver based on his expectations and past experience. This cycle of action-experience-reaction-consequent behavior is the basic unit of interaction between technical professionals and managers/administrators. Inevitably, these interactions are colored by values based on personal history, professional socialization and occupational experience.

Spirals of interactions, depicted schematically in Figure XIV engage persons occupying similar or different roles, in varying degrees of interdependence. Managers, for example, form and maintain expectations (1) about what technical directions should be taken and how they should be carried out. These expectations are the bases for activities (2) which reflect managers' interpretation of the organization's mission and the constraints under which the organization operates. As professionals and managers interact, either face-to-face or indirectly through the impersonal control mechanism, many of the experiences perceived by scientists and engineers (3) are shaped by managers' activities. Professionals evaluate these experiences on the basis of their expectations (4) for themselves as professional members of a complex organization.

Professional expectations are primarily supported by long years of training and by associations with other professionals inside and outside the organization. A secondary source of professionals' expectations comes, of course, from the organization and may often run counter to professional values, or make them more difficult to hold in unmodified form. Secondary sources of expectation are also apparent for managers who often have a technical background. The values of a generalized

FIGURE XIV

Model of Relationships Between Organizational Members



* Indicates influences of secondary impact.

professional community are likely to be a secondary source of expectation for them. As professional expectations are translated into activities (5) which carry out the work of research or development, they also become part of the perceived experience of managers (6), and are evaluated through the filters of their own expectations (1).

For the rest of the study, this cycle of action-reaction will be the underlying paradigm in explicating the relationship among major roles in research organizations. The content of experience, expectations, attributed meaning and evaluation becomes the basis for allocating work effort and resources among formal roles. It is also the basis for the normative evaluations technical professionals and managers make about the adequacy of their own experience and the performance of others around them. In essence, they are the basis for cooperation or conflict, trust or antagonism between highly interdependent, symbiotic roles.

Role Relationships and Exchange Behavior in Organizations

As organizational members, persons generally expect to contribute to group or organizational purposes. They also expect to derive satisfactions and secure rewards for such contribution, at least equalling the efforts required to make them. Role interaction then is a medium of inducement-contribution exchanges among members of an organization holding various resources needed by each other.[5]

What members are likely to accept as rewards and offer as contributions to group purposes are based on the kinds of expectations they hold for their particular role. Each member recognizes a range of rewards, such as renumeration, autonomy, and the esteem of others, that he associates with activities he is performing. The more deeply he values

these rewards and the more nearly he meets the standard of performance, the more likely he is to expect some mixture of rewards for that effort. For technical professionals, performance standards are based on intensive socialization, and reinforced by professional peer groups cutting across formal organizations, mediums of communication -- publications and meeting for exchanging information about performance -- and finally, in many professions, the government sanctions of licensing. Particularly important to professionals is the degree of autonomy they have in directing their own work. Autonomy is believed necessary to provide competent professional contributions and is a reward for that competence.

The contributions that others seek from a member and the rewards offered for them are directly related to the abilities possessed by that member and the needs others have for such ability. The more a role occupant possesses capabilities believed necessary by others to satisfy their own functions, the more likely inducements will be offered for such contributions. Managers and administrators can commit organizational resources in exchange with professionals; their cause/effect beliefs about professional motivations are highly significant in determining what they will offer scientists and engineers and the kinds of professional contributions they will seek. Of particular importance is managerial understanding of the place autonomy plays in the ideology of professionalism and professional direction.

In addition to the expectations held by organizational members for each other, two more variables affect the exchanges between roles.[6] First, the activities intrinsic to the technical processes of the organizational, i.e., the overall task logic, are limiting boundaries of the variations role behavior can exhibit. Typists type, secretaries

assist executives in collecting information, bakers bake, supervisors judge the quality of work done by their direct subordinates, etc. All roles have technical activities central to them. If they are not carried out it results either in major changes in role definition or, which is more likely, a withdrawal of support from those who depend upon reliable performance. A second boundary is the set of authority relations specified by the position for a role occupant: in other words, whose expectations and decision premises will he set and who will set his.

The intensity of expectations and demands that role occupants exert on each other is, of course, directly related to scarcity of resources. The degree of dependence a role occupant has upon resources commanded by other members, and the degree of their need for those he commands are important variables in fixing the value placed on rewards accepted and contributions offered. For example, if a scientist or engineer feels easily able to leave the organization for another in which he can obtain at least equivalent rewards, he is liable to cling closely to professional values. If these place him in conflict with organizational demands for contributions which do not return professionally rewarding inducements, then conflict and strain will result. However, if there are only few organizations able to provide equal rewards, then pressures from managers are likely to be much more strongly felt and a higher value placed on organizational inducements, even if they erode commitment to professional values.

Exchange Congruence and Role Systems

Within a role set, stable role consensus probably is highest in situations where there is: (1) high agreement about the legitimate expectations each role occupant should hold for himself and all other

members; and (2) sufficient resources available to each member so that he can provide inducements (i.e., his contributions) to others sufficient to win contributions from them without net loss in value exchanged. We shall term this latter condition exchange congruence: precisely, the condition obtained when parties to an exchange are able to provide contributions to each other at a rate which returns them as much or more inducement than effort spent in making contributions.

Complex organizations are made up of as many role sets as there are organizational members. Thus, high role consensus for the whole organization requires a distribution of expectations and resources, such that exchanges throughout the role system are relatively balanced. In this condition role sets have relatively low levels of strain and conflict.

Both the agreed legitimacy of role expectations and resource congruence are necessary for long-term role consensus. Without resource distributions appropriate to expectation levels, expectations are not likely to be met, even if they are recognized as important by role set members. For example, even if research managers recognize and agree with scientists that they need adequate equipment and a large degree of autonomy; if funds are limited and pressures from higher management are sharp, managers very well could feel required to deprive some researchers of necessary equipment and demand detailed accounting from them. It is cold comfort for scientists to know their managers regret both limitations. We would expect both scientists and managers to experience role conflict.

Above we suggested that organizational structure could profitably be seen as regularized role relationships, i.e., crystallized role

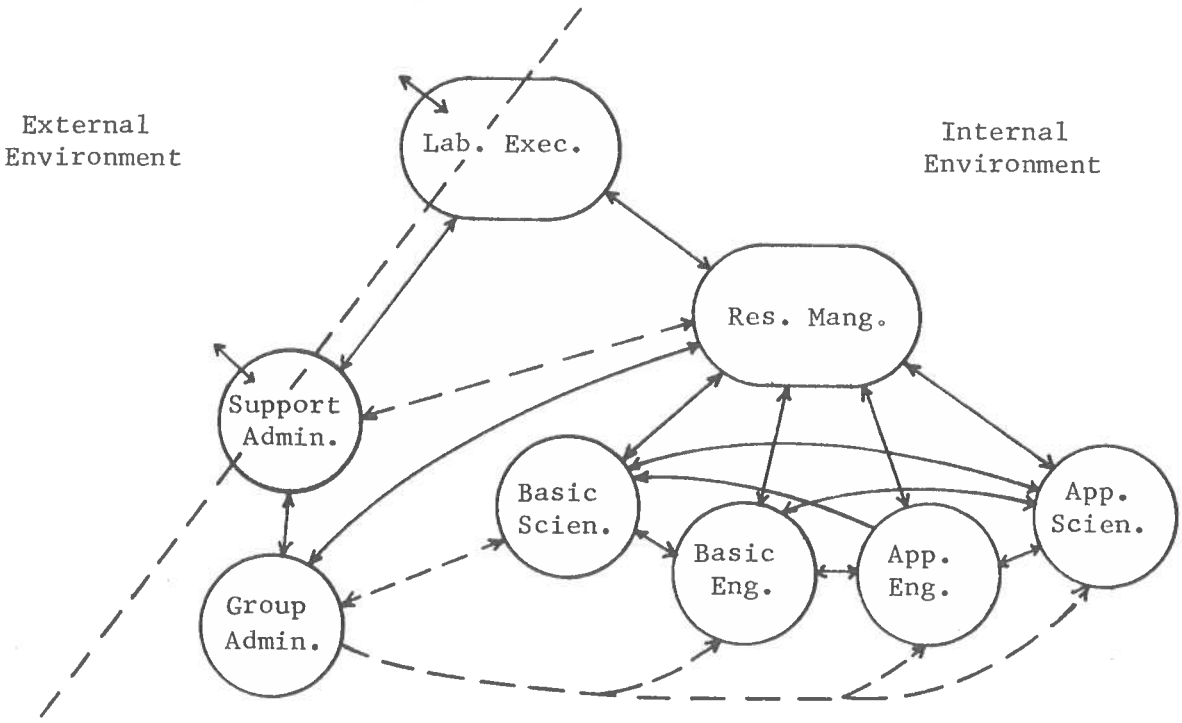
definitions, authority relationships and resource distribution prerogatives. Formal organization, then, denotes a partial pattern of role expectations for decision making, communications flow, and minimum work relationships. Changes in this structure represent changes in these expectations, often altering individual role sets and interrupting communication and decision pathways. Characteristics of formal structure may either match the distribution of expectations or have an ill fit with them.

Structural congruence occurs when there is a close structural fit of resource distribution and expectations; and exchange congruences of role sets reduce exchange imbalances to low levels throughout the organization. At the other end of this variable, incongruent structures are those in which there are quite out-of-balanced role sets scattered through the organization. An almost infinite number of intermediate positions are possible with a variety of incongruent pockets; particularly those role absorbing potential exchange imbalances in the role sets around them. In these cases, a particular role may be a decision link between two others, say, one above and one below the focal role in decision authority. In this interstitial position they may absorb demands from the higher status role thrust upon the lower status roles in such a way that they experience an exchange which is apparently balanced. If the demands were to be directly put, however, the imbalance would be evident. Thus in role systems -- probably most of them -- some roles absorb major portions of uncertainty and exchange imbalance. In so doing this heaps great amounts of role strain and anxiety on their occupants.

In Figure XV, the eight roles we discussed in Chapter Two are linked in their general directive, supportive and status relationships

FIGURE XV

Direct Role Exchange System



Direct Formal Authority Exchange

Support Services Exchange

in research laboratories. The interior boundary roles of research manager and group administrator are likely to experience incongruence when they buffer the technical professionals from coordination and conservation demands from upper management. Exterior boundary spanning roles at the executive and support administrative levels are also points of potential exchange imbalance. These internal and boundary spanning roles are most likely to be tension absorption roles. Exchange imbalances can occur between any number of organizational roles, either between two individuals or between categories of roles. Of course, the more generalized an imbalance between two role categories, say engineers and group administrators, the less structural congruence and the less stable the organization.

Sources of Incongruence

A state of nearly complete structural congruence is probably much like absolute zero, the speed of light or environmental homeostatis: theoretically possible, may exist in nature but is unattainable by man-contrived systems. Any organization continually exhibits congruency flux, as it were. As with the sources of uncertainty, the major sources of incongruence are found in the organization's external environment and in the behavior of its members.

The influences of conditions outside the research lab are the most unsettling, and -- when they are recognized -- create the most formal organizational activity to cope with them. Two important factors leading to incongruent structures are changes in demands placed on the laboratory from sources of support, and the variations of role conception held by new people recruited to the lab, especially at the executive level.

When the demands placed on a research laboratory remain stable, internal role expectations and resources can be adjusted over a period of time to achieve relative congruency. However, when goal or control demands begin to change or sources of support vary their requirements, for example in funding, this varies the amount of internal resources available for inducement distribution and, very likely, executives' expectations for the behavior of others in the organization. A rippling effect occurs which upsets the balance of exchange between various roles, especially between research managers and technical professionals. Thus, if there is a formal change of laboratory mission, dramatic changes in role relationships are likely to occur, clearly resulting in patterns of role strain and conflict.[7]

New members of the laboratory also may be the source of incongruent exchanges. As new members are recruited, they reflect expectations based on their past experience, education and general conceptions. They may bring into the laboratory similar though not necessarily coincident views about how scientists should behave, directions that should be pursued by executives, or priorities of resource distribution. When senior executives are recruited this can be particularly important, for they are in a position to change the major goals and relative importance of work already carried on, or introduce new activities. If this happens it is very likely to change the rules of distribution and result in strain and tension among subordinate roles and senior levels of the organization.

The other major element in prompting mismatches of resources and expectations is the experience of people already in the organization. As persons' tenure in an organization increases, they learn to adjust their self-definitions on the basis of their day-to-day activities.

For example, younger professionals may very well adjust their expectations upward as they discover their relative competence in comparison with older members who they had assumed were better prepared for technical work then themselves. This can result in altering their definition of suitable inducements and what should legitimately be expected of them.

Conflict and Accommodation in Professionalized Organizations

If we were to sum up the discussion in the more familiar language of the work already done in the study of professionals in complex organizations, the descriptions might be as follows.[8]

Large groups of professionals -- scientists and engineers in complex organizations -- set the stage for a clash of expectations: professional technicals value freedom and rigor; managers value controlled operations in accomplishing organizational goals. If a professional organization is to thrive, particularly in industry or government, some adjustment to the consequences of these different values must occur. The technical person's insistence on freedom to pursue his own self-defined path, and do it within the canons of methodological rigor, clash with the manager's need to set directions based on organizational goals, and control the activities of his professional subordinates.

When scientists and engineers enter a research organization, they are plunged into a quasi-bureaucratic environment. Four of its elements are particularly important to their work: the organization's goals, the routines and processes of the research group, authority relations within which they work, and resource supports for research activities. As these vary, so do the responses of scientists and engineers to the organization. Organizational goals, of course, become

major obligations and set broad boundaries for research activities. The other elements are means to both organizational and scientific ends. They provide the structure, coordination relationships, and resources required to carry out research.

> In general terms, when personal relationships and organizational conditions increase the perceived incompatibility of organizational goals and means and professional goals and means, tension and strain are heightened between scientists, engineers and managers.

Strain and tension are related to the requirements and expectations managers have for themselves and others in the organization. Managers base their expectations upon interpretations of organizational goals and the activities they think are necessary to accomplish them. To the degree that technical professionals' expectations differ significantly from their managers', the probability of conflict or tension between the roles increases. This is further increased if the activities of either professionals or managers make these differences visible, i.e., experienced by other role occupants.

The relationship of expectations to experience is most important in understanding the pattern of tension and conflict in complex professional organizations. If managers' expectations are not met in their experiences with professionals, they must either change their expectations, initiate managerial controls to change the activities of professionals, or both. The same is true for professionals if they do not experience conditions at or above the level they expect. They either will change their expectations and/or try to alter managers' expectations or activities that affect the professionals' environment. In both situations, reinforcement from organizational and professional

sources has a strong effect on the direction of change and the persistence of tension.

The most general type of expectation which managers have for professionals is that they will contribute to the organization's goals. Organizational goals, which normally include goals of survival and growth, are the major premises for more detailed definitions of research operations. Managers' and professionals' understanding of these goals may become basic issues between them. This can take the form of disagreement about the substantive form of research, e.g., whether emphasis should be placed on basic research, or more attention paid to organizational growth. The importance attached to various criteria used in day-to-day decision making, may also be a source of strain.

Managers' interpretations of what means will accomplish organizational goals provide their frame of reference for judgments on the important skills and attitudes that professionals should have. If managers think that certain things or conditions ought to be sought by scientists and engineers, these also become managers' expectations or requirements for technical professional. They are what managers believe to be required for the processes of acquisition, conversion, and transmission discussed in Chapter Two.

To the degree these interpretations of role expectations, and behaviors are not congruent among the various roles in research organizations, role conflict and strain result. The greater the incongruity, the greater the overall role conflict. It is unlikely, however, that overall conflict will remain high for very long. No organization can maintain itself and perform effectively while enduring high levels of internal strain or prolonged clashes of strongly held values between major groups within it.

In Chapter One, we argued that uncertainty born of complex contingencies and changing environments produces attempts to reduce it by both persons and organizations. Thus, persons occupying organizational roles seek stable, roughly predictable relationships. If uncertainty and ambiguity are high, we can expect attempts to reduce it. These attempts are likely to come from both technical professionals and managers as they work out strategies to return a better balance of inducement to contributions. Altering situations to increase exchange congruency among important roles in the laboratory are adjustments or accommodations to the role demands exerted in acting out the processes of research and development.

Mutual dependence and symbiosis among professionals and managers increases pressures for adjustment. On one hand, managers do not have the specialized competence in scientific matters to accomplish the organization's technical objectives. They depend on the contributions of professional knowledge and techniques offered by scientists and engineers. On the other hand, technical professionals depend on the organization to furnish needed facilities and salary as they pursue their work. Furthermore, professionals seem to need protection from the non-technical cares of administering expensive facilities and equipment if their efforts are to be mainly in creative technical ventures. Effective research management provides professionals with protection from distracting organizational matters, at the same time stimulating the conditions which nurture technical contributions to organizational goals as well as professional ones.

The most evident response in the accommodation of managerial and technical roles is in the structural variations within research

and development organizations. These structural strategies seek to distribute role expectations and resources so that relatively high exchange congruences will result and both technical and organizational values can be achieved. It is an empirical question whether various organizational forms perform the necessary translation of demands from different environments into the kind of stable and sheltered environment needed for competent scientific work. This is the burden of the research portion of this study, to which we will turn shortly.

Major Research Questions

Based on the notions outlined in Chapters Two and Three, a research project was carried out in three research and development organizations to examine: the relationships between scientists and engineers representing the technical professions, and managers and administrators representing the agents of formal organizational control; and the patterns of structure that had emerged in response to the requirements of inquiry and action. Our major research questions were:

First, what were the patterns of role relationships within the structure and process of research and development? All the laboratories were highly professionalized and formally engaged in both inquiry and action. Role definitions of organizational members were important to establish a basis for role interaction. Expectations of professionals regarding authority relationships, proper work climate and personal qualities were, therefore, central. The distribution of functions among roles was also important and, when combined with self-expectations, adds a significant factor in determining levels of role strain and conflict. Finally, the extent of role conflict, and its intensity within the laboratories was also a significant datum.

Second, what strategies had been employed, to what effect, by both management and professionals to achieve the measure of accommodation existing these organizations? If excessive strain and uncertainty are to avoided, coping strategies are likely to be evident. There are a number of recognized coping responses to strain; to what extent were they apparent in these laboratories?

Third, to what extent do variations in the environments of these organizations affect both organizational structure and role relationships? We argue that environmental contingencies have an important effect on the character of internal administrative structure. If there are environmental variations, we could expect variations in role definitions and relationships, perhaps distributions of internal resources, etc. We could also expect variations in the types of coping strategies and their effect among these laboratories.

These research questions are the basis for a number of general propositions and specific hypotheses developed in the following chapters. Each chapter also includes a brief discussion of research questions implied by the analysis and interpretation. Chapter Four is a brief description of the research sites themselves, the methodology and field portions of the study, the external environments of the laboratories and their internal formal structures. It is introduced by a discussion of common structural alternative evident among research organizations. Chapter Five includes descriptions of major roles and the effects of task logic on their configurations. Chapter Six through Eight present detailed analysis of data related to the propositions and hypotheses derived from our theoretical development. We conclude with a retrospective and interpretive chapter consolidating the findings, pointing

toward further research, and commenting on their implications for future organizations faced with uncertainty and the requirements of inquiry and action.

It is all too clear that most public organizations are confronting increasingly uncertain and complex environments. There seems no reason to suppose this will change in the future. In the face of such complexity, inquiry becomes a requisite to action. Changes in programs then may enhance desired conditions and eliminate error often demand continuous inquiry. Its organization for action is a major challenge to public management. Structural patterns in those organizations now attempting to respond to complexity and uncertainty provide clues to future development. Do these organizations establish similar patterns? How do they differ internally? Are there common responses to varied external conditions? These questions face all public organizations as they become more professionalized in response to uncertainty.

TECHNICAL APPENDIX, CHAPTER III

The summary equation for this section is

$$(Ex + S_tT)_i \longrightarrow U_j \longrightarrow (Op)_k \longrightarrow S_{(t+1)m},$$

when Ex is the complexity of the external environment, S_t is the degree of administrative complexity of the formal organization, T is the degree of technological complexity of the work process, U is the level of uncertainty perceived by the dominant coalition; Op is the degree of organizational professionalization and $S_{(t+1)}$ is the degree of administrative complexity at a time period after S_t.

In each case, these variables can be further subdivided into component parts to facilitate their operationalization.

A. Ex is (Dp + Ds)dx, when Dp is the number of connections from the organization to external sources of resource supports and demand inputs, Ds is the number of connections among Dp sources of support and demands, and dx is the rate of change of Dp and Ds.

B. T is (C + D + Ic)dx, when C is the number of groups/persons involved in the technical process, D is their relative differentiation and Ic is the degree of their interdependence or internal connectedness; dx is the rate of change of these variables.

These two summary variables can be combined into one Environmental Complexity variable $(Ex + S_tT)_i$ in which i ranges from 1 to 4.

When		are					
	Ex	:	Low	Low	High	High	,
	S_tT	:	Low	High	Low	High	
	i	is	1	2	3	4.	

C. U is $(B + I)_{e,t} + (Mg)_q$, when B is the perceived adequacy of cause/effect beliefs and I is the perceived adequacy of information about e, the external environment, and t, the technical process. Mg is whether formal management goals include inquiry only, action only, or both. Combining these two intermediate variables into the summary U_j, we can array the j's of U as follows.

When								
$(B+I)_{e,t}$	are	:	High	High	High	Low	Low	Low
$(Mg)_q$		:	Inq.	Act.	Both	Inq.	Act.	Both
j	is	:	1	2	3	4	5	6

D. Op is $(\frac{P}{N}) + x(P)_\alpha$, when P is the number of professionals in the organization, N is the total number of organizational members; and x(P) is the average educational level of those professionals, α is 1 = Bs; 2 = B.S. + to M.S.; 3 = M.S.+; 4 = Ph.D. Combining these two component variables into Op_k, k is as follows.

When						
$\frac{P}{N}$	are	:	Low	Low	High	High
x(P)		:	Low	High	Low	High
k	is	:	1	2	3	4.

E. S_m is a summary term covering four types of formal administrative organizations: m is 1 when there is the typical bureaucratic hierarchy; 2 when there is functional or specialty distribution of work; 3 when there is project organization, i.e., when specialties are coordinated around a specific project requiring interdisciplinary organization; and 4 when there is a "matrix" form mixing types 2 and 3. (See Chapter Four, pp. 1-12, for a discussion of these forms.)

FOOTNOTES, CHAPTER THREE

1. See Technical Appendix at the end of this chapter for a more detailed and quasi-operational discussion of these variables.

2. The conceptual definitions included here are taken mainly from N. Gross, W.S. Mason, and A.W. McEachern, Explorations in Role Analysis: Studies of the School Superintendency Role (New York: Wiley, 1957), Part I. This work includes a quite complete survey of role theoretic language up to 1957, and develops the terminology used here save for the notions of role-set, role ambiguity and role system. Later work by R. Merton, "The role-set: problems in sociological analysis," British Journal of Sociology, 8 (June, 1958), pp. 106-120; and R.L. Kahn, et al., Organizational Stress: Studies in Role Conflict and Ambiguity (New York: Wiley, 1964) discuss the first two of these notions respectively. A most interesting and literate examination of role notions was done by R. Dahrendorf in 1958 and published in English in R. Dahrendorf, Essays in the Theory of Society (Stanford, Calif.: Stanford University Press, 1968), ch. 2. Without question the most analytically detailed explication of role conceptions is found in B.J. Biddle and E.J. Thomas, eds., Role Theory: Concepts and Research (New York: Wiley, 1966), esp. Part I and II written by the editors. This book includes some of the best articles in the literature and has a very extensive bibliography up to 1965. While the Biddle and Thomas volume presents the most elaborate distinctions of role language, it is far beyond the operational character of nearly all studies of role. The language of the Gross study is sufficiently developed for the data presented in our work.

3. Phrases quoted below are taken from Gross, Mason, McEachern, op. cit., p. 67.

4. See W.J. Goode, "A Theory of Role Strain," American Sociological Review, 25 (August, 1960), p. 485. The discussion of role strain and conflict are based on Goode; R. Kahn, et al., op. cit., and Gross, Mason, McEachern, op. cit. See also L.A. Coser, The Functions of Social Conflict (Glencoe, Ill.: Free Press, 1956), Definitions of role conflict vary slightly, Kahn, et al., stressing role strain; Gross, et al., using the term role conflict.

5. Interpersonal exchange as a basis for social life is developed by G.C. Homans in The Human Group (New York: Harcourt, Brace, 1950) and Social Behavior: Its Elementary Forms (New York: Harcourt, Brace, 1961); and P. Blau, Exchange and Power in Social Life (New York: Wiley, 1964). For this notion used in understanding organizational behavior, see C.I. Barnard, The Functions of the Executive (Cambridge: Harvard University Press, 1938); H.A. Simon,

Administrative Behavior, 2d ed. (New York: Macmillan, 1957); J.G. March and H.A. Simon, Organizations (New York: Wiley, 1958); R.M. Cyert and J.G. March, The Behavioral Theory of the Firm (Englewood Cliffs: Prentice-Hall, 1963). See also J. D. Thompson, Organizations in Action (New York: McGraw-Hill, 1967) and A. Zeleznik, "Interpersonal Relations in Organizations," in J.G. March, ed., Handbook of Organizations (New York: Rand McNally, 1965), ch. 13.

6. For an interesting formalization of these variables mixing role and graph theory language, see O.A. Oeser and F. Harary, "Role Structure: A Description in Terms of Graph Theory," in Biddle and Thomas, op. cit., pp. 92-102.

7. P. Brown, "Bureaucracy in a Government Laboratory," Social Forces, 32 (March, 1954), pp. 259-268. Cf. Zeleznik, op. cit.

8. Particularly W. Kornhauser, Scientists in Industry: Conflict and Accommodation (Berkeley: University of California Press, 1962); and Notes , Chapter Two.

CHAPTER IV

CHALLENGES IN STRUCTURAL RESPONSE AND THE RESEARCH SETTING

In meeting the demands of taxing technical problems and complex external relations, research and development organizations have responded with several types of structural solutions. These have a strong influence upon the patterns of interaction among professionals and managers, and are a major constraint in adjusting to problems of change. In this chapter, these structural responses are introduced, then the particular national context of research and development organizations in this study is developed. Finally, the three organizations are described in some detail as a partial foundation for comparative analysis.

Challenges in Structural Design

The sources of contingency confronting dominant coalitions in research organizations represent a quite formidable array. At least two direct sources of external contingency are present: the sponsors of research and development, and the parent organization, though they sometimes are one and the same. In addition, the multiple professional communities often have an indirect influence. Immediately within research organizations are a multitude of activities called for by the logic of technical work and its support. These span the relatively autonomous activities of basic research, specialized applied research, advanced

design, and prototype construction. Arrangement of research groups, logistic, and coordination support activities are keyed to the character of the technical work. The closer one approaches the construction phase, interdependence between working groups rises rapidly, and is paralleled by coordination requirements. Finally, the professional requirements of scientists and engineers must be met so they will continue their contributions to the lab. Therefore, some way of supporting publication, travel to professional meetings, and allowing some unfettered research is necessary.

Many of these factors require some sort of structural solution as partial means for coping with the uncertainties they generate. This is demanding enough even when one is blessed with a relatively stable situation. Rapid changes in external demands, sources and levels of support, or technological processes enormously compound the organizational design problem. Formal structure, then, must somehow encompass very complicated internal technical and support relationships that are likely to be relatively unstable. This means that if the fine structure of formal organization, e.g., formal work groups, and chains of decision and information are treated as if they are to be permanent, it is likely to become inappropriate with surprising speed.

These conditions underlie all structural problems for organizations of inquiry and action. The highly sophisticated scientific and management techniques prompt very complex and shifting internal group structures as these techniques change and as technical problems are solved and replaced by new ones. Research and development organizations also produce new instruments and processes for controlling, modifying or monitoring physical and social phenomena <u>beyond the boundaries</u> of the

organization. Realizing the potential of these instruments, even partially, often results in unbalancing or destabilizing relationships with important sectors of the task environment. Examples can be seen in developments of new plastics, improved space exploration capacities, and changes in computer design. The effects of a lab's research success or failure often changes its relations with the professions, government agencies or legislatures. When a new technique in a fabrication process, for example, diffuses throughout an industry, it puts the inventing organization in competition with imitators for the engineers who initially developed the process. Or the failure of a program of research often radically alters the support a research organization receives. Congressional investigations of the Jet Propulsion Laboratory after six failures (before a success) in the Ranger moon probe series is an extreme example.

Changing external demands confound the development of stable structural solutions to technical problems. At the same time, the need for coordination seems to increase as the time available for trial and error learning is reduced. Furthermore, large numbers of professionals hired to reduce technical and task environment uncertainties become sources of uncertainty themselves. Increasing dependence of managers upon either technical and/or task environment professionals reduces managerial autonomy in decision-making, and lessens the likelihood of unquestioned compliance with management directives.

Designers of organizational structure, therefore, have three difficult challenges. First, the central task is to provide enough formal organization to facilitate research and engineering work at the bench and enhance coordination between groups. Second, an administrative

infrastructure is required that can effectively support technical work with purchasing and personnel services, technical assistance, and quality control. It must also seek to absorb demands and surprises from the outside, thus reducing their disturbing consequences for the technical core. Third, any particular or specific structural format must somehow take into account high probabilities of relatively unpredictable change in the internal technical processes and the task and support environments.[1]

Historically, structural solutions to large complex task systems have followed the bureaucratic image. Administrative officials directed technical operations, divided tasks into some logical order and provided a hierarchical coordination and decision system. The formal organization of these arrangements was solidified and became a cohesive social system with enforced norms. Resource and rewards schedules were designed to consolidate both the task division and the decision structure. Stimulated by the early work of Frederick Taylor and the Scientific Management School, solutions were based on the assumption that a logical and efficient division of labor (specialization) was knowable, could be constructed, and would be relatively effective for some time. Stability and only moderate task complexity were implicitly assumed.

In public and private organizations for which both these conditions can be assumed, the bureaucratic model is still probably quite effective. Tasks are divided into constituent activities; then workers are trained to perform various of these activities. "Norms and standards are not (fully) internalized so that a system of rules" specifying how the work is to be done is necessary, and some persons are given the job of enforcing them. Supervisory officials coordinate these activities so that the overall task will be accomplished. This is clearly the bureaucratic model, based on partial skill and external control.[2]

An alternative model has also been used. The craft or semi-professional structure requires that each worker is skilled in all the abilities needed to do the job, including internalized norms and standards governing his performance. Major controls are applied by craftsman or professional to his own work with very little external supervision. This model still assumes some external coordination of the substantive aspects of the larger task that can be known and rationalized. This is a reasonable assumption for moderately complex and stable task systems. It is also sensible for service oriented professions, such as general medicine or the law. In these fields professionals go through long socialization experience to learn well-established and stable skills that do not require tightly interdependent action in accomplishing technical tasks.

When very complex task systems under dynamic conditions are the main activity of an organization, as they are in R and D labs, neither bureaucratic nor craft-professional models are adequate. The first assumes both stable task division and task coordination capable of design by managers; the second still assumes the latter condition. Neither of these conditions are present for R and D organizations. The level of technical complexity and changefulness of the work is sufficiently high so that no one has purchase on the requisite design knowledge. Therefore, those skilled in the technical aspects of the task, the professionals, are continuously involved in the design of both task divisions and task coordination processes. Supervision and positive control are difficult, for the fundamental conditions of control do not exist. That is, managers are not able to tell when errors have been committed and/or are not able to designate detailed corrective action. Gross failing performances may

be detected, but specifying corrective action, however, is quite another matter. It requires intimate and highly sophisticated technical knowledge of many complex technical areas. Managers are almost forced to delegate both task division and coordinating functions to formally subordinate professionals. Detailed and close control in these situations has little utility. Control-by-exception is attempted, but it is intermittent and employed after a good deal of work has been done. Essentially, considerable trust must be placed on the quality of professional self-control. This radically alters traditional bureaucratic authority and reward structures.

Structural Alternatives for Research Organizations[3]

Organizational design problems in research laboratories are quite different and unfamiliar to most managers. In many other organizations, managers can assume that the organization's major goals will have predominant weight in gaining acceptance of formal arrangements among employees. However, technical professionals vary considerably in their acquiescence to policies and arrangements intended to accomplish these goals. The more deeply involved in basic research a group becomes, the less managers can make this assumption. In problems of organizational design, therefore, basic research groups are often considered apart from applied research or advanced design. This repository of highly skilled scientists and basic engineers is a major source of strain within organizations based on highly sophisticated technology. Here is a group of professionals many organizations know they need, but who do not easily accept organizational standards as the predominant cues for their behavior.

Several types of solutions to these conditions have been tried. In the main, they have addressed the need to coordinate various

professional groups in pursuit of complex technical goals; and to develop buffering administrative layers around the technical core. Various mixes of the responses are evident among the organizations in this study. The first, the project organization, is a quasi-bureaucratic response. Technical work is organized on the basis of major technical projects. Engineers and scientists representing different disciplines are grouped under a single project manager who acts as both technical director and administrative superior. He is responsible for both technical and organizational evaluations of their work in much the same way that a more traditional bureaucratic supervisor would be. The project group is treated by laboratory executives in much the same way as a single professional might be treated in the craft or semi-professional type of organization. There is very little direct or continuous supervision of the project group. The project manager is evaluated on the basis of the eventual success or failure of the whole project.

In this form, organizational goals are kept rather clearly in focus. Professionally valued conditions are often somewhat difficult to maintain. This is particularly true for technical professionals who have a strong disciplinary orientation. Interdisciplinary work on specific projects reduces the time available to devote to scientific problems which are of disciplinarily importance. Technical demands stemming from project work are not always susceptible to translation into important theoretical or experimental problems. Furthermore, projects are likely to require deflecting one's work from a particular physics problem, for example, to problems arising from the mix of discipline. Specific basic research groups are rare. When they exist, they are hidden within a sub-project.

In these cases, professionals may lose their disciplinary edge and risk a decline in approval from their scientific colleagues outside the organization. In effect, professionals pay a professional price for organizational goal achievement.

At the other extreme, R and D laboratories have grouped professionals by their discipline. Functional organizations have many of the characteristics of university departments. Save for teaching responsibilities, the style of activity is similar to regular academic departments although problems from the larger projects are assigned to them from time to time. Supervision is limited. If coordination of sub-projects is attempted it is by upper management. Standards of performance are primarily professional and the evaluation of research performance is conducted by the technical "chairmen" of the groups. This is often based upon publication records and the review of competent professionals outside the organization. Performance controls are almost exclusively applied by the professionals themselves.

This form of organization separates the technical and organizational goals rather markedly, unless organizational goals are clearly academically research oriented. Functional organizations are likely to have groups of quite competent professionals doing work not cleanly related to major projects central to the organization's mission. One of the continuing issues is the degree to which research groups serve the needs of engineering groups. In sum, the organization pays a price in short run efficiency for the maintenance of professionally valued conditions.

The type of structure an organization has reflects an attempt to cope with the "strains and accommodations between organization and

profession (and will) vary according to the kind of organization. The greater the organizational dependence on basic research for its objectives, the greater the likelihood that it will adapt to the demands of its scientists that they be allowed major responsibility to select research problems (and) determine research strategy. . . .."[4] Clearly, the more distinct they are from engineering and construction phases, the more this is possible.

Out of the dialectic of project versus functional organization has emerged the matrix organization.[5] This combines features of its predecessors in such a way as to more nearly balance the resources held by project managers and technical groups. A particular project staff, for example, has the formal authority to direct and coordinate a specific, large project. It has the funds to acquire material, facilities, and technical personnel. It must, however, use technical professional from the organization's technical groups. These groups are the organizational homes for scientists and engineers between project assignments. This form of organization is almost never used unless there are several large projects being conducted simultaneously within the organization. Therefore, project managers are required to compete with each other for technical services furnished by technical groups. Negotiations go on between a project manager, technical group heads, and individual professionals for temporary assignment to project work. This is a kind of "in-house" contract system in which the projects exchange money with technical groups for personnel during the specific time period of the project. When it is completed the professional (or that portion of his time obtained by the project) reverts to the technical group for reassignment and/or carrying on basic research for which he has obtained support from an outside sponsor.

Evaluation of professionals' work is done by both project manager and technical group head. Project managers are evaluated by lab executives on the basis of the project success much as in the project form of organization. Professionals are permanently located in homogeneous technical groups which reinforce their technical competence and commitment. In essence, the matrix organization is "a stream of ad hoc activities superimposed on the traditional functional organization."[6] It is a way of increasing "structural congruence" of resources and expectations and enhancing "exchange congruence" among technical and managerial roles.

These three forms of structures, in terms of the simplicity-complexity discussion in Chapter One, clearly show a development from the tree-like, semi-bureaucratic project form of organization to the very complex, overlapping sets of the "matrix organization." While not a true matrix in the mathematical sense, the "matrix organization" is clearly a well developed semilattice form. As research organizations take on different forms, the types of control and internal behavior change accordingly. In the highly developed "matrix organization," all the problems and advantages of highly interdependent and differentiated systems occur. It is likely to be highly adaptive and to demand quite different managerial behavior than the simpler "trees" of less complex systems. In general, management is more enabling, less directive.

Each of these forms is appropriate for a particular mixture of inquiry and action. Action without inquiry can probably be most neatly done with a quasi-bureaucratic project form, much as quantities of administrative actions are now done. Inquiry without action needs only a form paralleling the academic structures of functional or disciplinary organization. In rapidly changing, turbulent environments, however,

organizations based on complex technologies must inquire before, during, and after they act. Without inquiry, action becomes even more uncertain and unpleasantly surprising. Faced with these conditions, organizations are likely to move increasingly to the matrix of interdependence between men of knowledge and those of action.

All the research and development organizations in this study fall toward the high end of the simplicity-complexity scale. Although there is, as yet, no precise measure of complexity, every intuitive or subjective indicator one might use suggests that there was great differentiation and very high interdependence among technical professionals, managers, and administrators. We were studying three organizational responses to highly complex technical processes and very complicated external environments. We will search for the patterns of response in structure and attitude, as well as variations in responses to different environmental demands and supports.

Notes on the Laboratory Settings

In setting the context of this study, several aspects are important: our subjective sense of the laboratories, the criteria for selecting them, and the general environment of R and D they confronted.

Subjective Impressions

The first point of actual contact was always the registration lobby. "Sign in, please. Who are you seeing? What is the purpose of your visit? How long will you be here today?" You field each question, and sometimes wait for confirmation of your testimony from some distant office. After several of these rites of passage, you know the entry ritual necessary to penetrate the physical boundaries of each organization.

There is little question about what symbolizes membership, acceptance and/or authorization. This status is signified and embodied in small badges which neutralize inquisitive looks, open doors, and validate your presence as a "friend of the organization." They are also barriers. Varying in color and alphameric symbol, they signal to others what degree of penetration has been authorized. "Visitor" was used in two labs, and became a signal that we were not necessarily agents of management sent to ferret out "employee attitudes." This was necessary, for there was a legacy of tension between management and professionals. In the other lab, we were photographed, cleared, and issued full-fledged employee badges. Lab management had actively discouraged free talk to "outsiders." We needed "full membership."

After these rites of passage, one plunges into the muted social world of research and development. It is a collage of hushed studies, labs crammed with blinking instrumentation, unexpected large fabrication rooms filled with odd prototypes. Weakly countering the metallic mood of technology, the cafeteria collected the high-pitched murmur of extended chatter where women retreated in this masculine-dominated setting. R and D is clearly male, the feminine tones well down the status structure, mostly clustering in secretarial ranks.

Laboratories sprawl physically and intellectually across spaces, up hills, down new trails of technique, plowing up well worn ways of doing this or that. You see these sprawls everywhere, in the somewhat disordered arrangements of buildings grafted together, test facilities miles away, exotic titles on office doors, and scientists telling that they among five strewn around the world can talk sensibly about the work they do. Activities in basic science are almost all internal. They are

conducted behind office doors or in small labs, hidden from the obvious view of the outsider. Not so for advanced design and applied research. This action is obvious, often frantic, and drives men to the distractions of the highly interdependent.

These activities are housed in the neo-utilitarian architecture of contemporary industrial slab. Visual interest is piqued only in the very new construction or near the habitation places of laboratory executives. The rest has that straightforward dullness of public works modern -- long halls of offices, doors shut. Often there are temporary trailers taken permanent root. Inside the labs, one sees the care with which instruments are constructed and protected. Scientists and engineers lavish functional quality upon their tools. Precision is the value. It cannot be had by skimping.

Gaining entry and cooperation from each laboratory are stories in themselves -- no clear pattern emerged. We learned to expect almost anything in our initial conversations. One interview was much like a hostile doctoral oral of inquisitional intensity; another clearly mutual cooptation carried on in an open and supportive style. But uniformly, once the boundaries were breeched and confidence won, the association was very cordial and simply fascinating. Almost all those we talked with held implicitly that research, even social science research, was legitimate as an end in itself. They were seldom hostile or even irritated with us. Often a respondent appropriated the role of research participant, as well as source of data. Men of high intelligence and analytical skills, many had constructed hypotheses about their experience and had a nest of ideas about how and why research and development organizations worked the way they did. In a few cases, they were quite

willing to reformulate our questionnaire items and volunteer information they thought we should include. Interviewing several hundred highly intelligent people about experiences important to them and work to which they were committed was a very exciting time.

Selection Criteria

The three laboratories in this study, half of the labs approached as possible research sites, met the following criteria: 1) virtually total support from public funds, though through different legal arrangements; 2) located in the same general geographical region, so that subcultural variation could be discounted; 3) moderately large size, with approximately 1500 to 3000 employees; and 4) engaged in highly sophisticated scientific and engineering work, requiring heavy emphasis on electronics, physics, and communications, and dependent on quite complex devices for data collection and/or goal accomplishment. Essentially, they were from the defense-space family of research institutions; the biological sciences had only limited emphasis. Finally, 5) they represented a distribution of most existing types of laboratory relationship with funding sources. One was in a large industrial laboratory, Space Systems, Inc. Another was organic to one of the military services, Military Defense Laboratory. The third lab was a university non-profit lab, under contract to the Federal Government, Advanced Research Laboratory. In gross terms, the relative magnitude of their activities is indicated by the summary characteristics in Table I.

Data collecting devices were formal questionnaires, informal interviews to assure their fit with the language of each laboratory, and then, formal follow-up interviews with a sample of those who had

TABLE I

Summary Characteristics of Laboratories

	Number of Employees	Number of Technical Professional	Annual Budgets
Military Development Lab (Military, FY 63)		386	$
Research Branch; Space Systems, Inc. (Industrial, FY 63)	3530	1770	
Advanced Research Lab (University non-profit contract lab, FY 64)	4370	1321	234,000,000

answered the questionnaire. A description of the field process and methodology is included in the Technical Appendix to this chapter. See also Appendix A.

In many studies, the convention is to follow this introduction to the context of a study with a more detailed description of each organization. For these organizations, however, the external environment at the time of the study is particularly important to understand the results. Therefore, before a detailed look at each lab, a sketch of the national environment of Research and Development at the time of the study follows.

Characteristics of the National Environment

Social science research is forever context bound. In our case, the context is particularly important. The present reordering of national priorities for research and action, accompanied by a shift in resources for research may make the keen sense of optimism which pervaded

these organizations difficult to appreciate. Yet it was there. The reasons are to be found in the national climate of funding for the decade prior to the study.

Each laboratory was embedded in a national environment of research and development just at the peak of the federal support of organized R and D. Our data were collected during 1963 and 1964, the years closing a period of sustained, sometimes spectacular growth in nationally stimulated science and technology. In Chapter Two we have already sketched some of this background. Here we concentrate on the decade just prior to the field portion of this study. This was the most significant period for each lab and set the context for the perceptions held about the present and future.

Between 1954 and 1964, the community of research and development in this country experienced remarkable public support. Whether judged by the aggregate or by scrutiny of the sectors represented by our three labs, the picture is startlingly abundant. There is almost nothing to counter an optimism about personal or organizational futures. At a time when the Gross National Product was increasing by 78.6 per cent, total funds for research and development increased by 238.6 per cent. Federal contributions had increased from $3 billion to almost $14.7 billion, or 366.3 per cent (Table II.a). Since each lab was almost completely dependent upon federal funds for support, they were among the most potentially favored organizations in the country.

More specifically, the funding sector for each lab also showed spectacular growth, though there was not an even distribution among them (Table II.b). Organic to government, the Military Defense Lab's immediate funding environment had increased by 178.5 per cent in the

Table II

VOLUME AND SOURCES OF FUNDS FOR RESEARCH AND DEVELOPMENT
United States, 1954:1964

a. Funds for Research and Development (1954, 1964)[1]

	1954	1964	% increase
Gross National Product	364.8*	631.7	78.6
Total for R and D	5.7	19.2	238.6
Federal Funds for R and D	3.15	14.69	366.3

*Billions of dollars

b. Funds Transfer from Federal Government to Performing Sector (1954, 1964)[2]

	1954	1964	% increase
To Federal Agencies	1,020*	2,840	178.5
To Industry	1,750	7,720	341.1
To Federal Contract Centers	140	630	350.0

*Millions of dollars

c. Funds to Federal Agencies (1954, 1964)[3]

	1954	1964	% increase
To DOD	2,487*	7,487	201.0
To NASA	90	4,171	4,534.4

*Millions of dollars

Source: 1. Organization for Economic Cooperation and Development, Reviews of National Science Policy: United States (Paris, 1968), Table 1, p. 30.

2. Ibid., Table A.3, p. 488.

3. Ibid., Table 6, p. 37.

decade. Much more dramatically, both the industrial Space Systems, Incorporated, and the university contract laboratory, Advanced Research Laboratory, were in funding environments which had risen well over 300 per cent in the same period. Finally, both principal agencies to which these labs turned for funds had experienced substantial to spectacular growth (Table II.c). The Department of Defense had received some 200 per cent increases in R and D funds, while NASA had been the object of a phenomenal 4,500 per cent increase in that decade.

From any perspective, the fiscal climate of research and development in this country was extraordinarily stimulating. Congress and the Federal Executive had responded very vigorously to what an OECD report has termed "external challenges," i.e., defense and space exploration development in the USSR.[7] On the whole there were few "official" questions raised about accountability, and there were few dubious voices questioning the rate of funding growth. Not until 1963, with Derek de Solla Price's Little Science, Big Science, was there a careful study of the exponential growth of science and the implications for further expansion at those rates.[8] There was only a slight hint of public, academic, or official government notice of alarm at this situation. It was not until during the last field phases of our study that some Congressional concern was apparent. Quite objectively, the overall environment of R and D was extraordinarily abundant. It had all the characteristics necessary for a sense of confidence in the future.

Paralleling these funding conditions were strong indications from the technical press and trade journals that research and development was in a very healthy state. This was shared by a broad spectrum

of technical professionals and their managers. A national sample survey of scientists (N = 3,691) and technical managers (N = 1,060), by Vollmer in 1964-65 provides interesting data in this regard.[9] Over two-thirds of the scientists and almost three-fourths of the managers felt their particular research specialties would be in increasing demand over the next five to ten years. Similarly, about one-third of each group felt it would be "very easy" for them "to get a similar position in another organization."[10] Our own sample of technical professional and managers reflects even higher feelings of personal promise and benign environment. Almost 40 per cent of our research managers and over 45 per cent of both scientists and engineers felt they could very easily find a similar position in another organization.

We have interpreted these data as indicating a clear perception of promising futures in research and development. This is probably a combination of a recognition of personal technical competence and the character of the labor market in a time of overall expansion. In our sample, one explanation for the substantially increased feelings of possible mobility expressed by our technical professionals compared to the national study is that these men perceived their laboratories to be good ones, capable of hiring men of high quality, and enhancing their personal reputations. Professionals working in these labs recognize they are valued by other organizations partly due to their employment in these particular organizations.

If this is so, it is partially by our design. Each of the laboratories in this study also was selected to meet the additional criterion of high quality, vigorous organizations. There was no intention of making this a study of organizational pathology. Using rough

indicators, each lab was a relative effective one: it had a good reputation in its field; it was financially vigorous with only limited difficulties in getting the funds it sought; and it was thought to be a good place to work by its employees. This was true despite the quite different context of each specific organization.

For research purposes, one of the virtues of relative organizational affluence is that growth and development had occurred without the added problem of periodic resource crises. This meant that the structural and attitudinal responses to increasing contingency and complexity were not overwhelmed by such organizational traumas. Had there been several periods of critical resources, internal differentiation and increased capacity to deal with high levels of complexity would probably not have developed. Relative abundance of funds and legitimacy enabled each organization to expand its capacities to deal with technical and environmental uncertainty in a relatively orderly way. Let us turn now to these specific organizations.

The Research Setting: Organizations of Inquiry and Action

This preliminary reconnaissance includes a sketch of each organization's recent history, its relationship to its parent, and its overall characteristics.

Military Research and Development: The Military Defense Lab

The Military Defense Laboratory (MDL) represented the military "in-house" research organization in our sample. About as old as the non-profit, university related lab, it has not experienced the explosive growth rate evident in both our other labs. Begun in the mid-forties as a result of work done in universities during World War II, MDL was

burdened with the bureaucratic pressures which accompany a direct dependence upon a parent organization for support. In a way which neither other lab exhibited, the Military Defense Laboratory was a captive of its parent agency. Having funds neither from several agencies nor from industry, this lab was wholly dependent upon its parent military branch for both direction and support. It did not have a university connection to provide even symbolic opposition to pressures from its major sponsor. In operations, the procedures and regulations of the Defense Department, the Civil Service Commission, and the General Accounting Office provided a framework for defining the requirements and expectations of the technical work.

The major technical activities of MDL were related to the research and development of sophisiticated devices in electronics and communication and other aspects of defense preparedness. En toto the lab employed some 1500 persons, of whom 200 were military personnel, and about 450 technical professionals (Table III). The laboratory was self-contained and required integral maintenance and housekeeping activities which occupied most of the military personnel. There were no military people in mainly technical positions.

Relationships to the parent organization were quite direct and inclusive. Military officers ran the facilities within which the lab was housed; the Civil Service Commission had its representative as head of personnel. Technical support to various working sections was directly monitored by counterpart units in Washington headquarters of the parent organization. This meant that funding from the military parent required three-way negotiations between the technical leader of a particular Group, the Technical Director of the lab, and a technical

TABLE III

EMPLOYMENT SUMMARIES FOR THREE R AND D LABORATORIES

Total Employed (overall)	MDL		SSRD		ARL	
			3528		4372	
	Research	Develop.	Research	Develop.	Research	Develop.
Total Employed			611	2586	442	1774
No. of Professionals (BS and above)			577	1804	248	956
M.S./Ph.D.			152/180	306/27	141	300
Total Budgets (000)			4750	2130	20,000	114,000
No. of Contracts			39	9	- 3 -	

FIGURE XVI

Formal Hierarchy Nomenclature

Organization (Laboratory Management)	MDL	SSRD	ARL
Division	Technical	Research/Technical	Project/Technical
Laboratory/Group	Group	Lab/Group	Project(1-3)/Group
Section	Section	--- /Section	--- /Section
(Work) Units	---	--- /Unit	--- /Unit

counterpart in Washington, D.C. This laboratory was the clearest instance of purely project organization. It was partitioned into essentially project sections, keyed to the particular problems faced by the users of their devices. (See Figure XVI and XVII for nomenclature and formal organization structure.) Some 26 sections were gathered under three Groups headed by Associate Technical Directors who reported to a Technical Director. He was joined by the Commanding Officer as the two-headed executive "team" overseeing laboratory activities (see Figure XVII). Formally, the Technical Director was subordinate to the Military Commander, although in fact they divided the technical and facilities support functions quite cleanly. Attached to the Commander's Office were the personnel, fiscal, and facilities maintenance support groups.

The three technical groups were tacitly specialized in three areas: one had a basic research emphasis; another clearly had technological applied research and advanced design orientations, and a third had relatively recently taken on data analysis, test and evaluation functions. This latter group was implementing the new systems approach to the coordination of complex technical systems and performed both technical planning as well as coordinating activities. In a strict sense, the Data Analysis Group was not a research or engineering unit, and we will not treat it as such. The personnel distribution between the Communications Environment Group and the Electronics Technology Group paralleled the pattern in the other labs. The basic science Communications Group, numbering some (*) persons, was the most professionalized with (*) per cent of their technical professionals holding Ph.D. degrees. Only (*) per cent of the (*) professionals in the Technology Group were as highly educated (Table III).

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* Information not available at time of printing.

FIGURE XVII

Formal Structure (Partial) of MDL

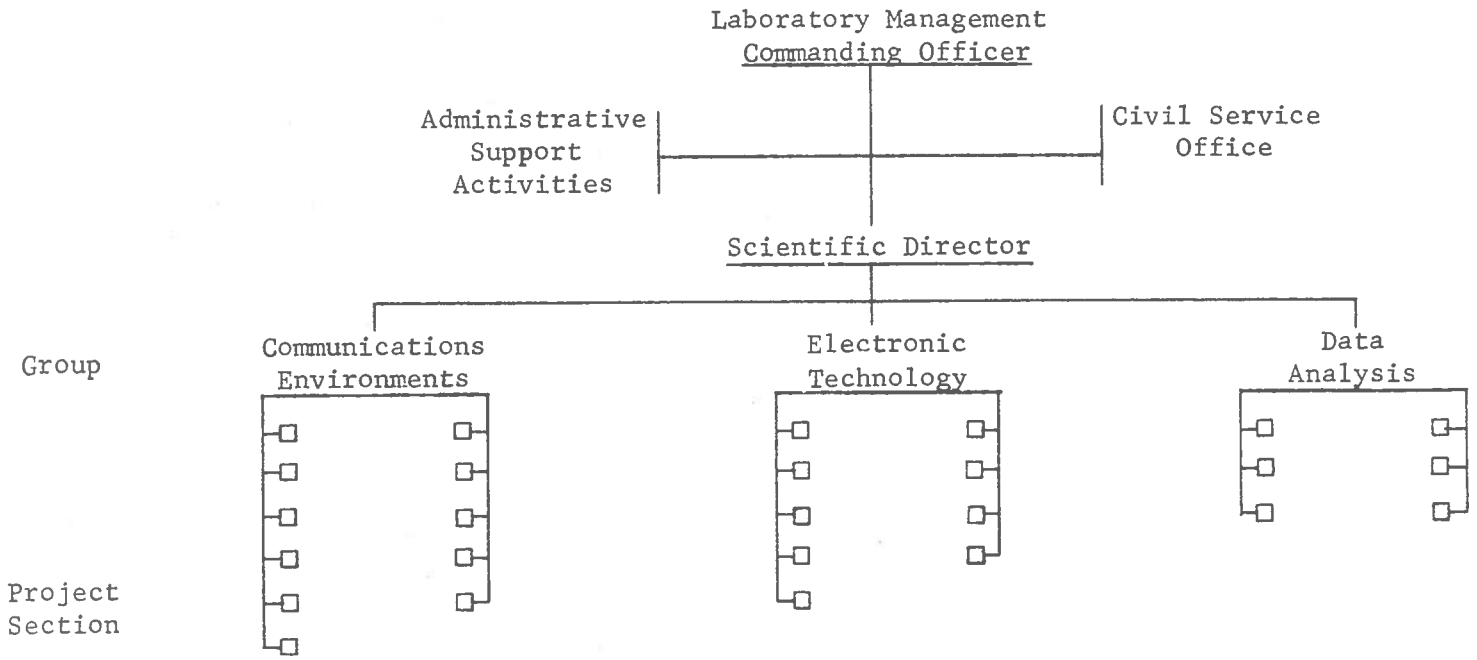
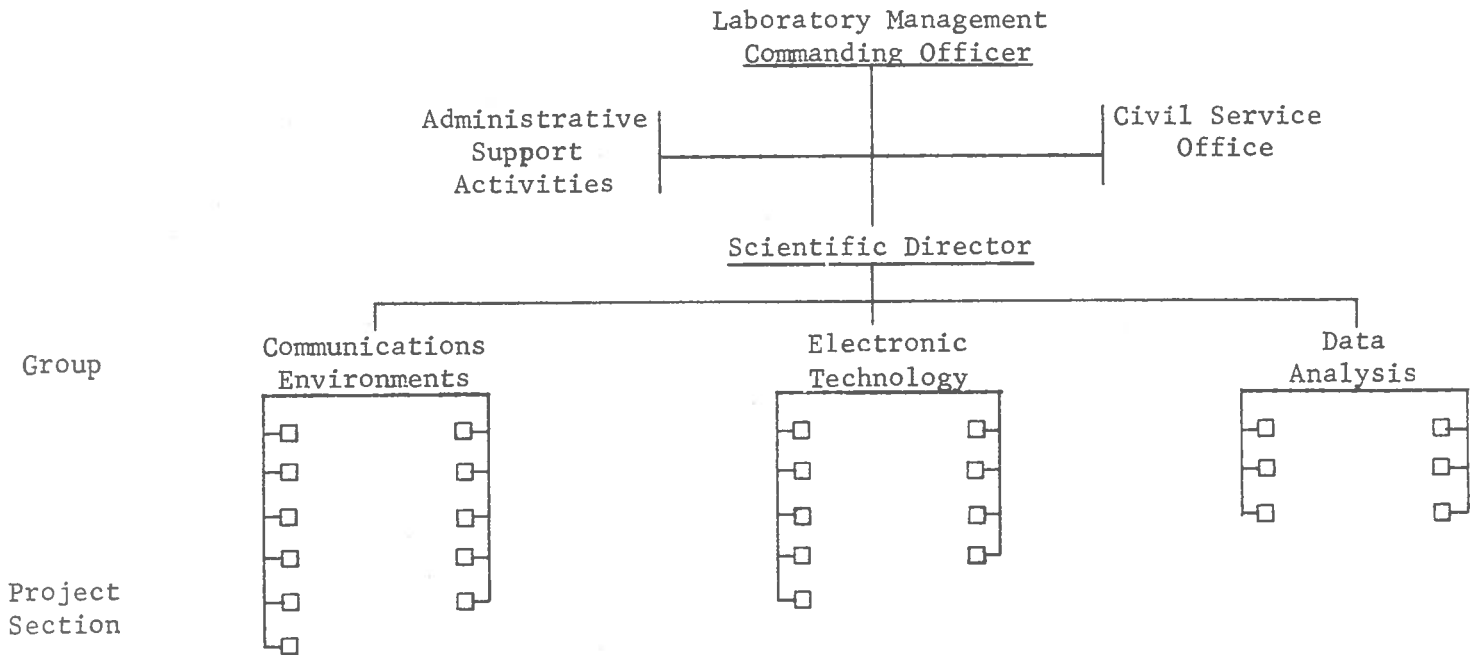


FIGURE XVII

Formal Structure (Partial) of MDL



Spatially, the laboratory sprawled over the sides of several hills and was made up of a collection of smaller buildings trailing out from a central administration and lab facility. The hilly topography had enabled the basic research sections to congregate "on the flats" some distance from both the administrative quarters and the technologically and control oriented groups. This physical separation symbolized what seemed to us the state of the laboratory's patterns of interaction. There was intensive interaction within Sections, less so within Groups, and very little between Groups. Finally, one of the more apparent differences between MDL and the others was the manner in which administrative support persons were used to facilitate group and section activities. In both the other labs there were formally assigned Group and Section administrative aides to these Technical managers. This did not obtain at MDL and proved the source of both frustration and informal accommodation.

Industrial R and D: Space Systems Research and Development

Representing the private industrial sector was the Research and Development Organization of Space Systems, Inc. (SSRD). The parent company was a wholly owned subsidiary of a well established and successful aircraft corporation. Space Systems, Inc., had been created to develop space technology capacities for the parent corporation in the mid-1950's, and had grown from a small handful of employees to a major industrial company employing more than 25,000 persons. The company had become a prime contractor for two large developments in missile and space satellite production, as well as holding numerous smaller contracts for research in related aerospace fields.

Both formally and informally, the Department of Defense as "customer" had significant impact on the operational conduct and planning strategies of the company. With two major projects underway, the two supporting defense agencies were heavily involved in many aspects of the company's operations. As in other companies with this relationship to the government, the Armed Forces Procurement Regulations were a most important guide to operations; and the General Accounting Office's requirements to enable swift audit shaped internal accounting practices. One of the most important conditions influencing the overall organization of the company was the fact that their two defense sponsors were competing agencies with differing attitudes about organizational methods and procedures. Organizationally, the major Projects were relatively autonomous, serving each customer's respective requirements. In essence, the company-wide organization was a compromise between the demands of their two major customers, the larger corporation, and the system required to research, develop and produce extremely complex and sophisticated devices.

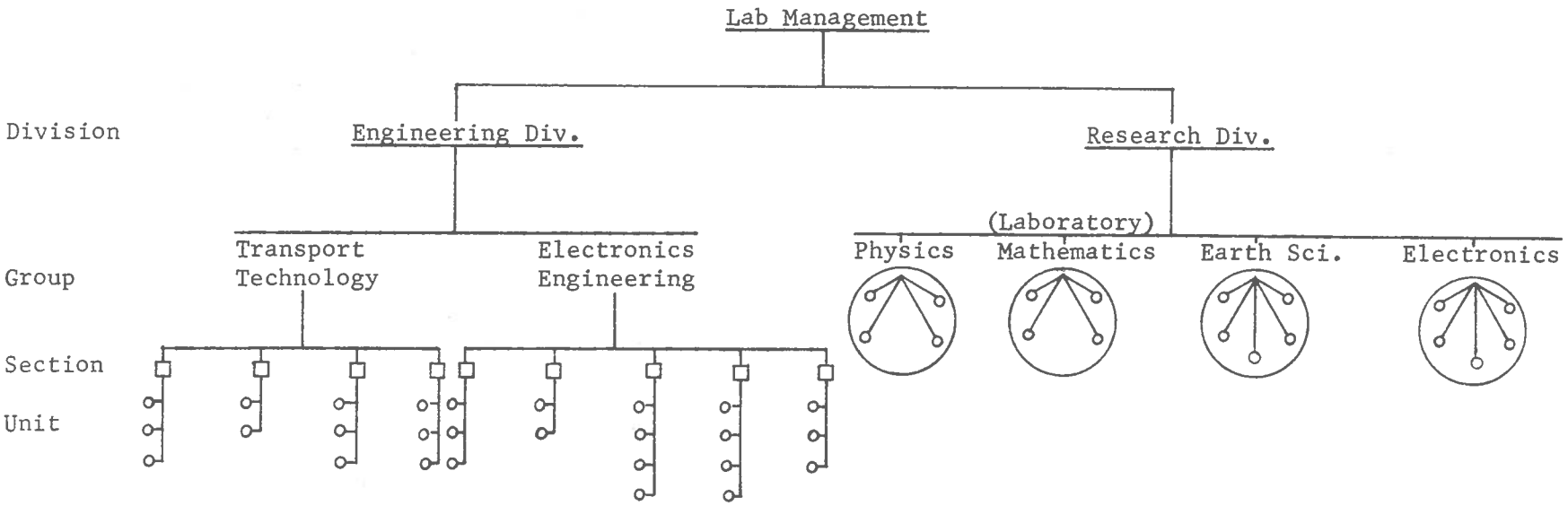
Within this huge and complex structure, the Research and Development Organization (SSRD) was in an immediate environment made up of the two major Project organizations, the larger company and corporate headquarters, the Department of Defense, and the scientific and engineering communities. These were the major sources of demand upon the scientists in the Research Division, and the engineers of the Advanced Engineering Division who together made up the R and D organization. From this multiple-faceted environment, the SSRD organization, numbering over 3500 employees, found financial support from: the major Projects; the company's relatively small amount of resources for "unsponsored research"; and directly from the federal government in contracts for research and development projects other than the two large "in-house" ones.

SSRD's internal organization was relatively complicated (see Figure XVI and Figure XVIII). Laboratory management had quite formally separated basic research activities from most applied research and advanced design work. With equal organizational status, these two divisions represented the company's attempt to solve the generic tensions between the requirements of inquiry and those of action. The Research Division was composed of over 600 persons, of which over half were highly skilled technical professionals, nearly equally divided between holders of Master's and Ph.D. degrees (Table III). This division was the least complex and was organized around four relatively specialized laboratories each with some 130 technical professionals, formally distinguished only by rank, i.e., staff and senior scientists. A small administrative staff was attached to the Research Director's office and to each Laboratory Director to aid in handling primarily administrative burdens of budget reporting, procurement and personnel matters. These labs were formally unstructured, though obviously some informal structure had developed. In essence, there was only one formal hierarchical level separating any research scientist from the Research Director. Technical work was done in relatively small teams headed by senior scientists.

The Engineering Division was much larger, more highly structured and internally specialized. There were three major Groups -- Electronics, Flight Technology and Information Systems -- supported by five smaller technical Groups and five test and planning Sections. The administrative support staff was a good deal larger, and work was considerably more directed and tightly controlled. The formal organization was broken down into some 47 separate units, divided among 12 Section Managers, who were grouped under three Technical Directors who reported to the Division

FIGURE XVIII

Formal Structure (Partial) of SSRD



Director along with the support Group manager. Of the some 2600 persons in the Engineering Division, only a little over 12.5 per cent held advanced degrees, only 1 per cent with Ph.D.s.

In effect, SSRD combined Divisions which were both functionally organized around academic disciplines, but varied in the amount of coordination and control exercised by managers. The Research Division was engaged in quite exotic work at the boundaries of knowledge; it was made up of high differentiated, semi-autonomous groups whose work was comprehensible only to very few scientists outside each group. The requisites for formal coordination and interdependence were difficult to meet.

On the other hand, the Engineering Division's work was more nearly comprehensible to its managers. It was considerably more integrated with quasi-bureaucratic coordinating arrangements dealing with less differentiated work groups. Tighter controls were possible and necessary to meet the production demands of the company's major projects. Both Division rank quite high on any complexity measure. Subjectively they seemed about equivalent; the high differentiation of the Research Division balancing the high interdependence of Engineering.

The relative separation of highly and moderately skilled technical professionals between the Research and Engineering Divisions was paralleled by a physical separation of the two facilities. This was sufficient so that movement between them required ground transport. Furthermore, there was a substantial difference in the number of discrete contracts held by the two groups. While Engineering had only nine, this was quadrupled for the Research Division, and reflects the relative autonomy of that Division. (See Table III.)

In sum, the organizational structure and activities of the two Divisions prompted a relatively clean separation of basic research and development work, both physically and in group style. The Research Division was university-like in tone, calm, almost leisurely, in outward appearance; while the Engineering Division had a bustling pace carried on amidst the buzz of coordinative conversation in large, open technical work rooms. Both the distance of separation and the almost mutual exclusiveness of technical activities seemed to reduce interaction to a minimum.

A Federal Contract Research Center

Perhaps one of the most interesting and complex arrangements for the conduct of research and development is the university-related laboratory funded by the government for research purposes. The Advanced Research Laboratory (ARL) represents this type of organization. It was a nationally recognized laboratory, with considerable technical achievements to its credit. It had started its organizational life at the beginning of World War II as a "spin-off" from work done at the major university, with which it is still related. After a period of relatively slow growth, the laboratory had experienced fairly rapid increases in size and support during the decade prior to our study.

ARL had been involved in a broad range of technologies conducting basic and applied research, advanced development and project design, and limited amounts of fabrication of highly sophisticated devices related to aerospace activities. During its existence, work had been done for both military and civilian agencies, and the lab recently had grown to some 4000 employees. The specific mixture of technical activities had

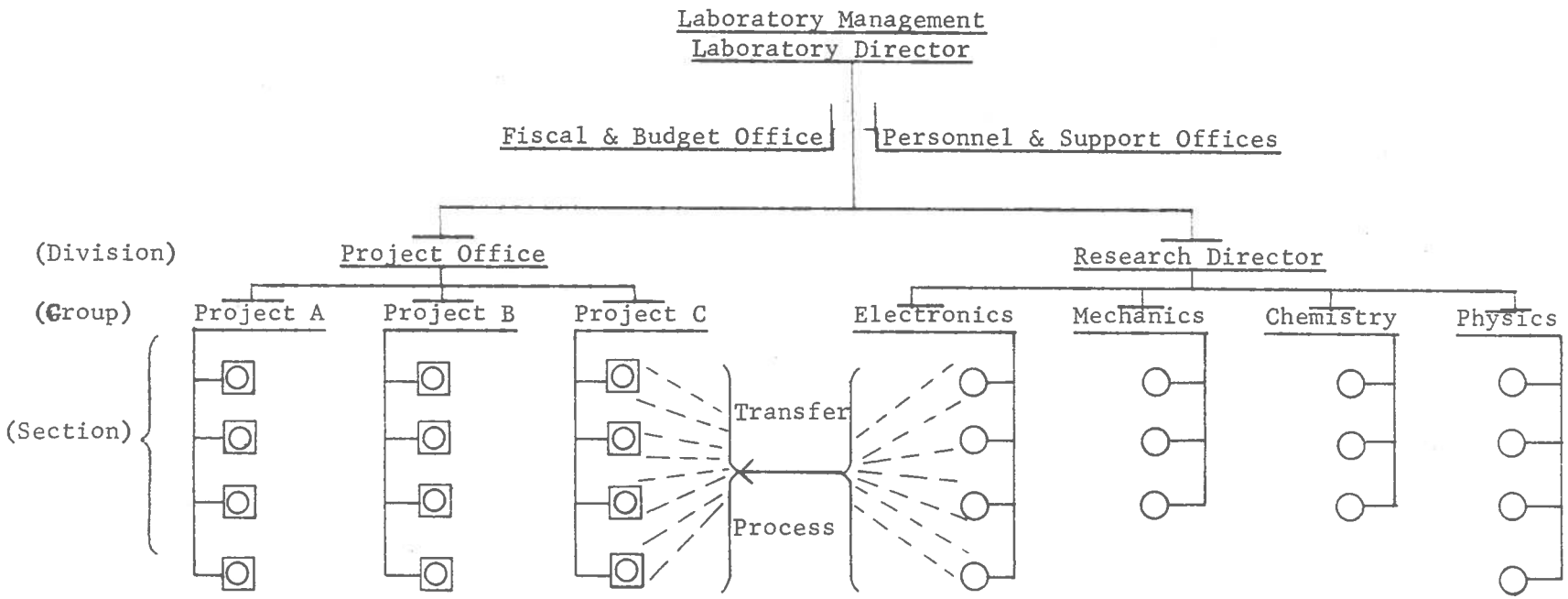
varied over the years, but some support had always been devoted to each phase of inquiry and action. As in SSRD, the relative emphasis had been on engineering development, but this was consistently accompanied by significant scientific research work.

All laboratory personnel were employed by the university, although only a very few number of ARL people were university faculty. The university and lab had the same board of trustees; however, there were separate administrative and housekeeping capacities. This prompted an administrative requirement, similar to MDL, for facilities support and operations integral to the lab and complicated its organizational structure. The policies and organizational goals which guided ARL's operation were established both by the parent academic institution and the government agency that funded the lab's work. ARL's environment was ambiguous due to this dual relationship with two critical institutions. It is unlike many university labs because of its strong relationship with a single government agency. This agency essentially owned the physical plant, though the lab's goal structure was clearly keyed to university values. Furthermore, it differed from industrial labs for it was avowedly non-profit. In many situations it had neither of the advantages of laboratories completely integral to a university or wholly within the federal government.

Internally, ARL was the most "mixed" of the labs in this study. Spatially, the lab was concentrated into a relatively high density of activity, spilling temporary buildings and parking spaces outside its permanent perimeters and growing upward rather than the rambling architecture of other laboratories. Organization structure was also densely constructed, resembling what we termed a "matrix organization" in Chapter Two. Groups were related structurally across each other, as well as intensely within themselves. (See Figure XIX.) There was a formal

FIGURE XIX

Formal Structure (Partial) of ARL



⊡ - indicates Project section with science/engineering team from Research Sections

division of technical work among groups having various technical specialties. These were the administrative and relatively permanent home for technical professionals. However, the funding from the agency was channeled through several quite large technical projects. Project Division managers essentially hired the professionals to do project work while these men remained under the administrative management of the Technical Division. For example, groups of technical professionals in, say, the Polymer Chemistry Unit, would be contracted to do work for a time on Project Overrun. At the termination of that work these professionals would revert back to the Chemistry Section and move on to other types of work. This meant that most technical Groups received overall guidance from the technical director of their Laboratory and relatively specific specifications from Project management. Technical management watched over the development of a Laboratory's overall competence, while Project management were the users of that capacity. This manner of relating technical skills to project needs, through the funding conduits of the major projects, resulted in an extraordinary number of cross-cutting relationships between technical groups. The intent was to maintain organizational flexibility in the face of changing technical developments and project demands.

One of the main outcomes of this structure was a protective atmosphere within the one section oriented primarily toward basic research. Its technical managers were consistently watchful that applied and design needs of the Projects did not overwhelm the basic research inclinations of that section. We shall discuss some of the problems prompted by this situation later in our analysis. Suffice it to say that this difference between basic research and applied orientations was structurally localized.

There was implicit recognition that one of the several Groups at ARL would house most of the scientists; other Groups shared the much larger numbers of engineers. This resulted in a distribution of professionals across the seven major Groups in which the Science Group had 248 of which 31.9 per cent had M.S./Ph.D. degrees and the other Groups shared the rest about equally (Table III).

Coordination of funding for various groups came from several sources. First, as we have already noted, in-house contracts with the major projects were a primary source. Second, there were two sources within the funding government agency which could be pursued for support: the major mission department of the agency, and the special projects research section of the same agency. The first type of funds sometimes involved the ARL staff in close interaction with university researchers, who used ARL facilities to conduct experiments with the help of ARL engineers assigned to provide technical support. The second type of funding required negotiations with the Special Projects section and sometimes was turned to if funding looked improbable from the major projects. In either case, funds were forwarded to ARL and disbursed internally for work ARL felt necessary for the success of the projects.

Overall, the Advanced Research Laboratory had responded to the requirements for inquiry and action with a pattern of internal interaction very much like a matrix. Outside demands from the government for standardized organizational structure among government labs were not present due to the university relationship. On the other hand, the <u>laissez faire</u> style of university research groups did not predominate due to the relatively immediate press of major technological projects. The result was an extraordinarily intertwined organizational structure

characteristically more flexible and mercurial than the other organizations in this study.

Prelude to Analysis

This chapter has attempted to provide an overview of the structural challenges of contingency-uncertainty and organizational complexity in both its theoretical and operational forms. The stage is now set for exploring the patterns of similarity and variance among and within three organizations whose response has been, in a rough sense, more than adequate. Our objective is to tease out from interview and questionnaire data and participant observation the apparent parameters of adequate responses to considerable uncertainty both within and outside each organization.

In a sense this is the study of public organizations of the future. Government involvement in an increasingly interdependent, technically based economy will grow. In a society that depends heavily upon technological processes to advance its material quality of life, adequate patterns of public organizational response are important to discern. Recent enthusiasm for using technology in the pursuit of social values simply makes it mandatory. If the interpenetration of government and private organization continues, as is very likely, then, various "private" organizational responses are also of interest. Perhaps most important is that we come to a refined understanding of the interaction between social complexity and organizational responses to it. One of the surest predictions about the future is that it will be more socially, economically, and political complex and interdependent. Our capacity to shape that future will rest in large measure on our ability to devise

systems of cooperation that will increase our intelligence and capacity to act in the face of uncertainty. We turn now to examine some of these patterns in three organizations of inquiry and action.

TECHNICAL APPENDIX, CHAPTER IV

Methodology: Instruments and Process

The data gathered from these laboratories were based on three criteria, a conceptual guide somewhat less refined than that in Chapters Two and Three; intuitive notions about what might additionally be important; and items negotiated with lab management. Our basic design followed a general structure-process framework with the lesser included notions of role relationships.[11] From past experience in laboratory activities, some items were included on an intuitive basis. Finally, in several cases, some data were collected in which one lab management was specifically interested.

Besides the usual gathering of written procedures, organizational histories, and so forth, three data collection instruments were used: informal interviews with selected high-level managers and administrators regarding organizational parameters; formal questionnaires administered to a sample of professional, managerial and administrative personnel; and formal interviews from a sample of persons who had completed the questionnaire. (See Appendix A for complete interview and questionnaire schedules.)

Informal interviews with high-level managers were conducted immediately after access to the organization was gained. These were intended to obtain a broad overview of the laboratory's history, formal organization, formal goal structure, the functions of different organizational units, number of employees in different categories, and other

information that would help us understand the meaning of language used to answer open-ended responses in the questionnaire and formal interviews. Informal interviews helped greatly in the minor modification of the instruments for each specific organization to assure a fit to the "language of the laboratory," and in understanding the significance of some interview data.

The formal questionnaires were administered only after they had been through a pretest process, to assure us that their language would be understandable to our sample in the way we intended. This meant in some cases changing our nomenclature to match that used in the labs so that, for example, hierarchical levels in each organization were designated in the specific terminology of the lab. We sought to avoid presenting lab members with ambiguous organizational terminology by using their own. The data have functional equivalency, if not complete terminological uniformity. Three slightly different versions of the questionnaire were used, in recognition of the three major role types -- technical manager, business skilled administrators, and technical professionals (scientists and engineers).

A non-proportional stratified random sampling procedure was employed in the selection of the sample for lower participants, i.e., scientists, engineers and some administrative units. These were based on complete listings of each major personnel classification. Starting with the high hierarchical levels of division and above, the entire population was used. Average time for completing the questionnaire was about 40 minutes, and the return rate was from 80 to 95 per cent. (See Appendix A for population, questionnaire and interview ratios, and retrieval procedures.)

The most time-consuming instruments were the formal interviews. These lasted about 90 minutes and were based on similar basic schedules for each lab. A few questions, however, were deleted in the last laboratory, the university non-profit lab, because they had proved to be insignificant or irrelevant to the theoretical questions raised in the study. Interviews were taken from almost all the relevant managerial population and a non-stratified random sample of professional and lower administrative personnel was used. The interview phase proved to be an unusual experience for us, for this interaction was characterized by highly articulate respondents who, in large measure, understood the research process and were remarkably cooperative.

We could have easily spent a good deal more time in each organization, but the time we did spend represented a sizeable subsidy by the organizations to our study as it was. Data collection, especially the formal interview phase, was costly in time and in some anxiety to management about arousing employees' interest in relationships best left unexplored, from their view. In order to gain access and facilitate a good working relationship within the labs, we were sensitive to the need to increase the possible benefit perceived by managers, to reduce their sense of subsidizing the study, and at the same time not to compromise our intention. Several things were done to accomplish this. First, in several cases, we acceeded to management requests that additional questions be included in the questionnaire to test for some attitudes specific to problems or issues within that lab. These questions were clearly marked as special ones of interest to lab management and included items such as attitudes about in-house publications, etc., which had little bearing upon our interests or possible contamination consequences for the rest of the questionnaire.

It was also our procedure to offer three kinds of feedback to the labs. We offered to discuss, with anyone the lab management chose, our impressions of the lab shortly after we had completed our interviewing. In each case this was accepted and we addressed ourselves to the general impressions we had about the lab, from our conceptual point of view. In all contacts with the lab, care was taken to protect the anonymity of people who assisted us, and we were never put in a position of having to refuse information for that reason. Second, we also committed ourselves to return to each lab after we had finished the preliminary analysis of the questionnaire data, for a presentation of what we found of most interest in that lab. Again, we did not specify who might be useful to talk with, but left it up to lab management. We were asked to do this by each lab. Presentations varied from a relatively small briefing of lab management to a full-dress lecture to anyone in the lab who wanted to come. In the latter case, a fairly formal presentation was made to several hundred people representing a large portion of our questionnaire sample. Finally, we offered -- but were never asked -- to provide data decks and code books of the questionnaire to the lab, with appropriate deletions to protect identities of respondents.

In each phase of the field study, we received most gracious cooperation from laboratory members at all levels. Almost always apparently open, sometimes challenging and almost never difficult to talk with, the scientists, engineers, managers and administrators of the labs made that part of the study a most valuable one.

FOOTNOTES, CHAPTER FOUR

1. For discussions of these problems and reactions to traditional forms, see W.G. Bennis and P.E. Slater, The Temporary Society (New York: Harper and Row, 1968), ch. 1, 3; D.I. Cleland and W.R. King, eds., Systems, Organizations, Analysis, Management: A Book of Readings (New York: McGraw-Hill, 1969), section 1; and Ch. 1, Note 26.

2. Scott, op. cit., p. 267, for a discussion of these models and their implications for professional tension in bureaucracies.

3. See Kornhauser, op. cit., pp. 50-56; Cleland and King, op. cit.; and C.J. Haberstroh, "Organizational Design and Systems Analysis," in J.G. March, ed., Handbook of Organizations (New York: Rand McNally, 1965), pp. 1171-1211.

4. Kornhauser, op. cit., p. 82.

5. Cf. J.F. Mee, "Matrix Organization," in Cleland and King, op. cit., p. 23ff; and Haberstroh, op. cit., p. 1206.

6. Mee, op. cit., p. 9.

7. Organization for Economic Cooperation and Development, Reviews of Science Policy: United States (Paris, 1968).

8. (New York: Columbia University Press, 1963).

9. H.M. Vollmer, Work Activities and Attitudes of Scientists and Research Managers (Menlo Park, Calif.: Stanford Research Institute, May 1965), Tables 5a, 5b, p. 32f.

10. Ibid.

11. See T. La Porte, Organization for Research: Conditions of Strain and Accommodation in an Industrial Research Organization (Stanford University, unpublished Ph.D. dissertation, 1963) and H.M. Vollmer, et al., Adaptations of Scientists in Five Organizations: A Comparative Analysis (Menlo Park, Calif.: Stanford Research Institute, R and D Studies Series, May 1964).