COMMUNICATION IN RESEARCH AND DEVELOPMENT
ORGANIZATIONS: AN INFORMATION PROCESSING APPROACH

by

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ABSTRACT

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Submitted to the Alfred P. Sloan School of Management on January 13, 1976, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Previous research indicates that patterns of technical communication are an important determinant of technical performance in Research and Development (R & D) laboratories. This thesis will use these studies as a base from which to extend the literature on communication in, and management of, R & D organizations. The premise of this research is that there is no one best way to organize a laboratory's communication network.

To pursue this fundamental idea, an information processing perspective will be developed. This perspective will guide the development of the hypotheses and the interpretations of the results. Basic to the information processing approach is the idea that technical communication patterns must attend to different sources of technical uncertainty, and that a project's information processing capacity must match the information processing requirements of its work. Task characteristics, task environment, and task interdependence are introduced as work characteristics which are sources of technical uncertainty. Technical communication, communication structure, and technical roles are introduced as components of a project's communication network which attend to the different sources of uncertainty. The thesis will develop and test a number of hypotheses and research questions elaborating the basic hypothesis that a project's communication patterns will be contingent on the nature of its work characteristics.

To study these questions, data was gathered on 62 projects in a large R & D facility. Weekly surveys were given to all professionals (n = 345) in the laboratory over a seven month period. Individual sampling days were chosen on a random basis. The survey obtained detailed information on the technical communication patterns of each professional. Data on other organizational and individual variables was collected early in the study while project performance data was collected late in the study.

The results indicate that technical communication is a very important organizational process. High performing projects had systematically different patterns of technical communication than the low
performing projects. Further, for the high performing projects, the patterns of technical communication were indeed contingent on the nature of the project's work. The results on the individual hypotheses begin to specify the nature of the contingent relations between characteristics of the work and the patterns of technical communication. These results permit the manager to better evaluate, design, and manage his laboratory's communication network. In all, this study finds that patterns of technical communication are important and that they must be managed-specialized to fit the information processing requirements of the work.

Thesis Chairman: Thomas J. Allen
Title: Professor of Organizational Psychology and Management

Committee Members: Ralph Katz
Paul R. Lawrence
Edgar H. Schein
To Marilyn and Jonathan
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This dissertation is the culmination of a number of years of effort. During these years I have benefited from contact with a number of distinguished individuals. If these acknowledgments are long, it is only because my indebtedness is great.

It was my experiences at Cornell University that initially sparked my interest in organizational behavior. Professors Leopold Gruenfeld and William F. Whyte were particularly instrumental in generating and sustaining my interest in organizational processes.

At M.I.T., the late Professor Donald G. Marquis introduced me to the areas of R & D management and the management of innovation. He also helped make my first year at Sloan intellectually exciting. Professor George F. Farris was more than generous with his time. A number of ideas and approaches in this study were originally developed during our discussions.

My dissertation committee has been active and stimulating. Professors Paul R. Lawrence and Ralph Katz were helpful in conceptualizing, carrying out, and interpreting the research reported here. Professor Lawrence was extremely helpful in the conceptualization, interpretation, and writing stages. Professor Katz's methodological and analytic skills permitted me to analyze a complex data base. His support and encouragement throughout the project were particularly appreciated. Professor Edgar H. Schein, while not involved in the details of this study, was influential in my graduate education in general and the writing of this thesis in particular. His demands for clarity, organization, and conciseness are reflected in this document and will be reflected in my future work.

Professor Thomas J. Allen, chairman of my dissertation committee, was instrumental in developing my interest in the management of innovation area; his influence on my thinking, research, and writing pervade this document. I am indebted to Professor Allen not only for his insights, stimulation, support, and encouragement, but also for his working definition of a professor's role. He has set an example for his students by emphasizing the importance of professional integrity, excellence, and standards integrated with the needs and demands of a family. He has been an effective and powerful role model.

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While the organization and the various participants in this study must remain anonymous, I thank them for their extensive cooperation and support.

I would like to express here my thanks to my families. Their guidance, support, and many sacrifices over the years have made it possible for me to reach this goal.

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Michael L. Tushman
Morningside Heights, New York
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CHAPTER I
INTRODUCTION AND OVERVIEW

1.1 Introduction

This study in its broadest sense is concerned with the management of technical innovation. The pace of technological change as well as a number of pressing social problems have made innovation a key concept in today's society. Every firm, every industry, and every nation is concerned with the introduction of new or improved products, processes, and programs that depend to some degree on technical innovation. Technical innovation is both a long and short term necessity. From a longer perspective, innovation has been acknowledged to contribute to economic growth and social benefits (e.g., Schmookler, 1966), while from a shorter perspective, innovation is essential for organizational survival in a competitive world (see Myers and Marquis, 1969; Utterback, 1974).

At the most macroscopic level, nations must be able to stimulate technological progress over time. The interest in technical innovation has been sparked by the realization that technical progress is of primary importance in the development of programs to meet human needs and social goals. Examples of current efforts to stimulate technical innovation are numerous, including: medical research, environmental
protection, energy alternatives, mass transportation, and space exploration. At a more microscopic level of study is the individual industry or firm. In many industries the ability to innovate over time is a dominant competitive issue (Myers and Marquis, 1969; Achilladeles et al., 1971). Similarly, organizations must be able to produce new and improved products or processes. If product life times are decreasing, as Gerstenfeld (1970) reports, then organizations must be sensitive to conditions that enhance their ability to innovate. This press for innovativeness holds not only for industrial organizations but also for nonprofit organizations (e.g., medical centers, social agencies, governmental agencies).

The commitment to innovate is great. One reflection of this commitment is the size of the national Research and Development (R & D) expenditure. During 1970, approximately 27 billion dollars was spent on R & D efforts. Gerstenfeld (1970) reports that the government financed approximately two-thirds of this work while the private sector did about 85 percent of the work. The nine billion spent by private industry represented an investment ranging up to four percent of a firm's annual sales. In short, the concern for and commitment to innovation through R & D efforts is substantial.

As in many areas of practical importance, there is much that is not known or understood about the process or management of innovation. While scientific and engineering development is of course important, there is substantial evidence which suggests that non-technical factors are intimately associated with the development of successful innovations. These non-technical issues can be subsumed as special
concerns of the management of innovation. The importance of this managerial perspective on the process of innovation has been commented on by the Panel on Invention and Innovation of the Department of Commerce. Their report, *Technological Innovation* (1967), concluded with this statement:

More important, therefore, than any specific recommendation... is one central proposal: The major effort should be placed on getting more managers, executives, and key individuals...to learn, feel, understand, and appreciate how technical innovation is spawned, nurtured,...and managed... (my emphasis)

This review has suggested that technical innovation is an important social as well as organizational concern. If so, then the management of innovation is an important area to research and understand. While the larger motivation is to better understand the process of technical innovation, this study will deal with only a piece of this larger concern. This research will focus on the R & D organization. Since most of the efforts to innovate are done in R & D laboratories, a greater understanding of R & D organizations will contribute to the understanding of the more general problem of technical innovation. This investigation will therefore focus on a set of issues concerning the management of R & D organizations.

Even in this more restricted area there is much to be learned. Gerstenfeld (1970) reports that more than 50 per cent of all R & D projects fail because of nontechnical (i.e., organizational) difficulties (see also Prakke, 1975 for a similar perspective). Myers and Marquis (1969) report that out of every ten projects that emerge from the R & D laboratory, only two become commercial successes. They also report that successful innovations were frequently based not on new
scientific or technical knowledge, but on existing and widely diffused
knowledge or on the simple adaptation of an existing product. In short,
there is sufficient evidence to suggest that organizational factors (i.e.,
nontechnical factors) are of critical importance in making the R & D
effort more effective.

In summary, if technical innovation is an important national and
organizational concern, and if the primary locus of work on innovation
is the R & D laboratory, then the study of R & D management has
clear relevance. The importance of managerial (or nontechnical)
concerns is accentuated by the studies which indicate that nontechnical
factors are of particular importance in the effectiveness of the
research and development effort. This study will contribute to the
growing R & D management literature by examining some determin-
ants of the patterns of technical communication and the effects of
patterns of communication on technical performance.
1.2 Technical Communication

in Research and Development Organizations

The research and development laboratory has been called the adaptive subsystem of the larger organization (Katz and Kahn, 1966). Katz and Kahn argue that this specialized system must provide the larger organization with an external or outward perspective. The R & D unit is therefore responsible for tracking external environmental conditions and developing products, processes, and ideas which permit the organization to exploit a changing environment rather than be exploited by it.

The primary task of the R & D laboratory is to keep the larger organization current through the systematic development and creative utilization of scientific and technical knowledge. This technical knowledge and effort is directed toward the production of materials, devices, methods, or processes for use in both the long and short run. The main task of R & D organizations is therefore technical problem solving (Rosenbloom and Wolek, 1970).

Technical problem solving can be seen as an information processing problem. For any particular task, the project must be able to effectively gather as well as process diverse bits of information. The project must keep track of technical and market information as well as take advantage of the organization's technical expertise. The project must also be able to effectively export information (i.e., ideas, solu-
tion approaches) to the larger organization and be involved in more short run coordination problems. Finally, at each point in this problem solving process, the project must be sensitive to feedback so that advantageous changes can be made. Each one of these problem solving phases involves the transfer and processing of information. Therefore, it may well be useful to conceptualize the R & D laboratory as an information processing system--information processing geared to problem solving and coordination ends.

Since communication is the means through which the transfer of information and meaning occur, one way to track information processing behavior is by tracing communication patterns. Communication can be broadly separated into oral and written channels. Allen (1966) and Gerstberger (1971) have reviewed a number of information channel studies and have found that oral channels are better suited for the effective transfer of technological information than are written ones. Gerstberger (1971) suggests that oral channels facilitate the exchange of complex concepts and thoughts through the availability of rapid feedback and the opportunity for extensive re-coding of information. In support of these reviews is a report prepared by the National Academy of Science (1969). This report suggests that oral communication is a particularly important medium for the transfer of information because: A) it is timely; B) it is interactive and therefore provides rapid feedback; C) it contains much technical information and experience that is not contained in the literature; and D) oral communication takes little effort and is inexpensive. Therefore, while there are several types of communication channels, the literature indicates that oral communication is the most effective for the transfer and dissemination of technical
information.

If R & D organizations can be usefully seen as information processing systems, and if oral communication is a particularly important medium for the transmission of technical information and experience, then R & D organizations can be seen as communication networks. If so, then different patterns of oral communication may well be associated with differences in technical performance. This logic indicates that there could be substantial payoffs to understanding the determinants of oral communication in R & D organizations. Roberts et al. (1974) echo this thought. They suggest that since communication seems to tie organizations together, then a greater understanding of the determinants of communication will contribute to our knowledge of organizations in general.

There are extensive precedents for studying communication patterns in R & D laboratories. Allen (1964, 1966, 1970, in press), Allen et al. (1968), Allen and Cohen (1969), Baker et al. (1967), Myers and Marquis (1969), Gerstenfeld (1967), Gerstberger (1971), Farris (1972), Conrath (1967), Rosenbloom and Wolek (1970), Utterback (1971) and Whitley and Frost (1973), to name only a few, have all investigated some aspect of communication in R & D settings. These studies have demonstrated the importance of taking communication both within and outside the laboratory seriously. These researchers have shown that the nature of communication within and between work areas is an important determinant of technical performance, and have suggested a number of ideas for managing communication in R & D organizations (see, for instance, Allen, in press; Gerstberger, 1971; or Prakke, 1975). This
literature will be reviewed in detail in the following chapters. This study will use these previous studies as a base from which to extend the R & D literature in particular and the work on technical innovation in general. This research will develop these areas by pursuing the simple idea that there is no one best way to organize a laboratory's communication network. This idea is based on the observation that R & D organizations are typically complex organizations made up of work areas facing very different amounts of technical uncertainty, and therefore, having very different information processing requirements. Since work areas within the laboratory have different information processing requirements, then they are likely to have different patterns of communication to deal with their particular information processing needs. If this logic has merit, then patterns of communication should be contingent on the nature of the work. Matching communication patterns to the requirements of the work should therefore be associated with high project performance.

It has been suggested that patterns of communication should match the information processing requirements of the work. To test and explore the specific implications of this basic proposition, a simple, yet general, information processing view of R & D organizations will be further developed. This perspective will lead to a set of hypotheses specifying the nature of the contingent relationships between characteristics of the project's work and characteristics of the project's communication network. Throughout the analysis, performance data will be used to further specify under what conditions different network characteristics are associated with high technical performance.
A major agenda for this research is to contribute to the literature that deals with communication in R & D organizations. There will, however, be additional payoffs from this research. Since the approach and the hypotheses will be derived from a general information processing model, the testing of the set of hypotheses will also be a test of this larger framework. Another major agenda of the research is to draw action implications from the research. More specifically, if the contingency idea has merit, then the results of this study should be useful for managers interested in designing effective communication networks, or as a framework for evaluating and acting on an ongoing communication system. The study will provide direction as to what organizational variables influence communication, and what communication patterns are more appropriate under the different laboratory work conditions. In all, this study is an attempt to further our understanding of the nature and effects of communication in R & D settings. This increased understanding should, in turn, be useful to those interested in managing technical communication.
1.3 Overview of the Study

Chapter II will further develop the information processing perspective introduced in this chapter. The information processing imagery will be used to develop the basic proposition that technical uncertainty is a critical determinant of communication in organizations, and that to be effective, a project's communication network characteristics must be capable of dealing with its information processing requirements. It will therefore be suggested that high performing projects which must deal with different amounts of uncertainty will have systematically different communication network characteristics. This basic proposition will be used to guide the development and interpretation of the specific hypotheses. Chapter II will also introduce the variables on which our focus will be directed: task characteristics, task environment, and task interdependence as sources of uncertainty, and project technical communication, project communication structure, and technical roles as network characteristics which deal with the different sources of uncertainty. In all, Chapter II will set the stage for the hypotheses development, analysis, and discussion in the rest of the study.

Chapter III will discuss the setting within which the study took place and the particular methods used for each variable. Chapters IV, V, and VI will each focus on a separate component of the communication network; technical communication, project structure, and the development of technical communication roles will be treated in that order. Each chapter will review the relevant literature and develop a set of hypotheses relating the network characteristics to the different work
characteristics (i.e., sources of uncertainty). The hypotheses will be tested and discussed in each chapter. Guiding each chapter will be the basic idea developed in Chapter II--that the project's communication network must be able to deal with its information processing requirements and that managers must, therefore, be sensitive to the different information needs within the laboratory. Chapter VII will review the major findings, draw some managerial implications dealing with the design and management of communication networks, and suggest some future research directions.
CHAPTER II

COMMUNICATION IN ORGANIZATIONS:
AN INFORMATION PROCESSING PERSPECTIVE

2.1 Organizations as Communication Networks

In any exhaustive theory of organization, communication would occupy a central place because of the structure, extensiveness, and scope of the organization are almost entirely determined by communication techniques.

--Barnard, 1938; p. 91

The capacity of an organization to maintain a complex, highly interdependent pattern of activity is limited in part by its capacity to handle the communication required for coordination.

--March and Simon, 1958; p. 162

Barnard and March and Simon emphasize the importance of communication in organizations. If they are on target, then communication should occupy a central position in the study of organizations. While there have been a number of studies focusing on communication patterns in organizations, reviews of the communication literature have commented on a lack of direction and momentum to this research. For instance, Allen (1969) has observed that "virtually nothing is known... concerning the nature of communication in organizations--yet communication is the keystone of organizational functioning (p. 24)." There is, then, a dilemma. While there has been a substantial amount of attention paid to communication processes, there has been relatively
little payoff in terms of understanding the determinants and effects of communication patterns in organizations.

Guetzkow (1965) and Porter and Roberts (in press), in separate reviews of the communication literature, have recognized this dilemma. They suggest that one of the reasons that organizational communication is not well understood is because of a lack of direction to the research on communication. Guetzkow and Porter and Roberts propose that a systematic research framework would be helpful in both integrating research results as well as guiding future research questions. Recognizing this dilemma, the present study will attempt to develop an information processing framework prior to the development and testing of the hypotheses. This framework will guide the research for the study and will hopefully be a useful organizing perspective for viewing previous research results.

In order to study social behavior, simplifications must be made. Organizations have been conceptualized as decision making systems (March and Simon, 1958), as goal-oriented systems (Blau and Scott, 1962; Parsons, 1951), and more recently as information processing systems (Weick, 1969; Galbraith, 1969; Duncan, 1973; Wilensky, 1967). An information processing perspective will be used to guide the analysis in this study. This view of organizations links the concept of organization to that of information transfer through communication. The information processing perspective highlights the importance of patterns of communication which must deal with uncertainty arising from work related problem solving and coordination requirements. To deal with technical uncertainty, the organization must gather, process, and export information as well as be attuned to feedback from different sources of information.
From this point of view, unless the organization can keep track of and deal with the different sources of uncertainty through appropriate patterns of information flow, it cannot remain viable.

Consider the R & D organization as an information processing system. R & D laboratories are problem solving organizations which face several sources of technical uncertainty—uncertainty due to technical and market conditions as well as uncertainty due to the requirements of coordination and technical transfer in the organization. Thus, while the information processing image should be appropriate for organizations in general, this perspective has particular relevance for R & D laboratories because of the amount of uncertainty that they must deal with and the importance of effective problem solving.

Information processing can be conceptualized as an ongoing problem solving cycle involving each area of the laboratory and the larger organization. For a particular task, the work area must effectively import technical and market information from the outside world; new and established information must be effectively processed within the work group; decisions and solution approaches must be worked on and coordinated with interdependent areas both within the laboratory and within the larger organization; and outputs (i.e., ideas, decisions, products) must be effectively transferred to the larger organization and eventually to the outside world. At each stage of the problem solving cycle, the work area must be sensitive to feedback and new information from internal and external sources. Finally, the outputs of this process (i.e., ideas, decisions, products) create the conditions for another set of problems, thereby initiating another information processing cycle.
FIGURE II-1
AN INFORMATION PROCESSING CYCLE

External Sources of Information  R & D Laboratory  Larger Organization

TECHNICAL AND MARKET ENVIRONMENTS

RESEARCH PROJECT (i.e., work area)

TECHNICAL SERVICE PROJECT

SALES MARKETING MANUFACTURING

output

Information or Communication Boundaries of Importance to the R & D Laboratory

Flow of Information or Communication
This information processing cycle is diagrammed in Figure II-1. What is most important about this perspective is that: A) it is systemic in nature—the perspective highlights the input, throughput, output, and feedback characteristics of open systems that must deal with uncertainty; B) the perspective highlights the importance of information flow not only within the laboratory but also with the larger organization and other external areas; C) the perspective suggests that there are several organizational boundaries which must be dealt with; and D) the perspective suggests that the information processing cycle is an ongoing organizational process.

Chapter I suggested that oral communication is a particularly effective medium for the transfer of information, ideas, and technology. Gerstberger (1971), Allen (1966), and Myers and Marquis (1969) have argued that oral communication is a particularly important medium for the transfer of complex ideas since it permits rapid feedback and extensive re-coding of information. These researchers have also argued that since technology is difficult to document, the importance of oral communication is further accentuated. While it will not be argued that all information is transferred orally, there is extensive evidence which suggests that oral communication is a very important medium through which information is gathered and processed (see, for instance, Baker et al., 1967; Hage et al., 1971; Keegan, 1974; Conrath, 1967; or Smith, 1970). An advantage of focusing on oral communication is that while information transfer is difficult to measure, oral communication is not.

If R & D organizations must effectively gather and process information in the execution of different tasks, and if an important medium
for the transfer and processing of information is oral communication, then R & D organizations can be usefully conceptualized as communication networks. Similarly, the information processing cycle can be seen as a communication cycle. From this perspective, communication ties the laboratory together as well as to the larger organization and to external areas. Oral communication is, therefore, a key laboratory process which has the added advantage of being relatively easily traced.

R & D organizations will, therefore, be conceptualized as communication networks. As Katz and Kahn (1966) suggest, these networks or patterns of communication are not random at all, but tend to be restricted, organized, and relatively stable systems. However, these networks are not homogeneous—all areas within the laboratory do not look alike. On the contrary, different work areas (or projects) have different communication patterns. Further, some work areas perform systematically better than other work areas facing the same task constraints. Why are there differences in patterns of project communication and under what conditions are the different patterns of communication associated with higher project performance? These two basic questions will be addressed in this study.

Two assumptions will be made to complement the information processing approach. The first assumption is that patterns of communication must attend to and deal with uncertainty. Therefore, differences in uncertainty will require different amounts and patterns of communication. The second assumption is that a project's work characteristics determine the amount of uncertainty which must be
dealt with during the execution of its task. Therefore, the communication patterns of work areas dealing with higher uncertainty will differ in their communication patterns from those which deal with less uncertainty. For example, projects involving a changing technology and extensive interdependence (high uncertainty) will have different patterns of communication than projects which have a stable technology and only limited interdependence with other areas (low uncertainty).

The relationship between project work characteristics (i.e., technical uncertainty) and patterns of project communication will be the major focus of this study. In order to specify the nature of the relations between these concepts, the information processing perspective must be used to distinguish both specific sources of work uncertainty as well as specific components of the communication network to deal with uncertainty. Section 2.2 will introduce project task characteristics, project task environment, and project task interdependence as work characteristics which are important sources of uncertainty. Section 2.3 will discuss project technical communication, project communication structure, and technical roles as information processing components of the communication network. Section 2.4 will develop a basic proposition which will relate these two sets of variables and guide the development of specific hypotheses and research questions.
2.2 Sources of Project Uncertainty--

Information Processing Requirements

This chapter has suggested that projects with different work characteristics must deal with different amounts of uncertainty. In order to handle the differences in uncertainty, it has been proposed that projects will require different patterns of communication. Three sources of work related uncertainty will be discussed here: project task characteristics, project task environment, and project task interdependence. It will be argued that the more complex the task, the more environmental variability; and the greater the task interdependence, the greater will be the task uncertainty reflected in problem solving and coordination complexity.

Project Task Characteristics

Task differences have been of considerable interest to organizational researchers (see review by Lynch, 1974). Structurally oriented analysts have focused on the relationship between task characteristics and organizational structure (e.g., Perrow, 1970; Woodward, 1965), while more micro-oriented analysts have focused on the effects of task differences on norms, group behavior, and satisfaction (e.g., Porter and Lawler, 1965; Hackman and Vidmar, 1970). Even with their different perspectives and often conflicting methods, these researchers have consistently seen task characteristics on a complexity dimension (e.g., routine--nonroutine; production--creative; stable--changing).
While the results of this research have not always been convergent (e.g., Hrebiniaik, 1974; Aldrich, 1972), a review of the task/technology literature indicates that task predictability is a thread which links the various studies together. Galbraith (1969) suggests that tasks differ in their amount of predictability and therefore, the amount of uncertainty which must be dealt with during the execution of the task. For instance, tasks that are well understood (i.e., routine) can be preplanned. For these tasks the information processing requirements are minimal. However, if the task is not well understood (i.e., nonroutine) or if it requires extensive coordination with other areas, then the information processing requirements are likely to be substantial. In all, this review indicates that task characteristics can be fruitfully seen as a source of complexity or uncertainty and therefore, as a source of information processing requirements. As Galbraith (1969) suggests, the greater the task uncertainty the greater the information processing requirements, and therefore, the greater the burden on the communication network.

The literature dealing with R & D organizations has long recognized that there are important task differences within the laboratory (e.g., Kornhauser, 1962; Allen, 1966; Whitley and Frost, 1973). Task differences within the R & D laboratory can be organized around two task dimensions: the degree to which the task is problem-focused and the degree to which means/ends relations are known. Research tasks, defined as the creation of new knowledge or information, are low on both dimensions. Technical Service tasks, defined as prototype development, testing, and short-term problem solving, are higher on both dimensions (Marquis and Straight, 1966). Applied research or advanced development
projects are high on one dimension yet low on the other (e.g., problem focused, yet means-ends relations are not clear). If the problem orientation and means-ends scales are combined to one dimension of task complexity, then research tasks are the most complex, while technical service tasks are least complex. Research projects will, therefore, have to deal with greater technical uncertainty than the technical service projects. Development tasks will be between research and service areas on this complexity/uncertainty dimension.

To determine project task characteristics, each respondent was asked to rate the objectives of his work on a scale from basic research to technical services. Individual scores were then pooled to get project task scores. Greater detail on the measures and on the pooling tests can be found in Chapter III.

The thrust of this section is that R & D organizations are made up of work areas whose tasks differ and that the task can be fruitfully seen as a source of uncertainty. If the task is a source of uncertainty, then different task areas will have different information processing requirements.

**Project Task Environment**

The environment has been a much used yet ill-defined term. Thompson (1967) and Evan (1966) provide direction by defining the task environment to include all those external actors that influence organizational decision making. This definition highlights the non-deterministic and perceptual nature of the environment (Negandi and Reinmann, 1973;
While the distinction can be made between internal and external task environments, this study will focus only on the external task environment. The task environment will therefore be taken to be what is outside the organization and attended to in decision making. Most analysts have focused on technological and market aspects of the external task environment (e.g., Burns and Stalker, 1965; Miller, 1971).

The environment is generally taken to be a source of uncertainty since areas outside the organization are not under organizational control and must be seen as potentially unstable. As with technology, organizational analysts have generated an extensive literature relating environmental variability to organizational conditions (e.g., Randall, 1973; Osborn and Hunt, 1974). This empirical work has largely substantiated the theoretical work by Thompson (1967), Katz and Kahn (1966), and Schein (1970) which suggests that the environment is a source of uncertainty to which the organization must respond. For instance, Burns and Stalker (1965) found that successful organizations in environments characterized as turbulent and dynamic (high uncertainty) were structured organically, while successful organizations in stable environments (low uncertainty) had more formal mechanistic structures.

While most of the literature deals with the organization's overall environment, there is growing interest in the environment of work areas within the organization. The most substantial work treating individual work areas and their environments has been done by Lawrence and Lorsch (1967) and Duncan (1972, 1973). Duncan has conceptualized the environment as a source of information processing requirements and has found that successful work areas had structural characteristics to
match environmental conditions—projects with stable environments had
greater structure than projects facing changing environmental conditions.
Other studies with similar concerns and findings include Dill (1958) and
Negandi and Reinmann (1974). These researchers suggest that it is
appropriate to consider perceived environment as a source of task
uncertainty. Their results indicate that work areas have different task
environments and that the more the environment is changing, the more
uncertainty the work area must deal with.

Both the macro and micro studies suggest that the environment
is a source of task uncertainty, and therefore, a source of information
processing requirements. It can be reasoned that the greater the
environmental variability the greater the uncertainty, and therefore,
the greater the amount of information processing that is required in the
execution of the task. While Jurkovich (1974) and Duncan (1973) empha-
size the importance of multiple environmental dimensions, this study
will opt for simplicity and only consider the amount of variability in the
market and technological components of the work area's external task
environment.

To measure environmental variability, each respondent was
asked to rate how rapidly the demands of their job were changing (1=
very little; 5 = to a very great extent). Individual scores were pooled to
get project scores. This measure combines the effects of technical and
market variability. Further, the measure is a perceptual measure of
environmental conditions. While tests for pooling indicated strong within
project consistency, the fact remains that the question measures a per-
ception of the environment rather than the objective environment (for
match environmental conditions—projects with stable environments had greater structure than projects facing changing environmental conditions. Other studies with similar concerns and findings include Dill (1958) and Negandi and Reinmann (1974). These researchers suggest that it is appropriate to consider perceived environment as a source of task uncertainty. Their results indicate that work areas have different task environments and that the more the environment is changing, the more uncertainty the work area must deal with.

Both the macro and micro studies suggest that the environment is a source of task uncertainty, and therefore, a source of information processing requirements. It can be reasoned that the greater the environmental variability the greater the uncertainty, and therefore, the greater the amount of information processing that is required in the execution of the task. While Jurkovich (1974) and Duncan (1973) emphasize the importance of multiple environmental dimensions, this study will opt for simplicity and only consider the amount of variability in the market and technological components of the work area's external task environment.

To measure environmental variability, each respondent was asked to rate how rapidly the demands of their job were changing (1 = very little; 5 = to a very great extent). Individual scores were pooled to get project scores. This measure combines the effects of technical and market variability. Further, the measure is a perceptual measure of environmental conditions. While tests for pooling indicated strong within project consistency, the fact remains that the question measures a perception of the environment rather than the objective environment (for
greater detail on setting and methods, see Chapter III). Future studies could explicitly separate out the environmental domains as well as attempt to develop a more objective measure of environmental conditions.

Project Task Interdependence

Thompson (1967) and Katz and Kahn (1966) have proposed that organizations are faced with several sources of technical and market uncertainty. To deal with this uncertainty, these theorists have hypothesized that sub-units evolve to cope with relatively homogeneous tasks and with a particular task environment. Organizations with multiple tasks and environments are therefore made up of different work areas which are interdependent with each other (i.e., they must work together) to varying degrees. Since interdependence requires coordination and joint problem solving, it must be considered as another source of task uncertainty, and therefore, as another source of information processing requirements.

The information processing requirements of task interdependence can be illustrated in the design of different types of cars. For high performance cars, because of weight and design constraints, a change in any one parameter will affect many other parameters. Therefore, the organizational sub-units must be able to deal with the coordination requirements of this substantial interdependence. In ordinary cars, however, there is more slack in the system such that a change in engine design, for instance, may not have much of an effect on the body characteristics. In this weakly interdependent system, the information
processing requirements are relatively minor compared to the example above. In short, the amount of task uncertainty, and therefore, the amount of information that must be processed, increases as the amount of interdependence increases.

Compared to task and environment, interdependence is an unstudied organizational variable. Even though March and Simon (1958), Thompson (1967), and Galbraith (1969) have used interdependence as a central source of problem solving and coordination requirements, except for one study, task interdependence has not been directly investigated. In one study that did deal specifically with interdependence, Gerstberger (1971) found that interdependence was an important organizational characteristic affecting the communication behavior of engineers. While Gerstberger did not view interdependence as a source of uncertainty, his study does support the idea that interdependence is a key variable for understanding communication in organizations.

This discussion indicates that the greater the project's interdependence with other areas, the greater the problem solving and coordination requirements, and therefore, the greater the uncertainty which must be dealt with. Interdependence must, therefore, be seen as a third source of information processing requirements. Since a project can be interdependent with different areas of the laboratory as well as with areas in the larger organization, this study will investigate a project's interdependence with areas in its Group, with other areas in the laboratory, and with areas in the larger organization.

To measure task interdependence, each respondent was asked to indicate (on a ten point scale) the degree to which his work was interrelated
with the work of: A) other Group members; B) other laboratory Groups; and C) other areas in the organization but outside the laboratory. Individual scores were pooled to get project scores. These interdependence measures, like the environment measure, are perceptual in nature. Objective measures would have been stronger measures. However, tests for pooling indicate a strong degree of consistency in project members perception of task interdependence (see Chapter III for greater detail on the measures and on the pooling tests). Barring objective measures, perceptual measures checked by various pooling tests remain a useful alternative.

In summary, three characteristics of a project's work have been isolated as sources of uncertainty. The more complex the task, the more variable the environment, and the more substantial the interdependence, the greater will be the burden on the communication network. From another perspective, projects with different work characteristics will face, and therefore must deal with, different amounts of uncertainty. The next section will introduce components of the laboratory's communication network which can be seen as different, yet related, ways of dealing with the various information processing requirements.
2.3 Communication in Organizations--

Communication Network Characteristics Which Affect

Information Processing Capacity

This chapter has argued that there is utility in conceptualizing R & D organizations as communication networks. It has been suggested that patterns of technical communication must be structured to deal with the information processing requirements of different work situations. The problem now is to specify components of a laboratory's communication network, for it is the specific patterns of communication that actually attend to work related uncertainty. This section will discuss the amount of technical communication, the structure of communication within projects, and the development of technical roles as separate, but related, aspects of a laboratory's communication network.

Project Technical Communication

As a communication channel, oral interactive communication has been shown to be a particularly effective medium for the exchange of ideas and concepts. As Gerstberger (1971) has extensively argued, oral communication is effective in the transmission and generation of ideas because it permits rapid feedback and critical evaluation as well as the opportunity for the re-coding and synthesis of information. The written medium, on the other hand, is a one way channel with delays separating the reader from the writer. Gerstberger (1971) concludes his review of channel effectiveness by observing that oral communication
is a particularly effective medium for the dissemination, translation, and synthesis of the diverse technical information possessed by the different areas of a complex R & D laboratory.

A similar argument has been made by Pelz and Andrews (1966). These researchers suggest that interactive technical communication is an effective means for problem solving and coordination since the exchange of ideas not only provides intellectual stimulation, but also provides a medium for error catching and critical feedback. Similarly, Allen (1966; 1964), Allen et al. (1968), and Myers and Marquis (1969) have all demonstrated the importance of oral technical communication in the transfer and generation of technical ideas and information. Myers and Marquis (1969) and Utterback (1971) have found that oral communication is particularly effective for technical problem solving.

Interactive communication has been demonstrated to be a particularly effective medium for dealing with idea generation, problem solving, and the transfer of technology. Oral communication can be divided into technical (i.e., work related) and nontechnical (i.e., social) components. Allen and Cohen (1969) have found that the technical network strongly overlaps the nontechnical network. However, they found that the nontechnical networks were far less influential in shaping the flow of critical ideas than were the technical networks. Since the two networks overlap, and since the technical network is more influential in directing the flow of critical ideas, this study will focus on the patterns of oral technical communication. Social, administrative, or other nontechnical communication will not be studied.

A project's technical communication can be separated into
communication areas. Since there are different work areas in the laboratory (see Chapter III for a detailed description of the laboratory), and since the laboratory exists within a larger organization and within an even larger external information world, this study will distinguish between several areas of technical communication. The study will investigate a project's internal communication as well as the amount of its communication with progressively more inclusive areas of the organization (i.e., Group, laboratory, larger organization). Finally, the amount of communication with areas outside of the organization will be measured.

This research, like Gerstberger's (1971) and Gerstenfeld's (1967) studies, will not pool the individual technical communication components since each communication area may represent different sources of information and feedback. If so, then each communication component could be a unique contributor to the problem solving and coordination efforts of the project.

The amount of project communication to the various areas was calculated by averaging individual project member's communications over fifteen sampling weeks. For example, the amount of intra-project communication was calculated by adding all internal communication for project members and dividing by their number. Similar averages were obtained for each project for the other communication areas (see Chapter III for greater detail, particularly regarding the sociometric survey).
Project Communication Structure

The overall amount of technical communication is one means through which a project can deal with the different sources of work-related uncertainty. Another characteristic of a project's communication behavior is the pattern of communication within the project. Do most individuals communicate directly with each other or must the communication pass through the supervisor to others in the project? The pattern of project communication will be referred to as project communication structure. Communication structure will be measured as the extent to which project communication follows hierarchical lines.

Gerstberger (1971) has argued that communication structure has an important impact on a project's ability to process information and deal with uncertainty. He argues that decentralized (or all connected) communication networks permit an efficient use of individuals as problem solvers since they increase the opportunity for feedback and error correction. Gerstberger argues that because of this feedback and error correction capacity, decentralized communication networks permit greater re-coding and synthesizing of information. Further, because decentralized networks are relatively independent of any one individual, they are less sensitive to information overload or saturation than are the more centralized networks. Since an increased opportunity for feedback and re-coding of information and relative independence from any one individual are related to a project's ability to deal with uncertainty, it can be concluded that decentralized communication networks have a greater information processing potential than hierarchical (or centralized) communication networks.
A number of studies have supported Gerstberger's logic and have demonstrated that the patterns of interaction among project members are an important determinant of project performance. Smith (1970) found that decentralized patterns of communication facilitate and stimulate the exchange of ideas necessary in complex problem solving. He found that decentralized communication was most appropriate for non-routine tasks, while centralized communication was more appropriate for more routine tasks. Similarly, Duncan (1973) has found that the amount of centralization (i.e., emphasis on hierarchy, explicit procedures, formal division of labor) has important implications for information gathering and processing. Duncan found that successful projects facing uncertain technical conditions dealt with the substantial information processing requirements by assuming decentralized project structures. The decentralized projects relied more on diverse and extensive communication and less on supervisory direction. The opposite characteristics were found for projects facing certain technical conditions. Very similar results have been reported by Hage et al. (1971) and in a set of studies that investigated the effects of network structure on group processes (see reviews by Shaw, 1964; or Gerstberger, 1971). In short, a number of researchers have found that project structure has important information processing implication, and that decentralized areas have greater information processing capacity than centralized areas.

This review suggests that patterns of project communication have important information processing implications. Centralized
projects have been consistently found to have less capacity to deal
with uncertainty and complex problems than decentralized projects.
Therefore, a second information processing component of a labora-
tory's communication network will be the pattern of project communi-
cation or project communication structure.

Project communication structure will be described on a centra-
lized-decentralized continuum. Projects where the technical staff has
little peer contact compared to supervisory contact can be considered
as more centralized than projects where there is relatively high peer
contact. While this measure is methodologically different than many
centralization measures (e.g., Duncan, 1973), it is conceptually
similar in that greater structure (i.e., centralization) can be seen as
a proxy for more formal authority, greater reliance on rules, and
more formal decision making processes. An advantage of this method
is its unobtrusive nature and the fact that it does not rely on percep-
tions of structure (see chapter III for greater details on the measure).

Technical Roles

Organizations which are made up of multiple tasks which have
different sources of environmental variability must develop sub-units
to cope with the information processing differences (Thompson, 1967;
Katz and Kahn, 1966). These theorists suggest that organizations
tend to be differentiated such that different sub-units have relatively
homogeneous tasks and face a particular task environment (for empiri-
cal examples see Lawrence and Lorsch, 1967; or Duncan, 1973).
This same logic holds for R & D laboratories which have multiple work areas—that is, sub-units (i.e., projects) evolve to work on a particular set of tasks which are associated with a particular task environment.

Organizational differentiation adds complexity to organizational analysis since the individual sub-units tend to develop systematic differences in attitudes, values, perceptions, norms, and coding schemes (Katz and Kahn, 1967; March and Simon, 1958). March and Simon (1958) term this phenomenon the development of local rationality. Allen (1966; in press) further suggests that this local rationality has important effects on how problems are defined, structured, and tested such that the same objective conditions may well be seen, defined, and worked on in very different fashions by different areas of the laboratory. In terms of information flow, this organizational differentiation creates communication boundaries. A kind of communication impedance at the subsystem boundaries constrains inter-area communication and exacerbates problem solving and coordination difficulties between interdependent areas. As described in Figure II-1, there are communication boundaries within the laboratory and between the laboratory and the larger organization, as well as between the laboratory and the outside information world.

Due to organizational differentiation and the attendant differences in coding schemes, ideas or solution approaches are subject to distortion when they are imported or exported across organizational boundaries (for examples see Dearborn and Simon, 1958; Wilensky, 1967). The disparity in coding schemes and the resultant distortion of information are the bases for this communication mismatch. Communication
across boundaries tends, therefore, to be inefficient: indeed, a number of studies have found that communication across the organization's external boundary is consistently associated with lower performance (e.g., Allen, 1966, 1970).

While external communication may be inefficient, reliance on internal sources of information alone would be unwise; since no project or organization can be entirely self-sufficient. Therefore, communication to external areas is both inefficient and prone to distortion, as well as vitally important for successful task completion. How is this dilemma resolved? This section will discuss the existence and function of technical roles. Technical roles are filled by individuals who are able to operate effectively in several coding schemes, and who are therefore able to reduce the boundary impedance and effectively couple the internal network to external sources of information.

What are technical roles in terms of a laboratory's communication network? To address this question, some basic terminology must be introduced. Communication networks have two basic components: branches (describing the direction in which information flows) and nodes (the points of origin or destination of information).

Technical communication deals specifically with communication branches, while communication structure deals with patterns of communication between the supervisor and other nodes (i.e., individuals) in the project. This section will deal with special nodes in the communication network—technical roles.

Communication network nodes can be further described on the basis of where their branches connect. Nodes with branches connecting
only with other nodes in the same work area can be distinguished from the nodes with branches connecting to both internal areas as well as to external areas. The subset of nodes with extensive (to be defined in Chapter III) internal and external communication will comprise the technical roles with which we shall be concerned (isolates; those nodes with very few internal branches, will be excluded in this study).

An extensive literature indicates that technical roles perform an important function in a laboratory's communication network (e.g., Allen, 1970, in press; Taylor, 1972). This literature suggests that information from external areas does not enter the laboratory directly, but is channelled through the technical roles into the internal communication network. Technical roles, then, mediate the communication between internal areas and external sources of information. Thus, while communication across boundaries may be difficult and prone to distortion, technical roles evolve to straddle different coding schemes and, therefore, facilitate the transfer of ideas and concepts across communication/information boundaries. In short, the existence of technical roles represents a third network characteristic to deal with information processing requirements. These roles counter the difficulties of cross-boundary communication and, as such, they are particularly important for importing and exporting information.

The bulk of the literature dealing with technical roles deals with the laboratory to extra-organization interface (i.e., gatekeepers). While this is an important boundary, laboratory differentiation and the attendant differences in norms and language create several other important communication boundaries. As suggested in Figure II-1,
this study will focus on the communication boundaries within the laboratory as well as the laboratory-organization interface. If these two other communication boundaries do exist, then the two-step communication process may well describe the communication across these boundaries. Laboratory liaisons will tend to the intra laboratory interfaces, while organization liaisons will tend to the laboratory-organization interface. In all, three technical roles will be investigated here: the gatekeeper and the two types of technical liaisons.

In summary, this section has argued that technical communication, communication structure, and technical roles are components of the laboratory's communication network. Each network characteristic affects the project's information processing capacity. Together, these network components attend to the information processing requirements due to the project's task characteristics, environmental conditions, and task interdependence. The nature of the relations between sources of uncertainty and technical communication patterns will be discussed in section 2.4.
2.4 Towards a Theory of Middle Range--A Basic Proposition

This chapter has begun the development of an information processing approach to R & D organizations. This approach is based on the idea that the R & D laboratory can be usefully seen as an information processing or communication network which must deal with several sources of uncertainty. It was proposed that if work areas have different amounts of uncertainty to be dealt with, then these differences in uncertainty will require contrasting patterns of technical communication.

What is the relationship between sources of technical uncertainty and technical communication patterns? The most simple relationship is one of congruency (see Galbraith, 1969, for a very similar congruency approach). The information processing model and the two assumptions discussed earlier lead to the following basic proposition: to be effective, projects must have communication network characteristics capable of processing the amount of uncertainty generated during the execution of their work. High performing projects which must deal with different amounts of uncertainty will therefore have different communication network characteristics. It is not suggested that characteristics of the project's work cause the differences in communication patterns. Rather, the basic idea is that the high performing projects will match the amount of information processing to the requirements of their work. In short, particularly for the high performing projects,
communication network characteristics will be contingent on the nature of the project's work.

This basic proposition will be used to guide the empirical inquiry. Sources of work uncertainty—task characteristics, environmental variability, and task interdependence—will be treated as a set of independent variables, while the components of the communication network—technical communication, project structure, and technical roles—will be the set of dependent variables. As presently defined, however, the proposition derived from the information processing perspective has only limited usefulness; it provides only a general direction to the analysis. Specific hypotheses must be derived from the proposition for it to have empirical and theoretical utility.

The basic proposition provides only insight as to what are appropriate variables to consider and the general direction for the analyses. The proposition does not provide more specific empirical direction. Therefore, guided by the information processing proposition, the specific literatures dealing with the dependent variables will be reviewed with an eye for developing specific hypotheses and research questions. The set of hypotheses will make more specific the nature of the contingent relations between network characteristics and the characteristics of the work. The set of hypotheses can then be taken as a test of the information processing perspective. The chapters will be organized around the dependent variables. Each chapter will develop a set of hypotheses and/or research questions concerning the specific effects of the sources of uncertainty on the individual
network characteristics. For each analysis, the overall relationship will be tested as well as the specific relationships for the high and low performing projects. Figure II-2 summarizes the set of ideas and variables developed in this chapter.

In summary, the basic proposition which will guide the analyses is based on the idea that for successful projects, the amount of information processing must match the project's information processing requirements. From this basic proposition, a number of hypotheses will be derived and tested in the following chapters. The testing of the set of hypotheses will not only specify the nature of the contingent relations between a project's communication characteristics and the nature of its work, but will also be a broad test of the larger information processing perspective. The process of model development, hypothesis development and testing, and model revision can be seen as another step in the attempt to better understand the nature of communication in R & D organizations in particular, and the nature of communication in organizations in general.
FIGURE II-2

A SCHEMATIC OF THE INFORMATION PROCESSING PERSPECTIVE

<table>
<thead>
<tr>
<th>Information Processing Requirements</th>
<th>Information Processing Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>INDEPENDENT VARIABLES (sect. 2.2)</td>
<td>DEPENDENT VARIABLES (sect. 2.3)</td>
</tr>
<tr>
<td>Characteristics of the Work</td>
<td>Communication Network Characteristics</td>
</tr>
<tr>
<td>(Sources of Technical Uncertainty)</td>
<td></td>
</tr>
</tbody>
</table>

A project's communication network characteristics must be capable of dealing with its information processing requirements (section 2.4).

The communication characteristics of high performing projects will be contingent on the characteristics of their work (section 2.4).
2.5 Some Neglected Areas

This view of organization, uncertainty, and information processing is a simplification. Simplification is required so that any piece of research does not have to study all things at once. Many important variables related to communication in organizations have therefore been ignored here. Among the variables that must be considered in a more comprehensive view of organizational communication include: information quality (O'Reilly and Roberts, 1974), individual differences (Gordon and Morse, 1974), colleague roles (Farris, 1972), organizational climate (Litwin and Stringer, 1968), demographic differences (Smith, 1971; Pelz and Andrews, 1966), physical design or architecture (Allen, 1970), project importance (Normann, 1971), and communication content characteristics (Walsh and Baker, 1972). If these areas influence overall communication, project communication structure, or technical roles, then the predictive utility of task characteristics, task environment, and task interdependence will be reduced. If strong relationships are found between the dependent and independent variables in the face of these simplifying assumptions, then the results must be considered robust. The integration of these unstudied issues remain for future work.
CHAPTER III

SETTING AND METHODS

This chapter will review the setting within which the study took place and describe how the different variables were operationalized. It will conclude with a brief discussion of some methodological issues.

3.1 The Setting

This field study took place at the Research and Development (R & D) facility of a large midwest American organization. The organization is a decentralized firm servicing several market areas with a range of products. The R & D facility is isolated from the rest of the organization and contains within it the corporate laboratories (i.e., basic research and advanced development) and the divisional laboratories (i.e., Groups servicing the different marketing areas). The laboratory's overall charter is two fold: to keep the diversified organization at the forefront of its core technology; and to assist the marketing and manufacturing areas in product development and engineering. All of the organization's products are related in that they share a common technological core. It is important to note that the basic technology facing this laboratory is relatively mature and that the laboratory has consistently been a leading developer of the
technology. The total R & D facility employs about 735 people, about half of whom are in various support roles. The study will focus on the members of the technical staff and thereby limit the sample to 345 professionals.

The laboratory is differentiated into seven Groups (i.e., divisional laboratories), one of which is located about five miles from the main facility. Two of the Groups are funded from general organizational sources, while the other five are funded from the various marketing-manufacturing divisions. The corporate and divisional laboratories were put in the same facility to "increase their synergistic potential." The Groups are organized similarly and average 40 professionals per Group. While one of the Groups is much larger than the others (105 professionals), except for the technical role analyses, it will not be treated differently since the individual work unit, or project, is the basic unit of analysis.

Within each Group there are sets of work or project areas, each with a supervisor. The work areas within a Group are related in that they face similar market and manufacturing constraints and often work on joint tasks. These work areas are technology or problem-specialized in that they focus on and develop special competence and experience in a continuing area of organizational interest (e.g., Chemical Analysis, Urethane Development, Manufacturing Support). These work areas are not short term project areas in the matrix organization sense (Galbraith, 1969) although within a work unit there may be several short term tasks. There are 62 work areas in the laboratory distributed throughout the different Groups. The work
areas average 5.3 members with a range from 2 to 15. Because of transfers and area enlargement, two work areas were eliminated from the sample. The remaining work areas (n = 60) remained stable over the period of the study and will be the focus of investigation.
3.2 The Dependent Variables

Since the study is based on conceptualizing R & D organizations as information processing networks, a primary methodological problem was to develop a technique which would give an accurate picture of the laboratory's communication network. Sociometric methods, which focus on patterns of contact, were used as the basic source of data for the dependent variables. Following the work of Allen (1966, 1970), Gerstberger (1971), and Whitley and Frost (1973), a communication survey was developed to sample all technically related communication over a period of time. A time series method was used so that the respondent could report actual daily contacts over a number of selected days. It was assumed that asking, at the end of the day, for actual daily contact would provide more reliable data than asking the more routine sociometric question of "who do you regularly converse with..." The marginal utility of this extra reliability must be weighed against the extra costs of data handling.

Every professional in the laboratory was asked to recall each work-related technical contact (including laboratory, organization, and extra organization communication) at the end of a series of specified days (see survey in appendix). The communication survey provided space for the respondent to write the names of the persons with whom he had a technical conversation. Respondents were asked not to report social contacts. The respondent was also asked to indicate
the content, type, and initiator of the contacts (see survey). If a person was away on business he was asked to complete the form when he returned, for his conversations during the sampled day. The survey form was developed with the laboratory's management and was designed to take no more than four minutes to complete. The format and explanation of the survey were explained to all technical personnel by the research team. Early in the study revisions were made to the survey format to better fit laboratory's requirements and the study's needs.

This sociometric data was collected over a seven month period. The communication survey was distributed on a randomly chosen day once a week. The days were chosen so that there would be an equal number of weekdays. At the beginning of the sampling day a set of secretaries distributed the survey to each professional. They were collected by the secretaries and mailed back to the Institute in bulk. Due to holidays and distribution mistakes, 25 weeks of data were collected and coded. The response rate for these weeks was 93 per cent. Another broad measure of quality, the reciprocity rate, was also relatively high at 68 per cent (see Weiss and Jacobsen, 1960, for comparative reciprocity rates). The average number of communications per day per individual was approximately 5.8. While this may underestimate the total volume of contact, there is no evidence that the data is biased by Group or task area.

Since the sociometric networks stabilized at approximately six weeks (this was determined by comparing sociometric maps for different sampling periods), only 15 of the 25 weeks of data were analyzed.
An equal number of weekdays were chosen from the seven month period. Since the response rate was so high over the sampling period, no adjustments were made to correct for absences, vacations, or non responses. The dependent variables, technical communication, project communication structure, and technical roles, were derived from this basic source of sociometric data.

**Project Communication.**-- Project communication was defined as the frequency of technically related personal contact with a particular area. Communication is therefore a measure of intensity of contact with a particular area. Because of the high degree of differentiation in the laboratory, six mutually exclusive communication areas have been specified and measured. These measures tap the amount of technical communication within the project, and between the project and other areas in the Group, other areas in the laboratory, to areas in the organization, as well as to professional (universities, professional associations), and operational (suppliers, vendors, customers) areas. Since the work area is the unit of analysis, individual responses were pooled to obtain the amount of project communication with the different areas.

The aggregation of individual responses is potentially complex. Should the analysis include all contacts, only those that are reciprocated, or some specified combination? The analysis will take what Gerstberger (1971) calls the union response set and consider all interaction, regardless of initiation or reciprocity. To correct for double counting and to permit comparability with external domains, communication scores where reciprocity is possible must be divided by two.
(project and Group). For external areas, where there is no possibility of reciprocity, only self report data can be used (laboratory, organization, and extra organization).

The amount of project communication to the various areas was calculated by averaging individual project member's responses over the 15 weeks. For instance, the amount of intra project communication for work area A was calculated by adding all intra project communication for project A and dividing by the size of the project. The result is the average amount of intra project communication per person in project A over the 15 weeks studied. Similar averages were obtained for each project for each of the communication areas.

After the amounts of communication with the different areas were calculated for each project, it was possible to test the implicit hypothesis central to Chapter II. Are the different communication areas independent of each other? Should the areas be differentiated? If the communication areas are highly correlated, then the analyses need not consider such communication complexity (see Table III-1).

The correlations between the six communication areas are weak. The mean absolute value of the 15 coefficients is 0.16. Of the four coefficients that are significantly greater than zero (p < 0.05), only two are greater than 0.30. Table III-1 therefore gives support to the idea that technical communication can be legitimately separated into communication areas. These communication areas are, for the most part, independent of each other. The distribution of communication means (Table III-1 B) indicates that communication is a decreasing function of organizational distance. Project size (see Table III-1 C) is
TABLE III-1
TECHNICAL COMMUNICATION

A) Correlation Matrix for the Different Communication Areas (n = 60)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Project</td>
<td>--</td>
<td>.08</td>
<td>.28**</td>
<td>.19*</td>
<td>.07</td>
</tr>
<tr>
<td>Group</td>
<td>--</td>
<td>.07</td>
<td>.26**</td>
<td>.14</td>
<td>.00</td>
</tr>
<tr>
<td>Lab.</td>
<td>--</td>
<td>-.04</td>
<td>-.07</td>
<td>.20*</td>
<td></td>
</tr>
<tr>
<td>Org.</td>
<td>--</td>
<td>.48***</td>
<td>.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational</td>
<td>--</td>
<td></td>
<td></td>
<td>.19*</td>
<td></td>
</tr>
<tr>
<td>Professional</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p < .10          ** p < .05          *** p < .01

B) Distribution of Communication Means (n = 60)

Average amount of communication per project per person over 15 weeks

C) Correlations between Communication and Project Size (n = 60)

<table>
<thead>
<tr>
<th>Project Group Lab.</th>
<th>Org.</th>
<th>Operational</th>
<th>Professional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>.24*</td>
<td>-.20*</td>
<td>.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>.07</td>
</tr>
</tbody>
</table>
weakly correlated with the amount of communication (average absolute \( r = 0.11 \)) and will be ignored in the remaining analyses.

**Project Communication Structure.**-- Patterns of communication can be summarized as sociometric structure (Alba, 1973; Mitchell, 1969). Patterns of project communication can therefore be summarized as project communication structure. The sociometric measure used here focuses on formal project structure and is based on patterns of contact between the supervisor and his subordinates. Work areas where the supervisor mediates the technical communication such that there is little direct peer contact can be termed sociometrically centralized (or more structured). Chapter II has argued that this kind of sociometric measure is analogous to the more traditional perceptual measures of structure.

The sociometric continuum of centralization can be seen as a degree of hierarchy (Hage, 1974). Centralized projects will be more hierarchical with the attendant consequences of greater rule reliance and less overall project participation. With the communication data, a centralization measure can be developed using a ratio of vertical (i.e., superior-subordinate) to horizontal (i.e., peer) bonds. Proportionately, the more vertical bonds or the fewer horizontal bonds, the more centralized (or hierarchical) is the project's communication structure. A ratio which reflects this idea is defined in Table III-2.

This measure of structure counts only within project bonds and is useful for projects with more than two members (\( n = 44 \)). Vertical bonds are those links to the supervisor, while horizontal bonds are all
### TABLE III-2
PROJECT COMMUNICATION STRUCTURE

Degree of Centralization =
\[
C = \frac{\text{number of vertical bonds}}{0.05 + \frac{\text{number of potential vertical bonds}}{\text{number of horizontal bonds}}} + \frac{\text{number of potential horizontal bonds}}{}
\]

- $C$ extends from 0 - 20
- $C = 1$ = all connected
- average $C = 5.7$ (0.3 - 20)
- median = 2.1
- $n = 44$

E.g.,

![Diagram showing communication structures with $C = 20$ and $C = 1$]

$\bigcirc$ = supervisor

<table>
<thead>
<tr>
<th>Correlations: Project Structure with Communication Project Size ($n=44$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Group</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Structure</td>
</tr>
</tbody>
</table>

* $p < .10$
** $p < .05$
*** $p < .01$
links between nonsupervisors within the project. Informal structure, that is, centralization around a nonsupervisor, is not measured with this method. With this definition, the measure of centralization extends from 0 to 20. (Twenty is an arbitrary upper limit so that the ratio does not explode). The greater the ratio, the greater the sociometric structure.

To derive measures of project structure, each work unit had to be sociometrically mapped. Because the inclusion of each contact would swamp the analysis, a threshold of seven bonds (over the 15 weeks) was used. For a bond to be included between person A and person B, either A or B would have to report at least seven contacts over the 15 weeks. All bonds whose strength was less than seven were not included, while all bonds greater than or equal to seven were treated alike.

Project structure has a median value of 2.1 with a range of 0.3 to 20 (see Table III-2). As is required by its definition, structure is negatively related to intra project communication. Project structure is weakly related to the other communication areas (the average absolute \( r = 0.11 \)) and to project size (\( r = -0.19 \)).

This measure of structure has made a number of assumptions. If the measure has utility, then future studies can investigate the effects of informal structure, directionality differences, intensity differences, as well as the effects of different threshold levels.

**Technical Roles.**—Technical roles as particular nodes in the information network are the last measures to be derived from the
sociometric data. The technical role analyses will utilize techniques used by Allen (1966, 1970) and Taylor (1972).

For technical role analyses, the first step is to locate internal communication stars. Technical stars are those individuals who are frequently consulted for technical advice or information. The Group will be the level of analysis for the role analyses. Internal stars will be defined as those individuals in the top fifth of the intra Group communication distribution. (This definition is entirely arbitrary—tighter or looser conditions could have been imposed.) Internal stars will be located for six of the seven Groups. The large Group will not be used in this analysis because of the great size difference and its likely impact on technical role behavior. Using the Group as the unit of analysis permits multiple internal stars spread throughout the laboratory (n = 50), yet does not permit role differentiation for each project.

The internal stars will be the basis for the technical role analyses. To test for technical roles, the amount of organization and extra organization communication between stars and nonstars must be compared. For a particular communication area, if stars have significantly more communication than nonstars, then technical role specialization exists (Allen and Cohen, 1969). If role specialization is found, the analyses will then focus on the subset of stars who are also strongly connected (top fifth of the appropriate external distribution) to the particular communication area of interest (Taylor, 1972). Technical roles will therefore be defined as individuals who are technical stars in both the internal and external communication domains. If, however, no role specialization is found, then identification of the
specific roles will not be done. Further detail of the role tests and specifications will be found in the technical role section of Chapter VI.

3.3 The Independent Variables

Data on project task characteristics, project environment, and project interdependence were collected early in the study. All the technical personnel, in groups of forty, were given the independent variable questionnaire. The research team took pains to explain the questions and to go over any ambiguities. Usable responses were obtained from 272 professionals (79 per cent of the laboratory). The bulk of the nonrespondents came from four work units. These projects were poorly represented and were therefore excluded from the analyses. The remaining nonrespondents were distributed throughout the laboratory. For the 58 remaining work units, there were an average of 4.1 respondents per project. It will be assumed that the independent variables are stable over the seven months studied. Interviews as well as the technical maturity of the industry support this assumption. Each independent variable will be discussed before attention is directed to the problems of pooling individual data.

Project Task Characteristics.-- Chapter II argued that the task characteristics could be ordered on a dimension from complex (non-routine) to less complex (routine). In R & D organizations, tasks can differ along several dimensions, including time span of feedback, specific vs. general problem orientation, and generation of new knowledge vs. using existing knowledge and experience (Rosenbloom and
Wolek, 1970). With these dimensions, four task categories were developed with the laboratory's management to form a complex (Research) to less complex (Technical Services) task dimension.

### TABLE III-3

**Task Characteristic Categories**

<table>
<thead>
<tr>
<th>I</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Research</td>
<td>Applied Research</td>
</tr>
<tr>
<td>Work of a general nature intended to apply to a broad range of applications or to the development of new knowledge about an area.</td>
<td>Work involving basic knowledge for the solution of a particular problem. The creation and evaluation of new concepts or components but not development for operational use.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development</td>
<td>Technical Services</td>
</tr>
<tr>
<td>The combination of existing or feasible concepts, perhaps with new knowledge, to provide a distinctly new product or process. The application of known facts and theory to solve a particular problem through exploratory study, design and testing of new components or systems.</td>
<td>Cost/performance improvement to existing products, processes or systems. Recombination, modification and testing of systems using existing knowledge. Opening new markets for existing products.</td>
</tr>
</tbody>
</table>

With these categories (see Table III-3) respondents were asked two questions concerning their work:

A) In which of these categories (see above) would you place the objectives of your work? The arabic numbers indicate the degree of refinement within each category, where 1 is "pure."

<table>
<thead>
<tr>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 3</td>
<td>1 2 3</td>
<td>1 2 3</td>
</tr>
</tbody>
</table>

[This scale was scored on a scale from 10 (basic research) to 47 (technical services)]
B) Roughly what percentage of the work required to accomplish the task's objectives falls in each of the four categories?

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(13)</td>
<td>(23)</td>
<td>(33)</td>
<td>(43)</td>
</tr>
</tbody>
</table>

[This was scored as the weighted average of the different percent scores.]

The individual responses to the two questions were highly correlated ($r = 0.83; p < 0.001$). Therefore, individual task scores were calculated by taking the average of scales A and B. The average task score was 33.7 with a range from 10 to 47 ($n = 237$).

Project Task Environment. -- Of the many environmental dimensions studied, Duncan (1972) and Negandi and Reimann (1973) suggest that the stable-changing dimension is a particularly important contributor to perceived uncertainty. Following Duncan's (1972) research, only the stable-changing dimension of the environment was investigated. Each respondent was asked to rate the environmental stability of his work. Each respondent was asked:

We are interested in how rapidly you see the demands of your job changing. To what extent are techniques or skills or information needed for your project(s) changing?

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>To a very little</td>
<td>Little</td>
<td>Some</td>
<td>Great</td>
<td>To a very great extent</td>
</tr>
</tbody>
</table>

The range of responses was from 1 to 5 with an average of 3.56 ($n = 265$). Objective measures of environmental conditions were not obtained. Tests for the consistency of perceptions indicated that individuals in the same project agreed on their environmental conditions. Even with this consistency, it is possible that project members consistently misperceived their environment. This alternative hypothesis can not be tested with the available data.
Project Task Interdependence.-- Project interdependence refers to the extent to which the project's task requires working with other areas of the laboratory or organization. Since there is no clear objective way of measuring task interdependence, this study relied on the individual's perception of interdependence. The several potential areas of perceived task interdependence were operationalized in the following fashion:

On the scales below, please indicate the degree to which your work is interrelated with the work of:

1) Other members of your project.

<table>
<thead>
<tr>
<th></th>
<th>Very Low Interrelationship</th>
<th>5</th>
<th>Moderate Interrelationship</th>
<th>10</th>
<th>Very High Interrelationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>5</td>
<td></td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

2) Other technical personnel in your Group.

| 1 | 5 | 10 |

3) Technical personnel in other laboratory Groups.

| 1 | 5 | 10 |

4) Technical personnel within the organization, but outside the laboratory.

<table>
<thead>
<tr>
<th>1</th>
<th>Very Low Interrelationship</th>
<th>5</th>
<th>Moderate Interrelationship</th>
<th>10</th>
<th>Very High Interrelationship</th>
</tr>
</thead>
</table>

Table III-4 indicates the mean and variance for each interdependence area. (As with the environment measure, tests for rater consistency indicated that individuals in the same project tended to agree with each other on the interdependence questions. While objective measures are preferable, perceptual measures checked for internal consistency are a step in the correct direction.)
<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project</td>
<td>7.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Group</td>
<td>4.4</td>
<td>8.1</td>
</tr>
<tr>
<td>Laboratory</td>
<td>3.4</td>
<td>18.1</td>
</tr>
<tr>
<td>Organization</td>
<td>4.0</td>
<td>7.6</td>
</tr>
</tbody>
</table>
Unit of Analysis. -- Since the unit of analysis is the work team, individual responses must be pooled to get the degree of a given variable for the unit as a whole. However, before averaging individual responses, the analyst must ask whether the individuals are responding to the same variables in the same way. If there are large differences in individual responses to a particular variable, then it is inappropriate to combine the responses. For pooling to be appropriate there must be some evidence that the dimension under consideration is perceived similarly by all those in the unit (Hage and Aiken, 1967; Duncan, 1972).

To investigate the appropriateness of pooling, three tests were performed on each of the independent variables. A one way ANOVA was done to test whether the within unit variance was less than the between unit variance for the 58 work teams. If the null hypothesis is rejected then the test indicates that there is intra unit homogeneity for the variable measured and pooling is appropriate. If the ANOVA hypothesis is accepted, then averaging is inappropriate. Another broad test used was Bartlett's M test (Dixon and Massey, 1969). This test specifically tests for the homogeneity of intra group variance. If the hypothesis of no difference is accepted then each unit has about the same variance for the variable tested. If, however, the null hypothesis is rejected, then the analyst must be concerned that some of the projects have significantly more variability than the others.

For variables that passed both of the above tests, a more stringent test was performed on each project. Each work unit variance was compared to the pooled variance for the particular variable studied. If the unit variance was significantly greater (p < 0.01) than
the pooled variance, then the project was not included in the analysis for that particular variable. In all, two broad tests and one specific set of tests were performed for each independent variable to check the validity of pooling. The results are summarized in Table III-5.

<table>
<thead>
<tr>
<th></th>
<th>ANOVA</th>
<th>Bartlett</th>
<th>Individual F tests (excluded proj.)</th>
<th>Residual N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>P</td>
<td>M</td>
<td>P</td>
</tr>
<tr>
<td>Task</td>
<td>2.25</td>
<td>.001</td>
<td>1.1</td>
<td>.19</td>
</tr>
<tr>
<td>Env't.</td>
<td>1.37</td>
<td>.09</td>
<td>.54</td>
<td>.10</td>
</tr>
<tr>
<td>Interdependence:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project</td>
<td>.85</td>
<td>.68</td>
<td>.74</td>
<td>.49</td>
</tr>
<tr>
<td>Group</td>
<td>1.44</td>
<td>.04</td>
<td>.72</td>
<td>.41</td>
</tr>
<tr>
<td>Lab.</td>
<td>2.15</td>
<td>.001</td>
<td>.86</td>
<td>.68</td>
</tr>
<tr>
<td>Org.</td>
<td>3.18</td>
<td>.001</td>
<td>1.06</td>
<td>.35</td>
</tr>
</tbody>
</table>

The ANOVA and Bartlett tests suggest that pooling is appropriate for each of the independent variables except project interdependence. Since there was no evidence of intra unit homogeneity for project interdependence, it was dropped from further analysis (note that Table III-4 indicates that there is little variance at all for project interdependence). The individual F tests eliminated between two and four projects per variable with the resultant usable n's as listed in Table III-5.

Individual responses were therefore averaged to get work unit data. With these pooled scores the implicit hypothesis regarding the independence of the different interdependence components can be tested.
As Table III-6 indicates, the different interdependence components are indeed independent and therefore should be kept separate in the analyses. Table III-6 also sheds light on the relations between the independent variables. As independent variables, task, environment, and interdependence should ideally be uncorrelated, or at least only weakly correlated with each other. The results suggest that task and environment \((r = .03)\) and environment and interdependence (average absolute \(r = .16)\) are essentially independent of each other. Task and interdependence are moderately related (average absolute \(r = .28)\). Research projects tend to report higher interdependence within the laboratory, while the service areas report higher interdependence with other organizational areas. The relatively weak correlations between the set of independent variables indicate that it is appropriate to treat each variable as a separate source of technical uncertainty.

The distribution of task characteristic scores falls into three clearly distinguishable categories. Task characteristics can therefore be used as a nominal variable with 13 Research tasks \(<32\), 22 Development tasks \((32 - 37)\), and 20 Technical Service tasks \(>37\). Since the distributions of environment and interdependence did not have clear boundary points, they will be split at the median when used as nominal variables.
### TABLE III-6

**Independent Variables: Correlations (n = 54)**

<table>
<thead>
<tr>
<th>Interdependence</th>
<th>GP.</th>
<th>Lab</th>
<th>Org.</th>
<th>Task</th>
<th>Env't.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>--</td>
<td>-.01</td>
<td>.01</td>
<td>.13</td>
<td>.17</td>
</tr>
<tr>
<td>Interdependence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lab</td>
<td>--</td>
<td>.11</td>
<td>-.25</td>
<td>.29</td>
<td>**</td>
</tr>
<tr>
<td>Org.</td>
<td>--</td>
<td></td>
<td>.46</td>
<td>-.02</td>
<td></td>
</tr>
<tr>
<td>Task</td>
<td>--</td>
<td></td>
<td></td>
<td>.03</td>
<td></td>
</tr>
<tr>
<td>Env't.</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* = p < 0.10  
** = p < 0.05  
*** = p < 0.01
3.4 Other Variables

Performance.-- Performance differences provide outcome information that enhances a study's pragmatic and theoretical utility (Allen, 1966; Frost and Whitley, 1971). This study will use performance as a moderator variable. Each analysis will test the overall relation as well as the separate results for high and low performing work units.

At the end of the study, each Group manager (n = 8) and laboratory director (n = 2) were individually interviewed. They were asked to evaluate all the projects with which they were technically familiar. They were instructed to base their evaluations on the overall technical performance of the work areas over the duration of the study. Each project was independently rated by at least four managers on a seven point scale (1 = very poor; 7 = very high). A comparison of the rater means and intercorrelations indicated that one of the respondents biased his results. His responses were excluded from further analyses. The average intercorrelation of the nine remaining judges was 0.47. The scores of the nine judges were then pooled to get project performance scores. Each project was rated by at least two judges with an average of 4.7 judges per project. The mean and median of the performance scores was 4.6 with a range from 3.0 to 6.4. Because of the relatively low average intercorrelation, project performance was categorized as either high or low by splitting the scores at the median.

Demographic.-- A set of demographic data was also collected in
the study. Approximately 80 per cent (n = 272) of the laboratory's professionals responded to a set of questions which asked for: age; educational background; number of professional or technical conferences attended in the past two years; number of papers presented or published during the past five years; number of years at the laboratory, in the Group, and in the current work area; and finally, whether or not the person had been transferred within the laboratory to another Group.
3.5 Some Limitations

This study could well be described as opportunistic research. A large R & D facility made itself available as a research site for almost a year. As opposed to many studies (e.g., Allen, 1966; Gerstberger, 1971; Whitley and Frost, 1973), the whole laboratory was available for study. Given the research questions and ideas as developed in Chapter II, the study was designed and initiated. Sociometric data provided, in a relatively unobtrusive fashion, objective data on the information network of the whole laboratory. Further, the laboratory was large enough to provide important variability for a set of interesting independent variables. The access opportunity combined with the size and diversity of the laboratory offered an unique situation to explore some important issues in the R & D management and communication areas.

However, the characteristics that make this research site unique and interesting also carry with it severe methodological problems which should be addressed. The most glaring methodological issue is one of inference. If this study focuses on work units within one laboratory with its specific market, history, and organizational structure, to what extent can the results be generalized to a wider range of R & D work teams? In a similar vein, since the study was a field study it did not control for the multiple threats to internal validity. How can the reader be certain that "other variables" (e.g., project importance,
project phase, organizational history do not confound and distort the results?

These questions of internal and external validity involve the issue of alternative competing hypotheses to explain the same patterns of data. Case studies, field studies, and any other less-than laboratory controlled research must face these competing explanations and at least begin to deal with them. Kaplan (1964) and Campbell and Stanley (1969) suggest collecting multiple sources of data. They argue that results derived from a triangulation of methods will be susceptible to fewer serious alternative explanations than results based on a single method. Another approach to dealing with competing hypotheses is based on the use of a theoretical framework. One of the purposes of a framework is to organize thought and to guide in the selection of variables and research questions. As such, a framework is another way of reducing or dealing with competing hypotheses. A test for the validity of competing hypotheses is one of goodness of fit. If a competing variable explanation does not fit the framework, then it can be given less weight. Further, even if an important variable is not controlled, a framework will at least make the analyst sensitive to its effects.

To the extent that this study is theoretically based and used multiple methods (i.e., survey, sociometric, interviews, observation), a number of competing hypotheses can be dealt with; however, many will remain. As with all scientific research, alternative explanations can only be directly dealt with through replication and more theoretically based multi-method research (Campbell and Stanley, 1969).
CHAPTER IV
TECHNICAL COMMUNICATION

Introduction and Overview

The process of technical communication within and between R & D laboratories has been of interest to a number of organizational analysts (e.g., Allen, 1964, 1970; Pelz and Andrews, 1966). From an information processing perspective, patterns of technical communication are of particular importance since R & D organizations must effectively gather and efficiently process relatively complex and often-times rapidly changing information. Interpersonal communication is an important medium through which laboratory personnel keep up with technical developments as well as provide each other with technical feedback and real time critical evaluation. Further, as Gerstberger (1971) notes, interactive technical communication is a particularly effective means through which coordination and complex problem solving take place.

Chapter II proposed that to be effective, a project's communication network characteristics must be able to deal with its information processing requirements. Task characteristics, environmental variability, and task interdependence were suggested as important sources of information processing requirements. This chapter will be divided into four
sections. The first three sections will deal with the effects of task characteristics, environmental variability, and interdependence on technical communication. Each section will review the relevant literature, develop and test a set of hypotheses, and discuss the results. The final section will review the results of the chapter.
4.1 Task Characteristics and Technical Communication

The effects of project or organizational task differences on communication have been studied by social psychologists, sociologists, and those interested in R & D management. The contributions of each discipline will be discussed below.

Research on Small Groups

Social psychologists have studied the effects of task differences on group behavior through the use of laboratory or artificial groups. The earliest studies dealing with the effects of different tasks on the amount and direction of communication were done by Bavelas (1951) and Leavitt (1951). These studies documented the effects of different network structures on problem solving (i.e., task) efficiency and individual satisfaction.

While much of the social psychology literature since the 1950's has dealt with task effects on group behavior, only a small subset has focused on the effects of task differences on communication patterns. Hackman (1969), Hackman and Vidmar (1970), Morris (1966), and Katz (1969) have found that task differences have systematic effects on group interaction patterns. Using a modified Bales approach, Hackman and Vidmar (1970) attributed 70 percent of group interaction variance to task differences. Sorenson (1971) found that problem solving tasks had higher levels of group interaction than did
production tasks. This effect was most pronounced for high performing groups. Sorenson suggests that more complex tasks require more interaction and problem solving to arrive at quality solutions than do the less complex tasks.

The small group literature suggests that the group's task is an important variable for understanding intra-group behavior. There has been, however, little attention given to the effects of task differences on extra-group behavior. Glanzer and Glaser (1961) and Cohen et al. (1969) have observed this intra-group bias and question the external validity of the small group literature. Cohen et al. suggest that studies of isolated groups can not provide insight on group behavior in organizations since the effects of organizational embeddedness are not taken into account. However, with this caveat, the social psychological literature does suggest that the more complex the task, the greater the amount of communication within the group. From an information processing perspective, this increased communication within the group is required to handle the greater information processing requirements of more complex tasks.

Organizational Research

In spite of the extensive work of organizational sociologists, there has been very little explicit concern with the effects of task or technology on communication patterns in organizations (O'Reilly and Roberts, 1974). There are, however, a few studies that provide
direct evidence on the effects of task differences on overall communication patterns, and others that provide tangential evidence.

In a review article, Udy (1965) hypothesized that the less operational the subgoals or the greater the task uncertainty, the greater the total amount of communication and the greater the proportion of horizontal communication in the organization. Conversely, he hypothesized that the more mechanized and less complex the task, the less the amount of overall communication and the greater the proportion of vertical communication. Landsberger's (1961) study of three business settings lends support to Udy's hypotheses. Landsberger found that the total amount of communication, as well as the horizontal to vertical communication ratio, were greater for sales organizations than for manufacturing organizations. Similarly, Hage et al. (1971) found that the more complex the organization's task, the greater the task-related communication.

Perrow (1965, 1970) has developed and partially tested a framework based on a routine (fixed responses and procedures)/non-routine (no cut and dried method for handling the task) dimension. Perrow (1965) hypothesized that if tasks are relatively routine, then there will be relatively larger spans of control, more rules, relatively low levels of discretion, and a relatively small amount of communication. The opposite patterns were hypothesized for non-routine tasks. There has been support for these hypotheses in hospital settings (Perrow, 1965, Coser, 1958), industrial settings (Hall, 1972; Simpson, 1959), and in social welfare organizations (Hage and Aiken, 1969).

Burns and Stalker (1965) studied twenty British firms and identified two ideal types of organizational patterns: organic and
mechanistic. Mechanistic organizations had a well defined hierarchy, formal rules and standards, high level decision making, and low levels of communication. Organic organizations had the opposite characteristics. While Burns and Stalker focused on environmental change as the source of organizational differences, the logic is unclear because environment and task differences were confounded. That is, the organizations in changing environments tended to be high technology operations, while organizations in stable environments were manufacturing organizations. The environmental change/organizational type results might also be explained as an effect of the different tasks: the more complex the task, the more the organic type organization is appropriate. In support of this task interpretation, Lorsch (1965) and Lawrence and Lorsch (1967) found that successful research departments were less formal and had more diverse communication patterns than did manufacturing or sales departments.

The results of the organizational level studies are quite consistent. These studies find that the more complex the task, the greater the overall amount of communication, as well as the greater the horizontal to vertical communication ratio. These results are analogous to the micro studies and fit well with the information processing perspective. The more complex the task, the greater the problem solving requirements, and therefore, the greater and more diverse the communication. Increased communication is a way of increasing information processing capacity by distributing the problem solving efforts throughout the organization or group. The results from the group and organizational studies emphasize the importance of considering the effects of task differences on technical communication. As with most
studies, however, these results also raise a number of questions. For instance, do research groups have more contact than technical service groups with all areas in the organization or is there specialization of communication patterns to different areas of the organization? These questions suggest studying, in more detail, the communication characteristics of different task areas.

R & D Management Literature

The R & D management literature has given special attention to the effects of technical communication in R & D settings. This literature has dealt with intra-project, organizational, and extra-organizational communication and is, therefore, more specific and detailed than the macro studies, and more encompassing than the micro studies. It is from this R & D literature that ideas concerning the more specific effects of task differences on technical communication can be generated.

The first set of studies deal with the importance of technical communication inside the R & D laboratory. Allen (1964, 1966) and Allen et al. (1968) have conducted a series of studies focusing on the relationship between technical communication and performance. In the first of these, Allen tracked the information seeking behavior of 156 proposal teams who were competing for 22 government contracts. Since four or more teams were involved in each competition, and since technical evaluations were obtained from the government agency, it was possible to compare the communication characteristics of high and low performing teams. Allen found a negative relation between
communication outside the laboratory and technical performance. On
the other hand, Allen found a positive relation between communication
inside the laboratory and technical performance. Allen (1966),
Gerstenfeld (1967), and Allen et al. (1968) have replicated these com-
munication results in a set of similarly designed, parallel project
studies. As a whole, these studies emphasize the importance of
internal laboratory consulting and the dangers of relying on communica-
tion and information from outside the organization.

Similar results have been reported by Shilling and Bernard (1964)
and Baker et al. (1968). Shilling and Bernard studied 64 industrial and
government laboratories and found a significantly positive correlation
between internal discussions and performance, yet a significantly
negative correlation between communication with external consultants
and performance. Baker and his colleagues focused on special
idea generating groups. By tracing the sources of ideas and utilizing
managerial evaluations, they found that all but 8 per cent of the best
ideas originated inside the organization. Finally, in a major study
that focused on internal communication, Pelz and Andrews (1966) found
that extensive internal consulting, both within the group and organization,
was positively related to technical performance. Pelz and Andrews go
on to suggest that extensive communication actually stimulates technical
performance.

Project members often do not have all the appropriate technical
information or support within their project. If not, then project mem-
bbers must import information and ideas from outside their project.
The studies cited above suggest that internal consulting, regardless of
the nature of the task, is positively related to performance, while
communication outside the organization is consistently negatively related to performance. Technical consultation within the laboratory seems to be a most efficient and effective source of technical information and support. The high performing individuals and groups are evidently able to capitalize on in house expertise.

Communication inside the organization is consistently associated with higher performance, yet, communication outside of the organization is just as consistently associated with lower performance. Why should this be so? Allen (1966) and Gerstberger (1971) have argued that the inverse relation between external communication and technical performance is due to the difficulties of accurate technical communication across organizational boundaries. Inter-organizational communication must cope with semantic and linguistic differences that exist between the sender and receiver of information. Allen (1966) has suggested that these linguistic differences introduce the possibility of an impedance mismatch, with the attendant difficulties in effectively communicating concepts and ideas. Thus communication outside the laboratory probably does not cause lower performance. What is more likely is that external sources of information are probably not able to supply the appropriate knowledge or insight as effectively as sources inside the laboratory.

The R & D management literature cited above clearly demonstrates the utility of internal technical consulting. With these results a more specific question can be raised. Does the pattern of internal consulting make a difference? Should internal consulting be encouraged throughout the laboratory, or are there more important locations of technical information for different task areas?
A beginning can be made in addressing these questions by focusing on two studies which seemingly contradict the results reported above. Hagstrom (1965), in a study of the communication characteristics of university scientists, found a strong positive correlation between communication outside the university to people in the same field and the number of publications. Further, unlike Allen's results, Hagstrom found only a weak correlation between communication within the department and the number of publications. Gordon's (1971) study of medical sociologists also found that communication inside the work environment was not related to performance, while communication to professionals outside of the work setting was positively related to performance.

Allen (1966, 1970) has explained Hagstrom's results by referring to the larger professional system of university scientists—the invisible college. The set of professionals with similar disciplinary backgrounds, interests, values and coding schemes, are able to provide effective technical feedback and evaluation better than other professionals within the heterogeneous university. From this perspective, communication with the relevant social system is positively related with performance, while communication outside the matching social system is negatively related to performance. This logic suggests that it may not be widespread internal communication, but rather, more specific communication to areas with similar coding schemes, disciplinary backgrounds, and problem orientations that is positively related to performance.

If an individual requires technical information or stimulation from outside of the project, effective consulting is important. It may be that organizational affiliation is less important than the degree of
match in the coding and linguistic schemes. In R & D settings, if the laboratory is highly differentiated, then within the laboratory there are likely to be areas with different time frames, goals and professional orientations. As March and Simon (1958), Katz and Kahn (1966), and Lawrence and Lorsch (1967) have observed, these differences in norms and values also carry with them different internal coding schemes. If there are different coding schemes and technical orientations within the laboratory, then it may well be that effective internal consulting should be directed specially to areas which have a similar technical orientation and problem focus. In short, this analysis suggests that if the R & D facility is organized into different task areas, then these areas are likely to have different patterns of internal consulting since they will have different sources of effective technical feedback and evaluation.

While not focusing on internal communication patterns, there are a few studies that support the idea that different task areas do have different sources of effective technical feedback and therefore, have different patterns of communication. Whitley and Frost (1973) found that research areas, in a large government laboratory, communicated heavily outside of the laboratory, yet relatively little inside the laboratory. The more routine service-oriented areas had the reverse pattern; they communicated heavily inside the laboratory, yet were only weakly connected outside the laboratory. Very similar results have been reported by Rosenbloom and Wolek (1970) and Taylor (1972).

Whitley and Frost (1973) argued that these results are due to the different professional foci of the different task areas. They hypothesized that research employees are more oriented to external professional
criteria, while the more operationally-focused service employees are more oriented to organizational criteria. While these studies focused only on internal and external communication, they do support the idea that different task areas within the laboratory do have different sources of technical information. Therefore, if the laboratory is large and organized into multiple task areas, then it makes sense to look at the patterns of internal consulting; there may well be important differences for the different task areas.

Since project members do not have all the necessary work-related information or insight, they must import information and ideas from outside the project. This review suggests that internal (i.e., within the laboratory) consulting is a particularly effective source of technical information and problem solving advice. However, the review further suggests that this internal consulting may well be organized around the characteristics of the task. The magnitude and direction of communication to areas outside the project should be a function of similarity in technical orientation and problem focus, since similar areas are best able to provide effective technical support and feedback. If this logic holds, then projects with the appropriate patterns of internal consulting should be higher performers.

In summary, the small group, organizational, and R & D literatures suggest that task characteristics should be a major contingent variable in any study interested in communication in organizations. These literatures support the notion that the project's task can be seen as a source of internal (i.e., within the project) problem solving differences as well as a source of extra project communication differences based on the different locations of technical information and support. More
specifically, this review suggests that project task uncertainty affects communication within the project, while the locus of technical information affects communication with areas outside the project.

This review suggests the following hypotheses:

4.1-1 The more complex the task, the greater the amount of technical communication within the project.

4.1-2 Extra project communication profiles will differ for different task areas. Communication outside the project will be directed to those areas that can provide effective critical evaluation, technical feedback, and technical information.

Results

Table IV-1 reports the average amount of technical communication for research and technical service projects with the different areas within and outside the laboratory. Before discussing the two hypotheses, it is instructive to note that there are no overall differences in the amount of technical communication between research and the technical service areas. However, as hypothesized, this overall equality hides important differences in technical communication patterns for the different task areas.

The small group literature suggested that the more complex the task the greater is the group's internal problem solving requirements. One way of dealing with the increased problem solving requirements is through increased technical communication. Hypothesis 4.1-1 suggested that the more complex tasks (i.e., research projects) would have greater project communication than the less complex
<table>
<thead>
<tr>
<th>TABLE IV-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEAN AMOUNT OF TECHNICAL COMMUNICATION BY TASK AREA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A) Total Sample</th>
<th>Communication within Organization</th>
<th>Communication outside Org.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Group</td>
<td>Laboratory Organization</td>
<td>Operational Professional</td>
</tr>
<tr>
<td>Research (n = 13)</td>
<td>31.5 21.7 10.4 6.0 1.8 1.1</td>
<td>72.7</td>
</tr>
<tr>
<td>Technical Service (n = 20)</td>
<td>21.9 36.6 5.4 14.5 4.1 1.0</td>
<td>83.9</td>
</tr>
<tr>
<td>(Significance)</td>
<td>* * ** **</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B) High and Low Performing Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication within Organization</td>
</tr>
<tr>
<td>Communication outside Org.</td>
</tr>
<tr>
<td>Project Group</td>
</tr>
<tr>
<td>Laboratory Organization</td>
</tr>
<tr>
<td>Operational Professional</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

| Research | 38.1 24.8 24.4 21.0 10.4 10.4 4.7 7.3 2.0 1.7 1.4 0.6 | 81.1 64.3 |
| Technical Service | 19.3 26.8 39.3 31.6 2.8 10.4 12.3 18.4 3.4 5.3 0.9 1.1 | 78.7 93.6 |
| (Significance)   | ** ** ** *** * *** | * |
| d.f.             | 17 12 |

* p < .10
** p < .05
*** p < .01 (all other differences not significant)
tasks (i.e., technical service projects). Table IV-1 supports this hypothesis. For the total sample, the difference in project communication between research and service areas is not statistically significant. However, the high performing research projects do have significantly greater project communication than the high performing service projects. Evidently, individuals in the high performing research projects deal with their increased task complexity through increased communication inside the project. The less complex technical service tasks require less problem solving and, therefore, less intense project communication. Task differences did not affect project communication for the low performing projects.

For the high performing projects, communication within the project is indeed contingent on the characteristics of the task. These results suggest that more communication is not always positively related to performance. High performing projects with complex tasks have relatively more project communication to handle the increased problem solving requirements. On the other hand, high performing projects with less complex tasks have smaller information processing requirements, and therefore, do not require the information processing capacity of intense project communication.

Hypothesis 4.1-2 deals with communication outside the project. It was argued that since projects do not have all the appropriate work related information or insight, each project must import technical information, ideas, and advice. Projects must have sources of technical feedback, critical evaluation, and technical information—in short, technical reference groups. Since different task areas may have different sources of technical information, hypothesis 4.1-2 suggested
that communication outside the project will be directed to different areas of technical support.

To test this hypothesis the location of technical information and feedback must be specified for the different task areas. Once specified, specific hypotheses can then be made for the extra project communication patterns. The research and technical service projects will be focused on here because they represent the opposite ends of the task complexity continuum. Information on the location of technical support and feedback was gathered through interviews and observations at the field site.

In this laboratory, research projects worked on the generation of new knowledge and information of relevance to the corporation. These projects were organized into stable, relatively small groups, each dealing with a specified and focused technical area (e.g., Glass Physics or Chemical Analysis). The work done by the research projects was not unconstrained. Each project had technical relevance to the development areas as well as to at least a few technical service areas. With this constrained research focus, areas within the laboratory were appropriate sources for technical knowledge, expertise, and technical feedback. Given the communication patterns of research-oriented professionals, it can also be expected that the research projects would be relatively strongly connected to universities, professional societies, and other professional areas outside of the organization. On the other hand, because of the technical problem specificity of the individual research projects, other projects within the same Group had very little in common with each other. For instance, the physicists in Metallurgy Development had very few technical or problem similarities with
the chemists in the Chemical Development project. Similarly, because of the differences in time frame and problem orientations, organizational areas outside of the laboratory were not a source of technical information or support for the research projects.

Technical service projects were very different from the research projects. Technical service projects worked on product improvement through the use of existing, relatively stable, knowledge and technologies. The service projects tended to be functionally organized (e.g., Furnace Technology, Melting Technology) and relied on a high component of technical experience. Technical Service projects often worked with other service projects in the same Group on problems defined by the manufacturing and marketing areas. Given the similar time frames and problem orientations, technical service areas relied heavily on technical feedback and support from areas within the Group as well as from areas outside the laboratory yet inside the corporation. Service areas also could get relevant external market and technical inputs from suppliers, vendors, and customers. However, the service projects had relatively little in common with other laboratory Groups and with professional areas outside of the organization because of the different product, market, and technical orientations.

This discussion of different sources of technical information and support leads to the following set of predictions for the relative amount of communication to the different areas: research projects should have relatively more technical communication within the laboratory and to professional areas outside of the organization, while technical service projects should have relatively more communication within the Group, to the corporation, and to operational areas outside of the
organization. These differences should be accentuated for the high performing projects.

To test these predictions, the average amounts of technical communication for research and technical service projects to each of the different areas are compared in Table IV-1. Figure IV-1 plots for high performing projects the mean amount of communication with each area. Each of the five overall differences are in the predicted direction and four of the five differences are statistically significant. Individuals in technical service projects tend to communicate within their Groups, to the larger organization, and to operational areas significantly more than individuals in research projects. However, individuals in research projects have significantly more communication inside the laboratory than do individuals in the technical service projects. There are no differences in the amount of communication to professional areas outside of the organization.

The overall communication data give strong support to communication specialization based on the location of technical information and support. However, these overall results do not provide evidence on the effect of this specialization on project performance. Do the high performing projects show the predicted communication specialization more so than the low performing projects? Table IV-1 indicates that for communication inside the organization, this specialization is accentuated for the high performing projects. In each case, the high performing projects show the predicted differences, while the low performing projects, with one exception, do not. High performing technical service areas have significantly more contact within their Groups and to the larger organization than do the high performing research projects.
FIGURE IV-1
AVERAGE COMMUNICATION FOR HIGH PERFORMING RESEARCH AND TECHNICAL SERVICE PROJECTS

= Research Projects
= Technical Service Projects

MEAN AMOUNT OF TECHNICAL COMMUNICATION/15 WKS

Project Group Lab Org. Oper. Professional
(p < .05) (p < .05) (p < .05) (p < .01) (N.S.) (N.S.)

Communication within Organization

Communication outside Organization
High performing research projects have significantly more communication inside the laboratory than the high performing service projects. Contrary to the predictions, communication to areas outside the organization is not specialized for the high performing projects. While service projects had more contact with operational areas, and research projects had more contact with professional areas, neither of these differences are statistically significant. Evidently communication inside the organization is specialized by task differences, while communication outside the organization is not.

In summary, these results indicate that there is communication specialization based on task differences. While there were no overall communication differences between research and service projects, the data support the hypotheses of intra project specialization based on differences in task uncertainty and extra project specialization based on the different locations of technical information and support. In each case this specialization was accentuated for the high performing projects. However, for the high performing projects, communication outside the organization was not effected by task differences. These results suggest that communication in the R & D laboratory is indeed important and that communication patterns within the organization are contingent on task characteristics. Communication should, therefore, be managed—specialized to fit the information requirements of the task.
4.2 Environmental Variability and Technical Communication

Environmental change or turbulence has been widely seen as a source of uncertainty to which organizations must respond. Thompson (1967), Weick (1969), and Schein (1970) have developed models of organizing in which the organization must attend and adapt to environmental conditions. The greater the environmental variability, the greater is the uncertainty to which the organization must respond. These theorists suggest that the most appropriate way to respond to environmental uncertainty is with an adaptive organization—one with roles open to redefinition, decision making at multiple levels, and widespread formal and informal contact. From the information processing perspective, the logic is straightforward. The greater the environmental uncertainty, the greater will be the information processing requirements. If technical communication is a way of dealing with increased information processing requirements, then environmental variability may be effectively dealt with through increased communication. The problem now becomes one of specifying the effects of environmental conditions on communication within and outside the laboratory.

Relatively little empirical work has been done on the effects of environmental conditions on work groups within organizations. While the social psychological literature has not empirically tested the environmental effects on network communication patterns, Glanzer and Glaser (1961) do hypothesize that groups will respond to changing environmental conditions by increasing internal communication and becoming less structured. Like the social psychological literature,
there are no studies in the R & D literature on the effects of environmental change on communication patterns.

At the organizational level of analysis, the work on organic/mechanistic organizational types provides evidence on the relationship between the environment and communication. Burns and Stalker (1965) (using their environmental interpretation) and Miller (1971) report that under conditions of changing task environments, successful organizations are characterized by intense and diverse communication. Negandi and Reimann (1973) found that under conditions of perceived environmental change, more successful organizations were more decentralized and had greater amounts of communication than less successful organizations. Very similar results have been reported by Hage and Aiken (1969) and Osborn and Hunt (1974).

Lawrence and Lorsch (1967) and Smith (1970) report similar results concerning the effect of environmental conditions on departmental communication. Both studies found that research departments had a greater diversity and intensity of communication than did sales or manufacturing departments. These results were explained by noting the significantly different amounts of environmental variability encountered by research and manufacturing departments. Finally, Duncan (1973) found that groups facing a changing environment reported greater group communication than did groups in more stable environments. In all, the results from the organization, department, and group levels of analysis suggest that if the environment is seen as unstable, successful units respond by increasing the amount of technical communication. In all of these studies, communication is measured at an aggregate level. No attempt is made to determine the extent of communication with the different parts of the
organization. Do projects facing a changing environment communicate more with all areas of the organization or is there increased contact only with specified areas?

The literature reviewed here has typically dealt with communication only tangentially. The task environment is, however, consistently seen as a source of uncertainty with which the project must deal. It can be hypothesized that environmental complexity most directly affects extra organizational and intra project communication since the project must both attend to and deal with external environmental uncertainty. Other areas in the laboratory and larger organization are potential sources of problem solving and technical feedback for the project. Since the location of technical support has been suggested to differ by task characteristics, it can be hypothesized that there will be no overall effect of environmental conditions on communication to the Group, laboratory, or organization areas.

This discussion leads to the following hypotheses:

4.2-1 The greater the perceived environmental variability, the greater will be the amount of communication within the project and outside of the organization.

4.2-2 There will be no relationship between environmental variability and communication to the Group, laboratory, or organization areas.

4.2-3 Hypothesis 4.1-1 suggested that the more complex the task, the greater will be the communication within the project. Hypothesis 4.2-1 suggested that the greater the environmental variability, the greater will be the communication within the project. The union of these two hypotheses suggests an interaction effect of
task and environment for project communication. Routine tasks facing an uncertain environment must still make relatively routine decisions. Under these conditions the information processing needs are still relatively low. However, for non-routine tasks, decision making under conditions of environmental complexity is predicted to require extensive information gathering and processing, and therefore, significantly increased communication within the project. Research projects then will respond to environmental variability through increased project communication more so than technical service projects. This logic leads to the hypothesis of a task-environment interaction for project communication. More specifically, it can be hypothesized that under changing environmental conditions, the difference in project communication between more and less routine tasks will be greater than under stable environmental conditions.

Results

To test these hypotheses the average amount of technical communication was compared for projects with changing and stable environmental conditions (see Table IV-2). As with the communication averages for the different task areas, there are no overall differences in the amount of communication for projects facing a changing environment and those projects facing a stable environment. However, unlike the task results, there are virtually no overall effects of environmental variability on technical communication to any area inside or outside the laboratory.
**TABLE IV-2**

**MEAN AMOUNT OF TECHNICAL COMMUNICATION FOR DIFFERENT TASK ENVIRONMENTS**

For the Total Sample (n = 56) and the High Performing Projects (n = 28)

<table>
<thead>
<tr>
<th>Environment</th>
<th>Project Total</th>
<th>Group Total</th>
<th>Laboratory Total</th>
<th>Organization Total</th>
<th>Operational Total</th>
<th>Professional Total</th>
<th>Total Total</th>
<th>Total High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changing</td>
<td>27.3</td>
<td>26.8</td>
<td>27.9</td>
<td>29.7</td>
<td>8.7</td>
<td>6.3</td>
<td>8.9</td>
<td>9.5</td>
</tr>
<tr>
<td>Stable</td>
<td>27.9</td>
<td>24.9</td>
<td>28.8</td>
<td>33.8</td>
<td>8.9</td>
<td>7.0</td>
<td>13.7</td>
<td>14.2</td>
</tr>
</tbody>
</table>

(Significance)

* * p < .10  (All other differences not significant)
(Environment scores were split at the median to get high and low categories)

**TABLE IV-3**

**CORRELATIONS BETWEEN TASK ENVIRONMENT AND TECHNICAL COMMUNICATION**

<table>
<thead>
<tr>
<th></th>
<th>Project</th>
<th>Group</th>
<th>Laboratory</th>
<th>Organization</th>
<th>Operational</th>
<th>Professional</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>-.06</td>
<td>-.02</td>
<td>-.15</td>
<td>-.12</td>
<td>-.02</td>
<td>.06</td>
<td>-.11</td>
</tr>
<tr>
<td>(n = 55)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Perf.</td>
<td>.00</td>
<td>-.13</td>
<td>-.14</td>
<td>-.15</td>
<td>.00</td>
<td>.02</td>
<td>-.13</td>
</tr>
<tr>
<td>(n = 28)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Perf.</td>
<td>-.10</td>
<td>.07</td>
<td>-.09</td>
<td>-.13</td>
<td>.02</td>
<td>.12</td>
<td>-.09</td>
</tr>
<tr>
<td>(n = 27)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(no coefficients significant at p < .10)
The logic of hypothesis 4.2-1 suggested that environmental variability would most directly affect communication outside the organization and within the project, since project members must both attend to and deal with the extra information processing requirements of environmental variability. Hypothesis 4.2-1 specifically predicts that projects facing a changing environment will have greater intra project and extra organizational communication than projects facing a stable environment.

The data in Table IV-2 indicate no support for hypothesis 4.2-1. None of the differences in the amount of technical communication for projects facing stable and changing environmental conditions are statistically significant; two of the three differences are in the opposite direction. Communication within the project and communication to operational areas are greater under stable environment conditions. Similarly, high performing projects facing changing environmental conditions do not have significantly more communication within the project or outside of the organization than high performing projects in stable environmental conditions. Contrary to the predictions, environmental variability seems to have no effect on intra project or extra organizational communication.

The correlations between environmental variability and technical communication (Table IV-3) lend further support to the lack of association between environmental conditions and intra project and extra organizational communication. None of the predicted correlations are significantly greater than zero. Indeed, two of the three total correlations are negative. In short, hypothesis 4.2-1 is soundly rejected.
While there are no overall effects of environmental conditions on intra project and extra organizational communication, there may well be more specific effects for the different task areas. Hypothesis 4.2-3 suggests that environmental conditions will affect research and technical service projects differently. It was argued that due to the differences in information processing and problem solving requirements between research and technical service projects, that environmental variability would significantly increase intra project communication for research projects and have less of an effect on intra project communication for technical service projects.

Figure IV-2 displays the average amount of project communication for the different task and environmental conditions. The figure indicates that research projects have more intra project communication than the service projects, and that environmental variability only weakly affects communication within the project. More importantly, figure IV-2 clearly shows the task-environment interaction in the direction hypothesized (in a multiple regression analysis, the task-environment interaction term is statistically significant, \( p < .10 \)). Under stable environmental conditions, the difference in project communication between research and technical service areas is small. However, under changing environmental conditions, project communication for research projects increases dramatically, while the technical service areas are relatively unaffected.

Environmental variability seems to be dealt with very differently for the different task areas. Research projects attend to the increased uncertainty and problem solving requirements through increased communication within the project, while technical service areas do not
FIGURE IV-2

Mean Amounts of Communication Within the Project for Different Task and Environmental Characteristics

Total Sample (n = 31)  High Performing Projects (n = 18)

Communication within the Project

Stable  Changing

Environmental Conditions

--- Technical Service Projects
--- --- Research Projects
seem to respond to this uncertainty with increased project communication. In all, while there are no overall effects of environmental conditions on project communication, the interaction analysis indicates that there are specific effects of environmental conditions for the different task areas.

Environmental conditions may also have specific effects on communication patterns outside the organization. To investigate this possibility, the task-environment interactions are graphed in figure IV-3. These figures show some interesting and unexpected patterns. While there are no overall effects of environmental variability on operational or professional communication, for the high performing projects, environmental conditions do seem to affect research projects quite differently than technical service projects. What is unexpected is the direction of the effects. For the high performing projects, differences in extra organizational communication between the task areas diminish as environmental variability increases.

These patterns are surprising. If professional areas are important to research projects as a source of state-of-the-art knowledge, and if the technical and knowledge base is changing, then research projects should increase their amount of contact to these professional areas. Similarly, if operational areas supply technical service projects with information on outside products and processes, technical service projects should increase their contact to these operational areas as the task environment becomes more variable. This logic suggests that differences in extra organizational communication should be increased as environmental conditions become more variable. However, Figure IV-3 indicates that in both cases the differences in technical communi-
FIGURE IV-3
Mean Amounts of Communication Outside the Organization for Different Task and Environmental Characteristics

A) Operational Communication (suppliers, vendors, customers)

Total Sample (n = 31)  High Performing Projects (n = 18)

B) Professional Communication (universities, professional societies)

Total Sample (n = 31)  High Performing Projects (n = 18)

---

= Technical Service Projects
--- = Research Projects
cation with areas outside the organization decrease as environmental variability increases. Since technical communication decreases to the relevant external areas as uncertainty increases, the question arises as to how the different task areas keep track of external technical and market conditions when these conditions are changing.

Focusing on communication within the laboratory and the larger organization, hypothesis 4.2-2 suggests that differences in environmental conditions should not affect technical communication to the Group, laboratory, or organization areas. Tables IV-2 and IV-3 support this broad hypothesis. None of the correlations between environmental conditions and technical communication are significantly greater than zero. Further, in only one case out of twelve is the average amount of technical communication for projects in a changing environment significantly different than the amount of communication for projects in a stable environment. These data then strongly support the hypothesis that environmental variability has no affect on technical communication to the Group, laboratory, or organization areas.

While the main effects of environmental conditions on technical communication are not statistically significant, the patterns of the means and correlations are striking and should not be ignored. In six out of seven cases the correlation between environmental conditions and communication is negative. Further, the correlations among high performing projects are generally more negative than among low performing projects. Similarly, six of the seven communication differences indicate that projects in a stable environment have more communication than projects in a changing environment. In short, there seems to be a weak, but consistent, inverse relation between environmental variability
and technical communication.

Discussion

Contrary to expectations, the data indicate that there are no overall effects of environmental variability on intra project or extra organizational communication. However, the interaction analysis indicates that environmental conditions do affect the task areas quite differently. High performing research projects have increased project communication under changing environmental conditions, while high performing technical service projects do not seem to respond to environmental variability with technical communication inside the project. These results may be because increases in environmental variability affect research projects more than they affect technical service projects. That is, routine tasks facing an uncertain environment must still make relatively routine decisions, while complex tasks facing the same environmental variability must handle significantly increased problem solving requirements. Therefore, under conditions of changing environmental conditions, research projects have increased communication within the project, while technical service projects do not show increased intra project communication.

Environmental conditions also had specific effects on technical communication to areas outside the organization. The effects of environmental conditions on communication to the operational and professional areas were contrary to expectations. Environmental variability seemed to decrease both the professional communication of the research projects and the operational communication of the technical
service areas. What is puzzling about these results is that environmental variability and the attendant increase in technical uncertainty do not seem to be dealt with through increased technical contact to areas outside of the organization. Environmental variability also had a weak, yet consistently negative, relationship with technical communication to each area in the laboratory and with areas in the larger organization. Increased environmental variability, therefore, tended to be consistently associated with a decrease in technical communication.

The data on the effects of environmental conditions on communication patterns suggest that environmental variability may not be perceived as a source of uncertainty, but rather as a source of overload or threat. Changes in the market or technical worlds seem to be handled by cutting back on communication to each area in the organization. Further, communication by research projects to the professional areas, and by technical service projects to the operational areas, each decreased as environmental variability increased. The question then arises, if environmental change is a source of uncertainty and problem solving requirements, and if projects must match information processing capacity to information processing requirements, how do projects deal with environmental variability if not through increased communication? These results suggest the possibility of specialized technical roles whose function would be to specifically attend to the extra information processing requirements that accompany environmental conditions. Thus, while the overall amounts of communication may decrease to areas inside and outside of the organization, special individuals may actually increase their communication to these areas. These individuals
then serve as communication liaisons to areas external to the project. Contrary to much of the literature, environmental variability may be most effectively dealt with by actually decreasing the overall amount of communication and simultaneously developing specialized roles to serve as liaisons both to the external environment and to other areas in the organization.
4.3 Task Interdependence and Technical Communication

The open systems view of organizing suggests that as organizations become complex, they become differentiated to attend to task and environmental differences. The differentiated units are then interdependent to varying degrees. To the extent that there is a need for joint decision making, interdependence will require coordination and problem solving. March and Simon (1958) and Thompson (1967) have used interdependence as a critical variable for understanding organizations. Both have conceptualized interdependence as a source of coordination difficulty. As Galbraith (1969) suggests, if interdependence is a source of complexity, the greater the interdependence then the more the uncertainty due to coordination requirements, and therefore, the greater the burden on the communication network.

Interdependence, however, has almost been empirically ignored. Even though interdependence has been conceptualized as a core organizational variable, research attention has been focused on the effects of task characteristics and environmental variability on organizational processes. This may be because interdependence has been seen as a task dimension (e.g., Lynch, 1974; Hrebiniaik, 1974). The lumping of task characteristics and task interdependence is a simplification that will be avoided here. Since there is no a priori reason to suggest that the characteristics of the task have a systematic relation to task interdependence, the two variables will be considered separately.

Allen (1970) and Taylor (1972) provide inferential evidence on the
effects of interdependence on communication. While Allen did not measure interdependence, he found that a high proportion of organizational liaisons had participated in an interdepartmental project. It can, therefore, be inferred that the existence of task interdependence tended to increase technical communication between the interdependent areas. Taylor found gatekeeper networks only where there was task interdependence between the organizational units. Gerstberger (1971), in one study that directly investigated interdependence, found that task interdependence was the most important predictor variable for both internal and external communication partners. In Gerstberger's study, interdependence was differentiated into internal and external components.

Following Gerstberger's (1971) lead, interdependence with several organizational areas will be examined. This review suggests that to the extent that work areas are interdependent with other areas, they must deal with the attendant integrative requirements. Increased task interdependence can be hypothesized to require increased technical communication to deal with the increased coordination requirements. This broad hypothesis can be made more specific to fit with the several areas of communication and interdependence.

4.3-1 Interdependence with area A (e.g., laboratory) will be positively related to the amount of communication with area A (i.e., laboratory).

4.3-2 Interdependence with area B (e.g., Group) will not be related to the amount of communication with areas A or C (i.e., laboratory, organization).
Results

Hypothesis 4.3-1 suggests that since interdependence carries with it coordination requirements, and since technical communication is a way of dealing with coordination, then interdependence should be positively associated with technical communication to the appropriate area. For instance, projects with substantial interdependence with areas in the laboratory should have greater laboratory communication than projects with low laboratory interdependence. Hypothesis 4.3-2 suggests that if the interdependence-communication relationship is strong, then interdependence with area A (e.g., the Group) should only be related to communication with area A. For example, Group interdependence should be related to Group communication and not related to any of the other communication areas.

One way to test these hypotheses is with correlations between interdependence and communication (see Table IV-4). For the total sample, both hypotheses are strongly supported. The congruent correlations (circled in Table IV-4) are each statistically significant and greater than the other row and column correlations. In support of hypothesis 4.3-2, only one of the off diagonal correlations is significantly greater than zero. This data indicate that interdependence with area A is strongly and specifically related to technical communication to area A. If the information processing logic holds, then the relationship between interdependence and communication should be accentuated for the high performing projects.

The correlations for the high and low performing projects suggest somewhat less support for hypothesis 4.3-1. For the high
TABLE IV-4
CORRELATIONS BETWEEN TASK INTERDEPENDENCE AND TECHNICAL COMMUNICATION

Total Sample (n = 54)

<table>
<thead>
<tr>
<th>Interdependence between project and:</th>
<th>Communication within</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group</td>
<td>Laboratory</td>
<td>Organization</td>
</tr>
<tr>
<td>Group</td>
<td>.35***</td>
<td>-.08</td>
<td>.01</td>
</tr>
<tr>
<td>Laboratory</td>
<td>.09</td>
<td>.36***</td>
<td>.25*</td>
</tr>
<tr>
<td>Organization</td>
<td>.07</td>
<td>-.13</td>
<td>.61***</td>
</tr>
</tbody>
</table>

High Performance (n = 27)

<table>
<thead>
<tr>
<th>Interdependence between project and:</th>
<th>Communication within</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group</td>
<td>Laboratory</td>
<td>Organization</td>
</tr>
<tr>
<td>Group</td>
<td>.22</td>
<td>-.04</td>
<td>.14</td>
</tr>
<tr>
<td>Laboratory</td>
<td>.20</td>
<td>.45***</td>
<td>.23</td>
</tr>
<tr>
<td>Organization</td>
<td>.13</td>
<td>-.19</td>
<td>.66***</td>
</tr>
</tbody>
</table>

Low Performance (n = 27)

<table>
<thead>
<tr>
<th>Interdependence between project and:</th>
<th>Communication within</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group</td>
<td>Laboratory</td>
<td>Organization</td>
</tr>
<tr>
<td>Group</td>
<td>.44***</td>
<td>.01</td>
<td>-.13</td>
</tr>
<tr>
<td>Laboratory</td>
<td>-.18</td>
<td>.33*</td>
<td>.30*</td>
</tr>
<tr>
<td>Organization</td>
<td>.11</td>
<td>-.13</td>
<td>.51***</td>
</tr>
</tbody>
</table>

* p < .10

*** p < .01
performing projects, while the correlation of Group interdependence with Group communication is greater than the other row and column correlations, it is not significantly greater than zero. Evidently, for the high performing projects, Group communication is not sensitive to Group interdependence. The effects of more organizationally distant interdependence (i.e., interdependence with laboratory and other organizational areas) are accentuated for the high performing projects. For both laboratory and organizational areas, the congruent (i.e., circled) interdependence-communication correlations of the high performing projects are larger than the congruent correlations of the low performing projects. In support of hypothesis 4.3-2, none of the off diagonal correlations are significantly greater than zero for the high performing projects.

This correlational evidence supports the idea that task interdependence, particularly with organizationally distant areas, is related to technical communication. However, correlations do not provide evidence on the average amount of communication for differences in interdependence. A corollary of hypothesis 4.3-1 is that projects with high interdependence to a particular area should have more communication to that area than projects with only a small amount of interdependence. Again, these patterns should be accentuated for high performing projects (see Table IV-5).

As predicted, for the total sample, projects with high interdependence to a particular area have significantly more technical communication with that area than do projects with a small amount of interdependence. When the projects are separated by performance, the results are accentuated in the predicted direction, but only for interdependence
### TABLE IV-5

**AVERAGE TECHNICAL COMMUNICATION FOR HIGH AND LOW DEGREES OF TASK INTERDEPENDENCE BY PERFORMANCE**

<table>
<thead>
<tr>
<th>Group Interdependence</th>
<th>Total</th>
<th>High Perform.</th>
<th>Low Perform.</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>33.8</td>
<td>35.9</td>
<td>30.1</td>
</tr>
<tr>
<td>Low</td>
<td>24.2</td>
<td>32.8</td>
<td>19.4</td>
</tr>
<tr>
<td>(Significance)</td>
<td>**</td>
<td>N.S.</td>
<td>***</td>
</tr>
<tr>
<td>(d.f.)</td>
<td>52</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Laboratory Communication</th>
<th>Total</th>
<th>High Perform.</th>
<th>Low Perform.</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>10.6</td>
<td>8.5</td>
<td>13.7</td>
</tr>
<tr>
<td>Low</td>
<td>5.9</td>
<td>3.4</td>
<td>7.9</td>
</tr>
<tr>
<td>(Significance)</td>
<td>***</td>
<td>***</td>
<td>N.S.</td>
</tr>
<tr>
<td>(d.f.)</td>
<td>53</td>
<td>26</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Organization Communication</th>
<th>Total</th>
<th>High Perform.</th>
<th>Low Perform.</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>15.1</td>
<td>15.7</td>
<td>14.0</td>
</tr>
<tr>
<td>Low</td>
<td>5.9</td>
<td>5.8</td>
<td>6.1</td>
</tr>
<tr>
<td>(Significance)</td>
<td>***</td>
<td>***</td>
<td>N.S.</td>
</tr>
<tr>
<td>(d.f.)</td>
<td>52</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

* p < .10
** p < .05
*** p < .01
with areas that are organizationally distant. High performing projects with high laboratory or organization interdependence report significantly more technical communication with the respective areas than do high performing projects with small amounts of interdependence. In each case, the low performing projects do not exhibit these differences. However, high performing projects with substantial Group interdependence (i.e., organizationally close) do not report significantly greater contact with other Group areas. Therefore, as found in the correlational analysis, Group communication seems to be insensitive to Group (i.e., organizationally close) interdependence, while communication to areas outside of the Group is strongly affected by differences in organizationally distant interdependence.

The results of this section support the basic idea that task interdependence is a source of coordination requirements. Since technical communication is one way of dealing with increased information processing demands, this section has tested the broad hypothesis that increased interdependence should be associated with increased communication. The results, however, suggest distinguishing between organizationally distant (i.e., laboratory, organization) and organizationally close (i.e., Group) interdependence. For the total sample, projects with high interdependence with organizationally distant areas reported greater communication to those distant areas than did projects with small amounts of organizationally distant interdependence. These differences were accentuated for the high performing projects. Interdependence with areas organizationally close (i.e., Group) did not affect the amount of communication. High performing projects had relatively high Group communication independent of the amount of
Group interdependence.

In all, these results suggest that technical communication is important--high performing projects have different patterns of communication than the low performing projects. The results of this section suggest that communication patterns, particularly to organizationally distant areas, are contingent on the amount of task interdependence. Communication should therefore be managed--specialized to fit the problem solving and coordination requirements of the task.
4.4 A Review of the Technical Communication Results

The analyses in this chapter have been premised on the ideas that technical communication is vital for R & D organizations, and that there is no one best way to organize communication within the laboratory. Chapter I suggested that due to information processing differences, project communication patterns would be contingent on the nature of the project's work. Task characteristics, environmental conditions, and task interdependence were postulated to be important work characteristics that affect a project's information processing requirements. This chapter, based on the organization behavior and R & D management literatures, has suggested and tested a number of hypotheses in an attempt to specify the relations between the nature of the work and the patterns of technical communication. The results will be reviewed here.

Task differences were hypothesized to affect technical communication both within and outside of the project. Differences in task predictability and the attendant differences in information processing requirements were hypothesized to affect the amount of communication within the project. The more complex research tasks were hypothesized to have greater communication within the project than the relatively more routine technical service tasks. As predicted, high performing research tasks did indeed have significantly more intra project communication than the high performing technical service areas. The low performing projects did not exhibit this difference.
The next set of analyses focused on communication outside of the project. Internal consulting has been consistently related to performance in R & D settings. Hypothesis 4.1-2 attempted to further specify the direction of effective internal consulting. Would there be differences for different task areas? For communication outside the project, it was hypothesized that the different task areas would consult more with areas that could provide technical feedback, help in setting criteria, and other problem solving assistance. This hypothesis was strongly supported for consulting within the laboratory and the larger organization. Research projects had significantly more communication than the service areas inside the laboratory, while the technical service areas had significantly more communication within their Groups and to the larger corporation than the research areas. Each of these differences were accentuated for the high performing projects. Communication outside the organization was not specialized by task characteristics. These results re-emphasize the importance of internal consulting and further add the idea that this consulting should be specialized to fit the requirements of the task.

The results of these task analyses indicated that projects with different task characteristics had different patterns of technical communication. These different patterns of internal consulting were most evident for the high performing projects. Thus, task differences did not cause communication differences; rather, high performing projects seemed to alter their communication patterns to fit the information requirements of the task.

Task interdependence can be seen as a source of information processing requirements since increased interdependence carries with
it increased coordination requirements. Hypothesis 4.3-1 suggested that projects with a substantial amount of interdependence to a particular area would have significantly more communication to that area than projects with only a small amount of interdependence. Hypothesis 4.3-2 suggested that the effects of interdependence would be specific—for instance, Group interdependence should only effect communication with the Group.

For the total sample, these hypotheses were strongly supported. However, the analyses controlling on project performance suggested distinguishing between organizationally close (i.e., Group) and organizationally distant (i.e., laboratory or organizational) interdependence. For the high performing projects, interdependence with other projects within the Group did not effect Group communication. However, projects with substantial interdependence with organizationally distant areas had significantly more communication to those areas than projects with a small amount of interdependence. These results were accentuated for the high performing projects. In all, projects with different amounts of organizationally distant interdependence had different patterns of technical communication. Like the effects of task differences on technical communication, distant interdependence did not cause increased technical communication. Rather, high performing projects seemed to adjust their communication patterns to fit the coordination requirements of organizationally distant interdependence.

The rate of change of technical and market conditions was hypothesized to be another source of uncertainty to which the project must respond. Hypothesis 4.2-1 reasoned that under changing environmental conditions, projects would have to both gather information from the
external technical and market worlds and begin to deal with that uncertainty. Communication outside the organization and within the project was, therefore, hypothesized to increase under changing environmental conditions. Contrary to the predictions, there were no overall effects of environmental variability on intra project or extra organizational communication. While there were no overall effects of environmental variability on intra project communication, hypothesis 4.2-3 reasoned that environmental conditions would affect the complex research tasks more so than the relatively routine technical service tasks. As hypothesized, increased environmental variability was associated with increased intra project communication for research projects, but not for the technical service projects.

The specific effects of environmental variability on intra project communication suggested looking at the possible specific effects of environmental conditions on communication with areas outside of the organization. This set of analyses uncovered some unexpected results. In the discussion of task differences on communication patterns, it was reasoned that due to professional interests and the location of relevant information, that research and technical service areas would communicate with different areas outside of the organization. More specifically, it was suggested that research personnel would communicate more with the external professional areas, while the technical service personnel would communicate more with external operational areas. It was further thought that if the technical and market worlds were changing, then to keep track of this increased uncertainty, research projects would increase their professional communication, while the technical service areas would increase their operational communication.
Contrary to expectations, for the high performing projects, environmental variability was associated with decreases in the amount of professional communication of research areas and in the amount of operational communication of technical service areas. Where technical communication outside of the organization was expected to increase, it in fact decreased. The question was raised as to how the project is connected to the external technical and market areas when those areas are in a state of flux. This seems to be a particular problem since the need to keep track of environmental conditions should be greatest when the environment is not stable.

Hypothesis 4.2-2 suggested that environmental conditions would not affect technical communication to areas inside the laboratory or to the larger organization. While there were no statistically significant effects of environmental conditions on technical communication, projects facing a changing environment consistently reported less communication than those projects facing a stable environment. This negative relationship tended to be accentuated for the high performing projects. If technical communication decreases throughout the laboratory and larger organization under changing environmental conditions, the question was raised as to how the project maintains the required amount of organizational communication in the face of these changing conditions. This should be particularly important since changes in technical or market conditions could affect problem parameters and require increased amounts of organizational decision making.

Unlike the task or interdependence results, the effects of environmental variability were, for the most part, unexpected. The environment results raised a number of questions. While there were no overall
effects of environmental conditions on technical communication, environmental variability was consistently associated with decreases in technical communication. These results suggested that environmental variability may be fruitfully seen as a source of information overload or threat. Under these threatening conditions all communication outside the project seemed to decrease. If technical communication does decrease as environmental variability increases, and if this variability increases the information processing requirements of the project, then the questions remain as to how the project keeps track of environmental conditions, and how the coordination and problem solving requirements in other areas of the organization are met, when the environment is in a state of flux. The chapter suggested that increased communication may not be required to deal with environmental variability. Technical roles may evolve to link the project to both the external technical and market worlds as well as to other areas in the organization. If so, while the overall amount of communication may decrease, the increased information processing requirements may be more directly attended to by these specialized roles. This interpretation suggests looking in greater detail at the distribution of technical communication. Internal and external communication may not be equally distributed throughout the laboratory.

In summary, the results of this chapter support the findings that internal consulting is important. These results go on to show that different areas in the laboratory have different patterns of internal consulting. For the high performing projects, patterns of technical communication are contingent on the nature of the work—particularly the characteristics of the tasks and the amount of task interdependence.
The results also indicate that the nature of the work does not cause different communication patterns. Rather, high performing projects seem to match their technical communication behavior to the problem solving and coordination requirements of task differences, interdependence differences, and the amount of environmental variability.

Communication inside the project should be greater the more complex the task, while communication outside the project should be directed to areas of task interdependence and other locations of technical feedback and support. What is surprising is that environmental variability seems to be only weakly related to communication and that high performing projects tend to have less communication under changing environmental conditions. It was suggested that the environment may be seen as a threat or overload. If so, then under changing environmental conditions, technical roles may evolve to link the project to the external technical and market areas as well as to other organizational areas.
CHAPTER V

PROJECT COMMUNICATION STRUCTURE

The Degree to which Project Communication is Centralized or Decentralized

Research and Development organizations must be capable of acquiring relevant information and effectively utilizing that information. Chapter IV focused on the overall amount and direction of technical communication. This chapter will focus on the determinants and effects of different patterns of technical communication within the project.

Patterns of intra project communication affect the information processing capacity of the project. Projects with relatively few rules and less emphasis on hierarchy tend to have more extensive and diverse patterns of internal contact. As Gerstberger (1971) notes, extensive face to face communication stimulates the exchange and evaluation of ideas and thereby enhances the problem solving capacity of the project. On the other hand, projects with more rules, standard procedures, and greater reliance on the supervisor, tend to have less intense and diverse technical communication. As discussed in Chapter II, the problem solving capacity of projects with these more formal characteristics is less than the problem solving capacity of the more informal projects.
Patterns of communication within the project will be described in terms of communication structure. Projects in which there is a high proportion of face to face contact among peers have a decentralized communication pattern. Projects where there is relatively less direct contact among peers and more communication that is mediated by the supervisor have a centralized, or hierarchical, communication pattern. Hierarchical communication patterns tend to be associated with formality and attention to rules within the project. Further, the degree of supervisory control is greater in centralized projects than in decentralized projects (Duncan, 1973; Hage et al., 1971).

Chapter II proposed that a project's communication network characteristics must be able to deal with its information processing requirements. The project's work characteristics were introduced as sources of technical uncertainty. Since project structure is a source of information processing capacity, if projects have different work characteristics, then the projects should have different degrees of structure. The basic idea is that there is no one best way of organizing communication within the project, but that project communication must be appropriate to the requirements of the work. This chapter will therefore investigate the effects of each source of problem solving requirements in an attempt to specify the nature of the contingent relationships hypothesized in Chapter II. Hypotheses dealing with the effects of task characteristics, environmental conditions, and task interdependence on project communication structure will be developed from the literature and tested. The chapter will conclude with a review of the results.
5.1 Task Characteristics and Project Communication Structure

The effects of task or technology differences on structure have been studied from both group and organizational orientations. Both perspectives will be reviewed here to provide insight on the effects of task characteristics on project communication structure.

Since Woodward's (1965) seminal study, the nature of the task has been treated as a primary variable affecting organizational structure. The advocates of a technological imperative (e.g., Aldrich, 1972) have presented a strong case although they have been criticized for the multiple operational definitions of technology (e.g., Lynch, 1974). The definitions tend to differ by level of analysis. Hickson et al.'s (1969) degree of automation, Harvey's (1968) frequency of major product change, and Woodward's (1965) complexity of the production process are all system-wide definitions. Perrow (1970), Hage and Aiken (1969, 1970), and Lynch (1974) use the individual task as their level of analysis. While the operationalizations differ, technology has been consistently seen as a dimension of complexity (e.g., routine-nonroutine). Further, the results from the different levels are generally quite consistent.

Woodward (1965), studying 200 small manufacturing firms, found that structural differences within technological categories
were smaller than differences between categories, thus indicating an effect of technology on structure. Woodward found that the structure of the organizations (number of levels in hierarchy, ratio of managers to nonmanagers) increased directly with the predictability of the tasks. Hage and Aiken (1969) studied social agencies and found that routine agencies (e.g., case worker) were more formalized and centralized than nonroutine (e.g., psychiatric) agencies. Both Perrow (1965), analyzing hospital organizations, and Khandwalla (1975) studying manufacturing organizations, found that organizations with more complex tasks were less structured than organizations with less complex tasks.

Like the studies at the organizational level, there have been a number of studies investigating the effects of task differences on departmental structure. Lawrence and Lorsch (1967) and Smith (1970), in a set of field studies, found that research departments were less formal and less structured than were manufacturing or sales areas. In more general terms, Van de Ven and Delbeque (1974) found that departments undertaking tasks that differed in difficulty and variability were structured differently. They hypothesized that complex tasks require less formality, less centralization, and fewer rules than do the less complex tasks. Similarly, Hall (1962) found that differences in departmental structure were due to the type of task performed by the department. Hall found that departments with routine tasks were more structured than departments with complex tasks. Hrebinjak (1974) found similar results after controlling for the effects of group supervision.
At the work group level of analysis, the small group literature dealing with communication networks is relevant to the task-structure relationship. Since the original studies by Bavelas (1955) and Leavitt (1951), much research has been done on the effects of small group sociometric structure. Shaw (1964), in an extensive literature review, concluded that centralized networks are more effective for simple problems, while decentralized networks are more effective for complex problems. However, Shaw warned of the lack of generalizability since the issue of embeddedness (i.e., interdependence) had not been addressed. Burgess (1968) has questioned Shaw's conclusions. He found no differences in network efficiency between centralized and decentralized networks if transient effects were allowed to dampen. A middle ground position has been supported by Snadowsky (1971). He found that decision phase makes a difference. For complex tasks, decentralized networks were best for the more complex problem definition phase, while a more centralized network was best for the more pragmatic operational phase. For simple tasks, the centralized network was best for both phases.

All of the small group studies were done in the laboratory. Glanzer and Glaser (1961) and Cohen et al. (1969) have questioned the theoretical and organizational utility of the results. Nevertheless, these results, although somewhat inconsistent, are suggestive when seen as a compliment to the organizational studies of task and structure.

Both the organizational and group studies can be interpreted within the information processing perspective. To the extent that the project's task is complex, the project must attend to increased
information gathering and processing requirements. The more complex the task, the less it is likely that the requisite task information will be with any one individual, including the supervisor. Structurally, this calls for greater project participation, emphasis on informal contact and flexible rules—in short, a decentralized pattern of project communication. On the other hand, tasks that are more routine are likely to have a greater potential for fixed programs, rules, and supervisory decision making. If so, then relatively routine tasks will have more hierarchical patterns of communication than less routine tasks.

This review suggests the following hypothesis:

5.1-1 The greater the task complexity, the more decentralized will be the patterns of project communication.

Results.—Hypothesis 5.1-1 suggests that the more complex tasks (i.e., research) will have less hierarchical communication patterns than the more routine tasks (i.e., technical service). For the total sample (see Table V-1), research projects are significantly less structured than the technical service areas. However, this pattern does not hold for both the high and low performing projects. For the high performing projects, the difference in project structure between research and technical service areas is accentuated in the predicted direction. The difference in amount of structure for the low performing projects did not approach statistical significance. There is further support for this hypothesis. A corollary of hypothesis 5.1-1 is that the correlation between task characteristics
### TABLE V-1

PROJECT STRUCTURE AND TASK CHARACTERISTICS

Average Structure for Research and Service Projects and Correlation of Task Characteristics with Project Structure

<table>
<thead>
<tr>
<th>Average Project Structure</th>
<th>Research</th>
<th>Service</th>
<th>Signif. (d.f.)</th>
<th>Corr.</th>
<th>Signif. (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3.2</td>
<td>7.5</td>
<td>* (21)</td>
<td>.22</td>
<td>* (41)</td>
</tr>
<tr>
<td>Performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1.2</td>
<td>7.4</td>
<td>** (13)</td>
<td>.26</td>
<td>* (22)</td>
</tr>
<tr>
<td>Low</td>
<td>5.6</td>
<td>8.0</td>
<td>N.S. (6)</td>
<td>.14</td>
<td>N.S. (19)</td>
</tr>
</tbody>
</table>

* * p < .10

** ** p < .05

Note: The higher the score the greater the degree of structure.

(see Chapter III for greater detail)
and project structure should be positive. The more routine the task
the more the project should have hierarchical patterns of communica-
tion. The correlation coefficients in Table V-1 support this
hypothesis. Again, the hypothesis holds only for the high performing
projects.

Hypothesis 5.1-1 is strongly supported. For the high perform-
ing projects, the amount of project structure is indeed contingent on
task characteristics. These results combined with the results of
section 4.1 indicate that high performing research projects deal with
their increased information processing requirements through increased
intra project communication and with more decentralized patterns of
intra project communication. High performing technical service
projects, on the contrary, deal with their relatively more routine
task requirements with less intra project communication and with
centralized patterns of communication within the project. It can be
inferred that there is greater supervisory involvement in the high
performing technical service projects than in the high performing
research project.

Patterns of communication within the project do seem to have
important information processing implications. High performing
projects have systematically different patterns of project communica-
tion than the low performing projects. Research projects have
greater information processing requirements and therefore have less
hierarchical patterns of project communication than the technical
service projects. Patterns of intra project communication should
therefore be managed to fit the information processing requirements
of the task.
5.2 Environmental Variability and Project Communication Structure

The project's task environment can be seen as a source of uncertainty to which the project must respond. The effects of environmental variability on structure have been studied from both micro and macro orientations. Both perspectives will be reviewed here to provide insight on the effects of environmental change on project communication structure.

At the organizational level of analysis, Thompson (1967), Schein (1970), and Katz and Kahn (1966) have suggested that the more complex the environment, the more uncertainty the organization must respond to and therefore, the more the organization must be flexible, adaptive, and less constrained by formal rules and procedures. Under conditions of a stable environment, more formal structures are hypothesized to be appropriate because of the reduced information processing requirements. Studies done testing these ideas have been generally supportive. Burns and Stalker (1966), Randall (1973), and Miller (1971) have found that for a changing task environment, the more successful organizations were less structured than the less successful organizations. For stable environmental conditions, the reverse patterns were found. Burns and Stalker (1966) found that successful organizations in stable environments were more formal and structured than the less successful organizations.
Lawrence and Lorsch (1967) and Duncan (1973) have brought environmental concerns to the department and group levels of analysis. Using systems logic, they hypothesize that the subunit is an appropriate unit of analysis for organizational studies, and that as the task environment becomes more unstable, the focal unit must evolve appropriate structural conditions. Duncan (1973) hypothesized that the same unit may face several environments, and therefore, may have different structures to deal with the different problem solving requirements. Lawrence and Lorsch (1967) and Negandi and Reimann (1974) report that under conditions of changing environments the more successful departments were less structured than the less successful departments. For stable environments, Lawrence and Lorsch (1967) found that the more structured departments were most effective. Similarly, Duncan (1973) found that the more successful groups in a changing environment were less structured than the less successful groups; he found the reverse results for projects in a stable environment.

All of these studies can be interpreted from the information processing perspective. If the environment is a source of uncertainty, then the focal unit must respond with an appropriate information processing structure. Different structures have different problem solving capacities (Maier, 1970; Smith 1970). As Chapter II suggested, an important characteristic of the project's structure is its ability to gather and process information. If the project has few rules, flexible roles, and little hierarchy, then its potential to handle uncertainty is high (Weick, 1969; Maier, 1970). Therefore, work units in unstable
environmental conditions should be decentralized. If however, environmental uncertainty is low, and information processing demands are correspondingly less, then the information processing capacity of a decentralized group may be unnecessary. Under stable conditions, the work unit may respond most effectively and efficiently by relying on formal rules, set procedures, and supervisory direction rather than by relying on extensive participation and flexibility.

This review suggest the following hypotheses:

5.2-1 The greater the environmental change, the more decentralized will be the patterns of project communication.

5.2-2 Hypotheses 5.1-1 and 5.2-1 suggest that task complexity and environmental change are sources of uncertainty. Both variables have been hypothesized to be negatively related to structure. The union of these two hypotheses suggest an interaction of task and environmental conditions. For routine tasks, increased environmental variability means more and perhaps more rapid routine decision making. Under these conditions the information gathering and processing needs are still predicted to be low, even though the response pressures may increase. The increased frequency of these relatively standard decisions can best be handled through greater supervisory control and greater group formalization (Thompson and Tuden, 1959). For nonroutine tasks however, increased environmental uncertainty increases the already complex information processing needs. The extremely high information processing requirements due to task and environmental
demands can best be attended to with a small amount of project structure and a high degree of internal flexibility (Maier, 1970; Weick, 1969). This logic suggests that under conditions of a changing environment, the difference in structure between research and service work units will be greater than under conditions of a stable environment.

Results.-- To test hypothesis 5.2-1, the degree of project structure for projects in a changing environment is compared to the degree of structure for projects in a stable environment (Table V-2). The results fall in the opposite direction to those predicted. While not statistically significant, projects in a stable environment tend to be less structured than those projects in a changing environment. This difference is accentuated for the high performing projects.

These unexpected results are further supported by the correlations of environmental variability and project structure. If the hypothesis is to be supported, the correlation coefficient should be negative; increased environmental variability should be associated with less structure. Again the results are opposite to those predicted (see Table V-2). The coefficient for the total sample is significantly greater than zero. Further, the strength of this positive association increases for the high performing projects.

Hypothesis 5.2-1 is therefore soundly rejected. Environmental variability does not seem to be attended to through less project structure. These results, like those in Chapter IV, suggest that environmental variability may not be seen as a source of uncertainty to be actively dealt with, but rather as a source of overload or threat.
**TABLE V-2**

PROJECT STRUCTURE AND TASK ENVIRONMENT
Average Structure for Stable and Changing Environments and Correlations Between Environment and Structure

<table>
<thead>
<tr>
<th></th>
<th>Stable</th>
<th>Changing</th>
<th>Signif.</th>
<th>Correlation</th>
<th>Signif.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (n = 42)</td>
<td>4.5</td>
<td>6.3</td>
<td>N.S.</td>
<td>.22</td>
<td>*</td>
</tr>
<tr>
<td>Performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High (n = 22)</td>
<td>3.7</td>
<td>6.1</td>
<td>N.S.</td>
<td>.31</td>
<td>*</td>
</tr>
<tr>
<td>Low (n = 20)</td>
<td>5.1</td>
<td>6.6</td>
<td>N.S.</td>
<td>.13</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

*p < .10

Note: The higher the score the greater the degree of structure.
(see Chapter III for greater detail)
This threat seems to be dealt with by increased communication with and through the supervisor.

However, care must be taken here. It may be that there are different effects of environmental conditions for the different task areas. Hypothesis 5.2-2 proposed that changing environmental conditions would affect the research and technical service areas quite differently. It was reasoned that for the nonroutine research tasks, increased environmental variability increases the already complex information processing requirements. If so, then research projects facing a changing environment should be unstructured to facilitate active and diverse problem solving. The reverse patterns were hypothesized for technical service areas. For these relatively routine tasks, it was suggested that increased environmental variability probably does not increase the problem solving requirements of the task. The problem solving requirements may still be relatively small, even though the pressure to respond may increase. If so, then the increased pressure for rapid, relatively routine decision making may be best dealt with through greater supervisory control and greater project structure. In short, hypothesis 5.2-2 proposes an interaction effect of task characteristics and environmental conditions.

To test for the importance of this interaction, a multiple regression was performed with a term representing the task-environment interaction (see Table V-3). The regression indicates that the hypothesized interaction effect is indeed an important predictor of project structure. In fact, for the total sample, the task-
TABLE V-3

INTERACTION ANALYSIS  Project Structure as a Function of Task Characteristics, Task Environment, Group Interdependence as well as the following Interaction Effects:

Interaction Terms and Abbreviations

Task and Environment (TE)
Task and Group Interdependence (TGP)
Environment and Group Interdependence (EGP)
Task, Environment and Group Interdependence (TEGP)

(Independent Variable = Project Structure)

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Total</th>
<th>High Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task Characteristics</td>
<td>7.6***</td>
<td>--</td>
</tr>
<tr>
<td>Environment</td>
<td>2.4*</td>
<td>-1.0*</td>
</tr>
<tr>
<td>Group Interdependence</td>
<td>-9.3***</td>
<td>-12.0***</td>
</tr>
<tr>
<td>TE</td>
<td>-9.4***</td>
<td>-2.4**</td>
</tr>
<tr>
<td>TGP</td>
<td>-1.9*</td>
<td>5.6**</td>
</tr>
<tr>
<td>EGP</td>
<td>11.9***</td>
<td>8.5***</td>
</tr>
<tr>
<td>TEGP</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>$R^2$</td>
<td>.54</td>
<td>.76</td>
</tr>
<tr>
<td>$F$</td>
<td>6.34***</td>
<td>7.00***</td>
</tr>
<tr>
<td>d.f.</td>
<td>6,32</td>
<td>5,14</td>
</tr>
</tbody>
</table>

* $p < .10$
** $p < .05$
*** $p < .01$
environment interaction term is larger than each of the individual (i.e., task, environment, and interdependence) terms. For the low performing projects, the interaction is not an important predictor of project structure.

The regression coefficient, however, does not provide information on the direction of the interaction effect. To more specifically test hypothesis 5.2-2, the average amount of project structure for different combinations of task and environmental characteristics are plotted in Figure V-1. This figure clearly shows the differential effects of environmental conditions on project structure. As found in hypothesis 5.1-1, technical service projects are more hierarchical than research projects. However, these results are accentuated under changing environmental conditions. Technical service projects become more hierarchical while research projects become less hierarchical as environmental variability increases. Therefore, in support of hypothesis 5.2-2, under changing environmental conditions, the difference in structure between research and technical service areas increases. The interaction effect is found only for the high performing projects.

Environmental conditions do affect project structure, yet the effects depend on the characteristics of the task. A similar specificity of effect was found for the overall amount of communication within the project (see section 4.2). Environmental conditions consistently affect the amount and the patterns of communication within the project. Chapter IV found that research projects have more technical communication inside their areas than the technical service
FIGURE V-1:

Mean Amounts of Project Structure for Different Task and Environmental Characteristics

Total Sample (n = 22)       High Performing Projects (n = 14)

Environmental Conditions

--- = Technical Service Projects
- - - - - = Research Projects
service projects. This chapter has demonstrated that the patterns of communication inside research projects tend to be less hierarchical than the corresponding patterns of communication within technical service projects. This section and section 4.2 have both found that environmental conditions affect the different task areas in opposite ways. For research projects, increased environmental variability is associated with greater intra project communication and a more decentralized pattern of intra project communication. Technical service projects, on the other hand, have less intra project communication and a more centralized pattern of communication as environmental variability increases. These differential effects are both accentuated for the high performing projects and are not found for the low performing projects.

Environmental variability, and the increased information processing requirements associated with that variability, are treated quite differently by the various task areas. Individuals in the technical service projects seem to take changing environmental conditions as a threat, and respond by relying more on supervisory direction and less on communication within the project. On the other hand, individuals in the research projects seem to respond to the increased problem solving requirements by increasing the amount of intra project consulting and by relying even less on supervisory direction.

Why should there be such differences in the response to environmental variability? The differences may be due to the differences in the location and distribution of technical expertise in the project. In the relatively routine technical service areas the supervisors are
likely to have more appropriate technical experience and up-to-date information than the nonsupervisors. For research areas, however, technical expertise is likely to be more equally distributed within the project. As environmental variability increases and technical and market information becomes more uncertain, then the dependency on technical experience and expertise probably increases. If so, then it makes sense that technical service areas should rely more on supervisory direction, while research projects should rely on internal project communication as environmental conditions become uncertain.

In summary, environmental variability has no simple overall effect on project communication structure. There are, however, important specific effects of environmental conditions on project structure depending on the characteristics of the work. Section 5.1 found that research projects are less structured than technical service projects. This section finds that environmental variability accentuates these differences. Thus, high performing research projects become even less structured, while high performing technical service projects become even more structured as environmental variability increases.

As found in section 5.1, high performing projects have systematically different patterns of communication within the project than the low performing projects. Project structure should therefore be managed-specialized to meet the problem solving and information processing requirements of task and environmental conditions.
5.3 Task Interdependence and Project Communication Structure

The previous sections have investigated the effects of task and environmental differences on project communication structure. The results indicate that the nature of the task has an important effect on project structure. This section will investigate the influence of organizational interdependence on project structure. That is, to what extent does the project's interdependence with other areas affect its patterns of communication within the project? Does the fact that a project exists in a setting with other task-related projects affect its degree of communication structure?

The information processing perspective suggests that interdependence between projects requires coordination. To the extent that work units are differentiated, yet are also task interdependent, then they must resolve the issues of coordination and joint problem solving. Section 4.3 suggested that increased interdependence must be handled with greater communication with the relevant areas. This section will deal with the interdependence-structure relationship. Because there is no literature in this area, the hypotheses will be developed from the information processing perspective.

From systems logic, organizations can be seen as made up of differentiated units with varying degrees of interdependence. This differentiation carries with it information processing implications. As Lawrence and Lorsch (1967) and March and Simon (1957) have
observed, differentiated subunits develop local rationality. This local rationality is associated with idiosyncratic norms, values, time frames, and coding schemes which make communication across boundaries difficult and prone to distortion (e.g., Dearborn and Simon, 1958). The more dissimilar (or the more organizationally distant) the communicating areas, the greater the communication mismatch. These communication difficulties will therefore be exacerbated as the number of organizational boundaries between interdependent projects increase. (In this study, physical distance and organizational boundaries can not be treated separately since organizationally distinct areas are also physically separated from each other). The ease of communicating within organizational boundaries, and the difficulty and inefficiency of communicating across organizational boundaries are the keys to the hypotheses on the effects of interdependence on project structure.

If projects have no task interdependence with other areas, then there are no coordination requirements. However, most projects have work interdependence with organizationally close and organizationally distant work areas. (Organizationally close areas are within a project's Group, while organizationally distant areas are outside of the laboratory in the larger organization). If the project's communication structure is influence by information processing requirements, and if interdependence is a source of information processing requirements, then there should be differences in project structure for differences in task interdependence. It can be hypothesized that if interdependent projects are organizationally close (i.e., communication
observed, differentiated subunits develop local rationality. This local rationality is associated with idiosyncratic norms, values, time frames, and coding schemes which make communication across boundaries difficult and prone to distortion (e.g., Dearborn and Simon, 1958). The more dissimilar (or the more organizationally distant) the communicating areas, the greater the communication mismatch. These communication difficulties will therefore be exacerbated as the number of organizational boundaries between interdependent projects increase. (In this study, physical distance and organizational boundaries can not be treated separately since organizationally distinct areas are also physically separated from each other). The ease of communicating within organizational boundaries, and the difficulty and inefficiency of communicating across organizational boundaries are the keys to the hypotheses on the effects of interdependence on project structure.

If projects have no task interdependence with other areas, then there are no coordination requirements. However, most projects have work interdependence with organizationally close and organizationally distant work areas. (Organizationally close areas are within a project's Group, while organizationally distant areas are outside of the laboratory in the larger organization ). If the project's communication structure is influence by information processing requirements, and if interdependence is a source of information processing requirements, then there should be differences in project structure for differences in task interdependence. It can be hypothesized that if interdependent projects are organizationally close (i.e., communication
does not have to cross Group boundaries), then the requisite coordination will be best accomplished through low structure, i.e., through informal contact, low reliance on the supervisor, and relatively high peer communication. This low structure-high interaction pattern will be effective because of the ease of communication between organizationally close areas and the efficiency of direct contact under these conditions.

On the other hand, if interdependent projects are organizationally distant (i.e., communication must cross laboratory boundaries), then the required coordination may not be best accomplished through low structure and widespread contact. Coding, linguistic, and task differences between the differentiated units make widespread informal face to face contact inefficient. Direct contact with organizationally distant areas will therefore be constrained. The contact that does exist may be mediated by the project supervisor. If supervisors become contact points to organizationally distant areas under conditions of high interdependence, then project communication structure will be more hierarchical since project members will have to coordinate their behaviors through the supervisor.

Organizational differentiation and the requirements of interdependence suggest the following hypotheses:

5.3-1 Projects with substantial interdependence with areas that are organizationally close will be less hierarchical than projects with a small amount of interdependence with areas than are organizationally close.
5.3-2 Projects that have substantial interdependence with areas that are organizationally distant will be more hierarchical than projects with a small amount of interdependence with areas that are organizationally distant.

Results. -- Interdependence has been discussed as a source of coordination requirements. This review has distinguished between organizationally close (i.e., within the same Group) interdependence and organizationally distant (i.e., outside of the laboratory in the larger organization) interdependence. Hypothesis 5.3-1 suggested that due to coding and linguistic similarities, interdependence with areas that are organizationally close would be best accomplished through widespread face to face contact, low reliance on the supervisor, and therefore, relatively low project communication structure.

Table V-4 displays the mean amount of project structure for conditions of high and low Group interdependence. For the total sample, projects with substantial Group interdependence are less structured than projects with a small amount of Group interdependence. When high and low performing projects are separated, the support for hypothesis 5.3-1 is stronger. High performing projects with substantial Group interdependence are significantly less structured than the high performing projects with a small amount of Group interdependence. The low performing projects do not exhibit this difference. Therefore, as predicted, interdependence with organizationally close areas is best dealt with through low project structure and therefore, less reliance on the supervisor.
<table>
<thead>
<tr>
<th>Interdependence</th>
<th>Group</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>5.0</td>
<td>5.4</td>
</tr>
<tr>
<td>Low</td>
<td>6.0</td>
<td>5.7</td>
</tr>
<tr>
<td>Signif.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

**Total (n = 41)**

<table>
<thead>
<tr>
<th>Performance</th>
<th>Group</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>High (n = 21)</td>
<td>4.6</td>
<td>7.0</td>
</tr>
<tr>
<td>Low (n = 20)</td>
<td>5.8</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>6.3</td>
<td>3.0</td>
</tr>
<tr>
<td>Signif.</td>
<td>*</td>
<td>**</td>
</tr>
</tbody>
</table>

* p < .10  
** p < .05 

one tail test
Hypothesis 5.3-2 proposed a positive relation between organizationally distant interdependence and project structure. Due to coding and linguistic differences and the attendant communication difficulties that exist between areas that are separated by organizational boundaries, it was suggested that organizationally distant interdependence would be most effectively handled through the project supervisor. Due to the communication difficulties, direct face to face contact was proposed to be ineffective. If so, then projects with substantial interdependence with areas in the larger organization should have more hierarchical communication patterns than projects with a small amount of organizationally distant interdependence.

Table V-4 displays the mean amount of project structure for conditions of high and low organizational interdependence. While there are no differences in the amount of project structure for the total sample, when high and low performing projects are separated, there is considerable support for the hypothesis. High performing projects with a large amount of organizationally distant interdependence are significantly more hierarchical than the high performing projects with a small amount of organizationally distant interdependence. The difference in structure for the low performing projects is statistically significant, yet in the opposite direction to the difference for the high performing projects.

These results indicate that project communication structure is contingent on the amount of task interdependence faced by the project. The specific relationship between interdependence and structure depends on the location of the interdependence. For high performing
projects, organizationally close interdependence is negatively associated with the degree of hierarchy, while organizationally distant interdependence is positively associated with project structure. These results were explained by citing the ease and effectiveness of intra Group communication and the difficulty and potential distortion of communication that must cross organizational boundaries.

A final, more specific, test can be made to explore the differential effects of organizationally close and distant interdependence. Projects which reported a substantial amount of Group interdependence and a small amount of organizational interdependence can be compared with projects that reported low Group interdependence and high organizational interdependence (Table V-5). If hypotheses 5.3-1 and 5.3-2 have merit, then projects with only Group (i.e., organizationally close) interdependence should have less hierarchical communication patterns than projects with only organizational (i.e., organizationally distant) interdependence. The results in Table V-5 indicate support for this logic. While there are no significant differences for the total sample, this overall result hides important differences between the high and low performing projects. As hypothesized, high performing projects with substantial organizationally close interdependence are significantly less hierarchical than projects with a substantial amount of interdependence with areas that are organizationally distant. The low performing projects do not exhibit this difference. In fact, the patterns for the low performing projects are the reverse of the high performing projects.

Chapter IV suggested that increased interdependence is attended
### TABLE V-5

**COMPARISON OF AVERAGE PROJECT STRUCTURES**

Projects with High Group and Low Organization Interdependence Compared with Projects with Low Group and High Organization Interdependence

<table>
<thead>
<tr>
<th></th>
<th>High Group and Low Organization Interdependence</th>
<th>Low Group and High Organization Interdependence</th>
<th>Signif.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (n = 20)</td>
<td>5.2</td>
<td>6.3</td>
<td>N.S.</td>
</tr>
<tr>
<td>Performance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High (n = 12)</td>
<td>3.2</td>
<td>9.0</td>
<td>*</td>
</tr>
<tr>
<td>Low (n = 8)</td>
<td>12.0</td>
<td>4.1</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

* * p < .10
to through increased technical communication. This section suggests that for high performing projects, this increased communication takes place in the context of different patterns of intra-project communication depending on the location of the interdependence. Interdependence with areas organizationally close seems to be best handled with a substantial amount of Group communication and a decentralized pattern of intra-project communication. Interdependence with areas that are organizationally distant is also dealt with through increased amounts of communication. However, because of the difficulty of communication across organizational boundaries, the increased communication seems to take place in the context of relatively centralized patterns of project communication. This section has suggested that the supervisor mediates the technical communication between project members and organizationally distant areas. In this way, the supervisor acts as a boundary spanner, or liaison, to other areas in the organization.

In summary, project interdependence does indeed have important effects on the patterns of project communication. Depending on the amount and location of the interdependence, high performing projects have systematically different amounts of project structure than the low performing projects. Therefore, patterns of project communication should be managed-specialized to fit the coordination and problem solving requirements of task interdependence.
5.4 A Review of the Project Communication Structure Results

To be most effective, projects in R & D settings must effectively gather and process technical information. This chapter has focused on the patterns of technical communication among project members. As Smith (1970) and Farris (1972) have shown, different patterns of project communication affect the information processing capacity of the project. Patterns of project communication can be described in a number of ways; this chapter has specifically looked at the extent to which project communication follows hierarchical lines. Projects with relatively more communication through the supervisor were termed centralized, while projects with relatively less supervisory-oriented communication and more peer-oriented communication were termed decentralized.

A basic assumption of the analysis was that a project's communication network characteristics should be able to deal with its information processing requirements. Since information processing requirements have been hypothesized to differ because of differences in the nature of the work, it was suggested that there would be no one best way to organize communication within the project. From Chapter II, sources of information processing requirements include task characteristics, environmental conditions, and the amount of task interdependence. Based on the literature, this chapter has investigated the effects of these variables on project structure in an attempt to specify the nature of the contingent relations hypothesized in Chapter II. The
Differences in task characteristics were hypothesized to affect project structure. Research tasks were hypothesized to have greater information processing requirements than the less complex technical service areas. It was further suggested that decentralized patterns of technical communication would be appropriate for complex problem solving situations, while a more hierarchical communication structure would be appropriate for more routine problem solving. The results indicated that research projects were indeed less hierarchical than the technical service projects. These results were accentuated for the high performing projects and did not appear for the low performing projects. Task characteristics, therefore, did not cause structural differences. On the contrary, high performing projects seemed to have the appropriate patterns of intra-project communication to fit the requirements of the task.

Environmental variability can be seen as a source of technical uncertainty to which the project must respond. Hypothesis 5.2-1 proposed that the greater the environmental variability, the greater the information processing requirements, and therefore, the more the communication inside the project should be decentralized. This hypothesis was rejected. There were no overall effects of environmental conditions on project structure. However, hypothesis 5.2-2 was supported. That is, the effects of environmental variability were different for the different task areas. High performing research projects dealt with changing external conditions by becoming less
structured--by relying on extensive and diverse communication within the project. Technical service areas, on the other hand, dealt with changing external conditions by increasing the amount of hierarchy--by relying more on supervisory-oriented communication and less on internal (to the project) consulting.

Therefore, as found in Chapter IV, while there were no overall effects of environmental conditions, these conditions had quite important specific effects on project structure and on the amount of intra project communication. Research projects acted as if changing environmental conditions were seen as a source of increased problem solving requirements, while technical service areas acted as if environmental variability was seen as a threat to be dealt with through decreased intra project communication and greater reliance on the supervisor. In neither case did environmental conditions cause differences in project structure. Rather, high performing research projects were less hierarchical, while high performing technical service projects were more hierarchical under changing environmental conditions. These effects were not found for low performing projects.

Interdependence was conceptualized as a source of information processing requirements since increased interdependence requires increased coordination efforts. Due to the ease and efficiency of face to face communication with areas that are organizationally close, section 5.3 hypothesized that substantial interdependence with organizationally close areas would be best dealt with through low project structure. The data strongly supported this hypothesis--particularly for the high performing projects. On the other hand, due to the
difficulties of communicating across organizational boundaries, it was hypothesized that substantial interdependence with areas that are organizationally distant would be best dealt with through less direct contact and greater reliance on the supervisor. In support of this hypothesis, high performing projects with substantial organizationally distant interdependence were significantly more hierarchical than projects with a small amount of distant interdependence. Interdependence with areas organizationally close did not cause less project structure, while interdependence with organizationally distant areas did not cause greater structure. Rather, high performing projects matched their project structure to the information processing requirements of the different amounts of task interdependence.

In summary, the set of results reported in this chapter indicate that project communication structure is contingent on the nature of the project's work. There is, therefore, no one best pattern of communication within the project. High performing projects have different patterns of project communication depending on the task characteristics, environmental conditions, and the amount and location of task interdependence. Thus the nature of the work does not cause different amounts of hierarchical communication; high performing projects adjust their patterns of project communication to deal with the information processing requirements of the work. These results indicate that patterns of project communication are important and that they should be managed-specialized to fit the requirements of the work.
CHAPTER VI
TECHNICAL ROLES

Introduction

This study focuses on the relationship between technical communication patterns and the nature of the project's work. It has been proposed that to be effective, projects must match their communication network characteristics (i.e., patterns of communication) to the information processing requirements of their task. Chapter IV dealt with the overall amount of communication inside and outside the laboratory, while Chapter V focused on the patterns of communication inside the project. Both chapters have found that for high performing projects the nature of the work has important effects on the patterns of technical communication. However, both chapters also raised questions as to how the project is effectively connected to external areas--that is, to other areas in the laboratory, in the larger organization, and to areas outside of the organization.

Chapter V discussed the difficulties of communicating across organizational boundaries. Following the arguments of March and Simon (1958) and Katz and Kahn (1966), it was suggested that communication across organizational boundaries is difficult because of the different coding schemes, norms, and values that characterize different areas of the organization. This communication mismatch makes
communication that must cross organizational boundaries prone to distortion and bias (for empirical examples see Dearborn and Simon, 1958; or Wilensky, 1967). Following this logic, Chapter V hypothesized that projects with substantial interdependence with areas that were organizationally distant should deal with the increased coordination requirements by having the project supervisor assume a linking role. In support of this hypothesis, projects that were more interdependent with organizationally distant units were more hierarchical than those that were less interdependent. It remains to be specifically tested, however, whether the supervisor actually performs a linking role for communication between the project and organizationally distant areas.

Chapter IV focused on the effects of environmental variability on project communication. It was found that environmental variability was consistently associated with less communication to areas in the laboratory, to the larger organization, and to areas outside of the organization. The question was raised as to how the project keeps track of external conditions and internal needs under conditions of a changing environment. It was suggested that technical roles may evolve to specialize on extra organizational and organizationally distant communication under conditions of increased task uncertainty.

Therefore, both chapters IV and V have suggested that technical roles evolve to handle the special information processing requirements that exist when communication is required across organizational boundaries. There is much precedent for the existence of special roles to mediate communication between a focal unit and external areas. Organizational analysts (e.g., Thompson, 1967; March and Simon, 1958; and Allen, 1966, 1970) as well as social influence
researchers (e.g., Lazarsfeld et al., 1948) have suggested that information from external domains crosses system boundaries through specialized roles. These analysts suggest that information enters the social unit in a two-step fashion. From this view, information enters the organization or Group through individuals occupying boundary roles. Such boundary roles are important nodes in the communication network since they are strongly connected to both the internal network and to a particular external domain. Therefore, due to the difficulties of communicating across organizational boundaries, communication with external areas is not distributed equally throughout the organization's staff, but is handled by a limited set of individuals in the information network. These roles then straddle two separate coding schemes and represent an important network specialization to efficiently connect internal areas with external information domains.

Each project or Group within the laboratory has a number of external areas with which it must communicate. Since no R & D laboratory can be effective if isolated from new technological or market developments, Allen (1966, 1970), Acheilledeles et al. (1971), Utterback (1971), and Von Hippel (1975) have emphasized the importance of continuing contact with external technical and market sources of information. The project faces other external areas, though. Langrish et al. (1970), Myers and Marquis (1969), Utterback (1971) and Prakke (1975) have stressed the importance of the laboratory to larger organization interface. If awareness of market need and manufacturing capabilities are important for successful innovation, then the R & D facility must be well integrated with marketing, sales, and manufacturing areas outside of the laboratory, yet within the larger organization. Finally,
Rosenbloom and Wolek (1970) and Lawrence and Lorsch (1967) have focused on the importance of integration within differentiated organizations. To the extent that different areas in the laboratory must work together and exchange accurate information, then the laboratory must deal with the problems of integration that accompany differentiation. In short, this review suggests that from the project's perspective there are at least three boundaries that are critical. If communication across these boundaries is important, and if communication across organizational boundaries is difficult, then there may well be technical roles to connect the project or Group to each area --that is, to areas outside the organization, to areas outside the laboratory in the larger organization, and to other areas within the laboratory. Special roles may evolve to handle each boundary or individual roles may specialize on several boundaries. These issues will be discussed and explored below.

This chapter will therefore focus on the technical role as a network adaptation to handle the special information processing requirements that exist when communication must cross organizational boundaries. This chapter will be different from the others in that it will develop hypotheses as well as explore a number of research questions. The chapter will be divided into three sections: the first deals with the existence of the several roles; the second with the characteristics of the different roles and the degree of role overlap; while the final section will focus both on the relationship between the number of roles and project performance and on the distribution of the technical roles in the laboratory.
6.1 The Existence of Technical Roles

This section will review the relevant literatures that deal with technical roles. There will be a separate discussion of gatekeepers, organizational liaisons and laboratory liaisons.

Gatekeepers

Thompson (1967), Weick (1969), and Katz and Kahn (1966) suggest that boundary roles must develop to keep track of external market and technical conditions. These theoretical essays have been supported by a number of studies documenting the importance of up to date market and technical information for organizational viability (Allen, 1966; Langrish et al., 1972; Czepiel, 1975). However, a number of studies have found a consistently negative relationship between R & D communication to extra organizational domains and organizational performance (e.g., Baker et al., 1967; Allen, 1964; Shilling and Bernard, 1964). If communication to extra organizational domains is negatively related to performance, yet this external information is important for organizational adaptation, then how are R & D organizations most effectively connected to extra organizational market and technical information worlds?

Allen (1966) and Allen and Cohen (1969) have suggested that key nodes in the laboratory information network mediate the technical communication from external domains into the internal information
network. Based on the opinion leadership and voting studies of the 1950's (Lazarsfeld and Katz, 1955) and on Rodgers and Shoemaker's work (1971) on the diffusion of innovation, Allen and Cohen (1969) hypothesized that there exist key people in a laboratory's information network. These key people, or internal communication stars, were hypothesized to serve as links to external information worlds. Allen and Cohen (1969) hypothesized that external information would be channeled into the organization through these key people. In a small research and applied research laboratory, Allen and Cohen (1969) identified internal technical communication stars (people whose communication exceeded the laboratory mean by at least one standard deviation) and found that the internal stars were indeed significantly more strongly connected to external sources of information (i.e., outside friends, journals, professional societies) than were the nonstars. Those internal stars who were also high on external contact were termed gatekeepers. In support of this network specialization idea, Allen (1970) found that while the overall relationship of external communication to performance was negative, for the technical stars the relation was positive. Allen (1970) replicated these gatekeeper findings in a large aero space firm. The gatekeepers in both studies were high technical performers, more educated than the nonstars, and 40 to 50 percent were first line supervisors.

In a recent review of a set of gatekeeper studies, Allen (in press) speculates on the relationship between individual and organizational characteristics and gatekeeper status. Allen suggests that technical competence is the primary causal factor in becoming a gatekeeper. He argues that technical competence is due, at least in part, to contact and familiarity with external sources of information. Competence in
turn attracts consultation from colleagues and may lead to promotion. Supervisory status further enhances the individuals ability to communicate with external areas and may increase the individuals technical reputation. Thus, supervisory status probably does not lead to the gatekeeper role. What is more likely is that technical competence leads to both colleague consultation and to promotion. If technical competence is the primary causal factor in leading to the gatekeeper role, and if there are different technical requirements in the laboratory, then there may be systematic differences in role characteristics and behavior for different areas of the laboratory.

The technological gatekeeper has stimulated much research. The results strongly support the existence of the gatekeeper role, yet suggest that there may be role differences based on the nature of the task. A set of the gatekeeper studies will be reviewed here.

Using Allen's methods, Taylor (1972) found gatekeepers in a large military laboratory. In this setting, the gatekeepers were more educated and had more experience than the non-stars and 50 per cent were supervisors. Frost and Whitley (1971) replicated Allen's study in an English metallurgical consulting firm. The gatekeepers in this setting were not more highly educated, but were older and had more experience than the non-stars. Further, a full 75 per cent of the gatekeepers were supervisors. Pettigrew (1972), studying the gatekeeper role in a manufacturing setting, found that each of the gatekeepers were supervisors. Finally, in another gatekeeper replication in a large government laboratory, Whitley and Frost (1973) found no gatekeepers in research areas, yet did find gatekeeper specialization in the more
routine technical service areas. The gatekeepers in the technical service areas were older than the non stars and were not more educated. As in their earlier study, Whitley and Frost found that 75 per cent of the gatekeepers were supervisors.

Each of the studies support the basic idea of the gatekeeper role to channel technical information from external areas into the organization. The results of these studies differed only in the characteristics of the roles. The studies done in organizations with complex tasks (i.e., Allen, Taylor) found the gatekeepers to be more educated than the non stars; further, in these studies only half of the gatekeepers were supervisors. However, studies done in organizations with less complex tasks (e.g., Frost and Whitley, Pettigrew) found that the gatekeepers were very likely to be supervisors and were not more educated than the non stars. These results support the idea that there are role characteristic differences based on the nature of the task. Differences in role characteristics will be discussed in greater detail later in this section.

Task differences may affect the gatekeeper role in another fashion. Since research projects require state of the art technical input, research projects must be connected to professional areas outside of the laboratory. Because of the importance of this professional communication bond, it may be that research gatekeepers direct their external communication more specifically to universities, professional societies, and to the professional literature. On the other hand, technical service areas require up to date information on new products, processes, and markets. If so, then the gatekeepers in the technical service areas
may focus their external communication more toward suppliers, vendors, and customers. This logic suggests that the gatekeepers may not attend to all external communication areas, but may focus on specific external domains depending on the requirements of the task.

There is inferential evidence for this gatekeeper specialization idea from the few studies that did not find extra organizational communication to be mediated by gatekeepers. Whitley and Frost (1973) found no support for the gatekeeper hypothesis in research areas. They argued that scientists do not have difficulty in communicating across organizational boundaries and that, therefore, gatekeepers should not exist. However, their measure of external communication lumped all external communication together. While there was no role specialization to all external areas, there may well have been role specialization to professional areas. Similarly, Walsh and Baker (1973), focusing on a single development project, found that stars did not communicate more than non-stars to professional areas (i.e., literature, professional societies). However, there may well have been role specialization for communication with suppliers, vendors, and customers. Since Walsh and Baker only measured professional communication, they could not test this hypothesis. In all, these studies lend support to the idea that gatekeepers do not attend to all external communication areas. It may be, however, that gatekeepers specialize their external communication activity to fit the requirements of their task area.

Due to the locus of relevant and important information, it can be hypothesized that for research projects the professional communication
boundary is more critical than the operational communication boundary. The reverse should hold true for the technical service areas. If so, it can be hypothesized that:

6.1-1 There will be gatekeeper specialization by task area. Stars in research projects will have significantly more communication than the non-stars to professional (i.e., universities, professional societies) areas outside of the organization. Similarly, stars in technical service areas will have significantly more communication than the non-stars to operational (i.e., suppliers, vendors, customers) areas outside the organization.

Technical Liaisons

The literature on technical roles deals mostly with gatekeepers. However, if organizations are differentiated systems, then there are at least two other external domains of importance to the project or Group. The literature dealing with innovation suggests that the R & D laboratory to corporation bond is critical (e.g., Von Hippel, 1975; Utterback, 1971; Gerstenfeld, 1970; Myers and Marquis, 1969). Further, both the innovation and organization literatures suggest that internal integration between differentiated subunits is also important (e.g., Achilladeles et al., 1971; Lawrence and Lorsch, 1967; Rosenbloom and Wolek, 1970). The intra-laboratory and laboratory-organization interfaces each present their own coding and linguistic barriers to accurate and unbiased communication. If areas within the laboratory and between the laboratory and the larger organization are
considered as external communication domains, then the two-step analysis can be extended to these areas.

Organizational Liaisons

Studies on the diffusion of innovation (Czepiel, 1975; Langrish et al., 1972) as well as on the process of innovation (Prakke, 1975; Utterback, 1971; Gerstenfeld, 1970; Myers and Marquis, 1969) emphasize the importance of the laboratory to corporation interface. These studies have found that market need and technical capacity must be matched for the development and production of successful innovations (Gerstenfeld, 1970; Gibbons, 1973). If these studies have merit, then communication between the laboratory and marketing and sales areas of the organization is of critical importance. Abernathy (1975) has expressed this integration problem in terms of problem solving between the laboratory and the larger organization.

As discussed earlier, contact across organizational boundaries is difficult because of task and coding differences between the differentiated areas. Following the gatekeeper logic, it can be hypothesized that specialized roles attend to this cross boundary communication. Indeed, what Myers and Marquis (1969) and Chakrabarti (1973) term key people or product champions are probably more than particularly active individuals; they may be key nodes in the information network bridging the laboratory and organizational areas. As suggested in Chapter V, communication between the laboratory and the larger organization may not be equally distributed among the laboratory personnel. What is more likely is that this inter-organizational
communication is accomplished through special technical roles—i.e., organizational liaisons. It will, therefore, be hypothesized that communication between the R & D laboratory and the larger organization will not be direct, but will be mediated by organizational liaisons.

6.1-2 Internal technical stars will have significantly more technical communication to areas in the larger organization than the non stars.

Laboratory Liaisons

A number of organizational analysts have emphasized the importance of organizational differentiation as well as the attendant integration difficulties (Lawrence and Lorsch, 1967; Katz and Kahn, 1966). If R & D organizations are differentiated systems, then they too face the problem of internal integration. There is much evidence concerning the difficulty of laboratory integration. For instance, Rosenbloom and Wolek (1970) found integration and communication problems in a set of R & D organizations due to the different information processing patterns of professional and operational task areas. Similarly, Whitley and Frost (1973), Taylor (1972), Lorsch and Morse (1975), Morton (1971), and Allen (1970) have found intra organizational network specialization and the attendant communication difficulties in several R & D organizations.

If R & D organizations are differentiated and restricted communication networks, then they face the problem of internal integration. This is particularly a problem when the differentiated areas are task
interdependent. From the project's or Group's perspective, internal differentiation presents very similar coding and linguistic problems as do organizational and extra organizational differentiation. With the same logic as used for gatekeepers and organizational liaisons, it can be hypothesized that the communication between differentiated areas within the laboratory occurs in a two-step fashion. Technical roles may evolve to connect the project or Group to other areas in the laboratory. Therefore, as with the organizational liaison, this analysis suggests that the communication between differentiated areas in the laboratory is not equally distributed throughout the technical staff, but takes place through a relatively few key network nodes--laboratory liaisons. It can be hypothesized that:

6.1-3 Internal technical stars will have significantly more communication with other areas in the laboratory than the non stars.

**Characteristics of Communication Stars**

The 'gatekeeper literature review indicated that the gatekeepers in research areas had different characteristics than the gatekeepers in the more routine task areas. These demographic differences should hold for technical stars in general. If technical role status is based on technical competence, and if different task areas require different skills, then there should be systematic differences in the characteristics of the stars for the different task areas.

There are wide differences in task requirements in the laboratory studied here. As discussed in Chapter III, research projects work to
develop new knowledge, concepts, or components. This work is not specifically problem-focused and has a long time span of feedback. On the other hand, technical service projects use existing knowledge in the modification of existing products and in short term problem solving. Technical service work tends to be problem focused with a short time span of feedback (for a similar distinction, see Rosenbloom and Wolek, 1970).

If technical role status is based on technical competence, then these basic task differences should have consequences for the characteristics of the technical stars. The work in research projects probably requires more educational training, more state-of-the-art "know-how", and more professional exposure than the work in the technical service projects. If so, then research stars should then be more professionally oriented than the technical service stars. More specifically, research stars should be more educated and have produced more publications than the technical service stars. On the other hand, work in technical service areas requires more organizational know-how and technical-product experience. If so, then the stars in technical service areas should be older and have more organizational tenure than the research stars. Also, given the locus of technical information and the importance of organizational experience in service projects, technical service stars are more likely to be supervisors than the stars in research areas. More specifically, it can be hypothesized that due to the differences in task requirements that:

6.1-4 Research stars will be younger, more educated, have more publications, and have less organizational tenure than the stars
in the technical service areas. The percentage of stars who are supervisors will be higher for the technical service areas.

Results

To test for the existence of technical roles, internal stars must first be located. Once identified, the external communication behavior of the internal stars can be compared with the non-stars and their characteristics can be contrasted. As discussed in Chapter III, stars were located in six of the seven Groups in the laboratory. The Group was used as the level of analysis since it was hypothesized that communication across Group boundaries would be mediated by technical roles. Further, using the Group as the unit of analysis insures that the roles will be distributed throughout the laboratory. For each Group, internal stars were defined as those individuals in the top fifth of the within Group communication distribution. Fifty stars were located.

To test for the existence of gatekeepers (6.1-1), organizational liaisons (6.1-2), and laboratory liaisons (6.1-3) the amount of external communication of stars and non-stars must be compared (see Table VI-1). There is strong support for the existence of both the technical liaisons; eleven of the twelve differences between stars and non-stars are statistically significant. Stars, as a set, have significantly more communication to the larger organization as well as to other areas in the laboratory than the non-stars. Therefore, as predicted, communication between organizationally distant areas is not direct. Rather, individuals communicate through technical roles to other areas in the
<table>
<thead>
<tr>
<th>Communication To:</th>
<th>HOMO. TECH. SERV. GROUP</th>
<th>HETEROGENEOUS GROUPS</th>
<th>HOMOGENEOUS RESEARCH GROUPS</th>
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<tr>
<td></td>
<td>Control Systems</td>
<td>Special Products</td>
<td>Product Testing</td>
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<td></td>
<td>s    ns</td>
<td>s    ns</td>
<td>s    ns</td>
</tr>
<tr>
<td>Laboratory</td>
<td>4    0**</td>
<td>22   18</td>
<td>37   14***</td>
</tr>
<tr>
<td>Organization</td>
<td>19   6***</td>
<td>26   10**</td>
<td>23   7**</td>
</tr>
<tr>
<td>Extra Organization</td>
<td>7    1**</td>
<td>3    3</td>
<td>4    2</td>
</tr>
<tr>
<td>Number of stars, and non stars</td>
<td>10   43</td>
<td>6    22</td>
<td>7    29</td>
</tr>
</tbody>
</table>

Mann-Whitney U Test - one tail

* p < .10  
** p < .05  
*** p < .01
larger organization.

Chapter IV found that the amount of technical communication to different areas in the laboratory and larger organization was dependent on task characteristics and interdependence requirements. Internal consulting was postulated to be important for the transfer of technical information as well as for working out coordination requirements. These technical role results add specificity to the internal consulting results. The role results indicate that due to the difficulties of communicating across organizational boundaries, communication to organizationally distant areas is not direct. Rather, this cross-boundary communication tends to be handled through key individuals who are able to operate within several coding schemes. The role results also support the idea in section 4.3 that technical roles act as a communication link between the project and interdependent areas that are organizationally distant.

In all, Table VI-1 gives strong support to the notion that communication networks evolve specialized roles to deal with the difficulties of communication across organizational boundaries. These technical roles are able to match the different coding and linguistic schemes and therefore, mediate the technical communication between organizationally distant areas and individuals inside the Group.

While support for both technical liaisons is strong, support for the gatekeeper role is not (see Table VI-1). In only two of the Groups do the stars have significantly more communication to areas outside of the organization than the non-stars. However, hypothesis 6.1-1 argued that there should be gatekeeper specialization to specific external
domains. It was hypothesized that given the need for state-of-the-art technical information in research projects, that research stars would focus their extra organizational communication on the professional domain (i.e., universities, professional societies). On the other hand, it was hypothesized that technical service stars would focus on operational communication (i.e., suppliers, vendors, customers) given the technical service areas' need for up to date information on new products and processes.

To test this specialization hypothesis, extra organizational communication was separated into two components: professional (universities, professional societies) and operational (suppliers, vendors, customers) communication. For each Group, the amount of communication to each external area for stars and non stars is compared in Table VI-2. At first glance, support for hypothesis 6.1-1 is still weak; in only three of the six Groups do the stars have significantly more communication to extra organizational areas than the non stars. However, if the Groups are separated into homogeneous and heterogeneous task areas, the support for the hypothesis is stronger. In the Control Systems Group, each of the projects are technical service projects, while in the Research and the Development Groups, each of the projects are research projects. The other Groups are made up of heterogeneous tasks--most having research, development, and technical service tasks under the same Group manager.

For the homogeneous Groups, the support for hypothesis 6.1-1 is strong. For the two research Groups, the stars have significantly more communication to professional areas than the non stars. In
<table>
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<tr>
<th>Communication To:</th>
<th>HOMO. TECH. SERV. GROUP</th>
<th>HETEROGENEOUS GROUPS</th>
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<td>s ns</td>
<td>s ns</td>
<td>s ns</td>
</tr>
<tr>
<td>Operational areas</td>
<td>6 1**</td>
<td>1 2</td>
<td>2 1</td>
</tr>
<tr>
<td>Professional areas</td>
<td>0 0</td>
<td>2 2</td>
<td>2 1</td>
</tr>
</tbody>
</table>

Mann-Whitney U Test - one tail

* p < .10
** p < .05
*** p < .01
support of the specialization hypothesis, there is no role specialization to the operational domain for these research Groups. For the technical service Group, the stars have significantly more communication to the operational domain than the non-stars. There is no specialization to the professional domain for this technical service Group. None of the heterogeneous Groups have gatekeeper specialization to either of the external domains. However, homogeneous sub-areas inside these Groups may indeed have gatekeeper specialization. Future gatekeeper analysis should focus on homogeneous sets of projects to investigate this possibility.

In all, for homogeneous Groups there is strong evidence of the Gatekeeper role. These key individuals connect the internal Group network to information areas outside of the organization. However, these gatekeepers seem to specialize their external communication attention to particular areas depending on the nature of the task. Research gatekeepers focus on professional areas, while technical service gatekeepers focus on operational areas. These results add support to Allen's (1970) and Allen and Cohen's (1969) hypothesis that gatekeepers specialize on different content areas (e.g., techniques vs. state-of-the-art information). These results indicate that the content specialization is handled by different technical roles who specialize in communicating with particular areas outside of the organization. What is particularly interesting is that this specialization is based on task differences.

This section has found considerable support both for the existence of technical liaisons for each Group and for gatekeepers in the technically
homogeneous Groups. It is now possible to test hypothesis 6.1-4. This hypothesis was based on the idea that technical role status is based primarily on technical competence. If technical competence is an important determinant in becoming a technical role holder, and if different task areas have different technical requirements, then stars in the research areas should have systematically different characteristics than the stars in the technical service areas. More specifically, hypothesis 6.1-4 proposed that research stars would be younger, more educated, have more publications, and have fewer years of service than the technical service area stars. It was also suggested that more of the technical service area stars would be supervisors.

The characteristics of the research and technical service stars are compared in Table VI-3. Hypothesis 6.1-4 is strongly supported. Research stars are indeed significantly more educated, younger, have more publications, and have less organizational tenure than the technical service stars. Further, while there is no statistically significant relationship between a star's supervisory status and the task area (see Table VI-4), technical service stars are more frequently supervisors (65 per cent) than the research stars (50 per cent). In all, research stars are more professionally oriented than the technical service stars, reflecting the requirements of technical expertise for research areas. Technical service stars, on the other hand, are more operationally oriented, reflecting the requirement for technical experience and organizational know how.

Technical transfers within the laboratory also seem to distinguish research from technical service stars (see Table VI-3). Technical
### TABLE VI-3

**CHARACTERISTICS OF RESEARCH AND TECHNICAL SERVICE STARS**

<table>
<thead>
<tr>
<th>Organization Level</th>
<th>Age</th>
<th>Education</th>
<th>Technical Conferences</th>
<th>Publications</th>
<th>Years in Lab</th>
<th>Years in Project</th>
<th>Years in Transfers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>3.25</td>
<td>39.4</td>
<td>3.44</td>
<td>3.25</td>
<td>1.82</td>
<td>6.62</td>
<td>3.37</td>
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<tr>
<td>Service</td>
<td>2.92</td>
<td>45.1</td>
<td>2.38</td>
<td>5.00</td>
<td>.91</td>
<td>9.46</td>
<td>5.31</td>
</tr>
<tr>
<td>Significance</td>
<td>N.S.</td>
<td>**</td>
<td>***</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

d.f. = 27

* p < .10  ** p < .05  ** p < .01

### TABLE VI-4

**NUMBER OF TECHNICAL STARS AS SUPERVISORS FOR RESEARCH AND TECHNICAL SERVICE AREAS**

<table>
<thead>
<tr>
<th></th>
<th>Supervisor</th>
<th>Non-supervisor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Service</td>
<td>11</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>16</td>
<td>37</td>
</tr>
</tbody>
</table>

\[ x^2 = .83 \]

d.f. = 1  p = N.S.
stars, as a whole, have significantly more laboratory transfers than the non stars (p < .10). This supports Allen's (1970) and Gerstberger's (1971) hypotheses on the effects of internal transfers on the development of an individuals communication network. However, Table VI-3 indicates that this overall difference between stars and non stars is due mostly to the research stars. Research stars report significantly more laboratory transfers than the technical service stars.

The previous results suggest that laboratory transfers may affect the development of stars in the research areas but not in the technical service areas. This result fits well with earlier results. Chapter IV found that high performing research projects had significantly more intra-laboratory communication than the high performing technical service projects. If an individual in a research project has an extensive intra-laboratory communication network due to internal transfers, it may well contribute to his technical competence, and therefore, to technical role status. However, laboratory consultation was not related to performance for technical service areas (see Table IV-1). If so, then in technical service areas the communication network developed from laboratory transfers is not likely to be related to technical competence. It therefore makes sense that technical service stars report very few laboratory transfers. Finally, if this logic holds, it can be hypothesized that another type of transfer is associated with the development of technical service stars. Since high performing technical service areas have significantly more organizational communication than the high performing research projects, it can be hypothesized that transfers to the larger organization will be related to the
development of technical service stars. This hypothesis must await further research.

The results of hypothesis 6.1-4 support the idea that technical competence is a primary determinant of technical role status. Therefore, technical role candidates must have the appropriate characteristics to match the information requirements of the task. The results of this analysis also suggest that task rotation can be used as a managerial strategy to stimulate the development of technical roles. The analysis and discussion indicate that task rotation must also be specialized to meet the requirements of the task. Laboratory rotation is appropriate for research areas, while it has been suggested that transfers to the larger organization are more appropriate for the technical service areas.

In summary, this section has found that technical roles evolve to mediate technical communication across three organizational boundaries. For each Group in the laboratory, laboratory liaisons were found to span the different Group interfaces, while organizational liaisons were found to span the laboratory-organization interface. Communication between organizationally distant areas was therefore not direct, but was channelled, in a two-step fashion, through technical roles into the Group. The analogous role specialization was found for communication from homogeneous Groups to extra organizational areas. Further, the gatekeepers were found to specialize their external communication to match the requirements of their task area.

The characteristics of the technical stars were found to be different for the different task areas. Supporting the primacy of
of technical competence in role development, research stars were professionally oriented while the technical service stars were operationally oriented. Technical transfers in the laboratory were associated with role development for research areas, while it was suggested that organizational transfers would enhance role development in the technical service areas. In all, the results of this section indicate that technical roles evolve to mediate communication across organizational boundaries and that the development and characteristics of these roles are different and can be managed-specialized to fit the requirements of the task.
6.2 Characteristics of the Different Technical Roles

Section 6.1 found that internal stars are particularly important nodes in the laboratory's information network in that they serve as communication links between the Group and different external areas. It was suggested that Technical role status is contingent on being a high technical performer. In support of this idea, stars were found to have characteristics to match the information requirements of the task. Given these results, it is now possible to explicitly focus on the individual technical roles. Several questions can be raised and explored here. For instance, are there different characteristics for the different roles?—do the different boundaries require different types of individuals? Is there role overlap? This section will not be hypothesis-oriented. It will focus on the characteristics of the different roles and then explore the amount of role overlap.

To address these questions, individuals fulfilling the requirements of each role must be identified. Following Allen (1970) and Taylor (1970), technical roles can be defined as those internal stars who also have extensive communication to the relevant external domain. For this study, extensive external communication has been defined as being in the top fifth of the appropriate external communication distribution. With this definition, the individual technical roles must be both internal and external stars. For instance, laboratory liaisons
were identified by selecting those internal stars who were also in the top fifth of the laboratory communication distribution.

The initial analyses will focus on the laboratory and organizational liaisons since they were identified for each Group in the laboratory. Using the operational procedures discussed above, 14 laboratory liaisons and 12 organizational liaisons were identified. Further, there was a large amount of role overlap. Fourteen individuals were found that satisfied the requirements for both roles—these individuals will be called double role holders or doubles. (There were 10 internal stars who did not communicate extensively with any of the external domains. These individuals were all in the research areas and will not be further discussed here.)

As found in section 6.1, for each Group in the laboratory there are laboratory as well as organizational liaisons. Laboratory liaisons specialize on the inter-Group interfaces, while the organization liaisons specialize on the laboratory-organization boundary. These boundaries are very different. Communication within the laboratory deals with technical problem solving and technical development, while communication with other organizational areas deals more with implementation problems, information transfer, and other organization-administrative issues. If these roles span different boundaries, and if these boundaries have different communication requirements, then there may well be systematic differences in the characteristics of the different liaisons (see Table VI-5). This is indeed the case. Laboratory liaisons are younger, more educated, and have a greater number of publications and less organizational tenure than do organizational liaisons. These demographic
<table>
<thead>
<tr>
<th>Liaisons</th>
<th>Organization Level</th>
<th>Age</th>
<th>Education</th>
<th>Number of Technical Conferences</th>
<th>Publications</th>
<th>Years in Lab</th>
<th>Project</th>
<th>Laboratory Transfers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory (n = 10)</td>
<td>3.4</td>
<td>34.8</td>
<td>3.3</td>
<td>4.3</td>
<td>1.5</td>
<td>7.1</td>
<td>5.7</td>
<td>.30</td>
</tr>
<tr>
<td>Organization (n = 9)</td>
<td>3.4</td>
<td>48.3</td>
<td>2.2</td>
<td>2.9</td>
<td>.44</td>
<td>10.3</td>
<td>3.6</td>
<td>.22</td>
</tr>
<tr>
<td>Significance</td>
<td>N.S.</td>
<td>***</td>
<td>***</td>
<td>N.S.</td>
<td>**</td>
<td>*</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

* p < .10

** p < .05

*** p < .01
differences indicate that the laboratory liaisons are more professionally oriented while the organizational liaisons are more operationally oriented. Both these orientations reflect the information requirements of the respective boundaries and suggest that technical roles evolve with the appropriate characteristics to match the particular information boundary.

This technical liaison analysis indicates that within each Group in the laboratory there are separate roles which connect the Group to different organizationally distant areas. These technical liaisons have systematically different characteristics and competences to match the respective interface requirements. Thus, in contrast to the liaisons reported by Allen (1970) and Whitley and Frost (1973), these technical liaisons are not average individuals, but are most likely high performing individuals with specialized characteristics to best fit the information requirements of the communication boundary.

The previous analysis indicates that there are special roles that attend to the intra-laboratory and laboratory-organization boundaries. There is, however, considerable role overlap for the two liaison roles. Of the 40 individuals identified as technical role holders, a full 35 percent (i.e., 14) are individuals who satisfy the requirements of both the laboratory and organizational liaisons. These individuals are able to span both the intra-laboratory as well as the laboratory-organization boundaries. As might be expected from the previous results (see Table VI-6), these double role holders have the professional characteristics of the laboratory liaisons (i.e., there are no statistically significant differences in educational level or the number of publications), as well
### TABLE VI-6

**Characteristics of Stars Who Were Both Laboratory and Organization Liaisons (N = 11)**

<table>
<thead>
<tr>
<th>Organization Level</th>
<th>Age</th>
<th>Education</th>
<th>Number of Conferences</th>
<th>Publications</th>
<th>Years in Lab</th>
<th>Years in Project</th>
<th>Laboratory Transfers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.45</td>
<td>42.2</td>
<td>3.18</td>
<td>13.5</td>
<td>2.18</td>
<td>11.3</td>
<td>7.8</td>
</tr>
</tbody>
</table>

### TABLE VI-7

**Number of Single Roles (Either Laboratory or Organization Liaisons) and Double Roles (Both Laboratory and Organization Liaisons) Above First Level Supervisor**

<table>
<thead>
<tr>
<th>Roles</th>
<th>Above First Level</th>
<th>First Level or Below</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double</td>
<td>7</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Single</td>
<td>4</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>25</td>
<td>36</td>
</tr>
</tbody>
</table>

\[ x^2 = 4.01 \quad \text{d.f.} = 1 \quad p < .05 \]
as the operational characteristics of the organizational liaisons (i.e., organizational tenure). The only statistically significant difference between the doubles and the individual role holders is that the double role holders are more likely to be supervisors (see Tables VI-6 and VI-7). In fact, a full 50 per cent of the double role holders are above the first level supervisory position.

These results indicate that there is an important amount of role overlap for the two liaison roles. Evidently, a substantial number of internal stars perform several roles. One possible explanation of these results is that the double role status is a function of supervisory position. Certainly, being a supervisor makes communicating with organizationally distant areas easier. However, supervisory status (particularly above first level supervisor) is not necessarily related to the number of publications or with the amount of internal consulting. Indeed, it can be argued (see Allen, in press; or Gerstberger, 1971) that promotion above first level supervisor is inversely related to both the publication rate and the amount of internal consulting.

Allen (in press) has suggested, and it has been inferentially supported in this chapter, that technical competence is a primary causal factor in attaining technical role status. The same process should hold for the double role holders. What is most likely is that high performing individuals have extensive laboratory and organizational communication networks developed from professional involvement and from organizational experience. These high performing individuals develop a reputation for broad technical competence which, in turn, further stimulates internal consultation and may lead to promotion.
If promoted, supervisory status then enhances the ability to function as a link between the several organizational boundaries. What is interesting is that technical consulting and technical role status extends beyond the first level of supervision. Group managers are able to retain their reputation for technical competence as well as their connection to individuals lower in the hierarchy. Technical role status does not seem to be limited to first level supervision and below.

Technical liaisons are network adaptations to deal with the difficulties of communicating across organizational boundaries. The results indicate that the liaisons have specialized characteristics to deal with the different boundaries, and that there are a substantial number of double role holders. It is now possible to investigate the gatekeeper role and compare it with the liaisons. Because the gatekeeper role was identified for only three Groups, this analysis will be based on only twelve individuals (see Table VI-8).

Gatekeepers were found in the two research Groups and in one technical service Group. What is most striking upon identifying the individual gatekeepers is that there are no individuals who simply tend to the external technical world (see Table VI-8). Rather, each of the twelve gatekeepers have extensive extra-organizational communication as well as extensive communication to areas inside the organization or laboratory. Further, a full 33 per cent of the gatekeepers (i.e., 4 of 12) also fulfill the communication requirements of both the laboratory and the organizational liaisons. These individuals are triple role holders in that they serve as links to the laboratory and to the larger organization, as well as to the relevant external communication area.
TABLE VI-8

GATEKEEPERS AS MULTIPLE ROLE HOLDERS

Number of gatekeepers that were also liaisons to other areas

<table>
<thead>
<tr>
<th>Gatekeepers in:</th>
<th>Total</th>
<th>Lab Liaison</th>
<th>Organization Liaison</th>
<th>Lab &amp; Organization Liaison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Groups</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Technical Service Group</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>12</strong></td>
<td><strong>4</strong></td>
<td><strong>4</strong></td>
<td><strong>4</strong></td>
</tr>
</tbody>
</table>
The gatekeepers who are not triple role holders tend to link their Group to a particular organizationally distant area. The technical service gatekeepers tend to focus on the laboratory-organization boundary, while the research gatekeepers focus on the intra laboratory boundary. This specialization fits with the results from section 6.1 which found that research gatekeepers attend to professional communication while the technical service gatekeepers attend to the operational communication domain.

The specialization of the gatekeepers to particular organizational boundaries indicate that the two-step flow of information is further specialized. State-of-the-art knowledge not only enters the research Groups through the research gatekeepers, but is made available to the larger laboratory by the gatekeepers who are also laboratory liaisons. Similarly, information on new products and processes enters the technical service Groups through the gatekeepers and is distributed to the larger organization by the gatekeepers who are also organizational liaisons. The gatekeepers then provide informational input not only to their own Group but also to the larger laboratory and organization. In short, gatekeepers are very special individuals in the information network who are able to serve as links across several organizational boundaries.

The gatekeepers have the same characteristics as the double role holders reported previously. They are supervisors (30 per cent are above first line supervisor) who have the same level of professional involvement as the laboratory liaisons, as well as the same amount of organizational experience as the organizational liaisons. As suggested
for the double liaisons, gatekeeper status is most likely a function of technical competence. This competence is, at least in part, a result of being exposed to multiple information sources as well as having extensive organizational experience. Competence attracts colleague consulting and may lead to a promotion. Supervisory status, then, enhances both the access to external areas as well as the individuals reputation. As found for the double liaisons, promotion above first line supervisor does not necessarily reduce the individuals contact with technical personnel lower in the hierarchy.

This analysis indicated that gatekeepers are particularly active individuals in the information network. The gatekeepers attended to much more than the extra-organizational information gate. A third of the gatekeepers spanned all three communication boundaries. The other gatekeepers focused on an extra organizational domain as well as another organization boundary; the particular boundaries being dependent on the nature of the task. If, as suggested throughout this analysis, communication across these boundaries is critical, and if the gatekeepers attend to several of these boundaries, then the importance of the gatekeeper is enhanced.

In review, this section has investigated the characteristics of the different technical roles as well as the amount of role overlap. Laboratory liaisons were found to be professionally oriented, while the organizational liaisons were more operationally oriented. These characteristics are due to the different information requirements that exist for the different boundaries. There was substantial role overlap--35 per cent of the technical role holders were both laboratory
and organizational liaisons. Gatekeepers were found to be multiple role holders and therefore, particularly important individuals in the communication network. A third of the gatekeepers linked the Group to each of the three external areas, while the rest of the gatekeepers served as links to an external area and a particular organizational area depending on the task. The characteristics of the gatekeepers and the double role holders were the same; they were frequently supervisors with substantial professional and operational experience.

Each of the technical roles are internal stars with a substantial amount of communication to an external domain. The internal technical stars are, therefore, particularly important individuals in a laboratory's information network. These individuals serve as communication links to important external areas. Further, these stars quite frequently tend to several communication boundaries. If all the roles are included, a full 50 per cent of the individuals identified fulfilled the requirements of at least two roles. Technical stars, therefore, tend to much more than the extra-organization communication gate. It remains for future investigation to explore the development of these technical roles over time.
6.3 Technical Roles and Project Performance--The Distribution of Technical Roles

Section 6.1 found that individuals tend not to communicate directly with external sources of information. Rather, technical roles evolve to couple Group members to external information areas. For each Group, communication was channelled through the technical role into the laboratory and to areas in the larger organization. A similar two-step process was found for extra-organizational communication. It was argued that because of the difficulty of communicating across organizational boundaries that this two-step flow would be a particularly effective mechanism for communication with organizationally separated areas. Since technical roles were found in each Group, the question can now be raised as to the distribution of the technical roles within the Group. Is there a relationship between the number of roles per project and technical performance? Do different task areas require a greater number of technical roles during the execution of the task? To address this question the level of analysis will shift back to the project and will focus on the number of roles per project.

What is the relationship between the number of technical roles and project performance? Although implicit in the literature, there is no direct evidence on how the number of roles and project performance are related. Given the argument based on organizational differentiation and the attendant barriers to communication, it can be
hypothesized that role specialization is related to network efficiency and, therefore, positively related to project performance. More specifically, it can be hypothesized that:

6.3-1 High performing projects will have more roles per project than the low performing projects.

Table VI-9 indicates the number of roles per project for high and low performing projects. Hypothesis 6.3-1 is soundly rejected--there is an inverse relationship between the number of technical roles and project performance. High performing projects have significantly fewer roles per project than the low performing projects. More specifically, the low performing projects have between two and three times as many roles per project than the high performing projects.

Table VI-9 indicates that the more effective projects have fewer roles to deal with their external communication requirements. It may be that it is most efficient to get external information from a few special individuals in the Group. Multiple sources of external information (from Table VI-9, about one role per project) seem to be redundant and indicate an over-specialization. However, care must be exercised here. While there is an overall inverse relationship between the number of technical roles and technical performance, there may well be work characteristics which modify this overall relation.

Chapters IV and V have indicated that different amounts of task uncertainty, reflected in the characteristics of the work, affect the patterns of technical communication. It may well be that the distribution of technical roles is also contingent on the nature of the work. As discussed earlier, network specialization is in response to the difficulties
### TABLE VI-9

NUMBER OF TECHNICAL ROLES PER PROJECT FOR HIGH AND LOW PERFORMING PROJECTS

<table>
<thead>
<tr>
<th>Performance</th>
<th>High</th>
<th>Low</th>
<th>Significance (d.f.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of roles per project</td>
<td>.40</td>
<td>.83</td>
<td>* (36)</td>
</tr>
<tr>
<td>Number of roles per project-normalized by project size</td>
<td>.06</td>
<td>.18</td>
<td>** (36)</td>
</tr>
</tbody>
</table>

* p < .10  
** p < .05  

### TABLE VI-10

NUMBER OF TECHNICAL ROLES PER PROJECT FOR DIFFERENT TASK AREAS AND BY PERFORMANCE

<table>
<thead>
<tr>
<th>Performance</th>
<th>Research</th>
<th>Technical Service</th>
<th>Significance (d.f.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>.64</td>
<td>.50</td>
<td>* (19)</td>
</tr>
<tr>
<td>High</td>
<td>.80</td>
<td>.50</td>
<td>N.S. (9)</td>
</tr>
<tr>
<td>Low</td>
<td>.50</td>
<td>.50</td>
<td>N.S. (8)</td>
</tr>
</tbody>
</table>

* p < .10
of communicating across organizational boundaries. Increased task uncertainty should exacerbate the difficulties of communicating across boundaries and, therefore, increase the need for role development. As suggested in Chapter II, task characteristics, environmental variability, and task interdependence are each sources of technical uncertainty. To the extent that each of these variables increase the information processing requirements of the task, then the need for role specialization should be greater. It can, therefore, be hypothesized that the greater the task complexity, the greater will be the number of roles to deal with that uncertainty. This core hypothesis leads to the following more specific hypotheses:

6.3-2 Research projects will have more technical roles per project than will the technical service projects.

6.3-3 Projects facing a changing environment will have more roles per project than projects facing a stable environment.

6.3-4 Projects with substantial task interdependence will have more roles per project than projects with a small amount of task interdependence.

Tables VI-10, VI-11, and VI-12 provide strong support for these hypotheses. Projects with more complex work requirements consistently have more roles per project than the projects with less complex work. For the total sample, research projects have significantly more roles than the technical service projects; projects facing a changing environment have significantly more roles per project than projects facing a stable environment; and projects with substantial task interdependence have significantly more roles per project than projects with
### TABLE VI-11
**NUMBER OF TECHNICAL ROLES PER PROJECT FOR DIFFERENT ENVIRONMENTAL CONDITIONS**

<table>
<thead>
<tr>
<th>Environment</th>
<th>Changing</th>
<th>Stable</th>
<th>Significance (d.f.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>1.00</td>
<td>.39</td>
<td>** (32)</td>
</tr>
<tr>
<td>Performance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>.85</td>
<td>.00</td>
<td>*** (12)</td>
</tr>
<tr>
<td>Low</td>
<td>1.11</td>
<td>.64</td>
<td>N.S. (18)</td>
</tr>
</tbody>
</table>

** p < .05
*** p < .01

### TABLE VI-12
**NUMBER OF TECHNICAL ROLES PER PROJECT FOR HIGH AND LOW DEGREES OF ORGANIZATIONALLY DISTANT INTERDEPENDENCE**

(Distant Interdependence is the sum of laboratory and corporate interdependence)

<table>
<thead>
<tr>
<th>Distant Interdependence</th>
<th>High</th>
<th>Low</th>
<th>Significance (d.f.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>.94</td>
<td>.50</td>
<td>* (32)</td>
</tr>
<tr>
<td>Performance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>.83</td>
<td>.12</td>
<td>* (12)</td>
</tr>
<tr>
<td>Low</td>
<td>1.10</td>
<td>.70</td>
<td>N.S. (18)</td>
</tr>
</tbody>
</table>

* p < .10
a small amount of task interdependence. Evidently, under certain technical conditions a small number of technical roles are able to handle the external information requirements, while more complex technical conditions require a greater number of roles to attend to the increased uncertainty. Therefore, in support of the core hypothesis, technical roles are indeed differentially distributed within the laboratory--the distribution depending on the characteristics of the work.

But what of the relationship between the number of technical roles and project performance? If the logic of the previous set of hypotheses holds, then the results found for the total sample should be accentuated for the high performing projects. Tables VI-10, VI-11, and VI-12 compare the number of roles per project for high and low performing subsets. As predicted, the results are each accentuated for the high performing projects; high performing projects facing greater information processing requirements (i.e., research tasks, changing environment, and high interdependence) have more roles per project than the high performing projects facing less task uncertainty. However, for the low performing projects the hypothesized differences decrease in magnitude and do not approach statistical significance.

The patterns in these tables can shed further light on the relationship between role density and technical performance. High performing projects facing stable environmental conditions or a small amount of task interdependence have very few roles per project (.00, .11 respectively). Evidently, external technical communication under relatively routine conditions is best handled through a small number of technical roles. However, high performing projects facing technical uncertainty
report significantly more technical roles per project to deal with that increased uncertainty. Increased uncertainty seems to be best dealt with through a greater number of technical roles. Therefore, only under certain conditions (i.e., technical uncertainty) is an increased number of technical roles associated with high performance.

However, the patterns of results also indicate that there can be too many roles even under conditions of high task uncertainty. For instance, high performing projects facing a changing environment or substantial task interdependence have fewer roles per project (.85, .83) than the low performing projects facing the same task conditions (1.11, 1.10). The high performing projects seem to share individual roles among several projects; for the high performing projects, the ratio of roles per project is consistently around .85. High performing projects facing similar technical conditions may well share the same technical roles. It remains for future analyses to look in greater detail at role networks. The low performing projects, on the contrary, have more than one role per project under conditions of a changing environment and high task interdependence. It may well be that the greater number of roles per project is redundant in that too much effort is focused on cross boundary communication.

In review, the number of technical roles per project is dependent on the characteristics of the work. More roles per project are not related to higher technical performance. Rather, for high performing projects, the number of technical roles per project is contingent on the nature of the work. The greater the task uncertainty, the greater the information processing requirements, and therefore, more roles
must evolve to deal with that increased uncertainty. However, the results just as clearly indicate that too many roles can be redundant. High performing projects shared technical roles with other projects. The results also indicate that high performing projects with a small amount of task uncertainty do not have extensive role development. The projects facing certain technical conditions are able to take care of their external information needs with relatively few technical roles.

In short, for the high performing projects, the number of roles per project was contingent on the characteristics of the work. An implication of this observation is that work characteristics do not cause technical role density; rather, high performing projects develop the appropriate number of technical roles to fit the requirements of the task. The obvious managerial implication is that the distribution of technical roles must be managed-specialized to fit the information processing requirements of the task.
CHAPTER VII

COMMUNICATION IN RESEARCH AND DEVELOPMENT
ORGANIZATIONS: A REVIEW, SOME MANAGERIAL
IMPLICATIONS, AND SOME RESEARCH DIRECTIONS

This study has postulated that there is utility in viewing the R & D organization as an information processing system. Since oral communication is a particularly effective medium for the transfer of information, the R & D laboratory was therefore specifically studied as a communication network. Work areas, or projects, within the laboratory were the unit of analysis. It was argued that the greater the technical uncertainty facing the project the greater would be the burden on its communication network. Chapter II suggested that the characteristics of the project's work could be seen as sources of uncertainty, and that projects with different work characteristics would have different communication patterns to deal with the different amounts of technical uncertainty. A number of hypotheses were tested in Chapters IV, V, and VI. These hypotheses were derived from the basic proposition that to be effective, a project's communication network characteristics must be able to deal with its information processing requirements. The set of results give strong support to this basic proposition, and thus support the usefulness of viewing the R & D laboratory as an information processing system. This final chapter will review the set of results, develop some managerial implications, and suggest some future research directions.
7.1 A Review of the Results and Some Implications for Managers

This study has developed and tested a diverse set of hypotheses and research questions dealing with technical communication in R & D organizations. With this diversity, there are two threads which tie the different results together. They are that: A) technical communication is an important organizational attribute; high performing projects have systematically different patterns of technical communication than the low performing projects; and B) that the patterns of technical communication are not the same within the laboratory. On the contrary, for the high performing projects, patterns of project communication are contingent on the nature of the project's work. In short, the results of this research indicate that technical communication is an important organizational process which deserves specific managerial attention.

The most basic result of this study is that technical communication should be managed. Managers should be aware that the various areas in the laboratory will have different information processing requirements and will, therefore, have to be treated differently. The results of this study permit greater specification of this rather obvious statement. If task characteristics, environmental variability, and task interdependence are sources of uncertainty which are systematically related to patterns of technical communication, then insight on the various specific relationships between technical uncertainty and patterns of communication will permit the manager to more effectively
evaluate, design, or effect changes in his laboratory's technical communication network. This section will, therefore, briefly review the results of this study with an eye for managerial implications. Section 7.2 will develop some of these managerial implications further.

Since the manager has some control of the laboratory's communication network, an awareness of the appropriate relations between characteristics of the project's work and its communication patterns would be a step towards helping the manager actually manage a project's communication patterns. Unlike the other chapters, this summary will be organized around the characteristics of the project's work (i.e., the sources of uncertainty). Uncertainty associated with the different work characteristics can be dealt with through patterns of technical communication. This review will discuss the more appropriate patterns of technical communication, project communication structure, and technical roles for different work characteristics by summarizing the results of the high performing projects. The section will review the communication requirements for different task characteristics (7.1 A), for different task environments (7.1 B), and for different amounts of task interdependence (7.1 C).

7.1 A Project Task Characteristics

The project's task characteristics can be described on a routine-nonroutine dimension. As discussed in Chapter II, research tasks are more complex and must deal with more technical uncertainty than technical service tasks. While not specifically studied here,
development tasks would lie between research and technical service tasks on this complexity dimension. High performing projects with different task characteristics have systematically different patterns of technical communication. By focusing on these projects, the appropriate patterns of technical communication, communication structure, and technical roles for research and technical service areas will be reviewed here (see Table VII-1A).

**Technical Communication.** Chapter IV suggested that technical communication would be an effective way to deal with technical uncertainty. It was argued that intense and diverse communication would stimulate solution approaches and enhance project problem solving. It was hypothesized that projects facing greater technical uncertainty would deal with that uncertainty with increased communication within the project. In support of this hypothesis, the high performing research projects had significantly more intra-project communication than the high performing technical service projects.

Communication to areas outside the project (yet within the organization) was also specialized. For the high performing projects, technical communication was directed to areas of technical information or support—that is, to technical reference groups outside of the project. The high performing research projects had systematically different amounts of Group, laboratory, and organizational communication than the high performing technical service projects. Technical communication outside the organization was not specialized by task area.
<table>
<thead>
<tr>
<th>Task Characteristics</th>
<th>Technical Communication Areas</th>
<th>Technical Roles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Project</td>
<td>Lab/Organization</td>
</tr>
<tr>
<td>Research</td>
<td>more</td>
<td>communication to areas of technical support and feedback</td>
</tr>
<tr>
<td>Technical Service</td>
<td>less</td>
<td>difference</td>
</tr>
<tr>
<td>Section Discussed</td>
<td>4.1</td>
<td>4.1</td>
</tr>
</tbody>
</table>

*For Tables VII-1 A-C, all results are statistically significant except where indicated with an *. 
In all, task characteristics had systematic effects on the amount and direction of internal consulting for high performing projects. These results indicate that internal consulting is important, but that it must be managed. The more complex the task, the more communication within the project should be encouraged, while communication outside the project should be directed to areas of technical feedback and support.

**Project Communication Structure.**-- Chapters II and V argued that project communication structure has important effects on a project's gathering and processing of information. It was suggested that decentralized projects have greater information processing capacity than centralized projects. Given these information processing differences, it was hypothesized that since research projects require greater problem solving capacity, that they would be less structured than the relatively more routine technical service projects. As hypothesized, high performing research projects were significantly less structured than the high performing technical service projects.

If these results are combined with the project communication results reported previously, then the high performing research areas deal with their greater information processing requirements with greater communication within the project as well as more decentralized patterns of project communication than the high performing technical service areas. The managerial implications are clear. The manager must manage the amount and direction of technical communication within the project. The greater the technical uncertainty the
more technical communication should be encouraged within the project. Further, the greater the technical uncertainty, the more this communication should be widespread within the project and the more the patterns of project communication should be decentralized.

**Technical Roles.** Communication across organizational boundaries is difficult and prone to distortion. As discussed in Chapter II and VI, technical roles evolve to deal with the communication difficulties that exist across boundaries. Chapter VI found important differences in the number of technical roles and their characteristics for the different task areas. Research projects are more complex than the technical service projects—they have greater information processing requirements. To deal with this greater complexity, the high performing research projects had more technical roles than the high performing technical service projects. The number of technical roles was contingent on the amount of technical uncertainty faced by the project.

There were other differences in the technical roles due to the nature of the task. The different task areas require specialized types of information—research areas require more professional information while the technical service areas require more operational information. To best deal with these different information domains, it was hypothesized that the research role holders would have professional characteristics, while the technical service role holders would have more organizational characteristics. As hypothesized, the research stars were significantly younger, more educated, had more publications, and had less organizational experience than the technical service stars. Finally, reflecting the differences in the information
requirements of the different task areas, the research gatekeepers focused only on the professional domain, while the technical service gatekeepers focused only on the operational domain. Therefore, there was gatekeeper specialization by information need.

In all, the number of technical roles, their characteristics, and their areas of specialization were systematically different for the different task areas. Managers should be aware of the effects of different task characteristics on technical role development. Just as with the technical communication and project structure, technical roles must be managed-specialized to meet the information needs of the task.

This set of results indicate that the project's task characteristics had an important impact on technical communication patterns inside and outside the laboratory. However, task characteristics did not cause these differences. The high performing projects seemed to match their information processing patterns to fit the requirements of the task. Therefore, managers should be aware of task differences within the laboratory and their effects on patterns of communication. Technical communication, communication structure, and technical roles must be managed-specialized to meet the information processing requirements of the project's task characteristics.

7.1B Project Task Environment

Projects may face different task and market conditions outside of the organization. As discussed in Chapter II, if the external
environment is changing, then the project must attend to and deal with that variability. Environmental conditions are therefore another source of technical uncertainty. The hypotheses concerning the effects of environmental variability were only partially supported. The set of results suggest that environmental variability may be seen more as a threat or overload than as a source of uncertainty to be directly dealt with. Further, to make this review even more complex, environmental variability frequently had very different effects on the different task areas. Therefore, this review must discuss task characteristics as well as environmental conditions. As with the previous section, this review will focus on the high performing projects (see Table VII-1B).

**Technical Communication.**-- The amount of technical communication to areas outside of the project consistently decreased as environmental variability increased. While these differences were not strong, the high performing projects withdrew from extra project communication as environmental variability increased. These results suggest that if environmental conditions were changing, then the high performing projects focused on technical problem solving within their projects. To deal with the continuing laboratory, organization, and extra organization information requirements, Chapter VI found that for the high performing projects, the number of technical roles increased under conditions of environmental variability.

The effects of environmental conditions on technical communication were unexpected. Most of the literature suggests that as environmental conditions become more variable, the amount of technical
<table>
<thead>
<tr>
<th>Environmental Variability</th>
<th>Project Communication with Project</th>
<th>Project Communication with Lab/Org.</th>
<th>Project Communication with Extra Org.</th>
<th>Project Structure</th>
<th>Number of Technical Roles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>more</td>
</tr>
<tr>
<td>Research</td>
<td>more</td>
<td></td>
<td></td>
<td>less</td>
<td></td>
</tr>
<tr>
<td>Technical Service</td>
<td>less</td>
<td></td>
<td></td>
<td>more</td>
<td></td>
</tr>
<tr>
<td>Stable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>less</td>
</tr>
<tr>
<td>Research</td>
<td>no</td>
<td></td>
<td></td>
<td>difference</td>
<td>less</td>
</tr>
<tr>
<td>Technical Service</td>
<td>difference</td>
<td></td>
<td></td>
<td>more</td>
<td></td>
</tr>
<tr>
<td>Section Discussed</td>
<td>4.2</td>
<td>4.2</td>
<td>4.2</td>
<td>5.2</td>
<td>6.3</td>
</tr>
</tbody>
</table>

* All results are statistically significant except where indicated with an *. 

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communication increases to deal with that uncertainty. If, however, the environment is seen as threatening or as an overload, then an alternative way to deal with that uncertainty is through less direct communication and greater reliance on technical roles. Indeed, for the high performing projects studied here, environmental variability was dealt with by decreasing the extra project communication and increasing the number of technical roles to deal with external information requirements.

There were no overall effects of environment conditions on the amount of communication within the project. However, environmental variability affected the intra-project communication of research projects very differently than it affected the technical service projects. Under conditions of a changing environment, high performing research projects had significantly greater intra-project communication than the high performing technical service projects. Research projects responded to the environmental variability with greater communication within the project, while the amount of intra-project communication in the technical service areas was not affected by environmental conditions. In short, while there was no overall effect of environmental variability on intra-project communication, environmental conditions accentuated the already significant difference in intra-project communication between the research and technical service projects.

Why should these results be so different for the different task areas? It may be that since technical expertise is more equally distributed in research projects, that under changing environmental conditions greater peer communication is associated with more
effective problem solving and therefore, high technical performance. However, in the technical service areas the supervisor generally has more task expertise, information, and experience. If so, he may be better able to make the relatively more routine decisions—particularly if the environment is changing. Therefore, increased environmental variability is not associated with increased amount of intra project communication in technical service projects.

Project Communication Structure. As with the technical communication results, environmental variability had no overall effect on project communication structure. Environmental conditions did, however, have important specific effects on project structure. For the high performing research projects, substantial environmental variability was associated with decentralized project communication structures. On the other hand, high performing technical service projects facing a changing environment had centralized project structures.

These results fit well with the results reported above. High performing research projects facing changing environmental conditions not only had more communication within the project, but also were significantly less structured than the high performing technical service projects. Research projects, therefore, dealt with environmental variability very differently than the technical service areas. Under changing environmental conditions, research projects increased their amount and diversity of intra-project communication, while the technical service areas relied more on supervisory direction and less
on peer involvement. In short, environmental conditions had important but specific effects on project communication structure as well as on the amount of intra project communication. Managers must, therefore, be aware of the basic effects of task differences on project communication characteristics, and the differential effects of environmental conditions on these characteristics.

Technical Roles.-- Chapter VI argued that communication across boundaries is difficult and prone to distortion. It was further suggested that since the task environment is a source of technical uncertainty, that increased environmental variability would be associated with an increased number of technical roles to deal with the substantial information processing requirements. This hypothesis was strongly supported for the high performing projects. While work areas decreased their extra project communication as environmental variability increased, technical roles evolved to attend to the various external information requirements. In this fashion technical roles and technical communication are related aspects of the laboratory's communication network. Managers should therefore be aware of the information processing requirements of environmental conditions, and manage both the technical communication as well as the number of technical roles to meet the information processing requirements of the work.

This set of results indicate that environmental variability has important, if complex, effects on technical communication, communication structure, and technical roles. In no case did environmental
conditions cause differences in communication network characteristics. Rather, the high performing projects seemed to match their communication characteristics to the information processing requirements of the task environment. Managers must, therefore, be sensitive to different environmental conditions and their impact on technical communication patterns—particularly as they accentuate the effects of task characteristic differences. In summary, technical communication, communication structure, and technical roles should be managed-specialized to meet the information processing requirements of the project's task environment.

7.1 C Project Task Interdependence

Projects exist in a setting in which they may have to work with other projects or functional areas. To the extent that a project must work with other projects, then the areas are task interdependent. Interdependence must be seen as another source of information processing requirements since the greater the interdependence the greater the coordination requirements, and therefore, the greater the uncertainty facing the project during the execution of the task. As discussed in Chapter IV, interdependence can be classified as being either organizationally close (i.e., communication does not have to cross organizational boundaries) or organizationally distant (i.e., communication must cross organizational boundaries). As with the other sources of information processing requirements, interdependence has systematic effects on the patterns of project communication. By focusing on the high performing projects, the appropriate patterns
of technical communication, communication structure, and technical roles for different amounts of interdependence will be reviewed here (see Table VII-1 C).

**Technical Communication.** Chapter IV argued that since interdependence is a source of technical uncertainty, and since technical communication is one way of dealing with uncertainty, that increased interdependence with a particular area would be associated with an increase in technical communication to that area. In support of this basic hypothesis, high performing projects with substantial interdependence with a particular area had significantly more communication to that area than the high performing projects with only a small amount of interdependence. The relations between interdependence and technical communication were strong and specific. Interdependence with area A was related to technical communication with area A only. While these results held for both organizationally close and distant interdependence, the differences were statistically significant only for distant interdependence. These results are straightforward and the managerial implications are clear: the greater the project's interdependence with an area, the more technical communication should be stimulated with that area.

**Project Communication Structure.** Chapter V suggested that task interdependence would have important effects on project communication structure, and that the specific relationships would depend on the location of the interdependence. It was hypothesized that because of the ease of communication with areas that are organizationally close
<table>
<thead>
<tr>
<th>Amount of Task Interdependence with areas that are:</th>
<th>Technical Communication with Group, Lab, Organization</th>
<th>Project Structure</th>
<th>Number of Technical Roles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organizationally Close</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Substantial</td>
<td>Communication only to areas where interdependence exists. (Weaker support for the effects of Group interdependence).</td>
<td>less</td>
<td>not</td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td>more</td>
<td>tested</td>
</tr>
<tr>
<td>Organizationally Distant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Substantial</td>
<td></td>
<td>more</td>
<td>more</td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td>less</td>
<td>less</td>
</tr>
<tr>
<td>Section Discussed</td>
<td>4.3</td>
<td>5.3</td>
<td>6.3</td>
</tr>
</tbody>
</table>
(i.e., within the same Group), close interdependence would be most effectively dealt with through direct communication and a relatively decentralized project structure. However, because of the difficulty of communicating across organizational boundaries, it was hypothesized that a substantial amount of distant interdependence would be most effectively dealt with through the supervisor (i.e., with relatively little direct contact) and with a relatively centralized project structure. For the high performing projects, both hypotheses were strongly supported. Managers must therefore be aware of the amount and the location of task interdependence. Close interdependence should be handled through decentralized patterns of project communication, while substantial organizationally distant interdependence should be handled through greater supervisory control and a more centralized project structure.

**Technical Roles.** — Chapter VI argued that technical communication across boundaries is difficult because of differences in norms and coding schemes. It was further suggested that increased technical uncertainty would exacerbate the difficulty of communicating across boundaries. Since interdependence is a source of technical uncertainty, it was hypothesized that projects with substantial organizationally distant interdependence would have more technical roles than those projects with only a small amount of distant interdependence. The increased number of roles would be required to deal with the extra information processing requirements. This hypothesis was strongly supported for the high performing projects. Therefore, as found with the task and environment analyses, projects facing substantial work
uncertainty have more roles per project than those projects facing a small amount of work uncertainty. Therefore, the distribution of technical roles is contingent on the nature of the project's work—the greater the technical uncertainty, the greater the number of technical roles that are required to deal with that uncertainty.

This set of results indicate that task interdependence has systematic effects on technical communication, communication structure, and the number of technical roles. As with the other sources of uncertainty, interdependence did not cause differences in communication network characteristics. On the contrary, the high performing projects matched their communication characteristics to the information processing requirements of the different amounts of interdependence. Therefore, managers must be aware of the effects of interdependence on the patterns of technical communication. Project communication patterns should be managed-specialized to meet the information processing requirements of the project's task interdependence.
7.2 Managing a Research and Development Laboratory's Technical Communication--A Beginning

Chapter II hypothesized that patterns of technical communication are important organizational processes, and that for the high performing projects, communication network characteristics would be contingent on the nature of the project's work. The results of this research provide strong support for these basic hypotheses. The several analyses have made progress in further specifying the nature of the various contingent relations between sources of uncertainty and patterns of technical communication. The set of results indicate that the project's information processing capacity must match the information processing requirements of its work. Patterns of technical communication must, therefore, be managed. A project's task characteristics, environmental conditions, and interdependence with other areas are sources of technical uncertainty which require particular patterns of technical communication, project communication structure, and technical roles to effectively deal with the uncertainty (see Tables VII-1 A-C). While these results must be treated as tentative, they do provide more specific direction to managers concerned with the design, evaluation, or management of a laboratory's communication network.

How can the results of this study be put to use? What do the information processing framework and the results reported here suggest beyond the importance of being sensitive to communication
requirements and differences in the laboratory? Assume that the set of results reported here are successfully replicated in a number of different R & D settings. If so, then there are more appropriate ways of organizing the laboratory's communication network—communication patterns must be specialized to fit the requirements of the project's work characteristics. Since technical communication, communication structure, and technical roles can be influenced by the manager, the overall perspective and set of results can be used as a diagnostic, evaluative, and action tool.

The information processing framework and the set of results can be used in a three-step fashion. The framework and the associated sets of variables can be used as a diagnostic guide. The perspective focuses on a set of organizational variables and another set of network characteristics. These sets of variables can be diagnosed or described by the manager. The information processing perspective then provides guidance in the evaluation of how the set of variables fit together. Does the project's information processing capacity match its information processing requirements? Do the communication characteristics fit with the requirements of the work's characteristics (see Tables VII-1 A-C)? The set of results permit the manager to evaluate the actual communication characteristics with what the information processing perspective suggests the ideal characteristics to be. If a discrepancy exists, the results of the diagnosis and evaluation should permit the manager to take some remedial action on a particular network characteristic.

An example may make this process more concrete. Visualize
an advanced research project with relatively little laboratory or organizational interdependence, but facing a substantial amount of environmental variability. What are the appropriate patterns of communication for this project? The results of this study suggest that the ideal patterns of interaction to deal with this substantial uncertainty would be: A) intense and diverse communication within the project as well as to areas of feedback and technical support within the laboratory; B) relatively little communication with other areas in the laboratory or with areas in the larger organization; C) a decentralized pattern of project communication; and D) a relatively large number of technical roles, focused on the professional domain, to deal with the changing environmental conditions as well as with other problem solving issues external to the project. If upon managerial diagnosis there is a discrepancy between the actual characteristics and the ideal characteristics, then action plans can be developed and the information processing mismatch dealt with.

This section has been speculative. It is clearly too early to use this set of results as a refined tool for managerial action. The analyses reported here must be replicated and extended in other laboratories before one can be too serious about what the ideal network conditions are for the different work characteristics. However, this kind of diagnostic, evaluative, and action tool is the kind of payoff that can be derived from research that focuses on several sources of uncertainty and their effects on different patterns of technical communication.

In summary, the results of this study indicate that technical communication within and outside the R & D laboratory is complex
yet organized. Further, technical communication makes a difference—high performing projects have systematically different patterns of technical communication than the low performing projects. For the high performing projects, the patterns of technical communication are contingent on the nature of the project's work. A contribution of this study is that it has begun to specify the nature of the contingent relations between the characteristics of a project's work and the project's communication characteristics. Since task characteristics, environmental conditions, and task interdependence are relatively easy to evaluate, and since technical communication, communication structure, and technical roles are relatively easy to measure and to influence, this increased understanding of the nature of communication in R & D laboratories can be used to design, evaluate, or manage a laboratory's communication network.

In conclusion, there is no one best way to manage a laboratory's communication network. Projects with different information processing requirements must be dealt with differently. A project's technical communication, communication structure, and technical roles must be managed—specialized to meet the information processing requirements of its work.
7.3 Some Research Directions

The research in this study has been based on the idea that organizations in general, and R & D laboratories in particular, can be usefully seen as information processing systems. This image suggests that the laboratory must be able to effectively gather and process information and deal with several sources of work-related uncertainty. The basic proposition that has guided the analyses and interpretations is one of congruence—a project's communication network characteristics must be able to deal with its information processing requirements. The set of results give strong support to this overall framework and approach. Since the results were based on several variables and a number of hypotheses, the overall support for the information processing perspective and approach is substantial. The information processing perspective is a general approach to organizations. However, the support for this framework reported here is based only on a single R & D laboratory. Future research must investigate the extent to which this approach is applicable to a wider range of settings. It will only be in these future independent studies that the information processing perspective will be more fully tested.

The information processing perspective is based on the idea that a project's communication characteristics must be able to effectively deal with several sources of technical uncertainty. It was argued that task characteristics, task environment and task interdependence are sources of technical uncertainty which the project must respond
to with appropriate patterns of communication. Hypotheses were
developed and tested specifying the nature of the appropriate patterns
of project communication for the different work characteristics. The
hypotheses concerning task characteristics and task interdependence
were generally supported. The more complex tasks and those tasks
with a substantial amount of interdependence faced greater amounts
of technical uncertainty. This uncertainty was dealt with through
different patterns of technical communication, communication struc-
ture, and technical roles as described in Tables VII-1 A-C. Future
research must replicate these results as well as begin to specify in
greater detail how a project's task characteristics and its amount
of task interdependence affect its communication patterns. For
instance, while project communication should be facilitated to areas
of technical support, does this mean that technical communication to
other areas is inappropriate?

As opposed to task characteristics and task interdependence, the
hypotheses concerning environmental variability were not, in general,
supported. Environmental variability seemed to have been treated as
a source of overload or threat. High performing projects seemed to
withdraw from extra project communication under conditions of a
changing environment. Thus the nature of uncertainty associated
with environmental conditions was different than that associated with
task characteristics or task interdependence. Duncan (1973) has
suggested that perceived influence over the source of the uncertainty
effects how the uncertainty is dealt with. Perhaps individuals felt that
they had less influence or control over the environment and therefore
decreased their external communication. It could also be that a changing environment made the task sufficiently complex so that more attention had to be directed inward leaving less time and effort for extra-project communication.

Whatever the reason for the decrease in extra-project communication, environmental variability is a source of uncertainty which must be attended to. Chapter VI found that technical roles evolved to link the isolated project to information areas outside of the project. Thus, contrary to much of the literature, environmental variability may be effectively dealt with by actually decreasing the overall amount of communication, and simultaneously developing technical roles to attend to external information processing requirements. Future research should consider under what conditions environmental variability is best dealt with through an increase in the number of technical roles, and under what conditions it is best dealt with through increased technical communication.

Another consistent set of results involved the technical roles. These special network nodes were found to mediate technical communication across three communication boundaries. These boundaries separated: A) Groups within the laboratory; B) the laboratory from the larger organization; and C) the laboratory from information areas outside of the organization. Separate technical roles were found to deal with each of these interfaces. While the laboratory to extra-organization boundary has received considerable attention, this research suggests that the other two "closer" boundaries are also important barriers to the direct flow of information. Further, for all three boundaries, the communication impedance was accentuated as the amount of
uncertainty facing the project increased. In all, there are a number of technical roles—gatekeepers and technical liaisons—that deserve specific attention since they are able to span several coding schemes and thereby connect the project to the different areas of information.

Given these technical role results, one reason that Allen (1966) and Allen et al. (1968) found so little internal consulting may be because communication boundaries within the organization are very difficult to overcome. To support this idea is the result that the technical liaisons were not ordinary individuals. On the contrary, the liaisons were internal stars with the appropriate characteristics to match the particular communication boundary.

In summary, this research indicates that there are a number of important communication boundaries facing the project, and that several types of technical roles evolve to deal with the different boundary requirements. Future research should give explicit attention to the several communication boundaries and to all three types of technical roles. For instance, how do these roles evolve over time? How stable are they? Do the different roles form larger role networks?

Finally, while more direct communication may well be related to higher performance (e.g., Prakke, 1975), future research must deal with ways of overcoming boundary impedance for those who are not technical liaisons.

This study has focused on patterns of technical communication as a response to different sources of work-related uncertainty. This approach has necessarily ignored many other important organizational and individual influences on communication patterns. Future studies
could complement this research by dealing with some of the neglected areas discussed in Chapter II (i.e., individual differences, quality of communication, colleague roles, etc.). Finally, the research reported here is cross sectional in nature. Patterns of communication over time and causal relationships could not be specifically studied. If future projects are designed as longitudinal research, then some of these neglected areas could be addressed. In short, there is no lack of researchable questions.

This study is one more step in developing an understanding of communication patterns in R & D laboratories. While this research area is not mature, there will be high payoffs for increased efforts in this area. Not only does this area of research have relevance for managers, but a greater understanding of the determinants and effects of communication in R & D settings can contribute to the understanding of communication in organizations in general.
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APPENDIX
Please complete this questionnaire for the above date, as close to the end of your work day as possible. We are interested in the frequency, type, and content of business communications on this day. For each communication, please print the name of the individual, and check the appropriate boxes concerned with the initiation, type, and content of the communication. If you discussed more than one subject during a communication, please check as many boxes as are appropriate. If communication with any one individual, on this day, has occurred on several occasions, indicate the number of communications of each type in the boxes. Write the letter C for a continuous, day-long communication. Please return the questionnaire to your secretary for transmission to MIT. Your cooperation is sincerely appreciated.

**CONTENT: CODE DEFINITION**

1. DISCUSSED OR DEVELOPED NEW IDEAS OR NEW APPROACHES TO TECHNICAL PROBLEMS
2. PROBLEM DEFINITION AND OR CRITICAL EVALUATION
3. LOCATING OR DISCUSSING TECHNICAL OR PRODUCT INFORMATION
4. ADMINISTRATIVE PROBLEMS OR ORGANIZATIONAL INFORMATION
5. OTHER

<table>
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<tr>
<th>INITIATION OF CONTACT</th>
<th>TYPE OF CONTACT</th>
<th>CONTENT OF CONTACT</th>
</tr>
</thead>
<tbody>
<tr>
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<td>OTHER</td>
<td>MUTUAL</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>TYPE OF CONTACT</th>
<th>CONTENT OF CONTACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELF</td>
<td>OTHER</td>
<td>MUTUAL</td>
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</tbody>
</table>

**Group I**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|

**Group III**

<p>| | | | | | | | | | |</p>
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**Group II**

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<table>
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<tr>
<th>Initiation of Contact</th>
<th>Type of Contact</th>
<th>Content of Contact</th>
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</thead>
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<tr>
<td>Self</td>
<td>Other</td>
<td>Mutual</td>
</tr>
<tr>
<td>Purple</td>
<td>Teal</td>
<td>Face to Face</td>
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<tr>
<td>Group IV</td>
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<tr>
<td>Group VII</td>
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<td>Group V</td>
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<tr>
<td>Group VI</td>
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- Staff Operations Support
- Accounting/Office Ser.
- Purchasing
- Facilities
- Photography Lab
- Government Contracts
- Library/Central Files

Personnel
Techno-Economic Analysis
2. If you have communicated, on this day, with anyone else at OCP, please complete the table below.

<table>
<thead>
<tr>
<th>ORGANIZATION</th>
<th>NAME OF DIVISION(S) OR PLANT(S)</th>
<th>INITIATION OF CONTACT</th>
<th>TYPE OF CONTACT</th>
<th>CONTENT OF CONTACT</th>
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<td>SELF  OTHER</td>
<td>FACE TO FACE</td>
<td>GROUP</td>
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<tr>
<td>CORPORATE ENGINEERING</td>
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<tr>
<td>OTHER TECHNICAL SERVICES</td>
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<tr>
<td>ADMINISTRATION</td>
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<td>MARKETING</td>
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<td>MANUFACTURING</td>
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<td>INTERNATIONAL DIVISION</td>
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<td>OTHER</td>
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3. If you have communicated on this day, with anyone outside of [OCP], please complete the table below.

<table>
<thead>
<tr>
<th>CONSULTANT</th>
<th>CUSTOMER</th>
<th>SUPPLIER</th>
<th>EDUCATIONAL ORG. (UNIV.)</th>
<th>PROFESSIONAL ORG.</th>
<th>OTHER: PLEASE SPECIFY</th>
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</thead>
<tbody>
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</tbody>
</table>
BIOGRAPHICAL NOTE ABOUT THE AUTHOR

Michael Lee Tushman was born in Worcester, Massachusetts on December 28, 1947. He attended public schools in Massachusetts and graduated from Medford High School in 1965. In 1970 he graduated with a B.S. in Electrical Engineering from Northeastern University. Five co-op semesters were spent in different areas of a small development engineering organization. Subsequently, he continued his graduate education at Cornell University, where he earned a M.S. in Organizational Behavior in 1972. Mr. Tushman was a Research Intern in the Organization Research and Development Department at Corning Glass Works while at Cornell. In September 1972 he began work for the Ph.D. at the Sloan School of Management. He concentrated on different areas of organizational behavior, specializing in R & D management and on issues in the management of innovation.

Mr. Tushman has had teaching experience at Cornell University and at the Massachusetts Institute of Technology. In 1974 he was a Summer Fellow at the Center for Creative Leadership in Greensboro, N.C. He has worked or consulted in a number of organizations including: the General Radio Company, Corning Glass Works, the Harvard and Tufts University Medical Centers, Owens Corning Fiberglas, Proctor and Gamble, and Bell Laboratories. He has recently joined the Management of Organizations faculty at the Graduate School of Business at Columbia University.