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RESEARCH PROJECT INITIATION

Date: 18 March 1974

Project Title: Flow of Scientific and Technical Information in the Innovation Process: An Analytical Study

Project No: G-43-603

Co-Principal Investigator Dr. Melvin Kranzberg & Dr. Patrick Kelly

Sponsor: National Science Foundation

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(Thru ORA)
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Assigned to: Social Science

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- _ Final Invoice and Closing Documents
- X Final Fiscal Report
- _ Final Report of Inventions
- _ Govt. Property Inventory & Related Certificate
- _ Classified Material Certificate
- X Other *Summary of completed project (NSF Form 98A) by Dr. Kranzberg/Dr. Kelly*

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THE FLOW OF SCIENTIFIC AND TECHNICAL INFORMATION IN THE INNOVATION PROCESS: AN ANALYTICAL STUDY

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CHAPTER I

INTRODUCTION

Technological innovation has been--and continues to be--a dominant problem-solving response in our society, and indeed, in much of the world. A measure of this dominance may be seen in the fact that problems arising from past technological achievements most often entail--or are seen to entail--further technological innovations for their resolution. Given the dominance of this problem-solving mode, it is not surprising that the process by which innovations come into being is a matter of considerable practical and scholarly interest, or that the process itself has undergone substantial changes over time.

Perhaps the most basic change in the process of technological innovation in this century is the increasingly strong trend toward the "institutionalization" of all its phases. The point here is not that only in this century did inventions come to require organizational skills and resources to turn them into useful innovations. James Watt who invented the steam engine in the late 18th century was dependent on the capital and the managerial and entrepreneurial expertise of Matthew Boulton to bring his inventions into use (Scherer 1965). Others such as Sperry and Edison were both inventors and able businessmen. The organizations they built were necessary in order for their inventions to become innovations (Hughes 1971; Josephson

1959). In short, the institutionalization of those phases of the innovation process that follow invention is not new.

That which has come to be handled differently, that which has come to be increasingly institutionalized in the 20th century, is the creative process itself--i.e., what we have come to call R&D. That this is possible is itself a bold and novel assumption, at least in the extent to which it is currently accepted and its actualization sought. As one writer has remarked:

> The historians of the future may well select the development of deliberate creativeness as the most important development of this century. We have passed through the age of random creativeness and are entering an age of deliberate creativeness (Rossman 1964, p. xii).

That the creation and introduction of novelty is now recognized and accepted as a part of the mission of so many organizations reflects the extent to which this assumption of deliberate creativeness--and thus the institutionalization of the whole innovation process--has taken root.

The emergence and rapid growth of R&D laboratories, especially in the years after World War II, is the major manifestation of this institutionalization phenomenon. Total U.S. R&D expenditures increased at an average annual rate of 10 per cent in the 1953--1970 time period (Mansfield, et al. 1971). Rubenstein (1957, p. 95), summarizing the growth in R&D activity along a different dimension, noted that the 1956 edition of the Industrial Research Laboratories of the United States lists 4834 R&D laboratories operated by 4086 companies. "A sizable proportion of these companies were not operating research programs 10 years ago, and a majority of them were not doing so 15 years ago. As for the programs that did exist then most have grown so fast that today they can hardly be recognized."

In Hamberg's (1955) words there has been a "research explosion": "R&D is being conducted on an unparalleled scale offering the potential for unprecedented advances in productivity increases." The extent to which such increases will in fact be realized depends, in large measure, on how effective the R&D process can become, and that depends in turn on our understanding the wide range of variables that impinge on the institutionalized process of innovation. Crucial among these variables are those that relate to the pool and flow of scientific and technical information--the focus of this report.

A. Scope and Objectives

This study is concerned with the informal pool and flow of scientific and technical information in the R&D laboratory. The study is designed to explore:

(1) not only "What do we know?" but also, "What do these things mean?";
(2) not only "What do we not know?" but "What should we know?" and "What is required before we can come to know these things?"; and, finally,
(3) "What is the practical import of all of this for the several groups of stakeholders?"

These questions may be recast in terms of the following objectives:

1. To describe the nature and function of the informal STI system in the R&D laboratory...

    <u>in terms of</u> an integrative conceptual framework in which the notion of informal groups is central;

    <u>with respect to</u> a range of variables that have been shown or hypothesized as impinging on STI pool and flow;

    <u>to the end that</u> the concerted influence of these variables may come to be studied, understood, and utilized as information-need indicators;

2. To utilize the results achieved in this integrative effort to examine the implications of the nature and function of the laboratory's informal STI system for...

    its interface with formal STI systems and services;
    its interface with the operating units of the laboratory's parent organization;

    the research "agenda" of scholars concerned with the innovation process, the R&D laboratory, and the pool and flow of STI.

These objectives are expanded in the following section.

B. Three Emphases of the Study

In the course of this inquiry into the patterns of STI pool and flow in the R&D laboratory three distinct but overlapping emphases emerged. The first involves a conceptual framework for integrating a range of variables that influence the laboratory's information processes. The approach here is a systemic one, dealing with the influence of these various influences in concert. Our second emphasis concerns the interface of the laboratory with external information sources. Here the question is how the laboratory researcher typically gets information from formal STI systems and services and from informal sources beyond his laboratory. The third emphasis of our study involves the informational dimension of the laboratory's interface with the operating units of its parent organization (or such other "clients" as may be recipients of R&D output). The question here is how information about operational constraints and opportunities flows to, and within, the R&D laboratory.

1. An Integrated Conceptual Framework

The scientific and technical information required in the conduct of R&D, and the ways in which this information comes to be available, are subject to a wide variety of influences. Among the influences to be examined are:

a. Differences in the nature of the several activities across the R&D spectrum.

Those activities toward the basic research pole are more heavily dependent on external STI sources (both formal and informal), while those toward the operations interface require a greater measure of in-house information (Rosenbloom and Wolek 1970). Corresponding differences exist in the manner in which this information flows, into and within the laboratory.

b. Differences in the information needs and information-seeking behaviors of the several professional fields or disciplines represented in the laboratory.

Other things being equal, scientists seem more oriented toward the formal literature and informal sources external to the laboratory, while engineers show a greater reliance on informal sources within the laboratory.[1]

c. Differences in the way in which the laboratory and/or project is structured.

It will be argued that laboratories organized by R&D function (e.g., research, development, and design), and by discipline within these functional units, create conditions more favorable to efficient informal STI pool and flow mechanisms than the "project-dominant" arrangement (i.e., multi-disciplinary units that work on long-term projects or service major product areas).

d. Differences between corporate and operating-division laboratories.

This difference in the location (and function) of the laboratory within its parent organization has implications for the kinds of information needed and the ways in which this information comes to be available. For instance central laboratories exhibit a much greater reliance on external information than do operating division laboratories (Rosenbloom and Wolek 1970, pp. 49-50).

e. The difference between stable and rapidly changing R&D missions.

Frequent and substantial shifts in R&D focus imply that the in-house STI pool more often proves inadequate--thus requiring more accretions from external sources--than in the case of the more stable mission.

f. <u>Differences in the rate of scientific and technological change within the industry of which the laboratory's parent organization is a part</u>.

This point, like the previous one, has to do with the relative adequacy of the laboratory's in-house information pool. Here, however, we will be concerned with the pace at which the state-of-the-art knowledge is changing rather than the frequency of organizationally-induced shifts in the laboratory mission. We argue that the higher the rate of scientific and/or technological change in the industry of which the laboratory's parent organization is a part, the greater the reliance on external information sources.

g. <u>Differences imposed by the magnitude of the innovative effort, i.e., incremental improvement vs. discontinuous or breakthrough efforts</u>.

The final influence we will consider lies, not in the conditions within the laboratory or its larger environment, but in the magnitude of the innovative effort itself. At one extreme, an innovative effort may represent a minor extension of what the organization is already producing--a small <u>increment</u> or next step. On the other hand, it may represent a radical departure--a <u>discontinuity</u> if you will. Most of the information required for the former typically exists as a part of the in-house pool; little is required from external sources. For discontinuous or breakthrough efforts, however, the matter is quite otherwise. Massive infusions of information from outside will likely be required.

Each of these influences on the STI needs and flow patterns within the laboratory admits of considerable complexity. Thus the evidence and arguments for them will have to be examined carefully. The more important point to be noted, however, is that these influences do not impinge singly, but in various combinations. As a matter of strategy, therefore, we will first deal with only one "set" of influences from among the several combinations inherent in the above types. This will provide a specific illustration of the conceptual framework we offer for their integrated treatment. In addition, explication of this specific combination of influences will serve as a "baseline" for gauging the differences introduced by alternative combinations.

We take the nature and function of informal groups as the key to understanding the pool and flow of STI in the R&D laboratory. Thus the notion of informal groups will constitute the basis of our integrated conceptual framework. Certain key individual roles--gatekeepers, supervisors, opinion leaders, liaisons--on the one hand, and the functioning of the laboratory's larger informal system or network on the other, will be interpreted in terms of the informal group. Likewise, the several variables listed above will be treated in terms of their influence on the nature and/or function of such groups.

2. The Interface with External Sources of Information

The second major emphasis of our study concerns the interface of the laboratory's informal STI pool and flow system with external information sources (The operating units of the parent organization as STI sources are excluded here, but will be treated in a separate section). These external sources are of two types--formal STI systems and services and informal contacts. Neither of these external sources will be examined in any detail in this study, since they are equally complex systems whose treatment would take us far beyond our R&D laboratory focus.

As to the formal STI systems, however, it should be noted that the growth of organized R&D, as described earlier, has contributed to a corresponding growth in the need for, and volume of, scientific and technical information. To disseminate, index, abstract, store, and provide this information quickly on demand, there has emerged a diversified and burgeoning STI industry. In other words, the institutionalization of technological innovation in the form of the R&D laboratory has contributed to parallel developments in this vital support function.

From the perspective of the information specialists who design and operate the wide range of formal STI systems and services, however, the interface with organized R&D has often been a frustrating one. With diligence, imagination, and no small commitment of resources, these formal systems have over the years become progressively more elegant and sophisticated. By every measure there has been impressive progress--every measure, that is, except the percentage of actual users.[2] Each enhancement of search capability, each time-saving increment, each surge in comprehensiveness, seems to be greeted by the potential laboratory-user population with about the same measure of indifference. To the STI specialist, this must be perplexing. What is the matter with these R&D "yoyos" anyway? Relevant and timely information is the very lifeblood of R&D; how can they possibly ignore the formal systems and services and still survive?

But not only does R&D survive, it thrives. The apparent lack of need must be even more frustrating than the demonstrated lack of use. Yet the researchers in the R&D laboratory show few signs of the sort of informational malnutrition that would result from unmet STI needs. They show only a rosy glow of informational good health and an apparently obstinate indifference to the formal STI systems and services.

Before those who design and manage the formal STI systems yield to frustration over the failure of their best efforts to meet the R&D researcher's informational needs, however, they should be sure that this failure is not more apparent than real. In this, the second of our three emphases, we will be looking closely at the behavior of these researchers who seem not to need the formal systems and services. At the same time, we will be looking at some of the assumptions about the R&D researcher that seem to shape the expectations of the formal systems professionals.

To provide a preliminary overview of this interface of the formal STI systems and services with the laboratory's informal systems, let us anticipate come of the practical conclusions that will emerge from our analysis.

a. <u>It is distorting and unhelpful to think in terms of "users" and "non-users" of the formal systems and services.</u>

The possible reasons for non-use of the formal STI systems and services are numerous, and most of them are quite sensible and unlikely to change. Furthermore, these reasons for non-use constitute no indictment of the formal systems or the non-users: the former are not negligent and the latter are not slothful. In aggregate, most of the information needs in the R&D laboratory either can't be met at all by the formal systems and services, or they can be met better, quicker, and with significant social-psychological payoff by the laboratory's informal system. The designation "non-user" distorts these realities by its implication that if only the formal systems or "those ninnies" were somehow different, then they too would become users. We see little to support this contention, however. Thus, the user/non-user way of thinking about the problem introduces a distorting dichcotomy that cannot yield much understanding of formal/informal systems interface. A distinction between <u>direct</u> and <u>indirect</u> users is a more accurate and helpful one.

The user/non-user distinction is also unhelpful when used --as it often is--to gauge the <u>value</u> of formal STI systems and services. The evidence indicates that the number of direct users is going to remain a very small fraction of the total number of researchers. Therefore, to judge the value of the formal systems and services by counting noses is to invite an unnecessary frustration. No matter what is done, the nose count is not going to get much better--they simply can't use the services at all, or have a better (i.e., indirect) access. There is an even more unhelpful implication than continued frustration, however. If you make the number of users the bottom line in evaluating what is provided, then that same yardstick is going to be picked up and used by those who pay the bills. In a crunch, that may spell budgetary disaster; and even if it does not, it is a serious misrepresentation of the value of the formal STI systems and services.

b. It is accurate and helpful to think in terms of service to informal groups--groups composed of both direct and indirect users.

We will argue that the market for the formal STI systems and services is composed, not of isolated individuals, but of highly interactive informal groups. These informal groups have been shown to be extremely effective information pools. Accretions to these informal pools from external sources, such as the formal STI systems and services, are typically by way of a very few group members. Allen has called these individuals "gatekeepers." For present purposes, we prefer the term "direct users," since it serves to highlight the fact that these individuals, in turn, serve their informal group, thus making their colleagues "indirect users."

This notion of direct and indirect users is really a very simple one. Just as far more people eat food than go grocery shopping, just so do far more researchers benefit from the formal STI systems and services than use them directly. It is also a helpful picture, for it calls attention to the overlapping nature of the boundaries between formal and informal STI systems. Once it is recognized that the formal systems serve groups, through the few direct users, then it becomes clear that the effective boundaries of such formal systems are indeed quite large. Indirect users are users nonetheless--a point which has been, but should not be, neglected.

c. <u>There are features of the R&D laboratory and its environment that can serve as "indicators" of information needs that the formal systems and services can meet.</u>

We argue that those characteristics of the R&D context listed above exert systematic and predictable influences on the laboratory's information requirements. These <u>information need indicators</u> thus offer the potential for "fine-tuning" formal STI systems and services to meet more adequately the needs of R&D laboratories and hence to encourage innovation. A word of caution is in order, however. The kinds of questions about information use in the R&D laboratory that have led us to posit these indicators have not all been directly addressed in the research literature. Thus the evidence for some of them is, at this point, largely indirect. We are convinced, however, that the approach is a fruitful one, and that the indicators we describe could prove useful. The needed acid tests, however, are careful empirical research by academics on the one hand, and the actual use, or at least laboratory testing, of these indicators by formal systems designers and operators on the other.

d. <u>At least in the short-run, fine-tuning the formal STI systems and services in terms of the "information need indicators" may require the assistance of "interpreters," i.e., those knowledgeable about the R&D process.</u>

At present, the formal STI systems and the informal systems of the R&D laboratory are largely independent mechanisms, interacting in unplanned ways that are often a puzzle. Ideally, however, they should function as interdependent subsystems of a larger whole. The initiative in designing and implementing this larger STI system--which would embrace both the formal and informal as interlocking components--must come from those involved with the formal systems. The reason is obvious. The informal systems, while enduring and extremely effective, are by their very nature the unplanned and mute creatures of past and present needs, who constrain the future but cannot design for it.

The question, then, is how can this better integrated system be designed? The answer is by fine-tuning the formal component to mesh with the informal, which simply exists, cannot be designed, and cannot speak for itself. To get beyond blind trial and error in this fine-tuning process, we think it is essential to involve those who might be able to "speak for" the informal component, i.e., those who are knowledgeable about the broader dimensions of the R&D process, the nature and function of informal laboratory groups, and the patterns of STI flow within them. Such individuals could play an important interpreter role in working out a more effective interface between the formal and informal STI systems.

We will return to these practical points in Chapter III after having developed the systemic, conceptual, and empirical foundation upon which they rest.

3. The Interface with Operations

The third emphasis in our analysis and integrative treatment of STI pool and flow in the R&D laboratory involves its interface with the operating units of its parent organization --its "clients" if you will. R&D converts ideas and information into potential technological innovations. These potential innovations must be transferred to, and successfully implemented by, the operating units of the organization before their success--or lack of it-- can be gauged by actual use. We take the success of this transfer from R&D to operations to be heavily STI-dependent. That is, the R&D effort, particularly in its latter stages, must be informed by and compatible with the technical constraints and opportunities inherent in the implementation process with is to follow.

The importance of a smooth transfer from R&D can be seen in economic terms. From their sample of firms in the chemical, mechanical and electronic industries, Mansfield et al. (1971) found that over 75 per cent of the total innovation expenditures occurred after the R&D phase.[3] Thus a poor interface not only threatens the investment already made in R&D, but can undermine the much larger expenditures to come. The difficulty inherent in this interface is emphasized by Quinn and Mueller who, after interviewing over 200 top operating and research executives, concluded that, "The key problem in research management today is getting research results effectively transferred into operations" (1963, p. 49).

In order to understand and thus deal more effectively with the risk and difficulty inherent in this transfer, it should be viewed, not as an event at some point in time, but as an STI dependent process in which informal laboratory groups have a significant role. In particular, the following exploratory hypotheses will be advanced:

a. Instances of smooth and effective transfer of an innovation are characterized by more substantial pool and flow of operations-dependent STI in the R&D laboratory than less smooth and effective instances;

b. The beginnings of a successful transfer to operations have often-unobtrusive roots that run far back in the R&D effort;

c. Informal laboratory groups, and certain key individuals within them, constitute the most significant pools and channels of operations-dependent STI within the laboratory.

d. Precisely those features of the laboratory's informal STI system that make it so effective in intra-laboratory pool and flow may constitute barriers to the laboratory's interface with operations.

Evidence for these exploratory hypotheses is, at this point, largely analytic and systemic rather than empirical and direct. We believe the case for them is strong enough, however, to impel their testing.

* * *

These three emphases or perspectives on the pool and flow of STI in the R&D laboratory--(1) a conceptual framework for integrating a range of impinging variables, (2) the interface with external information sources, and (3) the interface with operations--will constitute the foci of Chapters II, III, and IV respectively.

C. Study Methodology

The complexity inherent in the pool and flow of STI in the R&D laboratory, the unevenness in our current understanding of the process, and the practical pressures to improve it, converge to give this study the following characteristics:

1. It is analytic and interdisciplinary, i.e., it draws upon research results--and the assumptions underlying them--from a wide range of scholarly fields whose subject matters are central to or impinge upon information need and acquisition patterns in the laboratory;
2. It is integrative in the sense that it attempts to deal with variables and assumptions in concert rather than singly with a specious "other things being equal" caveat;
3. It is hypothesis generating, in that the conceptual framework which is proposed permits a new level of questioning;
4. It is practice-oriented, i.e., the new level of questioning that is introduced results, not only in a research "agenda" for academics, but also in recommendations for fine-tuning the formal STI systems and services on the one hand, and for facilitating the role of the laboratory's informal system on the other.

These characteristics dictate a method of study that combines both inductive and deductive modes of investigation in an iterative and cumulative process. That is to say, at certain points we are involved in piecing together the implications of a wide range of empirical studies that have been reported in the literature, while at others we are moving from a more general observation or hypothesis to its possible implications at the operational level. In an effort that is integrative as well as analytic, these methodological modes feed into, inform, and constrain one another. An illustration of this pattern is in order.

There is considerable empirical evidence regarding the relative frequencies with which information needs are met; through informal discussions as opposed to the formal literature, by in-house as opposed to external sources, through professional as opposed to trade literature, etc. Correlations have also been established between these information seeking behaviors and certain characteristics of the researcher (e.g., scientist or engineer), the nature of the activity in which he is engaged (e.g., research,development, or design), and differences between the laboratory setting and mission (corporate vs operating division laboratories). Analysis of these empirically demonstrated relationships have led us to posit others that need to be explored; e.g., the way in which the laboratory and/or project is structured, the stability of the laboratory's R&D mission, the rate of scientific and technical change in the industry, and the nature of the innovative effort itself.

The whole thrust of these existing and proposed correlation studies serve, in turn, to raise a number of questions as to the nature of the informal mechanisms by which STI (or literature references to it) is transferred. There is a growing number of studies of such informal transfers, especially as regards the role of certain key individuals called "gatekeepers." There are, however, two serious weaknesses in these studies of the informal STI channels and patterns. First, they exhibit an almost total neglect of the influences mentioned above that have been shown to correlate with different information-seeking behaviors. Thus it is unknown, for instance, whether the gatekeeper function is as important in basic research as in the design function, or to scientists as engineers, or in the corporate as opposed to the operating division laboratory. Piecing together an integrated picture of these relationships, calls for both the deductive and inductive modes of analysis.

The second weakness in the existing studies of the laboratory's informal STI system is that their emphasis on the gatekeeper function--as important as it indeed is--has been at the expense of a more balanced understanding of the whole informal system. For instance, our analysis leads us to believe that the gatekeeper function probably accounts for only a fairly small portion of the total flow of STI through informal channels.

Support of this contention rests on a nexus of inductive and deductive work.

Finally, our analysis of what is known about the information-seeking behavior of R&D personnel, the informal systems of which they are a part, and the range of influences that impinge upon both, has led us to emphasize the concept of informal groups. The range of phenomena requiring explanation cannot be treated adequately without a careful consideration of the manner in which information is informally pooled as well as the informal channels by which it flows. Informal groups are taken as the key to a more adequate understanding of both functions--and, indeed, to the integration of what is known about STI phenomena in the R&D laboratory.

Thus the methodology employed in this study is a complex of both inductive and deductive modes of investigation. Its legitimization rests upon three considerations: The internal consistency of the integration achieved; the compatibility of this integration with existing empirical results, and, finally, the fruitfulness of the hypotheses and practical actions to which it leads.

Chapter I

Footnotes

1. Price 1965; Allen 1964; 1966a,b; Hagstrom 1965; Shilling and Bernard 1964; Gerstberger and Allen 1968.

2. Herner 1954; Halbert and Ackoff 1959; OECD 1960; Scott 1962; Allen 1965, 1966; Auerbach Corporation 1965; Sherwin and Isenson 1966; Isenson 1967; North American Aviation 1966.

3. The breakdown of post-R&D expenditures was 29.1 per cent for prototypes and pilot plant, 36.9 per cent for tooling and manufacturing facilities, and 9.5 per cent for manufacturing start-up costs.

CHAPTER II

THE NATURE AND FUNCTION OF THE INFORMAL STI SYSTEM IN THE R&D LABORATORY

A. Introduction

In this chapter we will seek to:

1. Analyze the nature and function of the informal

   STI system in the R&D laboratory...

   in terms of an integrative conceptual framework in which the notion of informal groups is central;

   with respect to a range of variables that have been shown or hypothesized as impinging on STI pool and flow;

   to the end that the concerted influence of these variables may come to be studied, understood, and utilized as information need indicators.

This analysis, of the informal system and the pool and flow of STI it makes possible, will be grounded in the state of the art understanding of these phenomena. Where there exist gaps or weaknesses in this understanding, we will "effect closure" with such exploratory hypotheses and conceptual bridges as seem to us warranted. These leaps beyond what has been demonstrated will be indicated as such.

1. Neglect of the Informal System

The term "informal STI system" here refers to a communications network through which the researcher in the R&D laboratory may access, by personal contact, the "pool" of information that is possessed by the members of that network. That which is obtained by means of these informal channels may be either the needed scientific or technical information itself, or a reference to the formal literature or other source where the information may be found.

This definition of the informal system occasions a noting of the obvious, i.e., "that formal and informal communications are mutually dependent elements of the same system" (Wolek, undated working paper, p. 3). This interdependency has in the past been so badly neglected that formal and informal channels were at times seen as competitors, and use of the informal as a sign of weakness and need for better formal systems (this view is expressed, for instance, by Scott, 1962). While specialization of focus within the STI field is both legitimate and necessary, not to the extent of research and formal system designs that attempt to reinvent a well functioning wheel.

The informal STI systems depend for their existence on social systems--or if you prefer, are manifestations of social systems. Price (1970) makes this point and scolds those who would neglect it when he says:

> In short, hard science, soft science, technology, and nonscience may be all different social systems, and each system must have its own special machinery for...communication among people at the research fronts and behind these fronts too. I believe that ...a proper understanding of science as a social system will wipe away a lot of naive misunderstanding which shrouds the business of science information and makes us hope for the wrong sort of expensive solutions to what seems to be the problems (p. 22).

Let us juxtapose this contrast of formal and informal STI systems with a contrast between the informal STI system and the formal organization of R&D.

> The most intriguing aspect of this process [of informal transfer] is the fact that it has developed spontaneously, with no management intervention. There was scarcely a suspicion on the part of management that the network operated in this way (Allen 1970, p. 200).

There is an interesting parallel in these two quotes that contrast the informal system with two quite different kinds of formal systems. They both make the point that those concerned with these respective formal systems often do not understand the nature, role, and importance of the informal system very well. If this be the case, it makes all the more important our task of displaying the interdependencies between the informal systems and their formal STI counterparts on the one hand, and the formal structure of R&D organizations on the other.

2. <u>The Informal System: Praise and Criticism</u>

Scholars concerned with the informal STI system have at times been lavish in their assessment of its efficiency. Allen (1970) has said for instance:

> In fact, if one were to sit down and attempt to design an optimal system for bringing in new technical information and disseminating it within the organization, it would be difficult to produce a better one than that which exists (p. 198).

Others have been more cautious, even critical, of informal systems in general.

> While scientists working in related research areas are likely to come into contact, there is no certainty that this will occur. The informal system contains no mechanisms to assure that scientists with common interests will indeed attend the same meetings, and even if they do, actual face-to-face encounter is often a matter of chance. Informal communication, because of its very nature, is marked by its large random element (National Academy of Sciences 1967, p. 45).

As between these two divergent assessments, we find the former to be closer to the mark. It is a misunderstanding to assume that "informal" means "lacking structure." While informal systems by definition lack formal structure, this does not mean that they lack structure altogether (Menzel 1959; Allen 1970). The typical informal system at least within the R&D laboratory is, in fact, a rich network of interrelations for which "its large random element" is a specious characterization.

This point is convincingly illustrated in a study by Rosenbloom and Wolek (1970) in which more than 3000 engineers and scientists[1] were asked to, "think of the most recent instance in which an item of information, which you received from a source other than someone in your immediate circle of colleagues, proved useful in your work" (p. 124). The subjects were then asked to describe the circumstances leading up to acquiring this information. The responses were grouped into three categories, "according to whether the information had been sought for the specific use to which it was put, had been volunteered by someone else, or had been acquired in the course of 'competence development' activities such as keeping up with or reviewing a technical field" (p. 37). Table 1 shows the results obtained.

Table 1

Circumstances of Acquisition

	Total (N=1852)	Scientists (N=654)	Engineers (N=966)
Specifically sought	47%	42%	53%
Pointed Out	32%	33%	30%
General Competence	21%	25%	17%

As these percentages indicate, in almost one-third of the instances the information was transferred--not as the result of a search--but because someone volunteered it. This was the case even though the researcher's "immediate circle of colleagues" was excluded from the question.[2] It is difficult to fault for its randomness an informal communication system so powerful that a third of the time it delivers information even before the person knows he needs it!

There is an interesting prescription that has gained some currency among STI scholars that deserves mention in this connection.

> When you need to know something, ask somebody; If you don't know who to ask, ask someone who might know somebody; If you don't know someone who knows somebody, and can't wait, avoid, or change your need, then search the literature. (Kelly and Wolek 1976).

This prescription or "rule of thumb" occasions two comments about the informal STI system. First, while it refers to the way in which the informal systems work, even on its surface it recognizes the existence and necessity of the formal STI systems and services--though apparently as a last resort. But it is naive and distorting to take this rule of thumb as relegating the formal systems and services to merely a "last resort only" status. When you "ask somebody," what you may well get is a reference to the literature where the information may be found.

Second, this prescription is not an equally sound characterization of all the STI pool and flow patterns that may coexist in the same informal system. At one extreme, we suspect that there are patterns of STI flow that almost never include use of the formal literature--even as a last resort. On the other, there are patterns in which the literature is central and essential. While the above "rule of thumb" is not an invalid characterization of how the informal system works in even these polar extremes, it is more straightforwardly accurate in the intermediate range.

3. The Concept of Informal Groups

An R&D laboratory's informal STI system has been shown to be a cluster of highly interactive subsystems that are linked by interpersonal contact to one another, to the operational end of the organization, and to sources beyond the organization.[3] At some points the linkages between its constitutive subsystems are numerous and strong from frequent use. At other points the coupling may be as tenuous as an infrequent contact between only two individuals.

These constitutive units of the laboratory's informal STI system are small, informal groups of researchers, groups occasioned and sustained by the mutual social-choices of their members. We take these informal groups as the key to the integration of what is known about the nature and function of the laboratory's informal STI system--i.e., they seem to be the primary mechanism of informal STI pool and flow.

These informal--or mutual social-choice--laboratory groups typically exist wholly within single sub-units or departments of the formal laboratory structure (Allen 1970). Cartwright and Zander (1968) account for this fact as follows:

> Because the spontaneous formation of a group from a particular collection of acquaintances involves the development of interpersonal attractions among them, the composition of such groups may be expected to depend upon conditions that determine such attractions (p. 55).

The formal organizational units of the laboratory, by the nature of their specific R&D functions, provide a number of conditions for informal group formation--not the least of which is the acquisition of the scientific and technical information upon which the performance of such functions depends.

Informal groups typically arise <u>within</u> formal laboratory units, but are usually not co-extensive within them. Allen (1970) has shown that for the eight laboratory departments he studied there was a median of three informal groups in each. While the formal laboratory structure typically provides the focusing and boundary conditions for such groups, it does not account fully for their emergence or composition. This explanation seems to lie in the idiosyncrasies of mutual social choice. The reasons for such choices seem to involve the satisfaction of such individual needs as socialization, communication, and a greater measure of control over one's environment.[4] Efforts to satisfy such needs by participation in informal laboratory groups are well illustrated in the R&D literature.

The ways in which such individual needs converge with one another, and with conditions inherent in the formal organizations, to occasion the formation of informal groups in the laboratory are too numerous and social-psychologically complex to be treated in this study. A simple illustration is in order, however. In the course of a researcher's work on a project for which he has been formally assigned responsibility, he may encounter problems that lie outside his knowledge and expertise. To maintain (or increase) his measure of "control over his environment"--e.g., complete the project successfully, merit the approval of his supervisor and peers, enhance his career development, etc.--he needs information he does not possess. He needs to "communicate" with those knowledgeable in this problem area. He may not, however, even be able to ask very "good" questions about the problem. This being the case, he would likely seek out those he knows well, since there is less risk of embarrassment in posing possibly "dumb" questions to a friend.

> Simply stated, people are more willing to ask questions of others whom they know, than of strangers...To be told that you have asked a dumb or foolish question is the ultimate in rebuffs. Few people are willing to entertain such a risk. Now, out of all the people in the world there are hopefully only a small percentage who would meet even a truly stupid question with such a retort. Even given that this percentage is very small, however, many people will follow the strategy of minimum regrets and assume that everyone belongs to this set unless proven otherwise (Allen 1970).

Informal social contacts thus seem to provide a more comfortable context for seeking information, which if successful, reinforces these informal bonds. Informal groups, therefore, may be viewed as socialization mechanisms, which facilitate information flow, enabling the researcher to perform better on assigned tasks, and thereby to control more effectively his environment.

While informal laboratory groups thus perform similar social-psychological functions, our analysis of the literature leads us to hypothesize substantial differences in the manner, extent, and effect of their information transfer functions. To understand a particular group's role in STI pool and flow, it is necessary to specify the nature of the informal group and the conditions under which it is operating. The following variables have been shown, or are herein hypothesized, as important in this regard.

1. Differences in the nature of the several activities that may be identified across the R&D spectrum.

2. Differences in the information needs and information-seeking behaviors of the several professional fields or disciplines represented in the laboratory.

3. Differences in the way in which the laboratory and/or project is structured.

4. Differences between corporate and operating division laboratories.

5. The differences between stable and rapidly changing R&D missions.

6. Differences in the rate of scientific and/or technological change within the industry of which the laboratory's parent organization is a part.

7. Differences imposed by the magnitude of the innovative effort, i.e., incremental improvement vs. discontinuous projects.

Each of these influences upon the patterns of STI flow within the laboratory admits of considerable complexity. In addition, they do not impinge singly, but in various combinations. As a matter of strategy, we will first deal with only one commonly found set of influences from among the several combinations inherent in the above types. This will provide a specific frame of reference for illustrating the integrative and explanatory power of the informal group concept. In addition, the explication of this specific combination of influences will serve as a "baseline" for gauging in a more systematic fashion the differences introduced by the alternatives to be considered later.

B. A Baseline Integration

The baseline structural arrangement we have selected is a typical one in which a single corporate laboratory is structured in terms of R&D activities or functions--e.g., research, development and design.[5] Rosenbloom and Wolek (1970) have characterized these activities as follows:

> Research tasks have a high expected contribution to knowledge but are relatively remote from operations; design tasks fall at the opposite pole on each dimension. Relative to both of these tasks, development work occupies an interesting position. In relation to research it should yield a more direct contribution to operations, while in relation to design it has a much higher expected contribution to the state of

> knowledge. Development work is undertaken when there is some specific operational goal in mind, but it occurs at a phase in the R&D cycle in which first priority often is given to the synthesis, validation, and refinement of concepts and approaches (p. 82).

Given sufficient laboratory size, each of these functional units is here assumed to be subdivided along professional field or disciplinary lines. We also assume that the mission of the laboratory embraces the whole spectrum of R&D activities from basic research to the interface with operations, that the rate of technological change in the industry is moderate. Finally, we will take the magnitude of its innovative efforts to be toward the incremental improvement end of the spectrum, i.e., it is not currently involved in a major departure from that which the laboratory knows best.

1. The Informal Group

The influence of this particular combination of conditions on the nature and function of informal laboratory groups may be briefly summarized as follows. The way in which this laboratory is organized provides a doubly cohesive basis for the emergence and functioning of informal groups. First, since the laboratory has established separate functionally organized units for the conduct of the R&D, distinctive *formal* groups are thereby created. These formal groups share a common functional orientation, a common set of goals, and common problems. Second, developing the internal structure of these functional units along the lines of the researcher's professional fields or disciplines results in smaller *formal* groups that are even more cohesive. The members of these sub-units not only have a particular R&D function in common, but also share their disciplinary paradigms, coding schemes, expertise, etc.

The nature of the _informal groups_ that emerge--on the basis of mutual social choice--within this formal organizational structure is, in large measure, dictated by these formal arrangements, and thus reflects the doubly cohesive influence that they create. As Conrath (1968) has noted, "The very existence of a formal organization provides the _raison d'etre_ for the formation of informal interest groups." From the perspective of the individual researcher, the point here is that the ways in which his needs for socialization, communication, and a greater measure of control are manifested, are greatly influenced by the nature of the formal organizational units of which he is a part. The formal groupings not only focus his attention and effort by their nature and function, but also bring him into close contact with others who are similarly focused.

The formal units and sub-units of the laboratory thus occasion particular individual needs by their existence and function; but only incidentally can they meet these needs. Their function is primarily the satisfaction of organizational, not individual, needs. In addition to occasioning the particular manifestations of individual needs, however, they also occasion the emergence and continued existence of informal groups that can meet them. In meeting the needs of its members, the informal groups may also further the objectives of the organization.

The need for scientific and technical information is a case in point. Often a researcher requires information that he does not possess. The formal organization, which has occasioned this need by the task it has assigned the researcher may "possess" the information in the sense that it can be gained by searching the corporate technical library or computerized STI system provided. But it may be more readily available from a colleague, or from a source he knows. The frequency of such informational needs occasions, in part, the existence of informal communications networks.

Figure 1 shows the communications network for a typical functional department in a large R&D laboratory studied by Allen. By means of a graph-theoretic reduction the "strong components"[6]--what we have called informal groups--of this network are shown in Figure 2.

In the eight departments of about fifty researchers each studied by Allen, there was a median of three non-trivial (more than two members) strong components per department (Allen 1970, p. 198). These informal groups, unlike the laboratory units which embrace them, are not, with rare exception, formally recognized units of the organization. Within these groups the interpersonal linkages are numerous and strong from frequent use. Between them they are weaker, occasionally as tenuous as an infrequent contact between only two individuals. Thus the flow of information is not uniform throughout the departments or the laboratory. Our thesis is that these informal groups--though spontaneous in origin and

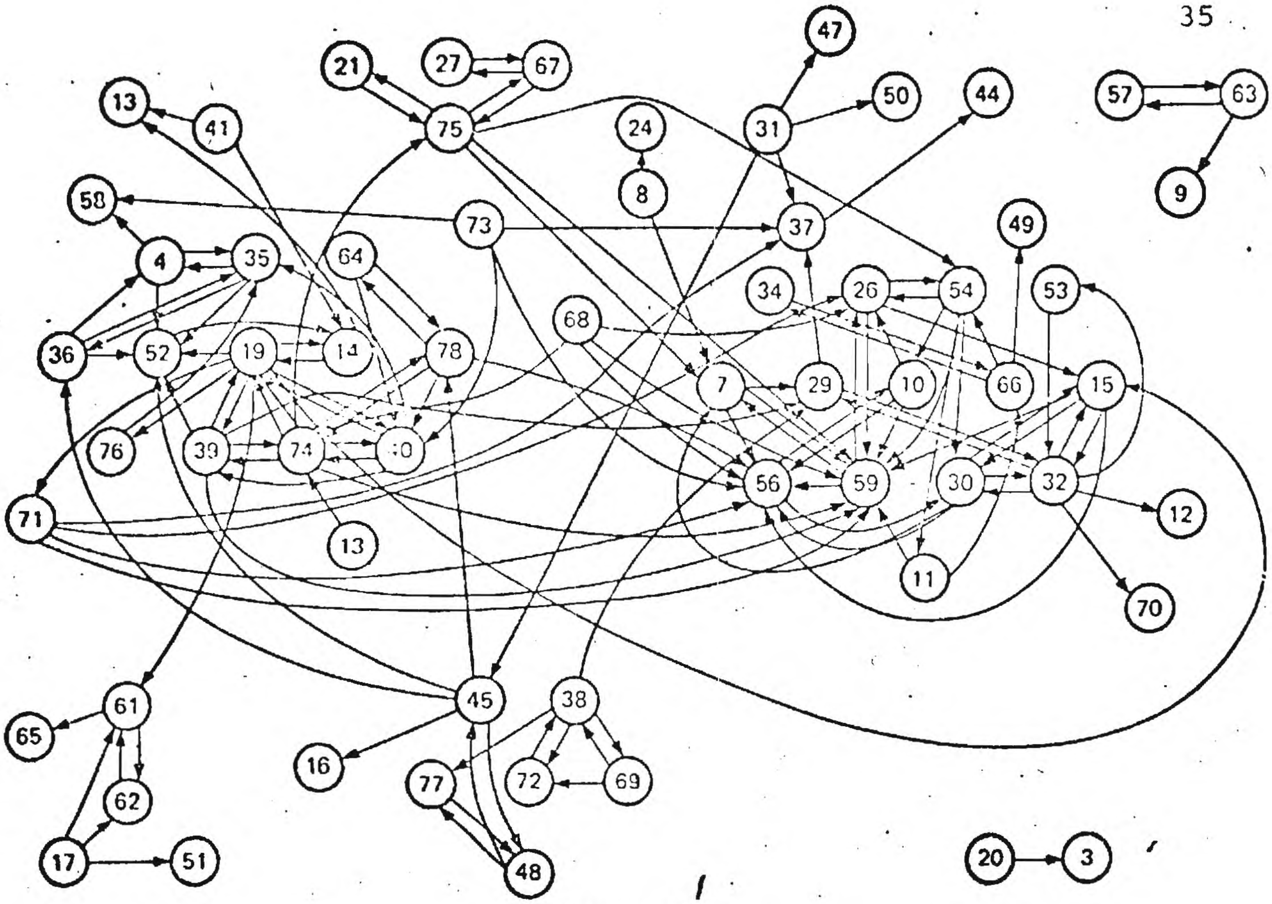


Figure 1
Communication Network of a Typical Functional Department of a Large R&D Laboratory (Allen 1970, p. 199).

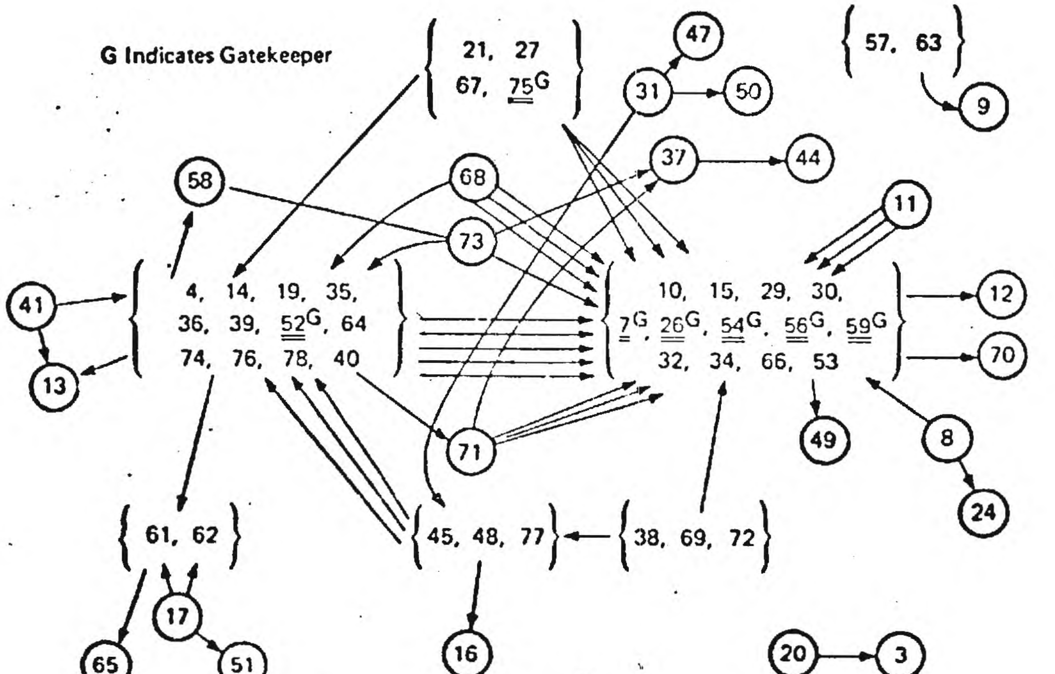


Figure 2
Departmental Communication Network After Reduction into Strong Components. (Strong Components are shown in brackets, and gatekeepers are shown by underlining with "G" superscript). (Allen 1970, p. 200).

informal and unrecognized in their existence--are in fact the core of the laboratory's informal STI system.

It should be noted that whatever the social-psychological motivations underlying the formation of such groups, once established, they are tenacious in maintaining themselves (Taylor and Utterback 1975). There is also evidence that in addition to their information transfer function, informal groups may also have a role in the shaping of technical "attitudes" within the laboratory. Let us explore this last point for a moment, as it may provide a further clue as to the "cement" which binds these groups together.

In a study by Allen and Cohen (1966) researchers in two large laboratories were asked to indicate their attitudes on each of three rather uncertain technical questions confronting their laboratories, in order to test the following hypothesis:

> Technological attitudes, attitudes toward such things as feasibility of particular approaches which are not yet physically testable, will be strongly influenced by the attitudes held by other members of the primary groups to which the engineer belongs (Allen and Cohen 1966, p. 7).

Credit for the formation of this hypothesis was given to Kurt Lewin and his followers who suggested that "when an opinion or attitude cannot be tested directly against 'physical reality' then the individual will resort to a test against 'social reality.' In other words, he will look to his peers for confirmation or disconfirmation and react accordingly" (Allen and Cohen 1966, p. 8).

A fairly strong correlation was found between the technical approaches favored by the individual researcher and the ones favored by those he sought out for technical discussion. Unfortunately, the nature of the data precluded determination of causal direction, i.e., whether technical discussion leads to attitude agreement or whether certain individuals are chosen for discussion on the basis of prior knowledge of agreement. A replication of this study is needed which would permit determination of this causal direction.

Whether formation or reinforcement turns out to be a basic function, it may be that part of the explanation of the strength of the informal group may grow out of this need to "test" one's ideas or position against "social reality." It is reasonable that such confirmation would be sought from those social peers with whom the researcher had established a base for interaction on technical matters.

Returning now to evidence for our thesis that informal groups within the laboratory are the core of the informal STI transfer system, it is common for a laboratory to develop small work groups along either disciplinary or project lines. Such work groups are typically _ad hoc_ arrangements, organized and disbanded as the work demands. This being the case, it is quite possible that the composition of such groups will _not_ reflect the composition of the researchers' informal groups. One's normal technical discussion partners may thus be in some other work groups for a period of time. There is evidence (Allen and Cohen 1966) that in such a situation there is a strong tendency to continue to seek out the informal group partners for technical discussion.

This conclusion finds additional support--but also an important qualification--in a study by Taylor and Utterback (1975). They found that if the work assignment of a discipline based group is in a substantially different technical area, then the old informal ties will break down grudgingly over time and new ones will ultimately emerge. In this case, the substantially different technical area apparently makes the old technical discussion choices less able to serve the new information needs. "Although the new assignment was in the same general technical field as before, a new set of contacts and information sources had to be developed. That the extent of disruption of existing patterns was not as great as expected, may be a result of the tenacity of habitual behavior..." (Taylor and Utterback 1975, p. 85). This tenacity we would read as reflecting the importance of the informal group.

This reading is reinforced if one looks at a second type of work group, one that is organized by project rather than discipline. The members of such project groups are drawn from different areas of specialization and thus lack the common bond of similar technical backgrounds. They do, however, have the common bond provided by the new activity in which they are jointly engaged. This does not seem to provide a sufficient basis for the development of new informal groups. Taylor and

Utterback (1975) collected data on the information pool and flow patterns for four such project groups before, immediately after, and again 18 months after their formation. Not only did these project groups not develop significant in-group technical communication patterns even after 18 months together, but as the investigators noted there was, if anything, even less communication at the time of the final measurement. The researchers in these groups did not suffer from "informational malnutrition," however. They continued to seek out members of their respective former groups for technical discussion.[7] That is, in fact, what the members of such project groups should do from the perspective of the organization, since their function is to bring together the perspectives of the several groups they represent.

Thus there is evidence from a number of contexts to suggest that the patterns of STI pool and flow within formal laboratory groups are not uniform throughout. Rather, the communication networks they embrace are characterized by highly interactive clusters linked to one another by relatively far fewer and more infrequently used personal contact channels. These clusters of informal groups we take to be the heart of the informal STI system. The functioning of this system is even more complicated, however, as we shall begin to see from an examination of the dynamics of the informal group itself.

2. Within the Informal Group: The Role of Gatekeepers

Just as information does not flow uniformly within the formal laboratory groups, but is concentrated within highly interactive informal groupings, so too is this pattern to be found within informal groups. For whatever reasons--peculiarities of technical background, social-psychological idiosyncracies, etc.--it turns out that individual researchers differ significantly in the extent to which they utilize information sources beyond their own group, and, consequently, in the extent to which they are sought out for technical discussion by others of their group. Allen[8] has used the term "gatekeeper" to refer to those individuals who specialize either in the formal literature or in informal contacts with information sources beyond the organization. In addition to a much higher than average usage of one of these channels to the outside,[9] these gatekeeper individuals are also the technical discussion "stars" of their groups. That is to say, because of the information they possess these individuals are much more frequently sought out for technical discussion by their colleagues than others in the group.

In addition to his central position in the informal group's communication network, the gatekeeper also makes significant direct contributions to the laboratory's technical mission. As indicated by Figures 3 and 4, he compares quite favorably with other professionals in the laboratory on a variety of performance measures. In addition, a significant

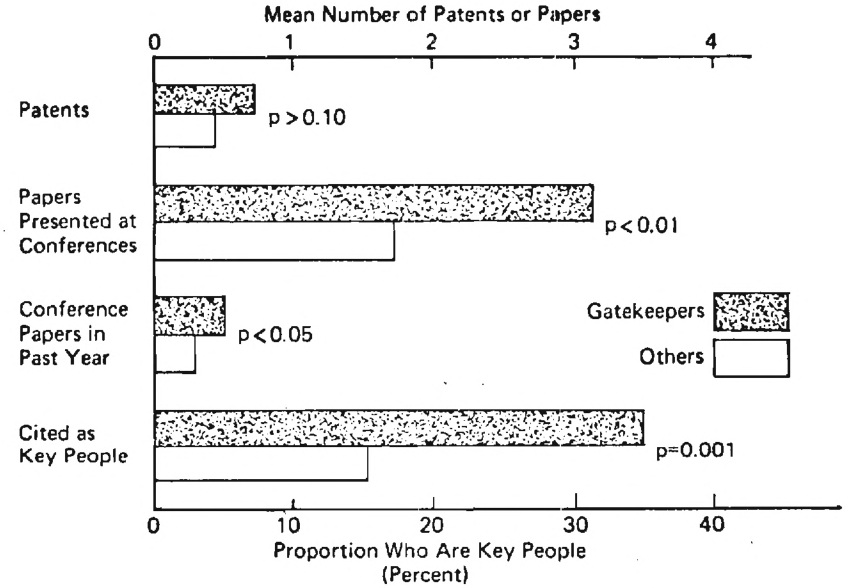


Figure 3* Performance of Technological Gatekeepers.

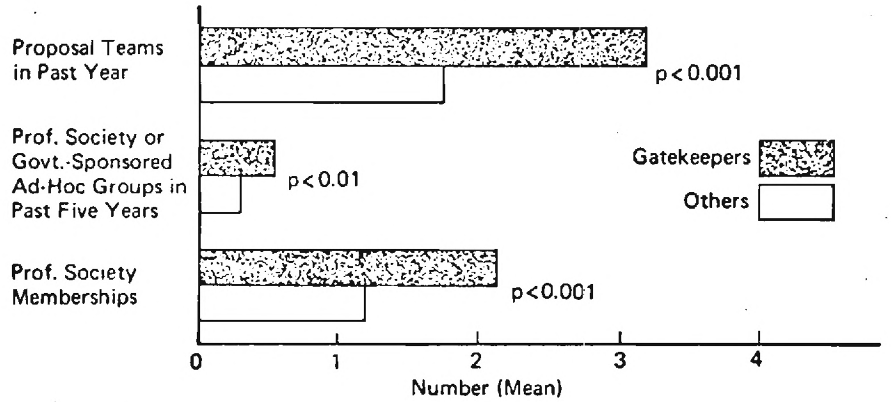


Figure 4* Organizational and Extra-Organizational Activities of Technological Gatekeepers.

*Source: Allen 1970, p 204.

number of first and even second-level supervisors have been identified as gatekeepers (Allen 1970, p. 197). Thus these individuals are indeed key people in terms of productivity as well as STI transfer.

Taylor and Utterback (1975), in their longitudinal study of work groups assigned to new and significantly different technical areas, have noted another important feature of the gatekeeper "profile." The members of these groups with changed technical assignments who had previously functioned as gatekeepers could not, of course, do so immediately after their reassignment. New sets of contacts and information sources had to be developed. Eighteen months after the new assignment was made, however, those who had functioned as gatekeepers before had reemerged to play this role again. Thus it would seem as if the ability to serve as a gatekeeper depends more on past training and/or social-psychological characteristics than on the particular circumstances of the work situation.

A final point about gatekeepers concerns their contact with one another. In connection with the typical communications patterns for the large R&D departments he studied (see Figure 2), Allen notes the following characteristics:

> . . .while there were in each functional department anywhere from one to six nontrivial strong components (primary groups), nearly all of the gatekeepers are grouped together in the same strong components. Although there is a total of twenty-one nontrivial strong components in the organization, 64 per cent of all gatekeepers can be found in eight of these,

> one for each of the five technological and three scientific specialities. In each technical specialty, there is one strongly connected subnetwork containing most of the gatekeepers. The gatekeepers, therefore, maintain close communication anomg themselves, increasing substantially their effectiveness in coupling the organization to the outside world (Allen 1970, p. 198).

Thus most of the accretions from extra-organizational sources to the informal group's pool of information--and in fact to each department's and the whole informal system's pool--seem to result from the propensity of certain individuals to specialize and excel in such transfers. They indeed seem vital to a laboratory's success in at least certain kinds of innovative efforts.

3. Why Are Informal Groups Rather Than Gatekeepers Here Taken as More Important in the Informal STI System?

Those conversant with the research literature might object at this point that our emphasis on the informal group is misplaced; i.e., that the key to understanding the informal system for STI transfer in the R&D laboratory is the technical information gatekeeper, not the informal group. After all, the group is heavily dependent on the gatekeeper for information, while the converse does not seem to be the case. It should be noted, however, that our emphasis has not been simply on informal groups, but rather on informal groups *within* formally constituted laboratory units engaged in a specific R&D activity. Unless informal groups are thus viewed as embedded in this formal-group nexus, it is difficult even to understand their role in the informal system, much less to claim centrality for it. By the same reasoning, to understand the role of gatekeepers, they too must be viewed as embedded--embedded in the informal groups they serve.

Thus our first response to the question of which is the more important, gatekeepers or informal groups, is to offer the caution that, while the question is not without meaning, it can be quite distorting if conceived of narrowly. Both have roles to play in the informal pool and flow of information, and both roles are important. In answer to the properly constrained comparative question, we have indicated earlier that we take the informal group to be the more important component of the informal STI system. Several considerations may be offered in support of this position.

First, to understand the transfer of STI, one must understand its storage as well[10]--unless it is assumed that there is essentially no time lag between acquisition and use. While the gatekeeper may himself store the information he brings from extra-organizational sources, this is only a part--and often a small part--the total information pool to which the informal group member has access. Much of a group's information pool exists by virtue of the training and past experience of its members; some portion of it comes from other units within the organization (and is apparently transferred by individuals other than the gatekeepers); and some portion is derived from analysis and experimentation conducted by members of the group in the normal course of their work. Thus while gatekeepers may make a contribution with regard to information from these sources, they are only a few among the many who do so. The informal group serves as the transfer mechanism for the bulk of this stored information, while the gatekeeper transfers only a portion--and a portion that in some R&D activity domains may be quite small.

Second, gatekeepers are themselves dependent on informal groups for the transfer of much of the information they bring into the organization. In the larger laboratories, gatekeepers cannot interact directly with everyone who ultimately benefits from the information they acquire. Thus the informal group--and in turn its channels to other informal groups --performs an essential transfer role even in those cases in which the gatekeeper initially provides the extra-organizational information. In fact, this role may be performed several times over (with significant time lags) for the same piece of information. As a result, in this sense it is as true to assert the dependency of gatekeepers on informal groups as the opposite.

Third, R&D activities vary considerably in how much information they require from outside the organization. Some, those toward the operations interface end of the spectrum, may require very little information from outside, in which case the external gatekeeper function would seem to be minimal. On the other hand, those involved in basic research may well be so dependent on external information sources in their work--and so well connected with both the literature and their profession's "invisible colleges" (Crane 1972)--that they may not need gatekeepers all that much either. That is to say, at the basic research end of the spectrum most researchers may be gatekeepers rather than only a few.

If this analysis is correct, then the importance of the gatekeeper function is not uniform across the range of R&D activities. It would seem to be most significant for those activities near the middle of the R&D process and drop off sharply toward each pole. There is no similar indication that the importance of informal groups is subject to such variability. Thus in seeking to account for the process of STI transfer across the whole range of R&D contexts, it would seem to be a mistake to attempt to do so in terms of the gatekeeper function. The informal group function, on the other hand, does seem to meet the necessary condition of ubiquity, and indeed, the sufficient condition of explanatory power as well.

To sum up, while we recognize the crucial role played by gatekeeper in the transfer of STI from external sources it does not seem to be sufficient for the whole range of phenomena requiring explanation. It should be noted that Allen and his colleagues at MIT, who have conducted most of the research on the gatekeeper concept to date, have not, to our knowledge, ever claimed for it the broad integratory power we are seeking. Their work has been so impressive, though, and the concept itself so intuitively appealing, that it is easy enough for others to attribute too much on it. In our best judgment, the gatekeeper function, as important as it clearly is in specific contexts, is subsidiary to, and dependent for its effect upon, the existence of informal groups.

4. Within the Informal Group: The Role of Intra-Organizational Liaisons

As has been indicated, information enters the informal group pool from sources within the parent organization as well as from outside, i.e., there are "internal" as well as "external" gates. For those activities toward the operations-interface end of the R&D activity spectrum, in particular, we argue that such internal information is typically much more important than flows from the outside. The question thus arises as to how this information from other groups and activities within the organization is transferred? Who tends these gates? Allen has shown that, as with the external gatekeeper, this function is performed by a relatively few individuals.

> Although most of the engineers and scientists reported little contact outside of their immediate departments, there existed a small subset who has a very large number of interdepartmental contacts (Allen 1970, p. 201).

Unlike their external gatekeeping counterparts, however, these interdepartmental liaisons did not stand out in terms of any of the performance characteristics measured.

> They had been with the organization no longer than the average; their performance, measured in several ways was just about average; and they did not occupy a very high level in the management hierarchy. As a matter of fact, they were very ordinary bench level engineers. Liaison among the eight departments was not accomplished at the top of the managerial hierarchy, through the chief engineers and scientists

> as one might expect. It was instead taking place as the bottom of the hierarchy, and it was being accomplished by the working level engineers and scientists (Allen 1970, p. 202).

Allen accounts for the fact that this important STI transfer function was being performed by indistinguishably rank and file personnel in a very straightforward way. Forty per cent of the liaisons identified were, at the time of the study, either participants on an interdepartmental project or on loan to another department. Thus their interaction was forced by the nature of work assignments. He also speculates that the liaison role may be a temporary one in which one's effectiveness in providing a link between departments may decrease with time after such an assignment. Kanno (1968) found that such effectiveness decayed exponentially with time in the analagous case of interdivisional transfers.

One might wonder about the adequacy of this account of the liaison function, however. While Allen's sample was in one sense quite large--some 400 researchers in eight departments of a large R&D laboratory--in another sense it was quite restricted. That is, while it included five engineering specialties and three scientific disciplines, and thus had quite a distribution along the professional orientation axis, the study seems to have represented a quite narrow slice of the R&D activity spectrum. In fact all eight departments seem to have been engaged in the same activity--applied research or development we suspect--though one cannot tell from the report.

We would hypothesize that if one studied those who perform the liaison function between each of the R&D activities, comparatively across the whole spectrum, and then between R&D and operations, that the results obtained would be quite different. In particular, we would hypothesize that as you approached the operational end of the spectrum, the actors in the liaison roles would tend to be more permanent, and the role itself more significant. The basis for this conjecture is that toward this end of the spectrum of activities, internal, operational information becomes more critical to the success of an endeavor, i.e., the tasks become increasingly constrained by that which is to follow. Thus those who can and do bridge the gap between activities, those who know, or can by informal contact determine, the constraints that will exist in the next phase of a project, perform a function that is too central to the success of the effort to be as happenstance and transitory as that portrayed above. In a nutshell, we are suggesting that the liaison who transfers in-house, operational STI in the latter stages of R&D is as central a figure as the gatekeeper who transfers STI from external sources in the middle stages.

In a later chapter we will extend this hypothesis to include consideration of STI transfers between the R&D laboratory and the operating units of the organization. For the moment, however, it suffices to say that very little is known about STI transfers between organizational units. To our knowledge, direct evidence for the existence of intraorganizational liaisons such as we have hypothesized--and for the importance of the function they perform--is not a part of the state of the art knowledge. The situation is analagous to that in which the existence of a planet has not been established by observation, but the analysis of the behavior of the whole planetary system entails its existence and impels a search for it. A program of research to determine the manner of intraorganizational STI transfer, and thus test our hypothesis concerning the existence and importance of liaisons in the later phases of R&D, would seem to merit a high priority.

5. Within the Informal Group: The Role of First-Line Supervisors

Two points about the role of supervisors in STI transfer have already been noted. Allen (1970) has shown that the proportion of gatekeepers who are also first-line supervisors is quite high. He has also found that the proportion of liaisons who were also supervisors is low--at least among those liaisons who link discipline-oriented departments within the same R&D activity. Later, we shall hypothesize a much more substantial liaison role for supervisors in the transfer of STI between R&D and operating units.

Beyond these findings of an often substantial role in transfers from the outside and, apparently, a meager role in intraorganizational transfers, one other important finding should be noted. Andrews and Farris (1967) found that the amount of freedom researchers enjoy was unrelated to innovative output if the supervisor did not consult with them prior to making decisions concerning their project. Where freedom was combined with consultation, however, a substantial increase in innovative behavior was observed. A key factor in the effectiveness of such consultation would seem to be the supervisor's own technical competence. In drawing some general conclusions from their research Andrews and Farris say:

> Greatest innovation occurred under supervisors who knew the technical details of their subordinates' work, who could critically evaluate the work, and who could influence work goals. Thus the widespread practice of including technical competence among the criteria for choosing supervisors seems to be sound. This does not mean that a supervisor should constantly "meddle" in his subordinates' activities. But he should be available, competent in the current "state of the art," actively interested in the project, and informed about it....
>
> What if this kind of structure is not possible or if a supervisor's technical competence has become obsolete? Again the data were clear: provide substantial freedom for subordinates. Freedom acted as a partial substitute for skilled supervision. But even where subordinates have freedom, the supervisor still makes some kinds of decisions. For freedom to be effective, the data showed that the supervisor must consult with his subordinates before making these decisions (Andrews and Farris 1967, p. 513).

The message here is clear; the technical competence of a supervisor, and thus his ability to participate in STI transfer can be an important factor in the quality of his group's innovative efforts--providing that he consults but does not meddle. Otherwise, the best interests of the organization seem to be served by his "staying out of the way" on the technical aspects of the group's work.

* * *

In summary, in this section we have tried to offer a "topographical map" of the laboratory's informal STI system under a specified set of conditions that impinge on the manner of its information pool and flow. It now remains to look at the complexity inherent in each of the influences identified above to see how they might alter this baseline "scenario."

C. Modifications of Baseline Scenario: Seven "Information-Need Indicators"

In this section we will offer a number of empirically supported as well as exploratory hypotheses concerning the influence of the variables listed earlier on the pool and flow of information in the laboratory. We refer to these variables as "information need indicators" because their influences--when better understood--may be sufficiently systematic and predictable to be used by R&D managers to strengthen the informal STI systems, and by those who design and/or operate formal STI systems to "fine tune" their services. Again, for ease of reference, these variables are:

1. Differences in the nature of the several activities that may be identified across the R&D spectrum.
2. Differences in the information needs and information-seeking behaviors of the several professional fields or disciplines represented in the laboratory.
3. Differences in the way in which the laboratory and/or project is structured.
4. Differences between corporate and operating division laboratories.
5. Differences between stable and rapidly changing R&D missions.

6. Differences in the rate of scientific and/or technological change within the industry of which the laboratory's parent organization is a part.

7. Differences imposed by the magnitude of the innovative effort, i.e., incremental improvement vs. discontinuous efforts.

We will examine each of these "situation variables" in turn, to suggest how the pool and flow of information in the laboratory might be otherwise than indicated in our baseline scenario if the conditions assumed there were altered.

1. <u>The Several R&D Activities</u>

In the baseline sketch of the informal STI system offered above, our hypothetical laboratory had separate departments for the conduct of research, development, and design. As a matter of fact, however, the research results utilized in the development of this scenario probably[11] reflected patterns characteristic of only a segment near the middle of the R&D spectrum, and were thus unrepresentative of the poles. This baseline scenario now needs to be refined in terms of differences inherent in the whole range of activities that may be embraced by the laboratory.

It is helpful in this regard to think of the range of R&D activities as a part of an even larger continuum. This larger array has the generation of new knowledge for its own sake (a pure academic activity) as one pole, and the actual production of artefacts or services as the other. The basic research function within R&D lies closest to the purely academic end of this spectrum, and what we have labeled "design" lies nearest the production or operations pole.

The information-need implications of these positions are fairly straightforward. Those in basic research, while not so free to pursue knowledge for knowledge's sake as their stereotypical counterparts in academia, are less constrained by operational realities than those in the laboratory who perform the later functions. By the same token, the information needed in their work seems less likely to exist in-house. Thus, basic research is much more dependent on external sources of information than the other R&D functions. This is not to say, however, that they are necessarily more heavily dependent upon gatekeepers. Those involved in basic research may well be so dependent on external information sources--and so well connected with both the literature and their professions' "invisible colleges"--that they may not need gatekeepers all that much. That is to say, at the basic research end of the spectrum, it may be a widely shared function.

At the other end of the spectrum, where R&D interfaces with operations, the information-need picture seems to be quite different. Here we argue that the work is so closely tied to operational needs and contraints as to typically require little STI from the outside. In-house information is so dominant in this late R&D phase that the need for gatekeepers is probably also minimal.

Finally, between these extremes--where the need for the formal STI systems, or the lack of it, is clear-cut--we find a mixed state of affairs. This middle ground, which we have called development, is both more constrained by organizational or mission necessity than the research phase, and more sensitive to the state of the technical art than the later design function. Just where the balance between in-house and external STI is struck in the conduct of the development function--and thus just how important the formal systems are to it--depends on other characteristics of the particular situation and cannot be determined by this single indicator. Factors which may tip this balance sharply in one direction or the other are offered below.

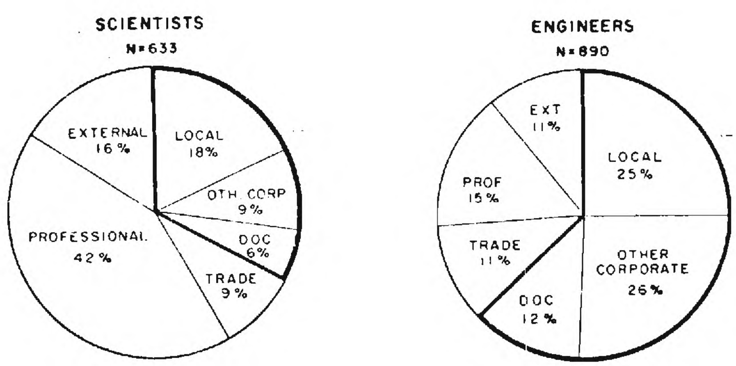
2. The Researcher's Professional Field or Discipline

The second variable in terms of which our baseline scenario of STI pool and flow must be refined concerns differences in information-seeking behavior of scientists and engineers. As Price (1966) has observed, science is an activity which is "papyrocentric." By contrast, the activity of technology is "papyrophobic." This difference is by no means fully explained by the fact that engineers usually work in mission-oriented organizations which have a proprietary interest in stemming the outgoing flow of information. More fundamental is the fact that science is an activity in which information is the end product, whose documentation and priority are established by publication (Price 1965). For technological activity, on the other hand, the innovation itself is the primary end-product, and information about it is secondary.

As a result of this fundamental difference, the engineer does not read very much in comparison with his scientific colleague, and the formal literature, therefore, is not a frequently used STI source.[12] A graphic display of these differing propensities toward the formal literature is provided by Rosenbloom and Wolek in Figure 5, which is based on their study of thirteen laboratories in four large corporations.

Figure 5

Differences Between Scientists and Engineers in the Use of Alternative Information Sources



I. Sources within the respondents' own company (enclosed by heavy line):
  (A) *Interpersonal* communication:
    (1) *Local* source — an engineer or scientist employed in the same establishment.
    (2) *Other corporate* source — another person employed by the same corporation.
  (B) *Written* Media:
    (3) *Documents* — any written source originating in the same corporation.

II. Sources outside of the company:
  (A) *Written* Media:
    (4) *Trade* documents — suppliers' catalogues, trade magazines, unpublished technical reports, etc.
    (5) *Professional* documents — published books, journal articles, or conference papers.
  (B) *Interpersonal* communication:
    (6) *External*-interpersonal — communication with any person employed outside the firm.

Source: Rosenbloom and Wolek 1970, p 35.

This fundamental difference between scientists and engineers regarding utilization of the formal literature is probably better documented and enjoys a wider community of agreement than any other characteristic of the STI field. In addition, its implication for the patterns of information pool and flow in the laboratory is a paradigm of clarity. Other things being equal, most scientists may be expected to rely heavily on the formal literature to meet their information needs, while most engineers will use this channel rarely, if at all. The "other things being equal" caveat reflects the fact that even these strong propensities may, upon occasion, be overriden by other variables (or combinations of variables) in the total laboratory environment.

An immediate corollary of the engineer's infrequent use of the formal literature is that his primary mode of information transfer is oral. Even here, however, the form is different from that of the scientist, who also enjoys extensive informal contacts. As indicated in Figure 5, the scientist relies more heavily on informal sources outside his organization. The engineer's oral communications are more likely to be with colleagues in his own laboratory. Marquis and Allen (1967) account for this difference in the following terms:

> Scientists working at the frontier of a particular specialty know each other and associate together in what Derek Price has called invisible colleges. They keep track of one another's work through visits, seminars, and small invitational conferences, supplemented by informal exchange of written

> material long before it reaches archival publication. Technologists, on the other hand, keep abreast of their field by close association with co-workers in their own organization. They are limited in forming invisible colleges by the imposition of organizational barriers (p. 1053).

This difference between the patterns of oral communications of scientists and engineers in the R&D laboratory is strengthened by the "R&D activities" variable considered above. Scientists function primarily in the early phases of the process where the reliance on external information sources is apt to be heavier. The engineering effort, on the other hand, seems to be concentrated in the middle to late phases, which are increasingly constrained by operational considerations--i.e., by information which is largely, or only, available in-house. Thus the propensities toward certain sources, inherent in the scientific and engineering disciplines is reinforced by the nature of the R&D activities in which they are typically engaged.

3. <u>Laboratory and/or Project Structure</u>

Our baseline analysis of the patterns of information pool and flow was restricted to laboratories structured in terms of R&D activities or functions. It is also common, however, to find a "project dominant" arrangement, i.e., multidisciplinary units that work on long-term projects or service major product areas. Such units are responsible for the whole spectrum of R&D functions, from such basic research as is necessary to the interface with operations. Given their multi-disciplinary make-up, such units seem to afford only a single basis for informal group cohesion--the project itself. As a result, the empirical evidence to date (e.g., Taylor and Utterback 1975) would lead one to believe that the informal STI system under this structure would be weaker, and thus the need for formal services greater. This is not to say that any one organizational arrangement is the best overall--many considerations other than informal system efficiency are relevant to this decision. It is to argue, however, that departures from the R&D function/professional field structure outlined earlier are probably made at some cost in the quality of the informal system, and thus that organizational structure may be an indicator of in-house STI pool and flow adequacy.

A brief example is in order. A group of researchers charged with carrying a project through all its phases may not have the highly specific knowledge or informal contacts of those who specialize in a single phase. Their research effort on a new project would thus involve a less informed and thus lengthier search of the literature. Their in-house informal groups, because of the nature of this formal structure, are more likely to be in this same "early learning" boat, and thus of less help than the informal groups under the functional structure described earlier. Because much of their time has been divided with areas other than research, these researchers would also have fewer invisible college contacts to turn to. For these reasons, their dependence on formal STI system and service professionals would be much greater. If we were to track the information needs of such a project-dominant group through the subsequent R&D phases, the picture should be similar, except that their relative informational deficiencies would show a progressive shift toward in-house STI as they approached the operations-interface end of the spectrum.

4. Corporate and Operating-Division Laboratories

The fourth variable which would seem to perturb our baseline analysis of the laboratory's STI pool and flow patterns is its location within the parent organization. Rosenbloom and Wolek (1970) have argued that:

> The mission of central research laboratories is substantially different from that of engineering and development departments in operating divisions.... The central laboratories are units that are organizationally (and usually geographically) separate from operations; their mission is the investigation of classes of technical and scientific phenomena that bear on the missions of the corporation. In contrast, the primary goal of R&D work within operating departments is the solution of technical problems relevant to the present or future operations of that department. As this implies, we classify the mission of research laboratories as one that attributes high relevance to contributions to knowledge and lesser importance to operational considerations. The mission of the operating department falls at the opposite pole on each scale (p. 83).

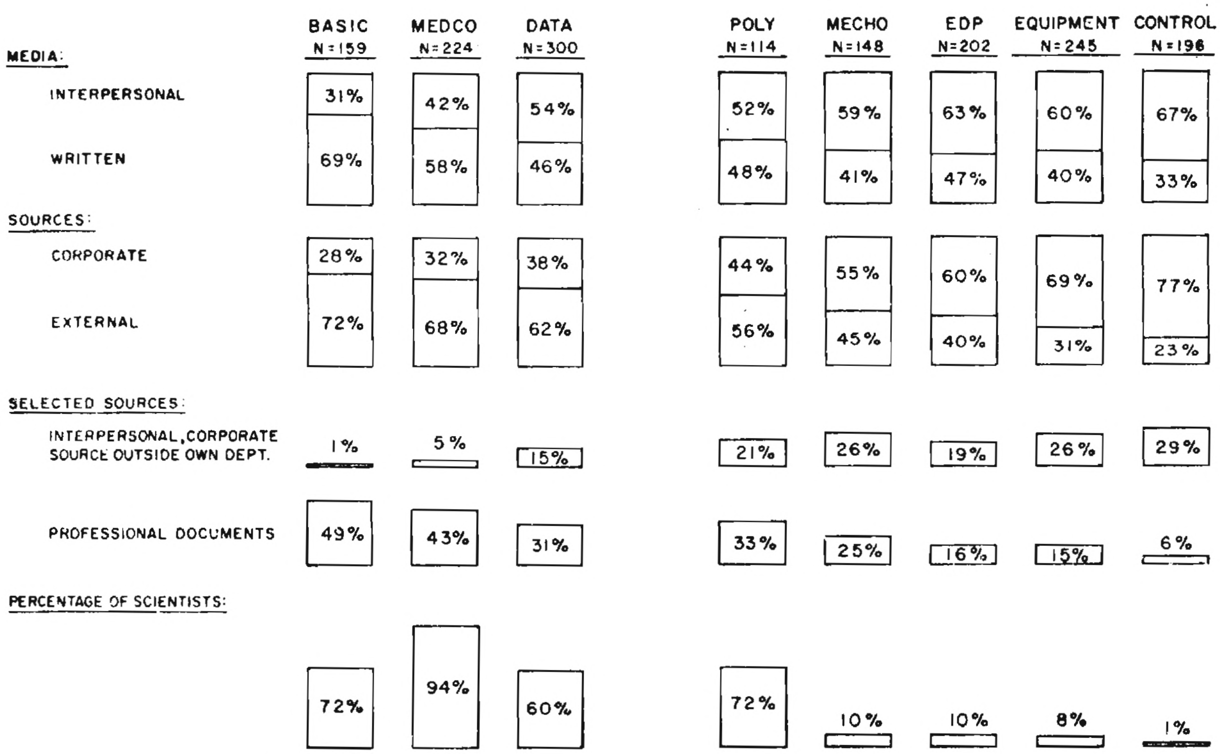
This difference in the missions of central and operating-division laboratories is shown by Rosenbloom and Wolek to have a substantial impact on the patterns of information flow into and within them. As indicated in Figure 6, in the three central laboratories they studied approximately two-thirds of the information sources used were external to

Figure 6

A Comparison of STI Sources Utilized in Corporate and Operating Division Laboratories

Central Research Laboratories

Laboratories in Operating Divisions



Adapted from Rosenbloom and Wolek (1970, p. 43).

the corporation. For the typical operating-division laboratory on the other hand, three-fifths to three-quarters of the sources utilized were within the firm.

Two other points emerge from these data that have broader implications for the integrative thrust and emphases of this study. The first relates to the independnece of the variables we are considering, i.e., whether or not some might be subsumable under, or explained in terms of, others. It might be argued, for instance, that the differences in patterns of information flow that we would take as arising from the corporate/operating-division laboratory distinction might be explained in terms of the second variable discussed above (the researcher's professional field or discipline), or the first (the nature of the several R&D activities). When Rosenbloom and Wolek controlled for the researcher's professional field in two cases (chemists and electrical engineers), the differences between those in the corporate and operating division labs is still quite significant for both (Figures 7 and 8). Those in the operating division contexts reported a substantially greater use of in-house sources than their professional counterparts in the corporate laboratories. Thus at least these three of the seven variables we are considering seem to exert demonstrably independent influence.

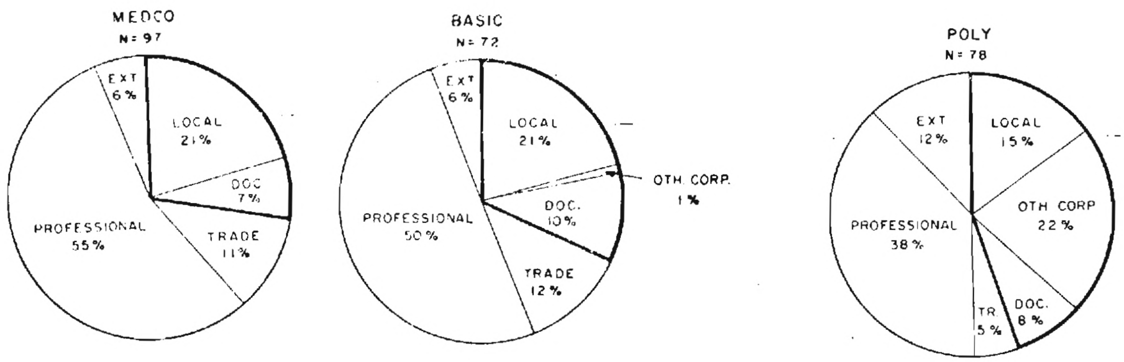
The second broader implication of the Rosenbloom and Wolek data for our study concerns our emphasis on the

Figure 7

Information Sources by Laboratory Setting
(Chemists Only)

Corporate Laboratories

Operating Division
Laboratory



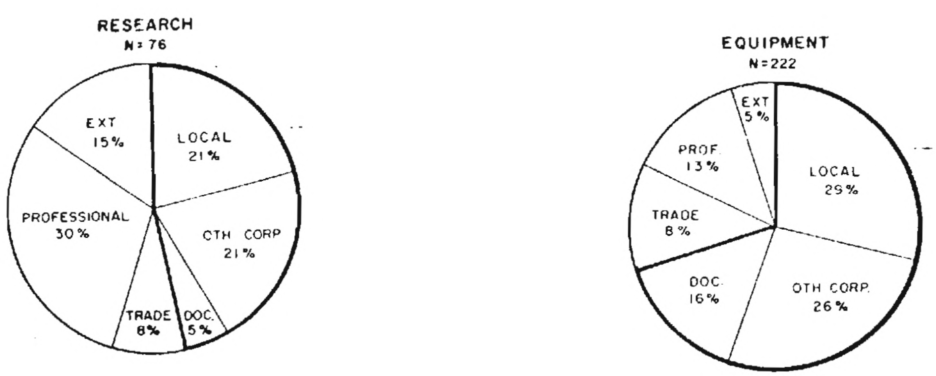
Rosenbloom and Wolek (1970), p. 44.

Figure 8

Information Sources by Laboratory Setting
(Electrical Engineers in DATA Corporation)

Corporate Laboratory

Operating Division
Laboratory



Rosenbloom and Wolek (1970), p. 45.

interface of the laboratory with operations. As is shown in Figure 6 above, the use of interpersonal sources outside the researcher's own department is small, even negligible, in the case of the corporate laboratory. For the operating division laboratories, on the other hand, such sources account for a fifth to a quarter of the total flow. This again suggests the systemic hypothesis that, as you move from the research end of the R&D spectrum toward the interface with operations, the R&D effort becomes progressively more sensitive to operational constraints and opportunities, and thus that in-house STI grows in its importance. It should again be noted, however, that the mechanisms of such flow remain poorly understood.

5. The Stability of the R&D Mission

Unlike the previous variable whose influence had been demonstrated empirically, we know of no data to support the contention here that the patterns of STI pool and flow may be substantially influenced by how stable or frequently changing the laboratory's mission is. However, we find the analytic argument sufficiently persuasive to warrant its further consideration and testing.

The contrast we have in mind here is a simple one, at least in the extreme cases. On the one hand, consider the organization whose laboratory, production facilities, and marketing force are wholly committed to a single product line (or close "family" of products). On the other, consider the organization with a laboratory, but no production facilities, i.e., one whose product is R&D itself. It is reasonable to expect that the latter, the contract organization, is going to have the greater, continuing need for external STI sources than the former. No matter how technically able its laboratory personnel, the frequent and substantial shifts in R&D focus with which they must deal would seem to assure that the in-house information pool will often be inadequate.

The contrast between the stable and the frequently changing R&D missions is often not sharp as we have drawn it here. The single product-line organization and the R&D contract shop do, however, constitute common and unambiguous opposite poles from which to begin an analysis of the influence of this variable or information need indicator. As with a number of the indicators we are suggesting, as you move away from the clear influence of the polar cases, there is a corresponding increase in the need for an analysis which compares and contrasts the influence of this factor with the influence of others.

In the following chapter, we will stress the practical potential of this particular variable as an incentive to conduct the empirical study necessary to move it beyond its present conjectural status. Should this, indeed, prove to be a significant indicator of the relative adequacy or inadequacy of a laboratory's in-house pool, it could serve as an important "fine-tuning" device for the STI industry. That is, a number of formal STI systems and services could use it as an additional criterion for segmenting their market and anticipating surges in laboratory STI needs.

6. The Rate of Scientific and/or Technical Change Within the Industry

This indicator of the need for external information, like the previous one, has to do with the relative adequacy of the in-house information pool. Here, however, we are concerned with the pace at which the state of the art knowledge is changing rather than the frequency of organizationally-induced shifts in the laboratory mission.

The basic hypothesis here is as straightforward as in the previous case: the higher the rate of scientific and/or technological change in the industry of which the laboratory's parent organization is a part, the greater the need for infusions of STI from external sources. It has been argued, for instance, that the significance of the gatekeeper function may depend, in part, on this variable.

> Most studies of technical communication have been concentrated in aerospace and related industries where the state of the art has been changing rapidly and the demand for current technical information is great. A more placid technical environment could well negate the need for a mediator in the flow of technical communications. Technical communication needs of the container industry, for example, might be such as to eliminate the need for the gatekeeper. (Taylor and Utterback 1975, p. 81; see also Lawrence and Lorsch 1967, on this point.)

Our analyses lead us to accept this as a sound hypothesis which merits empirical investigation. In this connection, we would also repeat a contention offered earlier, that the gatekeeper function may also vary significantly among the several R&D activities. It may be more important in the development phase, than in basic or applied research (where the dependence on external resources may be so great as to make it a widely shared function), or design (where there is the least reliance on external sources).

The rate of change in an industry would seem to have a direct bearing on the relative adequacy of a laboratory's in-house STI pool, and thus upon the criticality of flows from external sources. It should be noted, however, that even if the rate of change in an industry is very high--as is the case with electronics or ethical drugs--this is still but one variable among many. It should not be expected to override, or even alter significantly, the influence of <u>all</u> the variables we have considered, nor should it be expected to mitigate their several influences equally. For instance, while a high rate of scientific and/or technical change would seem to imply a <u>larger</u> laboratory role for basic and applied research, this does not necessarily mean that the <u>pattern</u> of information flow in these areas would be any different. The pattern would seem to reflect the nature of the activities rather than the proportion of laboratory effort devoted to them.

7. <u>Incremental vs. Discontinuous R&D Efforts</u>

The final variable or information need indicator we would mention lies, not in conditions within the laboratory or its larger environment, but in the nature of the innovative effort itself. The literature distinguishes between: (1) R&D projects which are concerned with incremental improvements to existing products or porcesses or with minor extensions to scientific or technological knowledge, and (2) projects which are concerned with new products or processes or with scientific or technological breakthroughs (e.g., Rubenstein 1964; Hollander 1965; Schwartz 1973). The terms "incremental" as applied to the former and "discontinuous" to the latter are relative terms, of course; they emphasize the degree of their departure from the organization's current products or processes or from the existing level of knowledge in the organization.

The bulk of the information required for the incremental effort would seem, typically, to exist as a part of the in-house pool, and little would be required of external sources. The organization that is now producing "widgets" should already possess most of the information required to develop a "widget with a twist." The matter is quite otherwise for innovative efforts that constitute a radical departure--a discontinuity--from that which the organization is doing and thus knows well. If it has never produced a widget or anything akin to one, substantial infusions of information from the outside will likely be required--and in an area where the organization's gatekeepers may not be "on top of things."

Inherent in these STI pool and flow implications of the incremental/discontinuous distinction are two others which relate to two of the variables discussed previously. First, the discontinuous innovative effort would seem to involve all of the activities or functions across the R&D spectrum. All would have to "gear up" informationally for the effort. Both the laboratory's interface with STI sources external to the firm and its interface with operations would feel the pressure of unfamiliar information demands. In Schwartz's (1973) terms a discontinuous effort is "disruptive to the culture of the firm." An incremental effort, on the other hand, would seem to typically involve only the latter phases(s) of R&D (in the terminology we have employed, perhaps only design, or development and design). In additionally, only the interface with operations would seem to be significant and that through already established informal channels.

The second point concerns the possible relationship between the magnitude of the innovative effort and the way in which the laboratory is organized. In organizational terms, incremental projects tend to be relatively small, single-phase projects which are carried on within a single organizational unit, involve one or only a few professional fields, require few R&D personnel to be assigned, and one of relatively short duration (up to a year). They are likely to be funded by R&D management out of their annual budgets and to require only the budgetary approval of top corporate management. In fact, except at an overview budget summary level, corporate management may be generally unaware of the incremental projects being conducted within the organization. By contrast, discontinuous efforts tend to be large, multi-year, multiphase projects which cut across organizational boundaries, may involve a number of scientific and engineering fields, and require a substantial R&D effort to carry the project from initial concept through to end item. The decision to undertake such projects often emanates from the highest level of corporate management. Because of the large requirements for organizational resources, top corporate management support must be maintained throughout the life of the project.[13]

It has been argued (Kelly et al. 1975, Vol. I) that, in organizational terms, a laboratory that is structured in terms of the several R&D activities or phases, as was the case in our baseline analysis (i.e., a phase dominant structure), is better suited for the conduct of incremental efforts. Discontinuous projects, on the other hand, seem to call for a project dominant structure, i.e., a laboratory that is organized in terms of multi-disciplinary units that work on long-term projects or service major project areas.

When this mesh of laboratory structures and the magnitude of the R&D project is considered in terms of STI pool and flow, a dilemma emerges. In-house pools are less adequate for discontinuous than incremental projects--thus the reliance on external sources is greater for the former. As we have argued earlier, however, there is reasons to believe that informal groups are more cohesive and stronger information flow mechanisms under the activity or phase dominant structure than they are under the project dominant. Thus, the laboratory structure that seems organizationally the better suited for the conduct of discontinuous projects seems to weaken the information flow capabilities of the informal system. And yet it is for just these discontinuous projects that vigorous STI flow is most essential, since, by their very nature, they render the in-house STI pools less adequate.

The reader should be cautioned that there is substantial unevenness in the present support for the several paths of analysis that converge to produce this dilemma. Some have substantial and direct empirical support, others are based on indirect empirical data, and still others rest on conceptual analysis and informed speculation. Therefore a critical caution is in order. At the same time, we are convinced that there is sufficient support for the convergence we have portrayed--and sufficiently onerous implications for the conduct of discontinuous R&D efforts if our analysis is correct--to give high priority to this research focus.

* * *

This completes our analysis of a range of variables that have been shown or hypothesized as impinging on the informal STI system and the pool and flow of information within it. It now remains to draw the implications of this conceptually integrated treatment for the laboratory's interface with external information sources, on the one hand, and the operations on the other. These tasks are undertaken in the two chapters that follow.

Chapter II

Footnotes

1. There were 1900 engineers and scientists in 13 laboratories of four large corporations, and 1200 members of the Institute of Electrical and Electronics Engineers (IEEE).

2. We have no way of knowing from the data whether the subjects understood "immediate circle of colleagues" to mean the work group to which he was assigned at the time, or his informal mutual-choice group. Whichever is the case, the exclusion can only serve to strengthen our point, since the percentage of instances in which the information was volunteered could only be increased by inclusion of the work and/or mutual choice group(s).

3. See Allen and Cohen 1966, 1969; Allen 1970, 1972; Taylor and Utterback 1975.

4. For discussion of the role of informal groups in the satisfaction of such needs, see Bernard 1938; Davis 1969; Cartwright and Zander 1969.

5. R&D process phases (or functions) are defined and designated variously by both scholars and R&D organizations. We want to assume a functional or "phase-dominant" organizational form here, but the particular "benchmarks" we have chosen (and our labels for them) do not affect the point at issue, which is that <u>whatever the functional distinctions in terms of which R&D efforts are organized, formal groups are thereby created and the members of each group thereby share a common orientation, common goals and common problems</u>.

6. Allen defines the term "strong component" as follows: "A strongly connected component, or strong component in a network is one in which all nodes are mutually reachable. In a communication network, a potential exists for the transmission of information between any two members of a strong component (Flament 1963; Harary, et al. 19). In other words, there is at least one path in each direction, between every pair of members of a strong component. Information held by one member can potentially be transmitted by any other member either directly or through intermediaries" (Allen 1970, p. 198).

7. The objectives of the Taylor Utterback study were such that it cannot be determined with certainty from the data whether the group contacts that were so doggedly maintained were with the researchers' primary groups or with others of their respective activity/professional field groups. We feel confident in assuming that it was the former on the basis of the Allen and Cohen (1966) and Allen (1970) findings mentioned above. If, as demonstrated by these studies, the bulk of a researcher's technical discussions were with his primary group--rather than others in the larger laboratory group of which it is a part--when <u>not</u> separated from them by organizational structure, there is little reason to believe that he will abandon them in favor of others in the larger unit when he becomes so separated.

8. See Allen 1964; 1966a; 1969a; 1969; 1970.

9. Allen defines "higher than average" here as meaning, " . . . either one standard deviation above the mean in readership of scientific or professional engineering journals or above the median in number of outside personal contacts." (Allen 1970, p. 192)

10. For a discussion of this point see Appendix A.

11. The qualifier "probably" here reflects the fact in many studies the R&D departments are not identified by function. That is, it is common, while focusing on other variables, to take the department as a study site, rather than as a possible variable in the process under investigation.

12. Auerbach 1965; Allen 1966; North American Aviation 1966; Scott 1962; Herner 1954; Halbert and Ackoff 1959; Organization for Economic Cooperation and Development 1960; Allen and Cohen 1969; Allen 1970.

13. For discussions of these contrasts between incremental and discontinuous projects, see Brandenberg 1966; Hollander 1965; Rubenstein 1964; Schwartz 1973.

Chapter III

Interface: The Laboratory's Informal STI System and the Formal STI Systems

In the preceeding Chapter we offered an integrated, holistic treatment of the R&D laboratory's informal STI system, and the patterns of STI pool and flow that seem to characterize this system under a variety of conditions. In the present Chapter we will draw some of the implications of that integration for the interface of the laboratory's informal system with the formal STI systems.

Our treatment of this formal/informal systems interface will be from the perspective of those who can improve this relationship. Thus our remarks will be directed to those information specialists who design and/or operate formal STI systems. The reason for this is quite simple. The informal systems, while enduring and extremely effective, are by their very nature the unplanned and mute creatures of past and present need, who constrain the future but cannot design for it. Thus the impetus to better integrate them with the formal systems must come from the latter.

Before effective interaction with an ongoing system can take place, however, it is essential that at least the broad outlines of its nature be properly understood. The broader picture of the R&D laboratory's informal system often does not seem to be well understood by many, who either study its more limited aspects or attempt to meet its STI needs.

Some of these misperceptions of the whole system may be caricatured by an analogy with one of Art Hoppe's recent syndicated columns. This was a zany piece about a spacecraft from Mars--the Vnnnggg I Lander--which touched down on our planet last May. Unfortunately for its mission, this Martian spacecraft--which was only 1/4" long--made its successful landing atop a medium-sized pepperoni pizza.

Their initial report back to mission-control on Mars went like this:

> Mission control, this is Vnnnggg I. As you can see from our television scanners, the surface of this planet is predominantely red, with patches of a cheesey looking white. Various inanimate lumps of brown and black are strewn across the landscape.
>
> Because of the amazing resemblance we have dubbed that black round object in the foreground "The Huge Olive," and that brown shiney one in the distance "The Giant Anchovy." What strange tricks Old Mother Nature plays.
>
> Our thermometer is recording a surface temperature of a blistering 156 _shnarbs_ while out seismograph informs us that only seven _klongs_ beneath us is a rubbery, but incredibly tough surface.
>
> It would appear that this planet is unique in the universe, being the only one known to have its seething interior _on top_ of a thin crust.
>
> We hoped to investigate the eight "canals" we observed on landing that seemed to radiate symmetrically from the center of the planet. But our soil scoop became mired in that white stringy, gooey substance on its initial effort and has been immobolized ever since.
>
> We hope to free it...Wait! Mission control can you see that huge row of white cliffs descending from above? And look, another row is emerging through the surface just ahead of us. Why, you would almost think they were someone's giant _TEETH_! _Teeeeth_!!

> The transmission ends there. From it, Martian scientists believe that conditions on the planet are far too inhospitable to sustain intelligent life. (Adapted from Hoppe 1976).

We call your attention to these observations of Earth from aboard the Vnnnggg I because it caricatures skewed perceptions of the market for STI services that are often found in the scholarly literature. Over the years there have been thousands of myopically empirical "user studies"--i.e., reports from academics and others, who have "soft-landed" in some R&D laboratory or other. Not seeming to realize that their landing site and its environment may be as atypical as a pepperoni pizza is of the earth's surface, they have solemnly reported their findings. "Scientists like their information thick and chewy, while engineers like theirs thin and crispy." or "Scientists come regularly to the library or computer console to feast upon their informational pizzas, while engineers--if they eat at all--rely on takeout orders delivered by a few colleagues called gatekeepers." etc.

Such reports have typically been rigorous and accurate enough given their perspective, but like those from the Vnnnggg I--or even the Viking I--they have raised more questions than they have answered. In aggregate, they have not been of as much help as one might hope in specifying the nature of the R&D laboratory market that the information centers and services must deal with.

But lest only the academics be offended, let us hasten to point out that the information professionals have been stumbling over their share of olives and anchovies too. Even the largely noncumulative and myopically empirical work of the academics has been sufficient to cure some of the bad assumptions about the laboratory market that seem to prevail. For instance, many information professionals seem determined to go on talking about the non-users as if they were just like the heavy users in every respect--except perhaps slothfulness. Acting on this assumption of an undifferentiated or mass market, these designers and operators just keep on trying to make their services easier and faster, as if this alone will sooner or later win over those non-user yoyos.

By comparison, those who sell beer are faced with very much the same market split or segmentation. The so-called "heavy half" of the beer drinkers' market--which is in fact only 17% of the total--consumes 88% of all the beer sold (White 1966). The beer industry has more fully accepted this obvious segmentation of their market, however, and has responded in a variety of ways that go far beyond making it easier and faster to buy this product.

Now that we have been critical of both the academics and the information professionals, let us hasten to add that this was not done from sheer contrariness, but to emphasize the manner in which each group sorely needs the other. This interdependence of the two communities is the underlying theme of this section. This theme will be developed in terms of how the formal STI systems might better meet the information needs of the R&D laboratory. First, we will summarize briefly the concept of market segmentation, then we will draw upon the integrated picture of the informal system developed in Chapter II to offer several broad-gauged conclusions about a better approach to the formal/informal systems interface, and to explore further the "information-need indicators" that were described there.

A. Market Segmentation

The concept of market segmentation was first articulated in a watershed article by Wendell Smith in 1956, and since its publication has come to be one of the most influential concepts in marketing. In the words of one author, it has, "permeated the thinking of managers and researchers alike as much, if not more, than any other single marketing concept since the turn of the century" (Frank 1968).

Briefly, market segmentation refers to a strategy that assumes:

1. That markets are not homogeneous, i.e., the users of a product or service are not all alike;

2. That some differences among users are related to differences in market demand, and

3. That segments or groups of users can be isolated within the overall market.

Thus a heterogeneous market is viewed as a number of smaller, isolatable, homogeneous markets, each of whose needs are different and predictable. It is important to note that the market strategist does not segment a market, but discovers that it is in fact segmented, and responds to the opportunities that this fact creates. In Smith's terms, "A sgement may be regarded as a force in the market that will not be denied" (Smith 1956, p. 33).

The key to segmentation as a marketing strategy lies, of course, in being able to identify homogeneous and serviceable segments. Academic researchers have been of some help in this regard, though what they have found has not always been presented in the clearest and most usable form. Our analysis and conceptual integration of the research literature has led us to identify a number of segments of the laboratory market for information that we take as providing substantial opportunities for the formal STI systems. We will discuss these segments in a moment. First, however, we need to set forth some of the broad-gauged conclusions we have reached as to how the formal/informal systems interface should be approached.

B. Some Conclusions as to the Proper Approach to the Formal/Informal Systems Interface

In Chapter I we anticipated four conclusions we have drawn as to the proper approach to the interface of the formal STI systems with the laboratory's informal system. Let us now re-examine each of these.

a. It is distorting and unhelpful to think in terms of "users" and "non-users" of the formal STI systems and services.

In light of the role of informal laboratory groups in STI pool and flow, and the range of variables that may skew the information needs of such groups, it seems inappropriate to take individuals as the market segment to be served by the formal systems. We would argue that even the gatekeeper function is inadequate as a justification for segmentation of the laboratory market to the individual level, since gatekeepers serve informal groups and thus reflect their STI needs.

In addition to these systemic considerations, there is little reason to believe that non-user individuals can be "converted" into users by virtue of some further incremental--or even breakthrough--advances in formal systems hardware, software, or mode of operation. Simply stated, the reasons for non-use are, by and large, independent of any "correctable weaknesses" in the formal STI systems. Rather, these reasons cluster around the fact that most information needs in the R&D laboratory either can't be met at all by the formal systems (e.g., operational information), or can be met better, quicker, and with significant social-psychological payoff by the informal system (i.e., the in-house pool and/or gatekeeper). This state of affairs is distorted by the designation "non-user" with its implication that they too would be users if only the formal system were somehow better.

Thus, the user/non-user distinction is a distorting dichcotomy that yields little understanding of the formal/informal systems interface. In addition, there is the obvious risk that such simplistic "nose-counts" may be used to evaluate the contribution of the formal systems to the R&D effort. Such a specious yardstick is a gross oversimplification of the complexity of the formal/informal systems interface, and a serious misrepresentation of the value of the formal STI systems to the R&D process.

b. It is accurate and helpful to think in terms of service to informal groups--groups composed of both direct and indirect users.

The thrust of Chapter II is that the R&D laboratory market for formal STI services is segmented along informal group lines. Depending on a variety of specifiable conditions, the extent of the dependence of these market segments on the formal systems ranges from very heavy to essentially non-existent. The *frequency* of such dependence (for those groups exhibiting more than negligible dependence) is a function of the same specifiable conditions, and ranges from essentially continuous to very infrequent.

Just as these informal group segments of the laboratory market differ significantly in the extent and frequency of their dependence on the formal systems, so too do the individuals within many of them. If we exclude groups of scientists engaged in basic research (who are heavy, continuous users) and engineers near the R&D/operations interface (who are essentially non-users), the remaining informal groups may be characterized as follows: there are a few heavy, *direct* users (gatekeepers) who meet most of the external information needs of their light-to-non-user colleagues. To do justice to this state of affairs and to the significance of the formal STI systems for R&D, it is much more accurate to conceive of those served by the gatekeepers as *indirect users* rather than non-users.

This shift of attention from individuals to informal groups permits a different and more helpful line of questioning about the segmentation of the laboratory market. The highly interactive informal group replaces the (speciously) isolated individual as the level of market disaggregation to be studied and designed for. Then, since the informal groups within the laboratory are not all equally dependent on external STI flows, attention comes to be focused on those group characteristics and conditions that influence the timing and extent of such dependence. Progress on this point--i.e., the identification of serviceable segments--should result in improved design and operation of formal STI systems.

c. There are features of the R&D laboratory and its environment that can serve as "indicators" of information needs that the formal STI systems can meet.

In Chapter II we examined the influence of seven variables on the pool and flow of information in the laboratory. Here we would suggest that these variables--or "information need indicators"--may be used by those who design and/or operate formal STI systems to "fine tune" their services. In other words, these information need indicators may be used to identify serviceable segments of the laboratory market. Let us comment briefly on the market implications of each of these variables.

1. Differences in the nature of the several activities that may be identified across the R&D spectrum.

Those involved in activities toward the basic research end of the spectrum are the "heavy half" of the laboratory market for formal STI services. They may be expected to have a continuing need for information from external sources, and thus to be regular users of the formal literature. On the other hand, those at the opposite end of the spectrum, where R&D interfaces with operations, find their work so closely tied to operational needs and constraints as to require little STI from the outside. They are typically an unrewarding market segment for the formal systems to focus on. Between these extremes--where the need for the formal systems, or the lack of it, is clear-cut--we find a mixed state of affairs. Here the role of the formal systems depends on other characteristics of the particular situation, and cannot be determined by this single indicator.

2. Differences in the information needs and information-seeking behaviors of the several professional fields or disciplines represented in the laboratory.

Other things being equal, scientists may be expected to rely heavily on the formal literature to meet their information needs, while most engineers will use this channel much more rarely, if at all.

3. Differences in the way the laboratory and/or project is structured.

We have argued that laboratories organized by R&D function and by discipline within these functional units create conditions more favorable to efficient informal STI pool and flow mechanisms than the project-dominant arrangement. As a result, other things being equal, the former structural arrangement should be informationally more adequate (and better able to utilize gatekeepers effectively) than the latter. Thus, we would hypothesize that the existence of a project-dominant structure provides an indication that the laboratory's need for the formal systems will be greater. It should be noted, however, that this indicator may be overriden by others in the particular context, and thus should not be utilized in isolation.

4. Differences between corporate and operating division laboratories.

In Chapter II we examined evidence to the effect that central laboratories exhibit a much greater reliance on external information than do operating division laboratories. This difference reflects basic differences in the missions of such laboratories, and thus would seem to constitute an important, continuing criterion for the segmentation of the R&D laboratory market.

5. Differences between stable and rapidly changing R&D missions.

In the final analysis, the need for formal STI systems depends on the inadequacy of the in-house information pool. We have argued that, other things being equal, the laboratory with the more stable R&D mission will have a more adequate in-house pool--and thus need the formal systems less--than one whose mission is subject to frequent and substantial shifts of focus. Thus the latter--e.g., a contract research organization--constitutes a better market for formal STI systems than the former.

> 6. Differences in the rate of scientific and technological change within the industry of which the laboratory's parent organization is a part.

Here we hypothesize that the higher the rate of scientific and/or technological change in the industry of which the laboratory's parent organization is a part, the greater its reliance on infusions of STI from external sources.

> 7. Differences imposed by the magnitude of the innovative effort, i.e., incremental improvement vs. discontinuous or breakthrough efforts.

At one extreme, an innovative effort may represent a minor extension of what the organization is already producing--a small increment or next step. In such cases most of the information required would typically exist as a part of the in-house pool Thus little would be required of the formal STI systems. On the other extreme, the innovative effort may represent a radical departure--a discontinuity if you will--from that which the organization has been doing, and thus knows well. In this case massive infusions of information will be required and the role of the formal systems will be substantial, perhaps crucial.

The final conclusion we have drawn concerning the interface of the formal and informal STI systems addresses the quite practical matter of its improvement in light of the above considerations.

d. <u>At least in the short-run fine-tuning the formal STI systems and services in terms of the "information need indicators" may require the assistance of "interpreters," i.e., those knowledgeable about the R&D process.</u>

The question here is how do we get from the present condition, in which the formal and informal STI systems are largely <u>independent</u> mechanisms interacting in unplanned ways, to one in which they function as <u>interdependent</u> subsystems of a larger whole? The answer must lie in accomodating, or "fine-tuning," the formal systems to mesh with the conditions that characterize their informal counterparts. In marketing terms, this means identifying serviceable segments of the laboratory market and exploiting the opportunities that they afford. The "information need indicators" described above are intended as, at least, first-approximation criteria for such segmentation.

The evidence for these indicators is uneven, however. In addition, how they impinge <u>in concert</u>, and with what effect on the laboratory's information needs, are matters for which there is currently little data. Until the research community can begin to close these gaps in our knowledge, we would recommend that the designers and operators of the formal systems avail themselves of the next best thing, i.e., interpreters.

The point here is that there are many people around the country who are quite knowledgeable about the R&D process, the range of research skills involved in it, the factors that may constrain its several phases, etc. Even if such individuals have not focused explicitly on the informational implications of the influences we have here called "indicators," they are nevertheless familiar with the dimensions of the R&D process and its context to which they refer. Thus, confronted with the sorts of questions that we have raised, they should be able to "speak for" the informal system. That is, they should be able to provide insight and guidance about the relative adequacy or inadequacy of the in-house STI pool under particular sets of conditions.

We recognize that the use of such "interpreters" may not always yield the precision of market segmentation that one could ideally desire, or even that a more complete knowledge base could produce. But that is beside the point, at least in the short run. The short-run question is, would such interactive assistance in identifying servicable market segments, and thus in the design and operation of formal STI systems, be superior to an approach which treats the laboratory as a homogeneous market--or worse yet segments it into users and non-users? We think that the answer is, yes.

Chapter IV

Interface: The Laboratory's Informal STI System and Operations

In the previous chapter we examined the interface of the laboratory's informal STI system with STI sources beyond the organization. In this chapter we will be looking at its interface with R&D's "clients," typically the parent organization's operating units. This interface is quite different from that with external STI sources, and the pool and flow of information reflects these differences.

In Chapter I we reported the results of a survey by Quinn and Mueller (1963) which indicated that the effective transfer of R&D results to operations was widely viewed as the most serious problem confronting research management. We also cited economic analyses (Mansfield et al. 1971) that indicate the magnitude of the investment that depends, in large measure, on the effectiveness of this transfer. Yet, in spite of the broad agreement about the difficulty of this interface and the strong economic incentive to render it more effective, there is surprisingly little research aimed at a better understanding of the variables upon which it depends. Grayson (1968, p. ii) and Young (1973, p. 31) both report a relative dearth of careful and systematic study. In Young's words, "The bulk of the writing has taken one of two forms: a general prescriptive solution or a specific solution" (p. 31). There is an almost complete lack of definitive, cumulative research; instead, there exist only a few isolated studies at each of several levels of aggregation.[1]

The flow of STI between the laboratory and operations is only one of the variables on which this interface depends, of course. Nonetheless, we take it to be a major variable, and poorly understood. In fact, of all the areas of STI pool and flow that we have examined there is none for which simultaneously the need to understand is higher and the state of knowledge lower. Organizational concerns about proprietary information may be a barrier to research here, but this problem notwithstanding, definitive, cumulative research is a pressing need.

Our assessment of this STI interface problem between R&D and operations is, unfortunately, not a very hopeful one. Given our argument for the centrality of the researchers' informal groups in information pool and flow, this assessment is not surprising. As we will argue in a moment, the difficulty is that precisely those features of the informal STI system that make it so efficient within the R&D laboratory would seem to work against effective interface with operations. This problem, inherent in the laboratory's informal system, is exacerbated by the difficulty of assigning responsibility for an innovation's success or failure once it has been transferred from R&D. Let us examine each of these problems in turn.

A. Informal Groups Exclude As Well As Include

Gatekeepers and intra-organizational liaisons both specialize in the transfer of STI from outside the informal groups and larger informal system they serve--the former from sources outside the parent organization, the latter from corporate sources. Which type of information is the more important to a laboratory effort depends on a number of the variables considered above. The gatekeeper's information would seem the more important: for the development phase, than for the research or design; for the engineer than the scientist; for the corporate than the operating division laboratory; for the more rapidly changing than the more stable R&D mission; for industries with a higher rate of scientific and technical change than slower changing areas; and for discontinuous R&D projects than incremental improvements. The intra-organizational liaison's information, on the other hand, should be more important for the design function than for research or development, and for the opposite of the gatekeeper's in each of the above contrasts. Considering an organization's innovative thrust as a whole, these two information transfer functions seem equally essential to success.

According to the data examined earlier, however, those who play these two roles have quite different "profiles," and vary significantly in the extent to which they are "appreciated" by their colleagues. The gatekeeper is a high producer who is viewed by others as a "key person." He is the technical discussion "star" of his group, as colleagues seek the information he possesses. The liaison, on the other hand, seems to be a "very ordinary" bench level engineer, "just about average" on every performance measure, and is not identified as one frequently sought out by his colleagues for technical discussion. How are we to account for these rather striking differences in light of the apparent equity in the importance of their roles?

First, it should be noted that the gatekeeper is a member of two informal groups; one defined by the intersection of R&D activity, professional identity, and mutual social choice <u>within</u> the organization, and the other by professional identity (and perhaps mutual social choice) <u>outside</u> the organization. It is precisely because of this dual membership--plus his own personal and professional characteristics--that he can perform his STI transfer function. The intraorganizational liaison, on the other hand, would seem to be a member of only one in-house informal group. He maintains contact with, but not membership in, another group, i.e., he is a member of an informal group in R&D and has an outsider's contact with some operating group, or vice versa. Given our thesis concerning the nature of the "cement" that binds STI transfer groups together, this could not really be otherwise. R&D and operating groups are quite different in terms of both the activities in which they are engaged and the professional identities their respective members share. Thus it is unrealistic to expect the same individual to participate fully in both.

As a result of his dual membership, the gatekeeper can bring to each group STI from the other that may prove "facilitating," i.e., information that may prove helpful in the resolution of the problems they are working on. It is for this reason he is so frequently sought out for technical discussion. The liaison who is a member of an informal R&D group and at the same time maintains contact with an operating group, can also bring information to his group--oftentimes information that is vital to the success of the overall innovative effort. It may well be, however, that the information he brings may not be viewed by his colleagues as nearly so "attractive" or potentially useful to their work as that of the gatekeeper. And, in fact, it may not be as "facilitating" in the narrower, technical-solution sense of the term. The STI transferred by the liaison may be more likely to be viewed, not as contributing to a technical solution, but as constraining the problem in ways that make its solution more difficult.

It may well be objected at this point that any professional "worth his salt" will view information that constrains on a par with information that facilitates. One can accept this point, however, and still argue for the cogency of the distinction. Reasonable people--especially those with significantly different professional identities who are engaged in quite different activities--may simply disagree about the desirability or unavoidability of a particular constraint. Add to this the communications handicaps inherent in different coding schema and infrequent contact through under-rewarded intermediaries, and the possibilities for disagreement and misunderstood intentions are increased.

Thus we argue that one of the major reasons for the difficulties encountered in transfers from R&D to operations is to be found in just those features of the informal STI system that make it so efficient within the R&D laboratory. The informal groups are such good information transfer mechanisms because of a cohesiveness born of shared activities and identities. These criteria of membership in the communications network exclude as well as include, however. They not only facilitate the flow of information within the group, but may serve as barriers to information from the outside. The gatekeepers are able to overcome these barriers because the information they bring is from sources with whom they, and those they serve, share at least the professional identity. Because the gatekeepers are members of such source groups, as well as the in-house group, they can not only access the information more fully but also effect such "translation" of it as different coding schemes may require.

The barriers to STI transfer thus seem most acute on the boundary between R&D and operations, for there differences in both professional background and orientation diverge quite markedly. There, also, significant differences in activity are strongly reinforced by organizational structures (at least in the typical situation). Thus liaisons would seem to find the barriers much less permeable than those faced by the gatekeepers. Not only do the R&D and operating groups differ more markedly on both criteria of membership, but also--unlike the gatekeepers--the liaisons cannot mitigate either of these differences by virtue of dual membership.

B. The Matter of Assigning Responsibility

The Visibility of Results

These difficulties in the R&D/operations interface are exacerbated by the problem of assigning responsibility for an innovation's success or failure once it has been transferred from R&D. In short, the question here is the "visibility" of the results of a reseacher's work.[2] The term "visibility" means both the ease with which research results may be assessed, and the manner in which they are assessed. The first of these relates to the clarity or obscurity of organizational goals.

> In an organizational setting where the owner of an organization or his representative can accurately evaluate the findings of a project in terms of organizational goals, he can encourage the researcher who shows high probability of solving such problems. As a consequence, the researcher is motivated to seek solutions to difficult but "relevant" problems in preference to less relevant but easier problems. In seeking a solution to the difficult problems, the researcher at times must abandon traditional methods and thinking (Gordon and Marquis 1966, p. 198).

From the researcher's perspective, the visibility of organizational goals depends in large measure on the ability of the supervisor to perceive and transmit them.

Regardless of the visibility of organizational goals, and thus the ease with which research results <u>may</u> be assessed, research results themselves are not visible until someone <u>actually</u> assesses them. This raises directly the question of the pattern or "style" of R&D management and its influence on innovative behavior. To get at this question Gordon and Marquis divided the research projects examined in their study into three groups.

> 1. Projects in which the project directors either stated that they had no administrative superior or that they did not discuss their research with their administrative superior. (Low visibility of results + freedom.)
>
> 2. Projects in which project directors had freedom to specify their research procedures and they discussed their research with their administrative superior. (High visibility of results + freedom.)
>
> 3. Projects in which the project directors stated that they had an administrative superior with whom they had discussions and who consistently influenced procedures. (High visibility of results + limited freedom.) (Gordon and Marquis 1966, p. 199)

On the hypothesis that both high visibility of research results and research freedom are important to creative activity the second of these three types of authority patterns should be expected to maximize such behavior, while the first and third should minimize it. That proved to be the case: two and one-half times more of the projects rated as most innovative by the independent evaluators were conducted under the ideal authority pattern (type 2) than under either of the non-ideal conditions.

Thus it would seem that creative behavior is more likely to occur where the results of such behavior are visible, i.e., where the organizational criteria for assessing research results are clear <u>and</u> where the supervisor keeps in touch with what the researcher is doing and how his work is going; but where at the same time the reseacher has freedom, i.e., he is not dominated by his superior.

Micro and Macro Assessments During R&D

When we apply the concepts and results of the Gordon and Marquis study to the problems of R&D/operations interface, a number of things became apparent. First organizational objectives--even if highly visible to the researcher--are typically too general to determine which among several technical options is best. They can serve to guide or enhance R&D efforts, but additional criteria are also necessary. Such criteria are provided by the technical orientation and expertise of the R&D management and personnel, the state of the art, "best practice" considerations, etc. The former, or organizational, objectives we shall refer to as the "macro" assessment standard, and the latter as the "micro" standard. The important thing to notice about these two standards is that while macro assessments include considerations of R&D/operations interface, assessments performed in terms of the micro standards typically do not. Before developing the implications of this point we need to introduce one further distinction.

R&D results may be--and in fact are--assessed at various points _during_ the R&D process, and at various points _after_ their transfer to operations. The ease with which macro and micro assessments of research results can be made--and more importantly the impact of such assessments on STI flow--would seem to differ significantly according to the point at which they are made.

Micro assessments of research results _during_ the R&D process are relatively easy to perform. Technical criteria appropriate to the particular R&D activity and the professional group(s) involved are utilized to determine how those responsible for the conduct of a project are doing. Even if the supervisor is not particularly competent in the area, it is usually not all that difficult to get a pretty good reading on the technical quality of the group's work. If such technical assessments are indeed performed at regular intervals they can provide research results with the sort of "visibility" that Gordon and Marquis have shown to be an important factor in the quality of innovative efforts.

Such visibility, arising from periodic micro (or, purely technical) assessments, should also provide an impetus to the STI transfer process. Other things being equal, we should expect to find more active informal systems--and within them more active gatekeepers--in those laboratory settings in which research results are made highly visible by virtue of periodic, and rigorous, technical review.[3] We know of no studies that have addressed this hypothesis, but it seems worthy of empirical test, since it may represent one of the few points at which the formal organization can directly influence the functioning of the informal STI systems.

Turning now to macro assessments of research results during the R&D process, we find a quite different situation. The supervisor bears an unusually heavy and difficult responsibility at this point. In Gordon and Marquis' terms, he must motivate the research group "to seek solutions to difficult but 'relevant' problems in preference to less relevant but easier problems." That is to say, research results that achieve a very high rating on the micro or technical-standards scale might fare poorly or even be unacceptable relative to the macro considerations of organizational goals or constraints. Further, the imposition of these macro considerations--which must be imposed if the potential innovation is to be implemented--may force the researchers to deal with a much more difficult technical task.

In order to perform the macro assessments necessary to insure the compatibility of R&D output and organizational objectives and constraints, the supervisor must himself be a liaison. In at least general terms, for instance, he must understand the limitations on the organization's present productive capabilities, which, if exceeded, will drive up sharply an innovation's implementation costs. Or, to take a different interface example, he must understand enough about the organization's present competitive position in a particular area to guide an innovative effort in ways that will hopefully make it successful in that market. These and other dimensions of macro assessments imply a wealth of STI that seems to be beyond the capacity of a supervisor to handle single-handedly. Either there exist STI liaisons between R&D and the several operating units that have simply not been recognized as yet--as the gatekeeper function was only recently recognized--or this interface is indeed a serious problem.

If supervisors are largely alone in the performance of this STI transfer function, then this fact has implications for the quality of R&D output that go beyond straightforward informational deficiencies. It means that supervisors will be standing virtually alone in imposing macro barriers--considerations of organizational relevance--to many of the highly rated technical solutions that are developed by project groups. The risk here is that the supervisor, perhaps against his better judgment, will be locked into a supervisory "style" that is viewed by those under him as to "meddlesome" or interfering. In Gordon and Marquis' terms he may be forced by circumstances into a "type three" style in which the project results are highly visible and the researcher's freedom is quite limited. As we have seen, this style proved far less conducive to high innovative results than the supervisory approach which coupled high visibility of results with substantially greater independence. Without other effective channels of information about operational "reality," the supervisor would seem to have little choice than to acquire it himself as best he can, and feed it into the R&D process through the mechanism we have called macro assessments.

Micro/Macro Assessments After the Transfer from R&D

After the results of R&D have been transferred to operations, assessments of the innovative effort continue, of course, both during and after implementation. After the transfer, however, the distinction we have been making between micro, or purely technical, assessments and the more macro assessments of organizational relevance comes to be blurred. Indeed, even the visibility of results, at least insofar as assigning responsibility for success or failure is concerned, becomes blurred. After the transfer from R&D, responsibility for the fate of the effort is shared by several organizational units, and thus the claim can always be made that the cause for failure lies elsewhere.

Given this situation, it is difficult to pinpoint a failure by an R&D group to gather the operational information necessary to make their work relevant and useful, as well as technically sound. Without this sort of after-the-fact visibility, there is far less incentive to seek and utilize such information in the course of their work. This should not be taken to mean that R&D personnel are indifferent to the ultimate success or failure of their work. It simply means that the factors in their situation that serve to focus their efforts on the technical dimensions of their work are, in combination, quite strong, and those that would lead them to emphasize the operational dimensions are weak by comparison. It is little wonder, then, that the R&D/operations interface is viewed by many as "the key problem in research management today."

A rather wide range of organizational forms have been experimented with--as alternatives to the typical functional structure--in an effort to overcome the problems inherent in transfers between R&D and operations. Quinn and Mueller (1963, pp. 61-62) have identified a number of these alternative forms:

> Task-Force Groups--These usually are made up of personnel from research, development, marketing, and manufacturing who are often given total responsibility for exploiting a new technology. The composition of the group is heavily weighted toward R&D people at first, but it shifts toward operating people as full-scale operations are approached.
>
> Corporate Development Units--These, having their own marketing staff and flexible pilot-scale facilities, pick up new research technologies and exploit them. The unit can be a profit center, deriving profits from sale of new products. As the products prove profitable, operating groups want to take them on. Thus, development is constantly forced to seek new technologies from research, and operating resistancies are eliminated.
>
> Outside Companies--At times, these are used to entrepreneur new products in specific cases. The research laboratory may take 49 per cent ownership in the new concern formed to exploit the technology. Or it may simply take license revenues. In some cases, large companies have given smaller companies (with special knowledge, facilities, or market access) exclusive rights, under a royalty agreement, to a new technology during a three to five year introductory period. When primary demand has been built up, the larger company has the option of continuing the arrangement or introducing its own branded version of the product.

Staff Groups at Corporate Level--These units serve to coordinate the introduction of new technologies through existing divisional and functional organizations. They are most effective when they either have functional authority over key aspects of line operations or have a budget with which to buy time from line units. Product managers perform this service successfully in some companies.

A Top Executive with Multifunctional Line Authority--This executive can effectively force new technologies into operations in small to medium-sized companies. In a medium-sized consumer products company, the president is also the top technical executive and founding genius. Because of his personal interest and follow-up, new products often move from research to the market in three to six months. He refuses to allow pilot-scale facilities to be built, feeling that they waste time and put less pressure on operating executives than do full-scale facilities.

A Research Group with a Special Budget to Buy Time on Operating Machines--This approach is effectively used in flow process industries (such as paper) where (1) the cost of a pilot facility is prohibitive, or (2) the scale of operation vastly affects technical approaches. There are always problems of scheduling these experiments; but, if an experiment is successful, research has little trouble in demonstrating its value to operations.

Individual Researchers Who Entrepreneur Their Ideas Through Pilot Facilities and into the Market--A pharmaceutical company sets up a profit center for each new product and encourages the researcher, if he has the talent and interest, to follow his idea to commercialization. If successful, he receives a share of the center's profits as additional compensation. Product policy is coordinated by product group managers at corporate level.

Multilevel Committee Responsibility--Such committees have been set up in some companies. In fundamental and early applied research, a research committee coordinates the program. In late applied and early development stages, coordination moves to an R&D committee. In late development, a new product committee takes over program progress. Before pilot scale facilities can be built, the operating committee must approve. A full scale operation requires executive committee approval. Because decisions tend to be slow and conservative under this system, it must normally be supplemented by one of the other organizations described here.

<u>An Entrepreneurial Group at Corporate Level</u>--Used by several of the companies most successfully diversifying through research-produced new products, these groups introduce technologies which are new to the company and which do not logically fit into the organizations of established operating groups. Where they are successful, these entrepreneuring units are headed by a commercially oriented dynamo with a technical background. He has at his disposal a technical group which reduces research ideas to practice, a special budget to build small-scale facilities and underwrite product introduction losses, and a small nucleus of commercially oriented technical men who simultaneously "ride two or three products into the market."

Major difficulties with this appraoch are (1) finding people with the complex of skills and attitudes necessary to entrepreneur new products; (2) replacing these people as they become committed to products they have "ridden into successful division status"; (3) developing the top management attitude toward the risk taking such operations must involve.

Although each of the above forms has proved useful in specific instances, none has been shown to have general applicability. The most suitable form varies from firm to firm and from innovation to innovation.

The risk that an organization runs in adopting one of these alternatives to the typical functional arrangement is that it may weaken or destroy the informal systems which seem to function with such remarkable efficiency in bringing STI into the organization, maintaining it in interrelated "pools" until needed, and transferring it to the appropriate parties. Such informal systems--or so we have argued--find the basis of their cohesion in the combination of shared R&D

activity and similar professional backgrounds and identities. Even if alternative organizational arrangements could create shared activities that occasioned as much group identity as the R&D activity, the other source of group cohesion, a shared professional identity, would--by the very nature of the alternative structures--not be satisfied. Thus we suspect that such alternatives, unless simply used on an occasional, *ad hoc* basis, would substantially weaken one of the organization's most remarkable and valuable assets in the conduct of R&D--the informal STI system.

* * *

In this Chapter on the interface of R&D and operations we have stressed the difficulties inherent in this interface, and have suggested that the informal systems themselves may, in some measure, be responsible for many of these difficulties. In so doing, we may have inadvertently been more negative than we intended. It seems to be the case, however, that nothing comes without price, and the price for having an effective informal STI system within R&D seems to be difficulties on the R&D/operations interface--difficulties for which we see no easy solution. Whether this price is too high, each organization must decide for itself; if the answer is yes then it should adopt some alternative structure.

Before making a move that may weaken the informal STI system, however, a finding of the Rosenbloom and Wolek (1970) study reported earlier should be considered carefully. It will be recalled that they found the informal system to be so efficient that one-third of time it provided the researcher with the information he needed even before he undertook a search for it. Such efficiency should make an organization seek long and hard for alternatives that will not impair the informal system.

Footnotes

1. In addition to the references cited above, there are a handful of studies at each of two levels of aggregation: (1) at the interpersonal level, see Douds and Rubenstein 1966, Morton 1964, and Bean 1968; (2) at the organizational level see also Pessemier 1966, Peterson 1972, Hill and Hlavacek 1972, and Pessemier and Root 1973.

2. For the concept of the "visibility of research results"--and indeed for the basic thrust of the next several paragraphs--we are indebted to Gordon and Marquis (1966). Their study, however, did not concern the R&D/operations interface. Thus responsibility for this new application of the concepts developed by Gordon and Marquis lies with the authors of this study.

3. This is not to say that the results achieved in such settings will also be more innovative, since this depends on other factors as well.

Appendix A

STI Pool and Flow: A Logical Analysis

Given an R&D laboratory setting, one might ask, "Where does the information that proves important to an innovative effort come from?" In the most general terms, the answer is that most of it can ultimately be traced to sources outside the organization, since even the largest R&D operation can generate on its own only a small fraction of the information it requires. This general answer is not very helpful however, since it says nothing about when or how the information enters the organization. To focus on the "when" and "how" of the matter, we might ask about the possible loci of a piece of information that is needed by a researcher in the course of his current work. The following possibilities exist:

1. He already knows it by virtue of his technical training or past experience (In-hand);

2. It is known by some member(s) of a group within the laboratory with whom the researcher has frequent contact (In-group, but not in-hand);

3. It is known by some other member(s) of the organization (In-house, but not in-group);

4. It is known (in existence, but not in-house);

5. It is not yet known (information must be generated).

Each of these possibilities may well occur in the course of the same innovative effort, with quite different implications for formal and informal STI systems.

a. <u>Possibilities 1 and 5: Not Instances of Transfer</u>

In the fifth possibility above, no transfer is possible since the information does not yet exist. The frequency of this occurrence depends on variables in Chapter II. Likewise, the first possibility does not involve a transfer of information, at least not subsequent to the need. The possession of presently needed information typically does imply an earlier transfer--in the course of one's education or previous work experience. From the organizational perspective, the initial employment of the individual was a form of STI transfer--commonly called "on the hoof" transfer--since his general and/or special skills constituted a major reason he was hired. Indeed, "on the hoof" transfer may be a crucial STI flow mechanism in particular instances (Burns 1961, p. 12; Langrish et al. 1972, p. 44, Table 7, p. 79). But in our example in which the transfer is subsequent to the need, the first possibility above, like the fifth, is not an instance of STI flow.

b. <u>Possibility 4: Information Exists, But Not Known In House</u>

With regard to the fourth possibility, in which the information exists but is not known in-house,[1] it may be; published in a professional or trade journal, available through extraorganizational personal contacts, a closely guarded piece of proprientary information of a competitor, a government-held patent or technical report, etc. Many studies have shown that, in aggregate,[2] R&D personnel make little use of the formal literature (see for example Scott and Wilkins 1958, OEEC 1958; Hanson 1964; Averback Corp. 1965; Allen 1966; North American Aviation 1966; Allen 1970). Thus, ignoring for the moment the possibly contrary influence of variables considered in Chapter II, it does not seem highly likely that our researcher will turn first to the literature to meet his need for information. He may get there by an indirect route or as a last resort, but it seems to be an infrequent first move in the typical case (As we saw, gatekeepers and scientists in basic research are the obvious individual exceptions to this generalization).

As for the possibility that our researcher may find the information he needs through an informal contact outside the organization, a number of studies have shown that while--for pre-project activities at least--it may be a frequently used channel in some instances, it is not a very effective one (Allen 1964; Allen 1966; Shilling and Bernard, 1964). In fact, in these studies there was found to be an inverse relation between the use of such extra-organizational personal contacts and the quality of the solutions proposed. In other words, "Better performing groups rely more than poorer performers upon sources within the laboratory, as contrasted with sources outside the lab (Allen 1969).

While such results seem to support our thesis about the centrality of the informal STI system within the laboratory, two points stand out as requiring explanation. First, why did the poorer performing researchers make more frequent use of these external sources in the course of pre-project efforts? Why didn't they, like their better performing counterparts rely more on the informal system within the laboratory? A partial answer to this question lies in the fact that there was also, "...an inverse relation between the size of a lab's technical staff and the extent to which outside sources were used (Allen 1969). This suggests that the in-house pool of information was inadequate in these cases, thus forcing external search. As we argued in Chapter II, one of the variables that perturbs a group's "characteristic" pattern of information flow is the extent to which the technical effort departs from that which the group knows well. The pre-project activities examined in these studies seem to represent substantial discontinuities for those groups who exhibited a heavy reliance on informal external sources.

The second question raised by the results of these particular studies is why did those groups that relied heavily upon external sources perform more poorly? A part of the answer may have to do with the point discussed earlier about the "social reality-testing" function of informal groups. A researcher may feel much freer to "check out" a technical idea with a member of his own group, by asking questions that may be poor ones, than with an outside "expert." Conversely, this closer relationship may permit him to be more probing and critical of an idea offered by a colleague than one offered by an outsider. It is perhaps the absence of the freer interactions characteristic of informal groups that Allen has in mind when he says; "When an engineer resorts to a consultant, he quite likely tends to overestimate the consultant's competence in the area and, as a result, does not exercise sufficient skepticism in assessing the idea" (Allen 1969).

Another part of the answer to this question may involve the notion of "boundary impedance," growing out of the distinctive ways in which an organization may have come to codify and refer to pieces of information with which they deal constantly. The commonality of organizational experiences and perspectives often results in the development of distinctive "coding schema," i.e., short-hand ways of thinking and talking which outsiders may be at something of a loss to understand. Not being privy to this way of coding information will impede communications with an external source and thus reduce that source's effectiveness.

To round out this analysis of the occasions on which the researcher may first seek needed information from an extra-organizational source, let us look at a study that seems to run counter to the results presented above. Hagstrom (1965) found a strong <u>positive</u> correlation between extra-organizational informal communication and productivity for scientists and mathematicians in the <u>university</u> environment (productivity in this case was measured in terms of papers published). While our concern is with STI flow in the <u>industrial</u> sector, this study is important for two reasons. First, it illustrates the fact that some highly interactive--and highly effective--informal groups have memberships that cut across organizational boundaries (see Price 1965; Crane 1972 for discussion of this point in terms of the "invisible college" concept). While productivity was here highly correlated with informal STI transfers external to the formal organization, such transfers were internal to the informal group. Thus the seeming contradiction between the results of this study and those examined above is specious. Here, as before, the role of the informal group is central to the transfer process. The difference is that whereas above the informal group was circumscribed by the organization, here it is not.

This distinction between wholly intra-organizational informal groups and inter-organizational ones has direct implications for the notion of "boundary impedence" discussed above.

> Members of industrial and governmental organizations acquire through common experience, and organizational imposition, shared coding schemes which can be quite different from the schemes held by other members of their discipline i.e. those in other organizations . This is not true for the academic scientists. They generally feel more aligned with scientists in similar research areas than with a particular university or department, and therefore tend to use a system of coding in common with other researchers. In other words, the "invisible college" now becomes the mediator of the coding scheme (Allen 1969, p. 97).

The impedence created by organizational coding schemes in the industrial sector might also serve as a partial explanation for the low frequency of direct use accorded to the formal literature in industrial R&D settings.

The second point to be noted in connection with the Hagstrom study concerns those groups working at the "basic research" end of the R&D activity spectrum. Such groups seem much more likely than others along the R&D activity continuum to utilize extra-organizational information sources--in terms of both informal contacts and the formal literature (Rosenbloom and Wolek 1970, p. 35). In this respect they tend to be much more "academic" than "organizational" in their orientation. Thus R&D personnel with basic research responsibilities are much more likely to participate in informal groups that include extra-organizational members. This, however, does not disturb our basic thesis about the centrality of informal groups in STI transfer. In fact, with the proviso that such groups need not be wholly in-house, it strengthens it.

c. <u>Possibilities 2 and 3: In-Group or In-House</u>

There remain two possible loci from which needed information might be secured; from the researcher's own informal group, or from elsewhere in the organization. We shall consider these two possible sources together on the hypothesis that the latter, or intra-organizational transfers of technical information, are most properly understood as inter-group flows, i.e., as transfers between one group and another within the informal STI system rather than between one individual and another.

One might object to this hypothesis as circuitous and question-begging. Even if the parties to an information transfer do happen to be members of different informal groups, why is it necessary, or even desirable, to think of it as an inter-group transfer? Surely people from different groups within the organization who may have different technical backgrounds, and are working on different tasks can, and do, simply speak for themselves on a technical matter without in any way involving their respective groups. And, of course, this is correct, but it may well also be atypical and thus of less interest from the point of view of understanding the dynamics of STI transfer. It seems reasonable to assume that a technical discussion partner from other than one's own group is typically sought out precisely because he <u>can</u> be expected to reflect the "best practice" or "state of the art" knowledge of that group. If, for instance, the technical problem concerned the smooth interface between one's development work on a project and the design or production work to be conducted later--or the mechanical constraints on the solution of an electronics problem--then one would hope that the information received reflected, somehow, the collective expertise and experience of that professional group, and not simply the views of an isolated individual.

Let us, therefore, assume for the moment that information transfer between members of different groups within the organization are best viewed as intergroup flows rather than simply personal exchanges. Given the hypothesized interdependency of these loci of information, we shall treat them together.

In part, we have structured this preliminary analysis of the researcher's information seeking behavior in terms of the possible loci of such information in order to correct an imbalance that is common in the literature on informal STI systems. The literature tends to emphasize the transfer or "flow" of information to the neglect of the manner in which it is stored or "pooled." It is important to recognize, however, that--like the formal STI systems--the informal systems are mechanisms for storage as well as retrieval. Without the recognition of this "information pool" function, which permits a lag between acquisition and use, it becomes impossible to account for the following apparently contradictory facts:

1. Most STI utilized by an organization was originally generated <u>outside</u> that organization, since no R&D laboratory, not even the largest and most diverse, can generate anew more than a small fraction of the information it needs;

2. Most of the information used by a typical researcher in the course of his work comes to him from sources <u>within</u> his own laboratory.

These facts require for their reconcilliation a distinction between <u>ultimate</u> and <u>immediate</u> sources of STI (Unless it is assumed that--with negligible time lags--information flows into the organization <u>only</u> as it is needed.[3]). This distinction, in turn dictates the existence--and indeed crucial importance--of in-house information pools.

The basic pool of information is the individual researcher's accumulated technical knowledge and experience.

By means of the informal networks that characterize the R&D laboratory, however, these individual stores of information may be aggregated into more comprehensive and diverse pools. How effective such pools are in meeting the information needs that arise depends not only on the size and competence of the group, the richness of its internal communications, and the nature of the activity in which it is engaged, but also on a number of variables to be considered later. In general, however, we would argue that the information pools constituted by the informal networks within the R&D laboratory are typically substantial enough to meet most of the information needs that arise in the course of their members work on most projects. Support for this generalization is presented in Chapter II.

The informal system's information pool is composed of:

1. What each member of the network knows by virtue of his professional training and experience;

2. Information about in-house analysis and experimentation in past organizational endeavors;

3. Information about the organization's operational capabilities and constraints;

4. Accretions of information from sources outside the organization.

The relative importance of each of these sources will vary according to the nature of the R&D activity and other variables considered in Chapter II. In the later phases of the R&D effort, for instance, the researchers' past professional training and experience, along with some measure of analysis and experimentation, may well be adequate, i.e., little input from external sources may be required. In other phases, such as basic research, the competence gained by past training and experience, plus the results of analysis and experimentation seems to be a necessary but not sufficient condition. Quality performance is here strongly dependent upon both extensive flows within the informal network, and a heavy reliance on the formal literature (Hagstrom 1965; Rosenbloom and Wolek 1970).

Information about the analysis and experimentation from past organizational endeavors is probably fairly uniform in its importance across the spectrum of R&D activities. There is probably a substantial unevenness, however, in the extent to which such information is available from sources other than the informal pool. Toward the basic research end of the spectrum there would seem to be an increasing probability that such results, if not in fact published, were at least written up as in-house technical reports. Toward the development end, on the other hand, it seems more likely that the results of analysis and experimentation--expecially negative results--exist only as a part of the informal pool. Much of what is called "how-to" information would seem to fall in this category. We know of no studies that speak directly to this point, but the hypotheses we offer seem consistent with such indirect evidence as exists (See Allen 1969).

As for the importance of that portion of the informal pool that we have characterized as "information about the organization's operational capabilities and constraints," it again depends on the nature of the R&D function (plus certain other variables). Such information would seem to be least important at the "basic research" end of the spectrum, and to increase rapidly in significance as you approach R&D's interface with operations. The reason for this is fairly simple. In the later R&D phases, the work is increasingly sensitive to operational considerations specific to the organization. While information about the opportunities and constraints posed by operational reality may occasionally be available in written form, most of it probably exists only as the "working knowledge" of those experienced in the interface.

The final type of information that we take to be constituent of the informal pool involves all accretions from sources outside the organization. This would include information from both the formal literature and informal contacts. The ways in which such information may come to be a part of the in-house pool have been discussed in Chapter II, as was its relative significance under a range of conditions.

Appendix A

Footnotes

1. Clearly information may exist in-house, e.g., on the shelves of the organization's technical library, without being known in-house. As Allen (1970, p.) has remarked, "The transfer of paper does not guarantee the transfer of information."

2. This statement, like a number of others throughout this Appendix may be less true for certain professional groups engaged in certain R&D activities than for others. It does, however, seem to be a strongly supported generalization about the information seeking behavior of R&D personnel as a total group. We will continue to "flag" such generalizations that may vary in their applicability at lower levels of aggregation by some caveat such as "in aggregate," or "on the whole."

3. This assumption is badly flawed since it requires one to presuppose: 1. that information needs are always sufficiently defined to make external searches possible; 2. that there is always someone at hand who can drop whatever else he is doing and locate the needed information; and 3. that the information stored by outside sources is so efficiently organized and appropriately coded that it may be retrieved with ease. None of these presuppositions is always true.

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G-43-603

GEORGIA INSTITUTE OF TECHNOLOGY

ATLANTA, GEORGIA 30332

OFFICE OF
THE DIRECTOR OF
FINANCIAL AFFAIRS

September 27, 1977

Division of Grants & Contracts
National Science Foundation
Washington, D. C. 20550

Gentlemen:

Enclosed in triplicate is the final fiscal report for Grant Number DSI74-13045 AO 4.

If you have any questions or desire additional information, please let us know.

Sincerely yours,

Evan Crosby
Associate Director of
Financial Affairs

EC/bs
enclosures:
cc: Dr. Melvin Kranzberg
Dr. Patrick Kelly
Mr. E. E. Renfro
Mr. A. H. Becker
File G-43-603, G-43-312

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INSTITUTION AND ADDRESS: Georgia Institute of Technology, Atlanta, Georgia	NSF PROGRAM: User Requirements	GRANT PERIOD from 4/1/74 to 12/31/76 *	REPORTING PERIOD from 4/1/74 to 9/7/77 **
GRANT NUMBER: SI74-13045 A0 4	BUDGET DUR. (MOS.): 6	PRINCIPAL INVESTIGATOR(S): Kelly	GRANTEE ACCOUNT NUMBER: G-43-603

	NSF Funded Man Months Cal.	Acad.	Summ.	NSF AWARD BUDGET	CUMULATIVE GRANT EXPENDITURES *Do Not Round*
A. SALARIES AND WAGES					
1. Senior Personnel					
a. 2 (Co)Principal Investigator(s)			2	$ 4,329	
b. Faculty Associates					
Sub-Total				$ 4,329	$ 33,553.99
2. Other Personnel (Non-Faculty)					
a. Research Associates—Postdoctoral					
b. Non-Faculty Professionals					
c. Graduate Students					
d. Pro-Baccalaureate Students					
e. Secretarial—Clerical					
f. 1 Technical, Shop, and Other				1,000	
TOTAL SALARIES AND WAGES				$ 5,329	$ 41,332.42
B. STAFF BENEFITS IF CHARGED AS DIRECT COST				476	2,974.33
C. TOTAL SALARIES, WAGES, AND STAFF BENEFITS (A + B)				$ 5,805	$ 44,306.75
D. PERMANENT EQUIPMENT					–
E. EXPENDABLE EQUIPMENT AND SUPPLIES				500	3,893.13
F. TRAVEL 1. DOMESTIC (INCLUDING CANADA)				4,500	1,466.32
2. FOREIGN					1,447.90
G. PUBLICATION COSTS					192.10
H. COMPUTER COSTS IF CHARGED AS DIRECT COST					194.99
I. OTHER DIRECT COSTS					
Conference Participants					1,692.54
J. TOTAL DIRECT COSTS (C through I)				$ 10,805	$ 53,193.73
K. INDIRECT COSTS 65% of $25,556.43=$16,611.68; 68% of $15,775.99=$10.727.67; 68% of Salaries & Wages $41,332.42 $27,339.35				3,624	27,339.35
L. TOTAL COSTS (J plus K)				$ 14,429	$ 80,533.08
M. AMOUNT OF THIS AWARD (ROUNDED)				$ 14,400	
N. CUMULATIVE GRANT AMOUNT				$ 80,800	
O. UNEXPENDED BALANCE (N. BUDGET MINUS L. EXPENDITURE)					$ 266.92

REMARKS: Use extra sheet if necessary

Grant period extended to 4/30/77 per letter dated 12/16/76.

* No obligations were incurred outside the grant period of 4/1/74 through 4/30/77.

SIGNATURE OF PRINCIPAL INVESTIGATOR	TYPED OR PRINTED NAME	DATE
	Melvin Kranzberg/Patrick Kelly	9-22-77

I CERTIFY THAT ALL EXPENDITURES REPORTED ARE FOR APPROPRIATE PURPOSES AND IN ACCORDANCE WITH THE AGREEMENTS SET FORTH IN THE APPLICATION AND AWARD DOCUMENTS

SIGNATURE OF AUTHORIZED OFFICIAL	TYPED OR PRINTED NAME & TITLE	DATE
	Evan Crosby, Associate Director of Financial Affairs	9/27/77

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Organ. Code	F.Y.	Fund ID	Prog. Code	Ob. Class	O/Dres.	Award No.	Amd.	Inst. Code	Unexpended Balance	Trans.	Lot
									$		

NSF Form 98, May 1975

SUPERSEDES JULY 1971 EDITION WHICH MAY BE USED UNTIL SUPPLY EXHAUSTED

Final

THE FLOW OF SCIENTIFIC AND TECHNICAL INFORMATION IN THE INNOVATION PROCESS: AN ANALYTICAL STUDY

Patrick Kelly Co-Principal
Melvin Kranzberg Investigators

Stanley R. Carpenter
Frederick A. Rossini

Department of Social Sciences
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Atlanta, Georgia 30332

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Patrick Kelly, Melvin Kranzberg
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Table of Contents

CHAPTER I

INTRODUCTION

Technological innovation has been--and continues to be--a dominant problem-solving response in our society, and indeed, in much of the world. A measure of this dominance may be seen in the fact that problems arising from past technological achievements most often entail--or are seen to entail--further technological innovations for their resolution. Given the dominance of this problem-solving mode, it is not surprising that the process by which innovations come into being is a matter of considerable practical and scholarly interest, or that the process itself has undergone substantial changes over time.

Perhaps the most basic change in the process of technological innovation in this century is the increasingly strong trend toward the "institutionalization" of all its phases. The point here is not that only in this century did inventions come to require organizational skills and resources to turn them into useful innovations. James Watt who invented the steam engine in the late 18th century was dependent on the capital and the managerial and entrepreneurial expertise of Matthew Boulton to bring his inventions into use (Scherer 1965). Others such as Sperry and Edison were both inventors and able businessmen. The organizations they built were necessary in order for their inventions to become innovations (Hughes 1971; Josephson

1959). In short, the institutionalization of those phases of the innovation process that follow invention is not new.

That which has come to be handled differently, that which has come to be increasingly institutionalized in the 20th century, is the creative process itself--i.e., what we have come to call R&D. That this is possible is itself a bold and novel assumption, at least in the extent to which it is currently accepted and its actualization sought. As one writer has remarked:

> The historians of the future may well select the development of deliberate creativeness as the most important development of this century. We have passed through the age of random creativeness and are entering an age of deliberate creativeness (Rossman 1964, p. xii).

That the creation and introduction of novelty is now recognized and accepted as a part of the mission of so many organizations reflects the extent to which this assumption of deliberate creativeness--and thus the institutionalization of the whole innovation process--has taken root.

The emergence and rapid growth of R&D laboratories, especially in the years after World War II, is the major manifestation of this institutionalization phenomenon. Total U.S. R&D expenditures increased at an average annual rate of 10 per cent in the 1953--1970 time period (Mansfield, et al. 1971). Rubenstein (1957, p. 95), summarizing the growth in R&D activity along a different dimension, noted that the 1956 edition of the Industrial Research Laboratories of the United States lists 4834 R&D laboratories operated by 4086 companies. "A sizable proportion of these companies were not operating research programs 10 years ago, and a majority of them were not doing so 15 years ago. As for the programs that did exist then most have grown so fast that today they can hardly be recognized."

In Hamberg's (1955) words there has been a "research explosion": "R&D is being conducted on an unparalleled scale offering the potential for unprecedented advances in productivity increases." The extent to which such increases will in fact be realized depends, in large measure, on how effective the R&D process can become, and that depends in turn on our understanding the wide range of variables that impinge on the institutionalized process of innovation. Crucial among these variables are those that relate to the pool and flow of scientific and technical information--the focus of this report.

A. Scope and Objectives

This study is concerned with the informal pool and flow of scientific and technical information in the R&D laboratory. The study is designed to explore:

(1) not only "What do we know?" but also, "What do these things mean?";
(2) not only "What do we not know?" but "What should we know?" and "What is required before we can come to know these things?"; and, finally,
(3) "What is the practical import of all of this for the several groups of stakeholders?"

These questions may be recast in terms of the following objectives:

1. To describe the nature and function of the informal STI system in the R&D laboratory...

   in terms of an integrative conceptual framework in which the notion of informal groups is central;

   with respect to a range of variables that have been shown or hypothesized as impinging on STI pool and flow;

   to the end that the concerted influence of these variables may come to be studied, understood, and utilized as information-need indicators;

2. To utilize the results achieved in this integrative effort to examine the implications of the nature and function of the laboratory's informal STI system for...

   its interface with formal STI systems and services;
   its interface with the operating units of the laboratory's parent organization;

   the research "agenda" of scholars concerned with the innovation process, the R&D laboratory, and the pool and flow of STI.

These objectives are expanded in the following section.

B. Three Emphases of the Study

In the course of this inquiry into the patterns of STI pool and flow in the R&D laboratory three distinct but overlapping emphases emerged. The first involves a conceptual framework for integrating some of the range of variables that influence the laboratory's information processes. The approach here is a systemic one, dealing with the influence of these various influences in concert. Our second emphasis concerns the interface of the laboratory with external information sources. Here the question is how the laboratory researcher typically gets information from formal STI systems and services and from informal sources beyond his laboratory. The third emphasis of our study involves the informational dimension of the laboratory's interface with the operating units of its parent organization (or such other "clients" as may be recipients of R&D output). The question here is how information about operational constraints and opportunities flows to, and within, the R&D laboratory.

1. An Integrated Conceptual Framework

The scientific and technical information required in the conduct of R&D, and the ways in which this information comes to be available, are subject to a wide variety of influences. Among the influences to be examined are:

a. Differences in the nature of the several activities across the R&D spectrum.

Those activities toward the basic research pole are more heavily dependent on external STI sources (both formal and informal), while those toward the operations interface require a greater measure of in-house information (Rosenbloom and Wolek 1970). Corresponding differences exist in the manner in which this information flows, into and within the laboratory.

b. Differences in the information needs and information-seeking behaviors of the several professional fields or disciplines represented in the laboratory.

Other things being equal, scientists seem more oriented toward the formal literature and informal sources external to the laboratory, while engineers show a greater reliance on informal sources within the laboratory.[1]

c. Differences in the way in which the laboratory and/or project is structured.

It will be argued that laboratories organized by R&D function (e.g., research, development, and design), and by discipline within these functional units, create conditions more favorable to efficient informal STI pool and flow mechanisms than the "project-dominant" arrangement (i.e., multi-disciplinary units that work on long-term projects or service major product areas).

d. Differences between corporate and operating-division laboratories.

This difference in the location (and function) of the laboratory within its parent organization has implications for the kinds of information needed and the ways in which this information comes to be available. For instance central laboratories exhibit a much greater reliance on external information than do operating division laboratories (Rosenbloom and Wolek 1970, pp. 49-50).

e. The difference between stable and rapidly changing R&D missions.

Frequent and substantial shifts in R&D focus imply that the in-house STI pool more often proves inadequate--thus requiring more accretions from external sources--than in the case of the more stable mission.

f. <u>Differences in the rate of scientific and technological change within the industry of which the laboratory's parent organization is a part</u>.

This point, like the previous one, has to do with the relative adequacy of the laboratory's in-house information pool. Here, however, we will be concerned with the pace at which the state-of-the-art knowledge is changing rather than the frequency of organizationally-induced shifts in the laboratory mission. We argue that the higher the rate of scientific and/or technological change in the industry of which the laboratory's parent organization is a part, the greater the reliance on external information sources.

g. <u>Differences imposed by the magnitude of the innovative effort, i.e., incremental improvement vs. discontinuous or breakthrough efforts</u>.

The final influence we will consider lies, not in the conditions within the laboratory or its larger environment, but in the magnitude of the innovative effort itself. At one extreme, an innovative effort may represent a minor extension of what the organization is already producing--a small <u>increment</u> or next step. On the other hand, it may represent a radical departure--a <u>discontinuity</u> if you will. Most of the information required for the former typically exists as a part of the in-house pool; little is required from external sources. For discontinuous or breakthrough efforts, however, the matter is quite otherwise. Massive infusions of information from outside will likely be required.

Each of these influences on the STI needs and flow patterns within the laboratory admits of considerable complexity. Thus the evidence and arguments for them will have to be examined carefully. The more important point to be noted, however, is that these influences do not impinge singly, but in various combinations. As a matter of strategy, therefore, we will first deal with only one "set" of influences from among the several combinations inherent in the above types. This will provide a specific illustration of the conceptual framework we offer for their integrated treatment. In addition, explication of this specific combination of influences will serve as a "baseline" for gauging the differences introduced by alternative combinations.

We take the nature and function of informal groups as the key to understanding the pool and flow of STI in the R&D laboratory. Thus the notion of informal groups will constitute the basis of our integrated conceptual framework. Certain key individual roles--gatekeepers, supervisors, opinion leaders, liaisons--on the one hand, and the functioning of the laboratory's larger informal system or network on the other, will be interpreted in terms of the informal group. Likewise, the several variables listed above will be treated in terms of their influence on the nature and/or function of such groups.

2. The Interface with External Sources of Information

The second major emphasis of our study concerns the interface of the laboratory's informal STI pool and flow system with external information sources (The operating units of the parent organization as STI sources are excluded here, but will be treated in a separate section). These external sources are of two types--formal STI systems and services and informal contacts. Neither of these external sources will be examined in any detail in this study, since they are equally complex systems whose treatment would take us far beyond our R&D laboratory focus.

As to the formal STI systems, however, it should be noted that the growth of organized R&D, as described earlier, has contributed to a corresponding growth in the need for, and volume of, scientific and technical information. To disseminate, index, abstract, store, and provide this information quickly on demand, there has emerged a diversified and burgeoning STI industry. In other words, the institutionalization of technological innovation in the form of the R&D laboratory has contributed to parallel developments in this vital support function.

From the perspective of the information specialists who design and operate the wide range of formal STI systems and services, however, the interface with organized R&D has often been a frustrating one. With diligence, imagination, and no small commitment of resources, these formal systems have over the years become progressively more elegant and sophisticated. By every measure there has been impressive progress--every measure, that is, except the percentage of actual users.[2] Each enhancement of search capability, each time-saving increment, each surge in comprehensiveness, seems to be greeted by the potential laboratory-user population with about the same measure of indifference. To the STI specialist, this must be perplexing. What is the matter with these R&D "yoyos" anyway? Relevant and timely information is the very lifeblood of R&D; how can they possibly ignore the formal systems and services and still survive?

But not only does R&D survive, it seems healthy. The apparent lack of need must be even more frustrating than the demonstrated lack of use. Yet the researchers in the R&D laboratory show few signs of the sort of informational malnutrition that would result from unmet STI needs. They show only a rosy glow of informational good health and an apparently obstinate indifference to the formal STI systems and services.

Before those who design and manage the formal STI systems yield to frustration over the failure of their best efforts to meet the R&D researcher's informational needs, however, they should be sure that this failure is not more apparent than real. In this, the second of our three emphases, we will be looking closely at the behavior of these researchers who seem not to need the formal systems and services. At the same time, we will be looking at some of the assumptions about the R&D researcher that seem to shape the expectations of the formal systems professionals.

To provide a preliminary overview of this interface of the formal STI systems and services with the laboratory's informal systems, let us anticipate some of the practical conclusions that will emerge from our analysis.

a. <u>It is distorting and unhelpful to think in terms of "users" and "non-users" of the formal systems and services</u>.

The possible reasons for non-use of the formal STI systems and services are numerous, and most of them are quite sensible and unlikely to change. Furthermore, these reasons for non-use constitute no indictment of the formal systems or the non-users: the former are not negligent and the latter are not slothful. In aggregate, most of the information needs in the R&D laboratory either can't be met at all by the formal systems and services, or they can be met better, quicker, and with significant social-psychological payoff by the laboratory's informal system. The designation "non-user" distorts these realities by its implication that if only the formal systems or "those ninnies" were somehow different, then they too would become users. We see little to support this contention, however. Thus, the user/non-user way of thinking about the problem introduces a distorting dichcotomy that cannot yield much understanding of formal/informal systems interface. A distinction between <u>direct</u> and <u>indirect</u> users is a more accurate and helpful one.

The user/non-user distinction is also unhelpful when used --as it often is--to gauge the <u>value</u> of formal STI systems and services. The evidence indicates that the number of direct users is going to remain a very small fraction of the total number of researchers. Therefore, to judge the value of the formal systems and services by counting noses is to invite an unnecessary frustration. No matter what is done, the nose count is not going to get much better--they simply can't use the services at all, or have a better (i.e., indirect) access. There is an even more unhelpful implication than continued frustration, however. If you make the number of users the bottom line in evaluating what is provided, then that same yardstick is going to be picked up and used by those who pay the bills. In a crunch, that may spell budgetary disaster; and even if it does not, it is a serious misrepresentation of the value of the formal STI systems and services.

b. It is accurate and helpful to think in terms of service to informal groups--groups composed of both direct and indirect users.

We will argue that the market for the formal STI systems and services is composed, not of isolated individuals, but of highly interactive informal groups. These informal groups have been shown to be extremely effective information pools. Accretions to these informal pools from external sources, such as the formal STI systems and services, are typically by way of a very few group members. Allen has called these individuals "gatekeepers." For present purposes, we prefer the term "direct users," since it serves to highlight the fact that these individuals, in turn, serve their informal group, thus making their colleagues "indirect users."

This notion of direct and indirect users is really a very simple one. Just as far more people eat food than go grocery shopping, just so do far more researchers benefit from the formal STI systems and services than use them directly. It is also a helpful picture, for it calls attention to the overlapping nature of the boundaries between formal and informal STI systems. Once it is recognized that the formal systems serve groups, through the few direct users, then it becomes clear that the effective boundaries of such formal systems are indeed quite large. Indirect users are users nonetheless--a point which has been, but should not be, neglected.

c. There are features of the R&D laboratory and its environment that can serve as "indicators" of information needs that the formal systems and services can meet.

We argue that those characteristics of the R&D context listed above exert systematic and predictable influences on the laboratory's information requirements. These information need indicators thus offer the potential for "fine-tuning" formal STI systems and services to meet more adequately the needs of R&D laboratories and hence to encourage innovation. A word of caution is in order, however. The kinds of questions about information use in the R&D laboratory that have led us to posit these indicators have not all been directly addressed in the research literature. Thus the evidence for some of them is, at this point, largely indirect. We are convinced, however, that the approach is a fruitful one, and that the indicators we describe could prove useful. The needed acid tests, however, are careful empirical research by academics on the one hand, and the actual use, or at least laboratory testing, of these indicators by formal systems designers and operators on the other.

d. At least in the short-run, fine-tuning the formal STI systems and services in terms of the "information need indicators" may require the assistance of "interpreters," i.e., those knowledgeable about the R&D process.

At present, the formal STI systems and the informal systems of the R&D laboratory are largely independent mechanisms, interacting in unplanned ways that are often a puzzle. Ideally, however, they should function as interdependent subsystems of a larger whole. The initiative in designing and implementing this larger STI system--which would embrace both the formal and informal as interlocking components--must come from those involved with the formal systems. The reason is obvious. The informal systems, while enduring and extremely effective, are largely the unplanned and mute creatures of past and present needs. They constrain the future in various ways, but are limited in their ability to design for it.

The question, then, is how can this better integrated system be designed? The answer is by fine-tuning the formal component to mesh with the informal, which simply exists, cannot be designed, and cannot speak for itself. To get beyond blind trial and error in this fine-tuning process, we think it is essential to involve those who might be able to "speak for" the informal component, i.e., those who are knowledgeable about the broader dimensions of the R&D process, the nature and function of informal laboratory groups, and the patterns of STI flow within them. Such individuals could play an important interpreter role in working out a more effective interface between the formal and informal STI systems.

We will return to these practical points in Chapter III after having developed the systemic, conceptual, and empirical foundation upon which they rest.

3. The Interface with Operations

The third emphasis in our analysis and integrative treatment of STI pool and flow in the R&D laboratory involves its interface with the operating units of its parent organization --its "clients" if you will. R&D converts ideas and information into potential technological innovations. These potential innovations must be transferred to, and successfully implemented by, the operating units of the organization before their success--or lack of it-- can be gauged by actual use. We take the success of this transfer from R&D to operations to be heavily STI-dependent. That is, the R&D effort, particularly in its latter stages, must be informed by and compatible with the technical constraints and opportunities inherent in the implementation process with is to follow.

The importance of a smooth transfer from R&D can be seen in economic terms. From their sample of firms in the chemical, mechanical and electronic industries, Mansfield et al. (1971) found that over 75 per cent of the total innovation expenditures occurred after the R&D phase.[3] Thus a poor interface not only threatens the investment already made in R&D, but can undermine the much larger expenditures to come. The difficulty inherent in this interface is emphasized by Quinn and Mueller who, after interviewing over 200 top operating and research executives, concluded that, "The key problem in research management today is getting research results effectively transferred into operations" (1963, p. 49).

In order to understand and thus deal more effectively with the risk and difficulty inherent in this transfer, it should be viewed, not as an event at some point in time, but as an STI dependent process in which informal laboratory groups have a significant role. In particular, the following exploratory hypotheses will be advanced:

a. Instances of smooth and effective transfer of an innovation are characterized by more substantial pool and flow of operations-dependent STI in the R&D laboratory than less smooth and effective instances;

b. The beginnings of a successful transfer to operations have often-unobtrusive roots that run far back in the R&D effort;

c. Informal laboratory groups, and certain key individuals within them, constitute the most significant pools and channels of operations-dependent STI within the laboratory.

d. Precisely those features of the laboratory's informal STI system that make it so effective in intra-laboratory pool and flow may constitute barriers to the laboratory's interface with operations.

Evidence for these exploratory hypotheses is, at this point, largely analytic and systemic rather than empirical and direct. We believe the case for them is strong enough, however, to impel their testing.

* * *

These three emphases or perspectives on the pool and flow of STI in the R&D laboratory--(1) a conceptual framework for integrating a range of impinging variables, (2) the interface with external information sources, and (3) the interface with operations--will constitute the foci of Chapters II, III, and IV respectively.

C. Study Methodology

The complexity inherent in the pool and flow of STI in the R&D laboratory, the unevenness in our current understanding of the process, and the practical pressures to improve it, converge to give this study the following characteristics:

1. It is analytic and interdisciplinary, i.e., it draws upon research results--and the assumptions underlying them--from a wide range of scholarly fields whose subject matters are central to or impinge upon information need and acquisition patterns in the laboratory;
2. It is integrative in the sense that it attempts to deal with variables and assumptions in concert rather than singly with a specious "other things being equal" caveat;
3. It is hypothesis generating, in that the conceptual framework which is proposed permits a new level of questioning;
4. It is practice-oriented, i.e., the new level of questioning that is introduced results, not only in a research "agenda" for academics, but also in recommendations for fine-tuning the formal STI systems and services on the one hand, and for facilitating the role of the laboratory's informal system on the other.

These characteristics dictate a method of study that combines both inductive and deductive modes of investigation in an iterative and cumulative process. That is to say, at certain points we are involved in piecing together the implications of a wide range of empirical studies that have been reported in the literature, while at others we are moving from a more general observation or hypothesis to its possible implications at the operational level. In an effort that is integrative as well as analytic, these methodological modes feed into, inform, and constrain one another. An illustration of this pattern is in order.

There is considerable empirical evidence regarding the relative frequencies with which information needs are met; through informal discussions as opposed to the formal literature, by in-house as opposed to external sources, through professional as opposed to trade literature, etc. Correlations have also been established between these information seeking behaviors and certain characteristics of the researcher (e.g., scientist or engineer), the nature of the activity in which he is engaged (e.g., research,development, or design), and differences between the laboratory setting and mission (corporate vs operating division laboratories). Analysis of these empirically demonstrated relationships have led us to posit others that need to be explored; e.g., the way in which the laboratory and/or project is structured, the stability of the laboratory's R&D mission, the rate of scientific and technical change in the industry, and the nature of the innovative effort itself.

The whole thrust of these existing and proposed correlation studies serve, in turn, to raise a number of questions as to the nature of the informal mechanisms by which STI (or literature references to it) is transferred. There is a growing number of studies of such informal transfers, especially as regards the role of certain key individuals called "gatekeepers." There are, however, two serious weaknesses in these studies of the informal STI channels and patterns. First, they exhibit an almost total neglect of the influences mentioned above that have been shown to correlate with different information-seeking behaviors. Thus it is unknown, for instance, whether the gatekeeper function is as important in basic research as in the design function, or to scientists as engineers, or in the corporate as opposed to the operating division laboratory. Piecing together an integrated picture of these relationships, calls for both the deductive and inductive modes of analysis.

The second weakness in the existing studies of the laboratory's informal STI system is that their emphasis on the gatekeeper function--as important as it indeed is--has been at the expense of a more balanced understanding of the whole informal system. For instance, our analysis leads us to believe that the gatekeeper function probably accounts for only a fairly small portion of the total flow of STI through informal channels.

Support of this contention rests on a nexus of inductive and deductive work.

Finally, our analysis of what is known about the information-seeking behavior of R&D personnel, the informal systems of which they are a part, and the range of influences that impinge upon both, has led us to emphasize the concept of informal groups. The range of phenomena requiring explanation cannot be treated adequately without a careful consideration of the manner in which information is informally <u>pooled</u> as well as the informal channels by which it <u>flows</u>. Informal groups are taken as the key to a more adequate understanding of both functions--and, indeed, to the integration of what is known about STI phenomena in the R&D laboratory.

Thus the methodology employed in this study is a complex of both inductive and deductive modes of investigation. Its legitimization rests upon three considerations: The internal consistency of the integration achieved; the compatibility of this integration with existing empirical results, and, finally, the fruitfulness of the hypotheses and practical actions to which it leads.

Chapter I

Footnotes

1. Price 1965; Allen 1964; 1966a,b; Hagstrom 1965; Shilling and Bernard 1964; Gerstberger and Allen 1968.

2. Herner 1954; Halbert and Ackoff 1959; OECD 1960; Scott 1962; Allen 1965, 1966; Auerbach Corporation 1965; Sherwin and Isenson 1966; Isenson 1967; North American Aviation 1966.

3. The breakdown of post-R&D expenditures was 29.1 per cent for prototypes and pilot plant, 36.9 per cent for tooling and manufacturing facilities, and 9.5 per cent for manufacturing start-up costs.

CHAPTER II

THE NATURE AND FUNCTION OF THE INFORMAL STI SYSTEM IN THE R&D LABORATORY

A. Introduction

In this chapter we will seek to:

1. Analyze the nature and function of the informal STI system in the R&D laboratory...

   in terms of an integrative conceptual framework in which the notion of informal groups is central;

   with respect to a range of variables that have been shown or hypothesized as impinging on STI pool and flow;

   to the end that the concerted influence of these variables may come to be studied, understood, and utilized as information need indicators.

This analysis, of the informal system and the pool and flow of STI it makes possible, will be grounded in the state of the art understanding of these phenomena. Where there exist gaps or weaknesses in this understanding, we will "effect closure" with such exploratory hypotheses and conceptual bridges as seem to us warranted. These leaps beyond what has been demonstrated will be indicated as such.

1. Neglect of the Informal System

The term "informal STI system" here refers to a communications network through which the researcher in the R&D laboratory may access, by personal contact, the "pool" of information that is possessed by the members of that network. That which is obtained by means of these informal channels may be either the needed scientific or technical information itself, or a reference to the formal literature or other source where the information may be found.

This definition of the informal system occasions a noting of the obvious, i.e., "that formal and informal communications are mutually dependent elements of the same system" (Wolek and Griffith 1974, p. 412). This interdependency has in the past been so badly neglected that formal and informal channels were at times seen as competitors, and use of the informal as a sign of weakness and need for better formal systems (this view is expressed, for instance, by Scott, 1962). While specialization of focus within the STI field is both legitimate and necessary, not to the extent of research and formal system designs that attempt to reinvent a well functioning wheel.

The informal STI systems depend for their existence on social systems--or if you prefer, are manifestations of social systems. Price (1970) makes this point and scolds those who would neglect it when he says:

> In short, hard science, soft science, technology, and nonscience may be all different social systems, and each system must have its own special machinery for...communication among people at the research fronts and behind these fronts too. I believe that ...a proper understanding of science as a social system will wipe away a lot of naive misunderstanding which shrouds the business of science information and makes us hope for the wrong sort of expensive solutions to what seems to be the problems (p. 22).

Let us juxtapose this contrast of formal and informal STI systems with a contrast between the informal STI system and the formal organization of R&D.

> The most intriguing aspect of this process [of informal transfer] is the fact that it has developed spontaneously, with no management intervention. There was scarcely a suspicion on the part of management that the network operated in this way (Allen 1970, p. 200).

There is an interesting parallel in these two quotes that contrast the informal system with two quite different kinds of formal systems. They both make the point that those concerned with these respective formal systems often do not understand the nature, role, and importance of the informal system very well. If this be the case, it makes all the more important our task of displaying the interdependencies between the informal systems and their formal STI counterparts on the one hand, and the formal structure of R&D organizations on the other.

2. <u>The Informal System: Praise and Criticism</u>

Scholars concerned with the informal STI system have at times been lavish in their assessment of its efficiency. Allen (1970) has said for instance:

> In fact, if one were to sit down and attempt to design an optimal system for bringing in new technical information and disseminating it within the organization, it would be difficult to produce a better one than that which exists (p. 198).

Others have been more cautious, even critical, of informal systems in general.

> While scientists working in related research areas are likely to come into contact, there is no certainty that this will occur. The informal system contains no mechanisms to assure that scientists with common interests will indeed attend the same meetings, and even if they do, actual face-to-face encounter is often a matter of chance. Informal communication, because of its very nature, is marked by its large random element (National Academy of Sciences 1967, p. 45).

As between these two divergent assessments, we find the former to be closer to the mark. It is a misunderstanding to assume that "informal" means "lacking structure." While informal systems by definition lack formal structure, this does not mean that they lack structure altogether (Menzel 1959; Allen 1970). The typical informal system at least within the R&D laboratory is, in fact, a rich network of interrelations for which "its large random element" is a specious characterization.

This point is convincingly illustrated in a study by Rosenbloom and Wolek (1970) in which more than 3000 engineers and scientists[1] were asked to, "think of the most recent instance in which an item of information, which you received from a source other than someone in your immediate circle of colleagues, proved useful in your work" (p. 124). The subjects were then asked to describe the circumstances leading up to acquiring this information. The responses were grouped into three categories, "according to whether the information had been sought for the specific use to which it was put, had been volunteered by someone else, or had been acquired in the course of 'competence development' activities such as keeping up with or reviewing a technical field" (p. 37). Table 1 shows the results obtained.

Table 1

Circumstances of Acquisition

	Total (N=1852)	Scientists (N=654)	Engineers (N=966)
Specifically sought	47%	42%	53%
Pointed Out	32%	33%	30%
General Competence	21%	25%	17%

As these percentages indicate, in almost one-third of the instances the information was transferred--not as the result of a search--but because someone volunteered it. This was the case even though the researcher's "immediate circle of colleagues" was excluded from the question.[2] It is difficult to fault for its randomness an informal communication system so powerful that a third of the time it delivers information even before the person knows he needs it!

There is an interesting prescription that has gained some currency among STI scholars that deserves mention in this connection.

> When you need to know something, ask somebody; If you don't know who to ask, ask someone who might know somebody; If you don't know someone who knows somebody, and can't wait, avoid, or change your need, then search the literature. (Kelly and Wolek 1976).

This prescription or "rule of thumb" occasions two comments about the informal STI system. First, while it refers to the way in which the informal systems work, even on its surface it recognizes the existence and necessity of the formal STI systems and services--though apparently as a last resort. But it is naive and distorting to take this rule of thumb as relegating the formal systems and services to merely a "last resort only" status. When you "ask somebody," what you may well get is a reference to the literature where the information may be found.

Second, this prescription is not an equally sound characterization of all the STI pool and flow patterns that may coexist in the same informal system. At one extreme, we suspect that there are patterns of STI flow that almost never include use of the formal literature--even as a last resort. On the other, there are patterns in which the literature is central and essential. While the above "rule of thumb" is not an invalid characterization of how the informal system works in even these polar extremes, it is more straightforwardly accurate in the intermediate range.

3. The Concept of Informal Groups

An R&D laboratory's informal STI system has been shown to be a cluster of highly interactive subsystems that are linked by interpersonal contact to one another, to the operational end of the organization, and to sources beyond the organization.[3] At some points the linkages between its constitutive subsystems are numerous and strong from frequent use. At other points the coupling may be as tenuous as an infrequent contact between only two individuals.

These constitutive units of the laboratory's informal STI system are small, informal groups of researchers, groups occasioned and sustained by the mutual social-choices of their members. We take these informal groups as the key to the integration of what is known about the nature and function of the laboratory's informal STI system--i.e., they seem to be the primary mechanism of informal STI pool and flow.

These informal--or mutual social-choice--laboratory groups typically exist wholly within single sub-units or departments of the formal laboratory structure (Allen 1970). Cartwright and Zander (1968) account for this fact as follows:

> Because the spontaneous formation of a group from a particular collection of acquaintances involves the development of interpersonal attractions among them, the composition of such groups may be expected to depend upon conditions that determine such attractions (p. 55).

The formal organizational units of the laboratory, by the nature of their specific R&D functions, provide a number of conditions for informal group formation--not the least of which is the acquisition of the scientific and technical information upon which the performance of such functions depends.

Informal groups typically arise <u>within</u> formal laboratory units, but are usually not co-extensive within them. Allen (1970) has shown that for the eight laboratory departments he studied there was a median of three informal groups in each. While the formal laboratory structure typically provides the focusing and boundary conditions for such groups, it does not account fully for their emergence or composition. This explanation seems to lie in the idiosyncrasies of mutual social choice. The reasons for such choices seem to involve the satisfaction of such individual needs as socialization, communication, and a greater measure of control over one's environment.[4] Efforts to satisfy such needs by participation in informal laboratory groups are well illustrated in the R&D literature.

The ways in which such individual needs converge with one another, and with conditions inherent in the formal organizations, to occasion the formation of informal groups in the laboratory are too numerous and social-psychologically complex to be treated in this study. A simple illustration is in order, however. In the course of a researcher's work on a project for which he has been formally assigned responsibility, he may encounter problems that lie outside his knowledge and expertise. To maintain (or increase) his measure of "control over his environment"--e.g., complete the project successfully, merit the approval of his supervisor and peers, enhance his career development, etc.--he needs information he does not possess. He needs to "communicate" with those knowledgeable in this problem area. He may not, however, even be able to ask very "good" questions about the problem. This being the case, he would likely seek out those he knows well, since there is less risk of embarrassment in posing possibly "dumb" questions to a friend.

> Simply stated, people are more willing to ask questions of others whom they know, than of strangers...To be told that you have asked a dumb or foolish question is the ultimate in rebuffs. Few people are willing to entertain such a risk. Now, out of all the people in the world there are hopefully only a small percentage who would meet even a truly stupid question with such a retort. Even given that this percentage is very small, however, many people will follow the strategy of minimum regrets and assume that everyone belongs to this set unless proven otherwise (Allen 1970).

Informal social contacts thus seem to provide a more comfortable context for seeking information, which if successful, reinforces these informal bonds. Informal groups, therefore, may be viewed as socialization mechanisms, which facilitate information flow, enabling the researcher to perform better on assigned tasks, and thereby to control more effectively his environment.

While informal laboratory groups thus perform similar social-psychological functions, our analysis of the literature leads us to hypothesize substantial differences in the manner, extent, and effect of their information transfer functions. To understand a particular group's role in STI pool and flow, it is necessary to specify the nature of the informal group and the conditions under which it is operating. The following variables have been shown, or are herein hypothesized, as important in this regard.

1. Differences in the nature of the several activities that may be identified across the R&D spectrum.

2. Differences in the information needs and information-seeking behaviors of the several professional fields or disciplines represented in the laboratory.

3. Differences in the way in which the laboratory and/or project is structured.

4. Differences between corporate and operating division laboratories.

5. The differences between stable and rapidly changing R&D missions.

6. Differences in the rate of scientific and/or technological change within the industry of which the laboratory's parent organization is a part.

7. Differences imposed by the magnitude of the innovative effort, i.e., incremental improvement vs. discontinuous projects.

Each of these influences upon the patterns of STI flow within the laboratory admits of considerable complexity. In addition, they do not impinge singly, but in various combinations. As a matter of strategy, we will first deal with only one commonly found set of influences from among the several combinations inherent in the above types. This will provide a specific frame of reference for illustrating the integrative and explanatory power of the informal group concept. In addition, the explication of this specific combination of influences will serve as a "baseline" for gauging in a more systematic fashion the differences introduced by the alternatives to be considered later.

B. A Baseline Integration

The baseline structural arrangement we have selected is a typical one in which a single corporate laboratory is structured in terms of R&D activities or functions--e.g., research, development and design.[5] Rosenbloom and Wolek (1970) have characterized these activities as follows:

> Research tasks have a high expected contribution to knowledge but are relatively remote from operations; design tasks fall at the opposite pole on each dimension. Relative to both of these tasks, development work occupies an interesting position. In relation to research it should yield a more direct contribution to operations, while in relation to design it has a much higher expected contribution to the state of

> knowledge. Development work is undertaken when there is some specific operational goal in mind, but it occurs at a phase in the R&D cycle in which first priority often is given to the synthesis, validation, and refinement of concepts and approaches (p. 82).

Given sufficient laboratory size, each of these functional units is here assumed to be subdivided along professional field or disciplinary lines. We also assume that the mission of the laboratory embraces the whole spectrum of R&D activities from basic research to the interface with operations, that the rate of technological change in the industry is moderate. Finally, we will take the magnitude of its innovative efforts to be toward the incremental improvement end of the spectrum, i.e., it is not currently involved in a major departure from that which the laboratory knows best.

1. The Informal Group

The influence of this particular combination of conditions on the nature and function of informal laboratory groups may be briefly summarized as follows. The way in which this laboratory is organized provides a doubly cohesive basis for the emergence and functioning of informal groups. First, since the laboratory has established separate functionally organized units for the conduct of the R&D, distinctive formal groups are thereby created. These formal groups share a common functional orientation, a common set of goals, and common problems. Second, developing the internal structure of these functional units along the lines of the researcher's professional fields or disciplines results in smaller formal groups that are even more cohesive. The members of these sub-units not only have a particular R&D function in common, but also share their disciplinary paradigms, coding schemes, expertise, etc.

The nature of the informal groups that emerge--on the basis of mutual social choice--within this formal organizational structure is influenced by these formal arrangements, and thus reflects the doubly cohesive influence that they create. As Conrath (1968) has noted, "The very existence of a formal organization provides the *raison d'etre* for the formation of informal interest groups." From the perspective of the individual researcher, the point here is that the ways in which his needs for socialization, communication, and a greater measure of control are manifested, are greatly influenced by the nature of the formal organizational units of which he is a part. The formal groupings not only focus his attention and effort by their nature and function, but also bring him into close contact with others who are similarly focused.

The formal units and sub-units of the laboratory thus occasion particular individual needs by their existence and function; but only incidentally can they meet these needs. Their function is primarily the satisfaction of organizational, not individual, needs. In addition to occasioning the particular manifestations of individual needs, however, they also occasion the emergence and continued existence of informal groups that can meet them. In meeting the needs of its members, the informal groups may also further the objectives of the organization.

The need for scientific and technical information is a case in point. Often a researcher requires information that he does not possess. The formal organization, which has occasioned this need by the task it has assigned the researcher may "possess" the information in the sense that it can be gained by searching the corporate technical library or computerized STI system provided. But it may be more readily available from a colleague, or from a source he knows. The frequency of such informational needs occasions, in part, the existence of informal communications networks.

Figure 1 shows the communications network for a typical functional department in a large R&D laboratory studied by Allen. By means of a graph-theoretic reduction the "strong components"[6]--what we have called informal groups--of this network are shown in Figure 2.

In the eight departments of about fifty researchers each studied by Allen, there was a median of three non-trivial (more than two members) strong components per department (Allen 1970, p. 198). These informal groups, unlike the laboratory units which embrace them, are not, with rare exception, formally recognized units of the organization. Within these groups the interpersonal linkages are numerous and strong from frequent use. Between them they are weaker, occasionally as tenuous as an infrequent contact between only two individuals. Thus the flow of information is not uniform throughout the departments or the laboratory. Our thesis is that these informal groups--though spontaneous in origin and

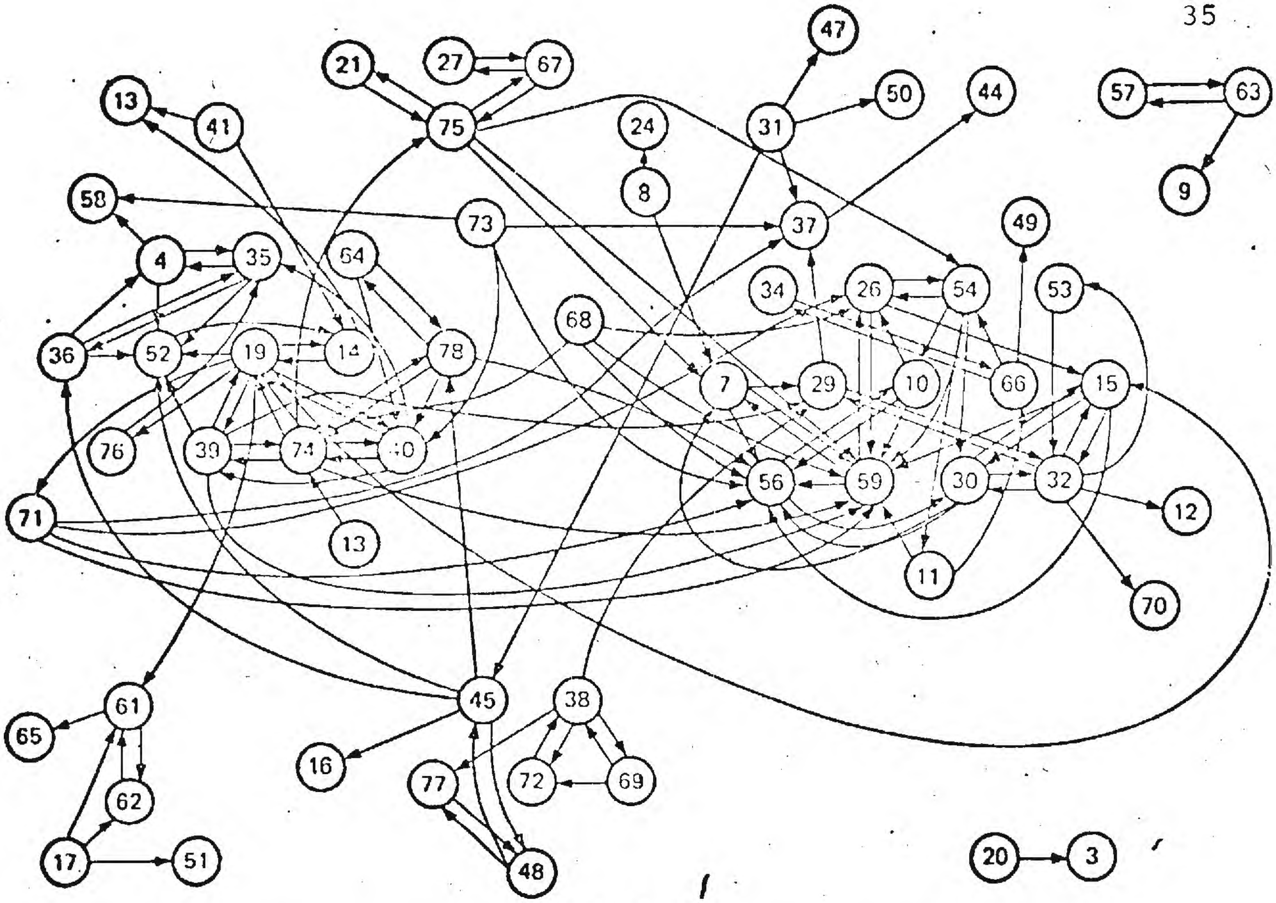


Figure 1
Communication Network of a Typical Functional Department of a Large R&D Laboratory (Allen 1970, p. 199).

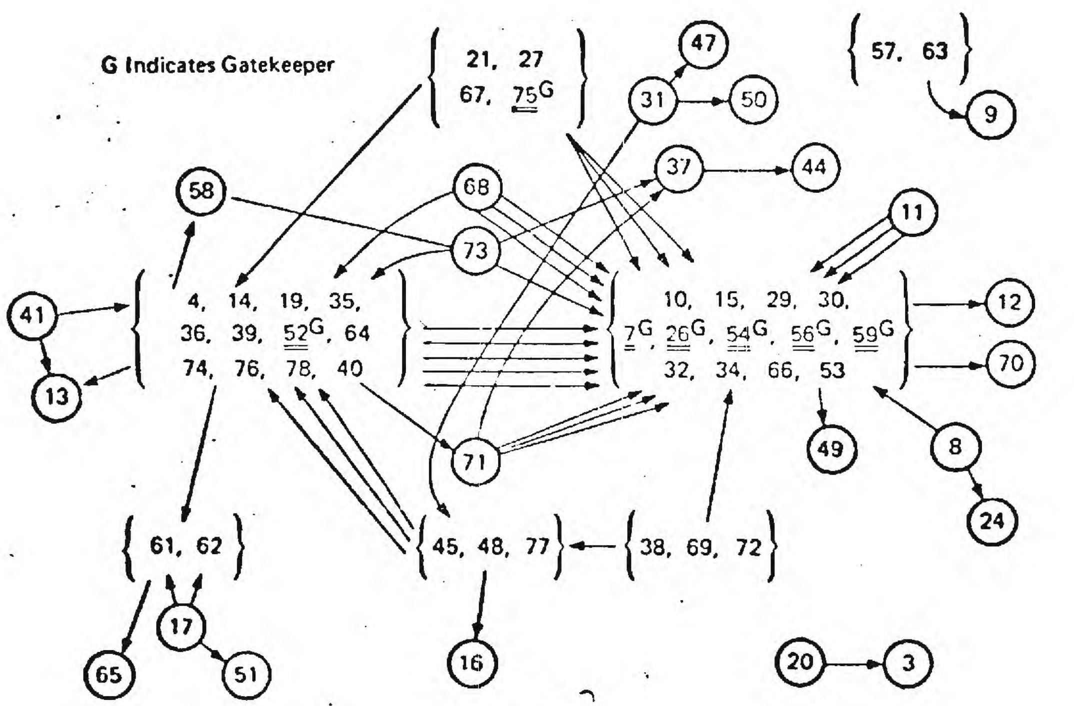


Figure 2
Departmental Communication Network After Reduction into Strong Components. (Strong Components are shown in brackets, and gatekeepers are shown by underlining with "G" superscript). (Allen 1970, p. 200).

informal and unrecognized in their existence--are in fact the core of the laboratory's informal STI system.

It should be noted that whatever the social-psychological motivations underlying the formation of such groups, once established, they are tenacious in maintaining themselves (Taylor and Utterback 1975). There is also evidence that in addition to their information transfer function, informal groups may also have a role in the shaping of technical "attitudes" within the laboratory. Let us explore this last point for a moment, as it may provide a further clue as to the "cement" which binds these groups together.

In a study by Allen and Cohen (1966) researchers in two large laboratories were asked to indicate their attitudes on each of three rather uncertain technical questions confronting their laboratories, in order to test the following hypothesis:

> Technological attitudes, attitudes toward such things as feasibility of particular approaches which are not yet physically testable, will be strongly influenced by the attitudes held by other members of the primary groups to which the engineer belongs (Allen and Cohen 1966, p. 7).

Credit for the formation of this hypothesis was given to Kurt Lewin and his followers who suggested that "when an opinion or attitude cannot be tested directly against 'physical reality' then the individual will resort to a test against 'social reality.' In other words, he will look to his peers for confirmation or disconfirmation and react accordingly" (Allen and Cohen 1966, p. 8).

A fairly strong correlation was found between the technical approaches favored by the individual researcher and the ones favored by those he sought out for technical discussion. Unfortunately, the nature of the data precluded determination of causal direction, i.e., whether technical discussion leads to attitude agreement or whether certain individuals are chosen for discussion on the basis of prior knowledge of agreement. A replication of this study is needed which would permit determination of this causal direction.

Whether formation or reinforcement turns out to be a basic function, it may be that part of the explanation of the strength of the informal group may grow out of this need to "test" one's ideas or position against "social reality." It is reasonable that such confirmation would be sought from those social peers with whom the researcher had established a base for interaction on technical matters.

Returning now to evidence for our thesis that informal groups within the laboratory are the core of the informal STI transfer system, it is common for a laboratory to develop small work groups along either disciplinary or project lines. Such work groups are typically *ad hoc* arrangements, organized and disbanded as the work demands. This being the case, it is quite possible that the composition of such groups will *not* reflect the composition of the researchers' informal groups. One's normal technical discussion partners may thus be in some other work groups for a period of time. There is evidence (Allen and Cohen 1966) that in such a situation there is a strong tendency to continue to seek out the informal group partners for technical discussion.

This conclusion finds additional support--but also an important qualification--in a study by Taylor and Utterback (1975). They found that if the work assignment of a discipline based group is in a substantially different technical area, then the old informal ties will break down grudgingly over time and new ones will ultimately emerge. In this case, the substantially different technical area apparently makes the old technical discussion choices less able to serve the new information needs. "Although the new assignment was in the same general technical field as before, a new set of contacts and information sources had to be developed. That the extent of disruption of existing patterns was not as great as expected, may be a result of the tenacity of habitual behavior..." (Taylor and Utterback 1975, p. 85). This tenacity we would read as reflecting the importance of the informal group.

This reading is reinforced if one looks at a second type of work group, one that is organized by project rather than discipline. The members of such project groups are drawn from different areas of specialization and thus lack the common bond of similar technical backgrounds. They do, however, have the common bond provided by the new activity in which they are jointly engaged. This does not seem to provide a sufficient basis for the development of new informal groups. Taylor and

Utterback (1975) collected data on the information pool and flow patterns for four such project groups before, immediately after, and again 18 months after their formation. Not only did these project groups <u>not</u> develop significant in-group technical communication patterns even after 18 months together, but as the investigators noted there was, if anything, <u>even less</u> communication at the time of the final measurement. The researchers in these groups did not suffer from "informational malnutrition," however. They continued to seek out members of their respective former groups for technical discussion.[7] That is, in fact, what the members of such project groups should do from the perspective of the organization, since their function is to bring together the perspectives of the several groups they represent.

Thus there is evidence from a number of contexts to suggest that the patterns of STI pool and flow within formal laboratory groups are not uniform throughout. Rather, the communication networks they embrace are characterized by highly interactive clusters linked to one another by relatively far fewer and more infrequently used personal contact channels. These clusters of informal groups we take to be the heart of the informal STI system. The functioning of this system is even more complicated, however, as we shall begin to see from an examination of the dynamics of the informal group itself.

2. Within the Informal Group: The Role of Gatekeepers

Just as information does not flow uniformly within the formal laboratory groups, but is concentrated within highly interactive informal groupings, so too is this pattern to be found within informal groups. For whatever reasons--peculiarities of technical background, social-psychological idiosyncracies, etc.--it turns out that individual researchers differ significantly in the extent to which they utilize information sources beyond their own group, and, consequently, in the extent to which they are sought out for technical discussion by others of their group. Allen[8] has used the term "gatekeeper" to refer to those individuals who specialize either in the formal literature or in informal contacts with information sources beyond the organization. In addition to a much higher than average usage of one of these channels to the outside,[9] these gatekeeper individuals are also the technical discussion "stars" of their groups. That is to say, because of the information they possess these individuals are much more frequently sought out for technical discussion by their colleagues than others in the group.

In addition to his central position in the informal group's communication network, the gatekeeper also makes significant direct contributions to the laboratory's technical mission. As indicated by Figures 3 and 4, he compares quite favorably with other professionals in the laboratory on a variety of performance measures. In addition, a significant

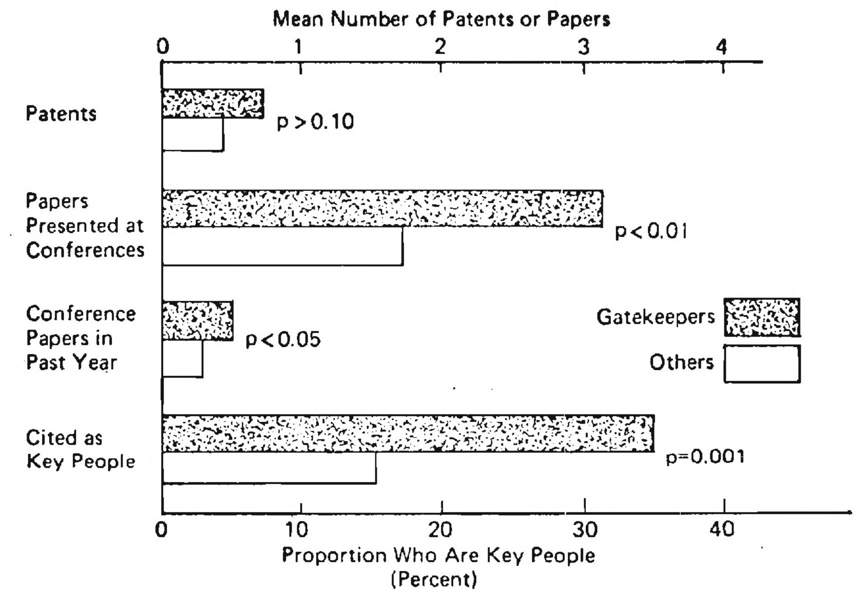


Figure 3* Performance of Technological Gatekeepers.

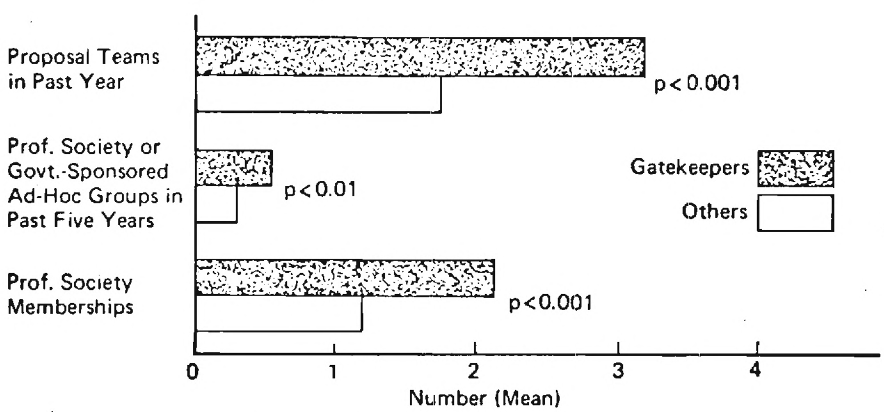


Figure 4* Organizational and Extra-Organizational Activities of Technological Gatekeepers.

*Source: Allen 1970, p 204.

number of first and even second-level supervisors have been identified as gatekeepers (Allen 1970, p. 197). Thus these individuals are indeed key people in terms of productivity as well as STI transfer.

Taylor and Utterback (1975), in their longitudinal study of work groups assigned to new and significantly different technical areas, have noted another important feature of the gatekeeper "profile." The members of these groups with changed technical assignments who had previously functioned as gatekeepers could not, of course, do so immediately after their reassignment. New sets of contacts and information sources had to be developed. Eighteen months after the new assignment was made, however, those who had functioned as gatekeepers before had reemerged to play this role again. Thus it would seem as if the ability to serve as a gatekeeper depends more on past training and/or social-psychological characteristics than on the particular circumstances of the work situation.

A final point about gatekeepers concerns their contact with one another. In connection with the typical communications patterns for the large R&D departments he studied (see Figure 2), Allen notes the following characteristics:

> . . .while there were in each functional department anywhere from one to six nontrivial strong components (primary groups), nearly all of the gatekeepers are grouped together in the same strong components. Although there is a total of twenty-one nontrivial strong components in the organization, 64 per cent of all gatekeepers can be found in eight of these,

> one for each of the five technological and three scientific specialities. In each technical specialty, there is one strongly connected subnetwork containing most of the gatekeepers. The gatekeepers, therefore, maintain close communication anomg themselves, increasing substantially their effectiveness in coupling the organization to the outside world (Allen 1970, p. 198).

Thus most of the accretions from extra-organizational sources to the informal group's pool of information--and in fact to each department's and the whole informal system's pool--seem to result from the propensity of certain individuals to specialize and excel in such transfers. They indeed seem vital to a laboratory's success in at least certain kinds of innovative efforts.

3. Why Are Informal Groups Rather Than Gatekeepers Here Taken as More Important in the Informal STI System?

Those conversant with the research literature might object at this point that our emphasis on the informal group is misplaced; i.e., that the key to understanding the informal system for STI transfer in the R&D laboratory is the technical information gatekeeper, not the informal group. After all, the group is heavily dependent on the gatekeeper for information, while the converse does not seem to be the case. It should be noted, however, that our emphasis has not been simply on informal groups, but rather on informal groups within formally constituted laboratory units engaged in a specific R&D activity. Unless informal groups are thus viewed as embedded in this formal-group nexus, it is difficult even to understand their role in the informal system, much less to claim centrality for it. By the same reasoning, to understand the role of gatekeepers, they too must be viewed as embedded--embedded in the informal groups they serve.

Thus our first response to the question of which is the more important, gatekeepers or informal groups, is to offer the caution that, while the question is not without meaning, it can be quite distorting if conceived of narrowly. Both have roles to play in the informal pool and flow of information, and both roles are important. In answer to the properly constrained comparative question, we have indicated earlier that we take the informal group to be the more important component of the informal STI system. Several considerations may be offered in support of this position.

First, to understand the transfer of STI, one must understand its storage as well[10]--unless it is assumed that there is essentially no time lag between acquisition and use. While the gatekeeper may himself store the information he brings from extra-organizational sources, this is only a part--and often a small part--the total information pool to which the informal group member has access. Much of a group's information pool exists by virtue of the training and past experience of its members; some portion of it comes from other units within the organization (and is apparently transferred by individuals other than the gatekeepers); and some portion is derived from analysis and experimentation conducted by members of the group in the normal course of their work. Thus while gatekeepers may make a contribution with regard to information from these sources, they are only a few among the many who do so. The informal group serves as the transfer mechanism for the bulk of this stored information, while the gatekeeper transfers only a portion--and a portion that in some R&D activity domains may be quite small.

Second, gatekeepers are themselves dependent on informal groups for the transfer of much of the information they bring into the organization. In the larger laboratories, gatekeepers cannot interact directly with everyone who ultimately benefits from the information they acquire. Thus the informal group--and in turn its channels to other informal groups --performs an essential transfer role even in those cases in which the gatekeeper initially provides the extra-organizational information. In fact, this role may be performed several times over (with significant time lags) for the same piece of information. As a result, in this sense it is as true to assert the dependency of gatekeepers on informal groups as the opposite.

Third, R&D activities vary considerably in how much information they require from outside the organization. Some, those toward the operations interface end of the spectrum,may require very little information from outside, in which case the external gatekeeper function would seem to be minimal. On the other hand, those involved in basic research may well be so dependent on external information sources in their work--and so well connected with both the literature and their profession's "invisible colleges" (Crane 1972)--that they may not need gatekeepers all that much either. That is to say, at the basic research end of the spectrum most researchers may be gatekeepers rather than only a few.

If this analysis is correct, then the importance of the gatekeeper function is not uniform across the range of R&D activities. It would seem to be most significant for those activities near the middle of the R&D process and drop off sharply toward each pole. There is no similar indication that the importance of informal groups is subject to such variability. Thus in seeking to account for the process of STI transfer across the whole range of R&D contexts, it would seem to be a mistake to attempt to do so in terms of the gatekeeper function. The informal group function, on the other hand, does seem to meet the necessary condition of ubiquity, and indeed, the sufficient condition of explanatory power as well.

To sum up, while we recognize the crucial role played by gatekeeper in the transfer of STI from external sources it does not seem to be sufficient for the whole range of phenomena requiring explanation. It should be noted that Allen and his colleagues at MIT, who have conducted most of the research on the gatekeeper concept to date, have not, to our knowledge, ever claimed for it the broad integratory power we are seeking. Their work has been so impressive, though, and the concept itself so intuitively appealing, that it is easy enough for others to attribute too much on it. In our best judgment, the gatekeeper function, as important as it clearly is in specific contexts, is subsidiary to, and dependent for its effect upon, the existence of informal groups.

4. Within the Informal Group: The Role of Intra-Organizational Liaisons

As has been indicated, information enters the informal group pool from sources within the parent organization as well as from outside, i.e., there are "internal" as well as "external" gates. For those activities toward the operations-interface end of the R&D activity spectrum, in particular, we argue that such internal information is typically much more important than flows from the outside. The question thus arises as to how this information from other groups and activities within the organization is transferred? Who tends these gates? Allen has shown that, as with the external gatekeeper, this function is performed by a relatively few individuals.

> Although most of the engineers and scientists reported little contact outside of their immediate departments, there existed a small subset who has a very large number of interdepartmental contacts (Allen 1970, p. 201).

Unlike their external gatekeeping counterparts, however, these interdepartmental liaisons did not stand out in terms of any of the performance characteristics measured.

> They had been with the organization no longer than the average; their performance, measured in several ways was just about average; and they did not occupy a very high level in the management hierarchy. As a matter of fact, they were very ordinary bench level engineers. Liaison among the eight departments was not accomplished at the top of the managerial hierarchy, through the chief engineers and scientists

> as one might expect. It was instead taking place as the bottom of the hierarchy, and it was being accomplished by the working level engineers and scientists (Allen 1970, p. 202).

Allen accounts for the fact that this important STI transfer function was being performed by indistinguishably rank and file personnel in a very straightforward way. Forty per cent of the liaisons identified were, at the time of the study, either participants on an interdepartmental project or on loan to another department. Thus their interaction was forced by the nature of work assignments. He also speculates that the liaison role may be a temporary one in which one's effectiveness in providing a link between departments may decrease with time after such an assignment. Kanno (1968) found that such effectiveness decayed exponentially with time in the analagous case of interdivisional transfers.

One might wonder about the adequacy of this account of the liaison function, however. While Allen's sample was in one sense quite large--some 400 researchers in eight departments of a large R&D laboratory--in another sense it was quite restricted. That is, while it included five engineering specialties and three scientific disciplines, and thus had quite a distribution along the professional orientation axis, the study seems to have represented a quite narrow slice of the R&D activity spectrum. In fact all eight departments seem to have been engaged in the same activity--applied research or development we suspect--though one cannot tell from the report.

We would hypothesize that if one studied those who perform the liaison function between each of the R&D activities, comparatively across the whole spectrum, and then between R&D and operations, that the results obtained would be quite different. In particular, we would hypothesize that as you approached the operational end of the spectrum, the actors in the liaison roles would tend to be more permanent, and the role itself more significant. The basis for this conjecture is that toward this end of the spectrum of activities, internal, operational information becomes more critical to the success of an endeavor, i.e., the tasks become increasingly constrained by that which is to follow. Thus those who can and do bridge the gap between activities, those who know, or can by informal contact determine, the constraints that will exist in the next phase of a project, perform a function that is too central to the success of the effort to be as happenstance and transitory as that portrayed above. In a nutshell, we are suggesting that the liaison who transfers in-house, operational STI in the latter stages of R&D is as central a figure as the gatekeeper who transfers STI from external sources in the middle stages.

In a later chapter we will extend this hypothesis to include consideration of STI transfers between the R&D laboratory and the operating units of the organization. For the moment, however, it suffices to say that very little is known about STI transfers between organizational units. To our knowledge, direct evidence for the existence of intra-organizational liaisons such as we have hypothesized--and for the importance of the function they perform--is not a part of the state of the art knowledge. The situation is analagous to that in which the existence of a planet has not been established by observation, but the analysis of the behavior of the whole planetary system entails its existence and impels a search for it. A program of research to determine the manner of intraorganizational STI transfer, and thus test our hypothesis concerning the existence and importance of liaisons in the later phases of R&D, would seem to merit a high priority.

5. Within the Informal Group: The Role of First-Line Supervisors

Two points about the role of supervisors in STI transfer have already been noted. Allen (1970) has shown that the proportion of gatekeepers who are also first-line supervisors is quite high. He has also found that the proportion of liaisons who were also supervisors is low--at least among those liaisons who link discipline-oriented departments within the same R&D activity. Later, we shall hypothesize a much more substantial liaison role for supervisors in the transfer of STI between R&D and operating units.

Beyond these findings of an often substantial role in transfers from the outside and, apparently, a meager role in intraorganizational transfers, one other important finding should be noted. Andrews and Farris (1967) found that the amount of freedom researchers enjoy was unrelated to innovative output if the supervisor did not consult with them prior to making decisions concerning their project. Where freedom was combined with consultation, however, a substantial increase in innovative behavior was observed. A key factor in the effectiveness of such consultation would seem to be the supervisor's own technical competence. In drawing some general conclusions from their research Andrews and Farris say:

> Greatest innovation occurred under supervisors who knew the technical details of their subordinates' work, who could critically evaluate the work, and who could influence work goals. Thus the widespread practice of including technical competence among the criteria for choosing supervisors seems to be sound. This does not mean that a supervisor should constantly "meddle" in his subordinates' activities. But he should be available, competent in the current "state of the art," actively interested in the project, and informed about it....
>
> What if this kind of structure is not possible or if a supervisor's technical competence has become obsolete? Again the data were clear: provide substantial freedom for subordinates. Freedom acted as a partial substitute for skilled supervision. But even where subordinates have freedom, the supervisor still makes some kinds of decisions. For freedom to be effective, the data showed that the supervisor must consult with his subordinates before making these decisions (Andrews and Farris 1967, p. 513).

The message here is clear; the technical competence of a supervisor, and thus his ability to participate in STI transfer can be an important factor in the quality of his group's innovative efforts--providing that he consults but does not meddle. Otherwise, the best interests of the organization seem to be served by his "staying out of the way" on the technical aspects of the group's work.

* * *

In summary, in this section we have tried to offer a "topographical map" of the laboratory's informal STI system under a specified set of conditions that impinge on the manner of its information pool and flow. It now remains to look at the complexity inherent in each of the influences identified above to see how they might alter this baseline "scenario."

C. Modifications of Baseline Scenario: Seven "Information-Need Indicators"

In this section we will offer a number of empirically supported as well as exploratory hypotheses concerning the influence of the variables listed earlier on the pool and flow of information in the laboratory. We refer to these variables as "information need indicators" because their influences--when better understood--may be sufficiently systematic and predictable to be used by R&D managers to strengthen the informal STI systems, and by those who design and/or operate formal STI systems to "fine tune" their services. Again, for ease of reference, these variables are:

1. Differences in the nature of the several activities that may be identified across the R&D spectrum.
2. Differences in the information needs and information-seeking behaviors of the several professional fields or disciplines represented in the laboratory.
3. Differences in the way in which the laboratory and/or project is structured.
4. Differences between corporate and operating division laboratories.
5. Differences between stable and rapidly changing R&D missions.

6. Differences in the rate of scientific and/or technological change within the industry of which the laboratory's parent organization is a part.

7. Differences imposed by the magnitude of the innovative effort, i.e., incremental improvement vs. discontinuous efforts.

We will examine each of these "situation variables" in turn, to suggest how the pool and flow of information in the laboratory might be otherwise than indicated in our baseline scenario if the conditions assumed there were altered.

1. The Several R&D Activities

In the baseline sketch of the informal STI system offered above, our hypothetical laboratory had separate departments for the conduct of research, development, and design. As a matter of fact, however, the research results utilized in the development of this scenario probably[11] reflected patterns characteristic of only a segment near the middle of the R&D spectrum, and were thus unrepresentative of the poles. This baseline scenario now needs to be refined in terms of differences inherent in the whole range of activities that may be embraced by the laboratory.

It is helpful in this regard to think of the range of R&D activities as a part of an even larger continuum. This larger array has the generation of new knowledge for its own sake (a pure academic activity) as one pole, and the actual production of artefacts or services as the other. The basic research function within R&D lies closest to the purely academic end of this spectrum, and what we have labeled "design" lies nearest the production or operations pole.

The information-need implications of these positions are fairly straightforward. Those in basic research, while not so free to pursue knowledge for knowledge's sake as their stereotypical counterparts in academia, are less constrained by the realities of production than those in the laboratory who perform the later functions. By the same token, the information needed in their work seems less likely to exist in-house. Thus, basic research is much more dependent on external sources of information than the other R&D functions. This is not to say, however, that they are necessarily more heavily dependent upon gatekeepers. Those involved in basic research may well be so dependent on external information sources--and so well connected with both the literature and their professions' "invisible colleges"--that they may not need gatekeepers all that much. That is to say, at the basic research end of the spectrum, it may be a widely shared function.

At the other end of the spectrum, where R&D interfaces with operations, the information-need picture seems to be quite different. Here we argue that the work is so closely tied to operational needs and constraints as to typically require little STI from the outside. In-house information is so dominant in this late R&D phase that the need for gatekeepers is probably also minimal.

Finally, between these extremes--where the need for the formal STI systems, or the lack of it, is clear-cut--we find a mixed state of affairs. This middle ground, which we have called development, is both more constrained by organizational or mission necessity than the research phase, and more sensitive to the state of the technical art than the later design function. Just where the balance between in-house and external STI is struck in the conduct of the development function--and thus just how important the formal systems are to it--depends on other characteristics of the particular situation and cannot be determined by this single indicator. Factors which may tip this balance sharply in one direction or the other are offered below.

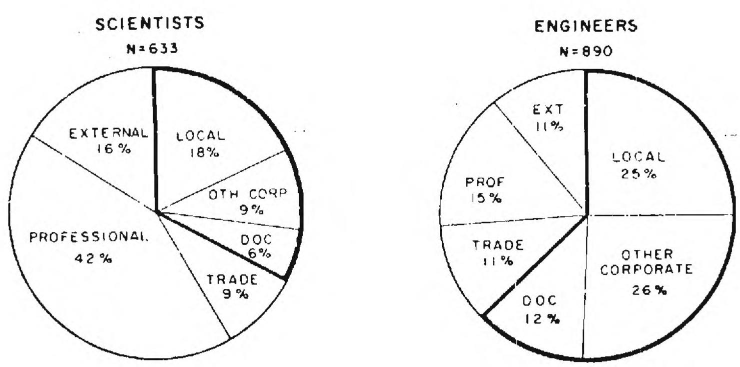
2. The Researcher's Professional Field or Discipline

The second variable in terms of which our baseline scenario of STI pool and flow must be refined concerns differences in information-seeking behavior of scientists and engineers. As Price (1966) has observed, science is an activity which is "papyrocentric." By contrast, the activity of technology is "papyrophobic." This difference is by no means fully explained by the fact that engineers usually work in mission-oriented organizations which have a proprietary interest in stemming the outgoing flow of information. More fundamental is the fact that science is an activity in which information is the end product, whose documentation and priority are established by publication (Price 1965). For technological activity, on the other hand, the innovation itself is the primary end-product, and information about it is secondary.

As a result of this fundamental difference, the engineer does not write or read professionally very much in comparison with his scientific colleague, and the formal literature, therefore, is not a frequently used STI source.[12] A graphic display of these differing propensities toward the formal literature is provided by Rosenbloom and Wolek in Figure 5, which is based on their study of thirteen laboratories in four large corporations.

Figure 5

Differences Between Scientists and Engineers in the Use of Alternative Information Sources



I. Sources within the respondents' own company (enclosed by heavy line):
  (A) *Interpersonal* communication:
    (1) *Local* source — an engineer or scientist employed in the same establishment.
    (2) *Other corporate* source — another person employed by the same corporation.
  (B) *Written* Media:
    (3) *Documents* — any written source originating in the same corporation.

II. Sources outside of the company:
  (A) *Written* Media:
    (4) *Trade* documents — suppliers' catalogues, trade magazines, unpublished technical reports, etc.
    (5) *Professional* documents — published books, journal articles, or conference papers.
  (B) *Interpersonal* communication:
    (6) *External*-interpersonal — communication with any person employed outside the firm.

Source: Rosenbloom and Wolek 1970, p 35.

This fundamental difference between scientists and engineers regarding utilization of the formal literature is probably better documented and enjoys a wider community of agreement than any other characteristic of the STI field. In addition, its implication for the patterns of information pool and flow in the laboratory is a paradigm of clarity. Other things being equal, most scientists may be expected to rely heavily on the formal literature to meet their information needs, while most engineers will use this channel rarely, if at all. The "other things being equal" caveat reflects the fact that even these strong propensities may, upon occasion, be overriden by other variables (or combinations of variables) in the total laboratory environment.

An immediate corollary of the engineer's infrequent use of the formal literature is that his primary mode of information transfer is oral. Even here, however, the form is different from that of the scientist, who also enjoys extensive informal contacts. As indicated in Figure 5, the scientist relies more heavily on informal sources outside his organization. The engineer's oral communications are more likely to be with colleagues in his own laboratory. Marquis and Allen (1967) account for this difference in the following terms:

> Scientists working at the frontier of a particular specialty know each other and associate together in what Derek Price has called invisible colleges. They keep track of one another's work through visits, seminars, and small invitational conferences, supplemented by informal exchange of written

> material long before it reaches archival publication. Technologists, on the other hand, keep abreast of their field by close association with co-workers in their own organization. They are limited in forming invisible colleges by the imposition of organizational barriers (p. 1053).

This difference between the patterns of oral communications of scientists and engineers in the R&D laboratory is strengthened by the "R&D activities" variable considered above. Scientists function primarily in the early phases of the process where the reliance on external information sources is apt to be heavier. The engineering effort, on the other hand, seems to be concentrated in the middle to late phases, which are increasingly constrained by production-oriented considerations--i.e., by information which is largely, or only, available in-house. Thus the propensities toward certain sources, inherent in the scientific and engineering disciplines is reinforced by the nature of the R&D activities in which they are typically engaged.

3. Laboratory and/or Project Structure

Our baseline analysis of the patterns of information pool and flow was restricted to laboratories structured in terms of R&D activities or functions. It is also common, however, to find a "project dominant" arrangement, i.e., multidisciplinary units that work on long-term projects or service major product areas. Such units are responsible for the whole spectrum of R&D functions, from such basic research as is necessary to the interface with operations. Given their multi-disciplinary make-up, such units seem to afford only a single basis for informal group cohesion--the project itself. As a result, the empirical evidence to date (e.g., Taylor and Utterback 1975) would lead one to believe that the informal STI system under this structure would be weaker, and thus the need for formal services greater. This is not to say that any one organizational arrangement is the best overall--many considerations other than informal system efficiency are relevant to this decision. It is to argue, however, that departures from the R&D function/professional field structure outlined earlier are probably made at some cost in the quality of the informal system, and thus that organizational structure may be an indicator of in-house STI pool and flow adequacy.

A brief example is in order. A group of researchers charged with carrying a project through all its phases may not have the highly specific knowledge or informal contacts of those who specialize in a single phase. Their research effort on a new project would thus involve a less informed and thus lengthier search of the literature. Their in-house informal groups, because of the nature of this formal structure, are more likely to be in this same "early learning" boat, and thus of less help than the informal groups under the functional structure described earlier. Because much of their time has been divided with areas other than research, these researchers would also have fewer invisible college contacts to turn to. For these reasons, their dependence on formal STI system and service professionals would be much greater. If we were to track the information needs of such a project-dominant group through the subsequent R&D phases, the picture should be similar, except that their relative informational deficiencies would show a progressive shift toward in-house STI as they approached the operations-interface end of the spectrum.

4. Corporate and Operating-Division Laboratories

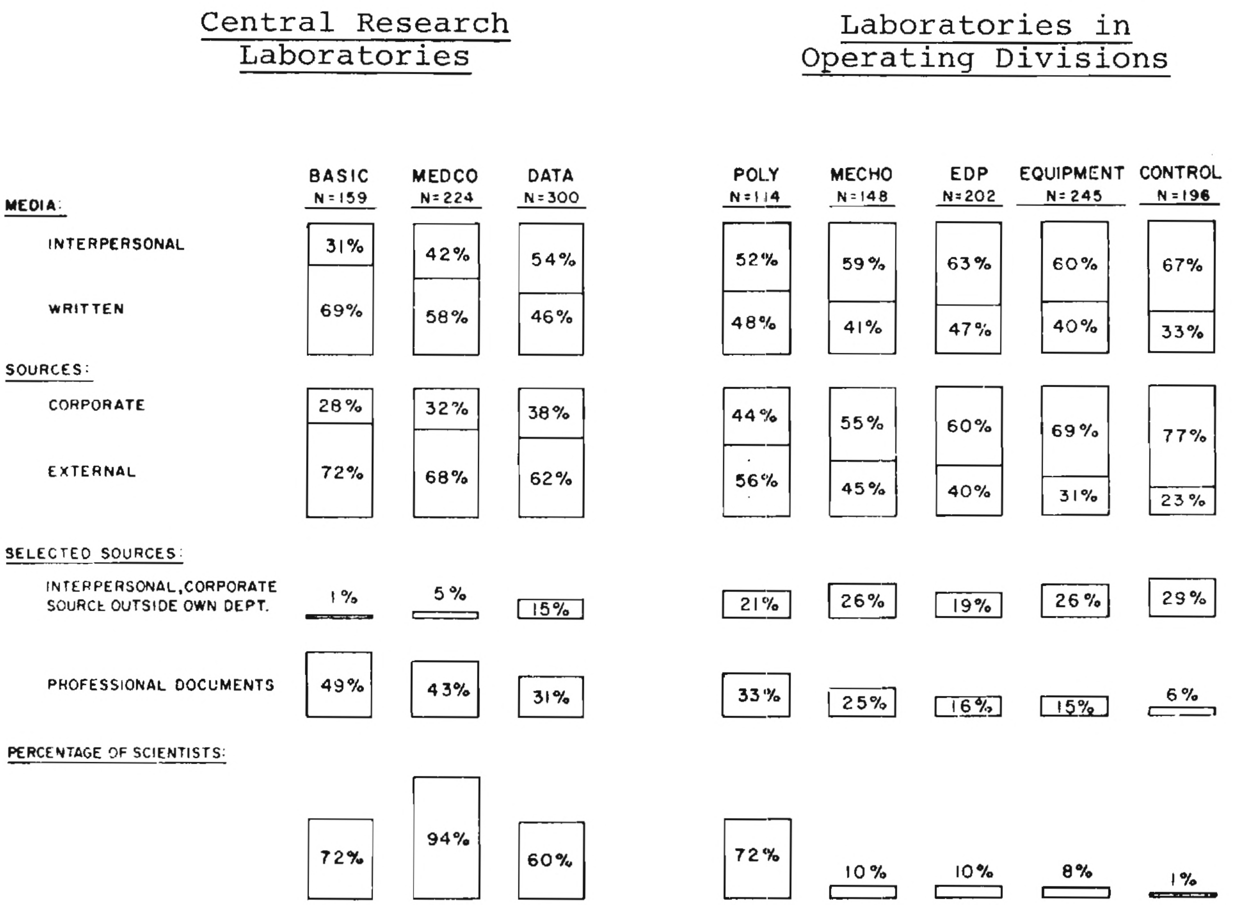
The fourth variable which would seem to perturb our baseline analysis of the laboratory's STI pool and flow patterns is its location within the parent organization. Rosenbloom and Wolek (1970) have argued that:

> The mission of central research laboratories is substantially different from that of engineering and development departments in operating divisions.... The central laboratories are units that are organizationally (and usually geographically) separate from operations; their mission is the investigation of classes of technical and scientific phenomena that bear on the missions of the corporation. In contrast, the primary goal of R&D work within operating departments is the solution of technical problems relevant to the present or future operations of that department. As this implies, we classify the mission of research laboratories as one that attributes high relevance to contributions to knowledge and lesser importance to operational considerations. The mission of the operating department falls at the opposite pole on each scale (p. 83).

This difference in the missions of central and operating-division laboratories is shown by Rosenbloom and Wolek to have a substantial impact on the patterns of information flow into and within them. As indicated in Figure 6, in the three central laboratories they studied approximately two-thirds of the information sources used were external to

Figure 6

A Comparison of STI Sources Utilized in Corporate and Operating Division Laboratories



Adapted from Rosenbloom and Wolek (1970, p. 43).

the corporation. For the typical operating-division laboratory on the other hand, three-fifths to three-quarters of the sources utilized were within the firm.

Two other points emerge from these data that have broader implications for the integrative thrust and emphases of this study. The first relates to the independnece of the variables we are considering, i.e., whether or not some might be subsumable under, or explained in terms of, others. It might be argued, for instance, that the differences in patterns of information flow that we would take as arising from the corporate/operating-division laboratory distinction might be explained in terms of the second variable discussed above (the researcher's professional field or discipline), or the first (the nature of the several R&D activities). When Rosenbloom and Wolek controlled for the researcher's professional field in two cases (chemists and electrical engineers), the differences between those in the corporate and operating division labs is still quite significant for both (Figures 7 and 8). Those in the operating division contexts reported a substantially greater use of in-house sources than their professional counterparts in the corporate laboratories. Thus at least these three of the seven variables we are considering seem to exert demonstrably independent influence.

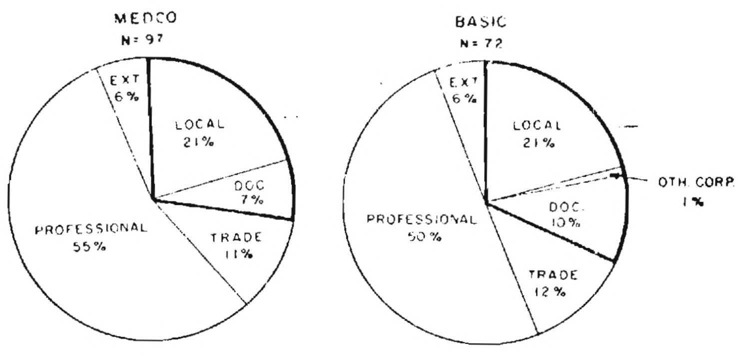
The second broader implication of the Rosenbloom and Wolek data for our study concerns our emphasis on the

Figure 7

Information Sources by Laboratory Setting
(Chemists Only)

Corporate Laboratories

Operating Division
Laboratory



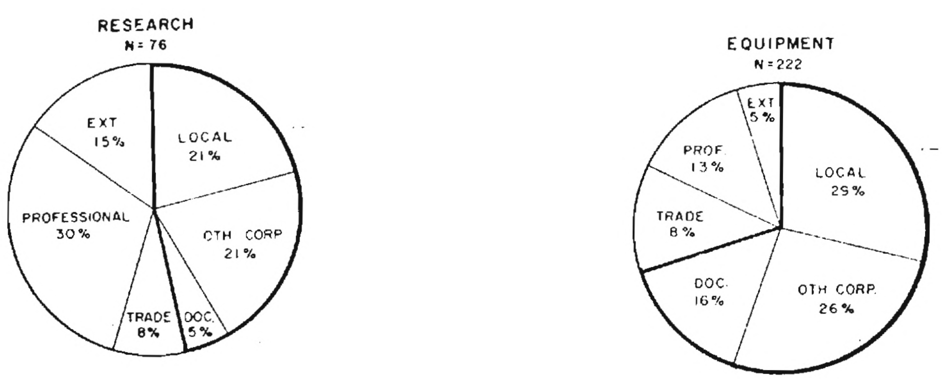
Rosenbloom and Wolek (1970), p. 44.

Figure 8

Information Sources by Laboratory Setting
(Electrical Engineers in DATA Corporation)

Corporate Laboratory

Operating Division
Laboratory



Rosenbloom and Wolek (1970), p. 45.

interface of the laboratory with operations. As is shown in Figure 6 above, the use of interpersonal sources outside the researcher's own department is small, even negligible, in the case of the corporate laboratory. For the operating division laboratories, on the other hand, such sources account for a fifth to a quarter of the total flow. This again suggests the systemic hypothesis that, as you move from the research end of the R&D spectrum toward the interface with operations, the R&D effort becomes progressively more sensitive to operational constraints and opportunities, and thus that in-house STI grows in its importance. It should again be noted, however, that the mechanisms of such flow remain poorly understood.

5. The Stability of the R&D Mission

Unlike the previous variable whose influence had been demonstrated empirically, we know of no data to support the contention here that the patterns of STI pool and flow may be substantially influenced by how stable or frequently changing the laboratory's mission is. However, we find the analytic argument sufficiently persuasive to warrant its further consideration and testing.

The contrast we have in mind here is a simple one, at least in the extreme cases. On the one hand, consider the organization whose laboratory, production facilities, and marketing force are wholly committed to a single product line (or close "family" of products). On the other, consider the organization with a laboratory, but no production facilities, i.e., one whose product is R&D itself. It is reasonable to expect that the latter, the contract organization, is going to have the greater, continuing need for external STI sources than the former. No matter how technically able its laboratory personnel, the frequent and substantial shifts in R&D focus with which they must deal would seem to assure that the in-house information pool will often be inadequate.

The contrast between the stable and the frequently changing R&D missions is often not sharp as we have drawn it here. The single product-line organization and the R&D contract shop do, however, constitute common and unambiguous opposite poles from which to begin an analysis of the influence of this variable or information need indicator. As with a number of the indicators we are suggesting, as you move away from the clear influence of the polar cases, there is a corresponding increase in the need for an analysis which compares and contrasts the influence of this factor with the influence of others.

In the following chapter, we will stress the practical potential of this particular variable as an incentive to conduct the empirical study necessary to move it beyond its present conjectural status. Should this, indeed, prove to be a significant indicator of the relative adequacy or inadequacy of a laboratory's in-house pool, it could serve as an important "fine-tuning" device for the STI industry. That is, a number of formal STI systems and services could use it as an additional criterion for segmenting their market and anticipating surges in laboratory STI needs.

6. The Rate of Scientific and/or Technical Change Within the Industry

This indicator of the need for external information, like the previous one, has to do with the relative adequacy of the in-house information pool. Here, however, we are concerned with the pace at which the state of the art knowledge is changing rather than the frequency of organizationally-induced shifts in the laboratory mission.

The basic hypothesis here is as straightforward as in the previous case: the higher the rate of scientific and/or technological change in the industry of which the laboratory's parent organization is a part, the greater the need for infusions of STI from external sources. It has been argued, for instance, that the significance of the gatekeeper function may depend, in part, on this variable.

> Most studies of technical communication have been concentrated in aerospace and related industries where the state of the art has been changing rapidly and the demand for current technical information is great. A more placid technical environment could well negate the need for a mediator in the flow of technical communications. Technical communication needs of the container industry, for example, might be such as to eliminate the need for the gatekeeper. (Taylor and Utterback 1975, p. 81; see also Lawrence and Lorsch 1967, on this point.)

Our analyses lead us to accept this as a sound hypothesis which merits empirical investigation. In this connection, we would also repeat a contention offered earlier, that the gatekeeper function may also vary significantly among the several R&D activities. It may be more important in the development phase, than in basic or applied research (where the dependence on external resources may be so great as to make it a widely shared function), or design (where there is the least reliance on external sources).

The rate of change in an industry would seem to have a direct bearing on the relative adequacy of a laboratory's in-house STI pool, and thus upon the criticality of flows from external sources. It should be noted, however, that even if the rate of change in an industry is very high--as is the case with electronics or ethical drugs--this is still but one variable among many. It should not be expected to override, or even alter significantly, the influence of all the variables we have considered, nor should it be expected to mitigate their several influences equally. For instance, while a high rate of scientific and/or technical change would seem to imply a larger laboratory role for basic and applied research, this does not necessarily mean that the pattern of information flow in these areas would be any different. The pattern would seem to reflect the nature of the activities rather than the proportion of laboratory effort devoted to them.

7. Incremental vs. Discontinuous R&D Efforts

The final variable or information need indicator we would mention lies, not in conditions within the laboratory or its larger environment, but in the nature of the innovative effort itself. The literature distinguishes between: (1) R&D projects which are concerned with incremental improvements to existing products or porcesses or with minor extensions to scientific or technological knowledge, and (2) projects which are concerned with new products or processes or with scientific or technological breakthroughs (e.g., Rubenstein 1964; Hollander 1965; Schwartz 1973). The terms "incremental" as applied to the former and "discontinuous" to the latter are relative terms, of course; they emphasize the degree of their departure from the organization's current products or processes or from the existing level of knowledge in the organization.

The bulk of the information required for the incremental effort would seem, typically, to exist as a part of the in-house pool, and little would be required of external sources. The organization that is now producing "widgets" should already possess most of the information required to develop a "widget with a twist." The matter is quite otherwise for innovative efforts that constitute a radical departure--a discontinuity--from that which the organization is doing and thus knows well. If it has never produced a widget or anything akin to one, substantial infusions of information from the outside will likely be required--and in an area where the organization's gatekeepers may not be "on top of things."

Inherent in these STI pool and flow implications of the incremental/discontinuous distinction are two others which relate to two of the variables discussed previously. First, the discontinuous innovative effort would seem to involve all of the activities or functions across the R&D spectrum. All would have to "gear up" informationally for the effort. Both the laboratory's interface with STI sources external to the firm and its interface with operations would feel the pressure of unfamiliar information demands. In Schwartz's (1973) terms a discontinuous effort is "disruptive to the culture of the firm." An incremental effort, on the other hand, would seem to typically involve only the latter phases(s) of R&D (in the terminology we have employed, perhaps only design, or development and design). In additionally, only the interface with operations would seem to be significant and that through already established informal channels.

The second point concerns the possible relationship between the magnitude of the innovative effort and the way in which the laboratory is organized. In organizational terms, incremental projects tend to be relatively small, single-phase projects which are carried on within a single organizational unit, involve one or only a few professional fields, require few R&D personnel to be assigned, and one of relatively short duration (up to a year). They are likely to be funded by R&D management out of their annual budgets and to require only the budgetary approval of top corporate management. In fact, except at an overview budget summary level, corporate management may be generally unaware of the incremental projects being conducted within the organization. By contrast, discontinuous efforts tend to be large, multi-year, multi-phase projects which cut across organizational boundaries, may involve a number of scientific and engineering fields, and require a substantial R&D effort to carry the project from initial concept through to end item. The decision to undertake such projects often emanates from the highest level of corporate management. Because of the large requirements for organizational resources, top corporate management support must be maintained throughout the life of the project.[13]

It has been argued (Kelly et al. 1975, Vol. I) that, in organizational terms, a laboratory that is structured in terms of the several R&D activities or phases, as was the case in our baseline analysis (i.e., a phase dominant structure), is better suited for the conduct of incremental efforts. Discontinuous projects, on the other hand, seem to call for a project dominant structure, i.e., a laboratory that is organized in terms of multi-disciplinary units that work on long-term projects or service major project areas.

When this mesh of laboratory structures and the magnitude of the R&D project is considered in terms of STI pool and flow, a dilemma emerges. In-house pools are less adequate for discontinuous than incremental projects--thus the reliance on external sources is greater for the former. As we have argued earlier, however, there is reasons to believe that informal groups are more cohesive and stronger information flow mechanisms under the activity or phase dominant structure than they are under the project dominant. Thus, the laboratory structure that seems organizationally the better suited for the conduct of discontinuous projects seems to weaken the information flow capabilities of the informal system. And yet it is for just these discontinuous projects that vigorous STI flow is most essential, since, by their very nature, they render the in-house STI pools less adequate.

The reader should be cautioned that there is substantial unevenness in the present support for the several paths of analysis that converge to produce this dilemma. Some have substantial and direct empirical support, others are based on indirect empirical data, and still others rest on conceptual analysis and informed speculation. Therefore a critical caution is in order. At the same time, we are convinced that there is sufficient support for the convergence we have portrayed--and sufficiently onerous implications for the conduct of discontinuous R&D efforts if our analysis is correct--to give high priority to this research focus.

* * *

This completes our analysis of a range of variables that have been shown or hypothesized as impinging on the informal STI system and the pool and flow of information within it. It now remains to draw the implications of this conceptually integrated treatment for the laboratory's interface with external information sources, on the one hand, and the operations on the other. These tasks are undertaken in the two chapters that follow.

Chapter II

Footnotes

1. There were 1900 engineers and scientists in 13 laboratories of four large corporations, and 1200 members of the Institute of Electrical and Electronics Engineers (IEEE).

2. We have no way of knowing from the data whether the subjects understood "immediate circle of colleagues" to mean the work group to which he was assigned at the time, or his informal mutual-choice group. Whichever is the case, the exclusion can only serve to strengthen our point, since the percentage of instances in which the information was volunteered could only be increased by inclusion of the work and/or mutual choice group(s).

3. See Allen and Cohen 1966, 1969; Allen 1970, 1972; Taylor and Utterback 1975.

4. For discussion of the role of informal groups in the satisfaction of such needs, see Bernard 1938; Davis 1969; Cartwright and Zander 1969.

5. R&D process phases (or functions) are defined and designated variously by both scholars and R&D organizations. We want to assume a functional or "phase-dominant" organizational form here, but the particular "benchmarks" we have chosen (and our labels for them) do not affect the point at issue, which is that <u>whatever the functional distinctions in terms of which R&D efforts are organized, formal groups are thereby created and the members of each group thereby share a common orientation, common goals and common problems</u>.

6. Allen defines the term "strong component" as follows: "A strongly connected component, or strong component in a network is one in which all nodes are mutually reachable. In a communication network, a potential exists for the transmission of information between any two members of a strong component (Flament 1963; Harary, et al. 19). In other words, there is at least one path in each direction, between every pair of members of a strong component. Information held by one member can potentially be transmitted by any other member either directly or through intermediaries" (Allen 1970, p. 198).

7. The objectives of the Taylor Utterback study were such that it cannot be determined with certainty from the data whether the group contacts that were so doggedly maintained were with the researchers' primary groups or with others of their respective activity/professional field groups. We feel confident in assuming that it was the former on the basis of the Allen and Cohen (1966) and Allen (1970) findings mentioned above. If, as demonstrated by these studies, the bulk of a researcher's technical discussions were with his primary group--rather than others in the larger laboratory group of which it is a part--when not separated from them by organizational structure, there is little reason to believe that he will abandon them in favor of others in the larger unit when he becomes so separated.

8. See Allen 1964; 1966a; 1969a; 1969; 1970.

9. Allen defines "higher than average" here as meaning, " . . . either one standard deviation above the mean in readership of scientific or professional engineering journals or above the median in number of outside personal contacts." (Allen 1970, p. 192)

10. For a discussion of this point see Appendix A.

11. The qualifier "probably" here reflects the fact in many studies the R&D departments are not identified by function. That is, it is common, while focusing on other variables, to take the department as a study site, rather than as a possible variable in the process under investigation.

12. Auerbach 1965; Allen 1966; North American Aviation 1966; Scott 1962; Herner 1954; Halbert and Ackoff 1959; Organization for Economic Cooperation and Development 1960; Allen and Cohen 1969; Allen 1970.

13. For discussions of these contrasts between incremental and discontinuous projects, see Brandenberg 1966; Hollander 1965; Rubenstein 1964; Schwartz 1973.

Chapter III

Interface: The Laboratory's Informal STI System and the Formal STI Systems

In the preceeding Chapter we offered an integrated, holistic treatment of the R&D laboratory's informal STI system, and the patterns of STI pool and flow that seem to characterize this system under a variety of conditions. In the present Chapter we will draw some of the implications of that integration for the interface of the laboratory's informal system with the formal STI systems.

Our treatment of this formal/informal systems interface will be from the perspective of those who can improve this relationship. Thus our remarks will be directed to those information specialists who design and/or operate formal STI systems. The reason for this is quite simple. The informal systems, while enduring and extremely effective, are by their very nature the unplanned and mute creatures of past and present need, who constrain the future but cannot design for it. Thus the impetus to better integrate them with the formal systems must come from the latter.

Before effective interaction with an ongoing system can take place, however, it is essential that at least the broad outlines of its nature be properly understood. The broader picture of the R&D laboratory's informal system often does not seem to be well understood by many, who either study its more limited aspects or attempt to meet its STI needs.

Some of these misperceptions of the whole system may be caricatured by an analogy with one of Art Hoppe's recent syndicated columns. This was a zany piece about a spacecraft from Mars--the Vnnnggg I Lander--which touched down on our planet last May. Unfortunately for its mission, this Martian spacecraft--which was only 1/4" long--made its successful landing atop a medium-sized pepperoni pizza.

Their initial report back to mission-control on Mars went like this:

> Mission control, this is Vnnnggg I. As you can see from our television scanners, the surface of this planet is predominantely red, with patches of a cheesey looking white. Various inanimate lumps of brown and black are strewn across the landscape.
>
> Because of the amazing resemblance we have dubbed that black round object in the foreground "The Huge Olive," and that brown shiney one in the distance "The Giant Anchovy." What strange tricks Old Mother Nature plays.
>
> Our thermometer is recording a surface temperature of a blistering 156 <u>shnarbs</u> while out seismograph informs us that only seven <u>klongs</u> beneath us is a rubbery, but incredibly tough surface.
>
> It would appear that this planet is unique in the universe, being the only one known to have its seething interior <u>on</u> <u>top</u> of a thin crust.
>
> We hoped to investigate the eight "canals" we observed on landing that seemed to radiate symmetrically from the center of the planet. But our soil scoop became mired in that white stringy, gooey substance on its initial effort and has been immobolized ever since.
>
> We hope to free it...Wait! Mission control can you see that huge row of white cliffs descending from above? And look, another row is emerging through the surface just ahead of us. Why, you would almost think they were someone's giant <u>TEETH</u>! <u>Teeeeth</u>!!

> The transmission ends there. From it, Martian scientists believe that conditions on the planet are far too inhospitable to sustain intelligent life. (Adapted from Hoppe 1976).

We call your attention to these observations of Earth from aboard the Vnnnggg I because it caricatures skewed perceptions of the market for STI services that are often found in the scholarly literature. Over the years there have been thousands of myopically empirical "user studies"--i.e., reports from academics and others, who have "soft-landed" in some R&D laboratory or other. Not seeming to realize that their landing site and its environment may be as atypical as a pepperoni pizza is of the earth's surface, they have solemnly reported their findings. "Scientists like their information thick and chewy, while engineers like theirs thin and crispy." or "Scientists come regularly to the library or computer console to feast upon their informational pizzas, while engineers--if they eat at all--rely on takeout orders delivered by a few colleagues called gatekeepers." etc.

Such reports have typically been rigorous and accurate enough given their perspective, but like those from the Vnnnggg I--or even the Viking I--they have raised more questions than they have answered. In aggregate, they have not been of as much help as one might hope in specifying the nature of the R&D laboratory market that the information centers and services must deal with.

But lest only the academics be offended, let us hasten to point out that the information professionals have been stumbling over their share of olives and anchovies too. Even the largely noncumulative and myopically empirical work of the academics has been sufficient to cure some of the bad assumptions about the laboratory market that seem to prevail. For instance, many information professionals seem determined to go on talking about the non-users as if they were just like the heavy users in every respect--except perhaps slothfulness. Acting on this assumption of an undifferentiated or mass market, these designers and operators just keep on trying to make their services easier and faster, as if this alone will sooner or later win over those non-user yoyos.

By comparison, those who sell beer are faced with very much the same market split or segmentation. The so-called "heavy half" of the beer drinkers' market--which is in fact only 17% of the total--consumes 88% of all the beer sold (White 1966). The beer industry has more fully accepted this obvious segmentation of their market, however, and has responded in a variety of ways that go far beyond making it easier and faster to buy this product.

Now that we have been critical of both the academics and the information professionals, let us hasten to add that this was not done from sheer contrariness, but to emphasize the manner in which each group sorely needs the other. This interdependence of the two communities is the underlying theme of this section. This theme will be developed in terms of how the formal STI systems might better meet the information needs of the R&D laboratory. First, we will summarize briefly the concept of market segmentation, then we will draw upon the integrated picture of the informal system developed in Chapter II to offer several broad-gauged conclusions about a better approach to the formal/informal systems interface, and to explore further the "information-need indicators" that were described there.

A. Market Segmentation

The concept of market segmentation was first articulated in a watershed article by Wendell Smith in 1956, and since its publication has come to be one of the most influential concepts in marketing. In the words of one author, it has, "permeated the thinking of managers and researchers alike as much, if not more, than any other single marketing concept since the turn of the century" (Frank 1968).

Briefly, market segmentation refers to a strategy that assumes:

1. That markets are not homogeneous, i.e., the users of a product or service are not all alike;
2. That some differences among users are related to differences in market demand, and
3. That segments or groups of users can be isolated within the overall market.

Thus a heterogeneous market is viewed as a number of smaller, isolatable, homogeneous markets, each of whose needs are different and predictable. It is important to note that the market strategist does not segment a market, but discovers that it is in fact segmented, and responds to the opportunities that this fact creates. In Smith's terms, "A segment may be regarded as a force in the market that will not be denied" (Smith 1956, p. 33).

The key to segmentation as a marketing strategy lies, of course, in being able to identify homogeneous and serviceable segments. Academic researchers have been of some help in this regard, though what they have found has not always been presented in the clearest and most usable form. Our analysis and conceptual integration of the research literature has led us to identify a number of segments of the laboratory market for information that we take as providing substantial opportunities for the formal STI systems. We will discuss these segments in a moment. First, however, we need to set forth some of the broad-gauged conclusions we have reached as to how the formal/informal systems interface should be approached.

B. Some Conclusions as to the Proper Approach to the Formal/Informal Systems Interface

In Chapter I we anticipated four conclusions we have drawn as to the proper approach to the interface of the formal STI systems with the laboratory's informal system. Let us now re-examine each of these.

a. It is distorting and unhelpful to think in terms of "users" and "non-users" of the formal STI systems and services.

In light of the role of informal laboratory groups in STI pool and flow, and the range of variables that may skew the information needs of such groups, it seems inappropriate to take individuals as the market segment to be served by the formal systems. We would argue that even the gatekeeper function is inadequate as a justification for segmentation of the laboratory market to the individual level, since gatekeepers serve informal groups and thus reflect their STI needs.

In addition to these systemic considerations, there is little reason to believe that non-user individuals can be "converted" into users by virtue of some further incremental--or even breakthrough--advances in formal systems hardware, software, or mode of operation. Simply stated, the reasons for non-use are, by and large, independent of any "correctable weaknesses" in the formal STI systems. Rather, these reasons cluster around the fact that most information needs in the R&D laboratory either can't be met at all by the formal systems (e.g., operational information), or can be met better, quicker, and with significant social-psychological payoff by the informal system (i.e., the in-house pool and/or gatekeeper). This state of affairs is distorted by the designation "non-user" with its implication that they too would be users if only the formal system were somehow better.

Thus, the user/non-user distinction is a distorting dichcotomy that yields little understanding of the formal/informal systems interface. In addition, there is the obvious risk that such simplistic "nose-counts" may be used to evaluate the contribution of the formal systems to the R&D effort. Such a specious yardstick is a gross oversimplification of the complexity of the formal/informal systems interface, and a serious misrepresentation of the value of the formal STI systems to the R&D process.

b. It is accurate and helpful to think in terms of service to informal groups--groups composed of both direct and indirect users.

The thrust of Chapter II is that the R&D laboratory market for formal STI services is segmented along informal group lines. Depending on a variety of specifiable conditions, the extent of the dependence of these market segments on the formal systems ranges from very heavy to essentially non-existent. The frequency of such dependence (for those groups exhibiting more than negligible dependence) is a function of the same specifiable conditions, and ranges from essentially continuous to very infrequent.

Just as these informal group segments of the laboratory market differ significantly in the extent and frequency of their dependence on the formal systems, so too do the individuals within many of them. If we exclude groups of scientists engaged in basic research (who are heavy, continuous users) and engineers near the R&D/operations interface (who are essentially non-users), the remaining informal groups may be characterized as follows: there are a few heavy, direct users (gatekeepers) who meet most of the external information needs of their light-to-non-user colleagues. To do justice to this state of affairs and to the significance of the formal STI systems for R&D, it is much more accurate to conceive of those served by the gatekeepers as indirect users rather than non-users.

This shift of attention from individuals to informal groups permits a different and more helpful line of questioning about the segmentation of the laboratory market. The highly interactive informal group replaces the (speciously) isolated individual as the level of market disaggregation to be studied and designed for. Then, since the informal groups within the laboratory are not all equally dependent on external STI flows, attention comes to be focused on those group characteristics and conditions that influence the timing and extent of such dependence. Progress on this point--i.e., the identification of serviceable segments--should result in improved design and operation of formal STI systems.

c. There are features of the R&D laboratory and its environment that can serve as "indicators" of information needs that the formal STI systems can meet.

In Chapter II we examined the influence of seven variables on the pool and flow of information in the laboratory. Here we would suggest that these variables--or "information need indicators"--may be used by those who design and/or operate formal STI systems to "fine tune" their services. In other words, these information need indicators may be used to identify serviceable segments of the laboratory market. Let us comment briefly on the market implications of each of these variables.

1. Differences in the nature of the several activities that may be identified across the R&D spectrum.

Those involved in activities toward the basic research end of the spectrum are the "heavy half" of the laboratory market for formal STI services. They may be expected to have a continuing need for information from external sources, and thus to be regular users of the formal literature. On the other hand, those at the opposite end of the spectrum, where R&D interfaces with operations, find their work so closely tied to operational needs and constraints as to require little STI from the outside. They are typically an unrewarding market segment for the formal systems to focus on. Between these extremes--where the need for the formal systems, or the lack of it, is clear-cut--we find a mixed state of affairs. Here the role of the formal systems depends on other characteristics of the particular situation, and cannot be determined by this single indicator.

2. Differences in the information needs and information-seeking behaviors of the several professional fields or disciplines represented in the laboratory.

Other things being equal, scientists may be expected to rely heavily on the formal literature to meet their information needs, while most engineers will use this channel much more rarely, if at all.

3. Differences in the way the laboratory and/or project is structured.

We have argued that laboratories organized by R&D function and by discipline within these functional units create conditions more favorable to efficient informal STI pool and flow mechanisms than the project-dominant arrangement. As a result, other things being equal, the former structural arrangement should be informationally more adequate (and better able to utilize gatekeepers effectively) than the latter. Thus, we would hypothesize that the existence of a project-dominant structure provides an indication that the laboratory's need for the formal systems will be greater. It should be noted, however, that this indicator may be overriden by others in the particular context, and thus should not be utilized in isolation.

4. Differences between corporate and operating division laboratories.

In Chapter II we examined evidence to the effect that central laboratories exhibit a much greater reliance on external information than do operating division laboratories. This difference reflects basic differences in the missions of such laboratories, and thus would seem to constitute an important, continuing criterion for the segmentation of the R&D laboratory market.

5. Differences between stable and rapidly changing R&D missions.

In the final analysis, the need for formal STI systems depends on the inadequacy of the in-house information pool. We have argued that, other things being equal, the laboratory with the more stable R&D mission will have a more adequate in-house pool--and thus need the formal systems less--than one whose mission is subject to frequent and substantial shifts of focus. Thus the latter--e.g., a contract research organization--constitutes a better market for formal STI systems than the former.

6. Differences in the rate of scientific and technological change within the industry of which the laboratory's parent organization is a part.

Here we hypothesize that the higher the rate of scientific and/or technological change in the industry of which the laboratory's parent organization is a part, the greater its reliance on infusions of STI from external sources.

7. Differences imposed by the magnitude of the innovative effort, i.e., incremental improvement vs. discontinuous or breakthrough efforts.

At one extreme, an innovative effort may represent a minor extension of what the organization is already producing--a small increment or next step. In such cases most of the information required would typically exist as a part of the in-house pool Thus little would be required of the formal STI systems. On the other extreme, the innovative effort may represent a radical departure--a discontinuity if you will--from that which the organization has been doing, and thus knows well. In this case massive infusions of information will be required and the role of the formal systems will be substantial, perhaps crucial.

The final conclusion we have drawn concerning the interface of the formal and informal STI systems addresses the quite practical matter of its improvement in light of the above considerations.

d. <u>At least in the short-run fine-tuning the formal STI systems and services in terms of the "information need indicators" may require the assistance of "interpreters," i.e., those knowledgeable about the R&D process.</u>

The question here is how do we get from the present condition, in which the formal and informal STI systems are largely <u>independent</u> mechanisms interacting in unplanned ways, to one in which they function as <u>interdependent</u> subsystems of a larger whole? The answer must lie in accomodating, or "fine-tuning," the formal systems to mesh with the conditions that characterize their informal counterparts. In marketing terms, this means identifying serviceable segments of the laboratory market and exploiting the opportunities that they afford. The "information need indicators" described above are intended as, at least, first-approximation criteria for such segmentation.

The evidence for these indicators is uneven, however. In addition, how they impinge <u>in concert</u>, and with what effect on the laboratory's information needs, are matters for which there is currently little data. Until the research community can begin to close these gaps in our knowledge, we would recommend that the designers and operators of the formal systems avail themselves of the next best thing, i.e., interpreters.

The point here is that there are many people around the country who are quite knowledgeable about the R&D process, the range of research skills involved in it, the factors that may constrain its several phases, etc. Even if such individuals have not focused explicitly on the informational implications of the influences we have here called "indicators," they are nevertheless familiar with the dimensions of the R&D process and its context to which they refer. Thus, confronted with the sorts of questions that we have raised, they should be able to "speak for" the informal system. That is, they should be able to provide insight and guidance about the relative adequacy or inadequacy of the in-house STI pool under particular sets of conditions.

We recognize that the use of such "interpreters" may not always yield the precision of market segmentation that one could ideally desire, or even that a more complete knowledge base could produce. But that is beside the point, at least in the short run. The short-run question is, would such interactive assistance in identifying servicable market segments, and thus in the design and operation of formal STI systems, be superior to an approach which treats the laboratory as a homogeneous market--or worse yet segments it into users and non-users? We think that the answer is, yes.

Chapter IV

Interface: The Laboratory's Informal STI System and Operations

In the previous chapter we examined the interface of the laboratory's informal STI system with STI sources beyond the organization. In this chapter we will be looking at its interface with R&D's "clients," typically the parent organization's operating units. This interface is quite different from that with external STI sources, and the pool and flow of information reflects these differences.

In Chapter I we reported the results of a survey by Quinn and Mueller (1963) which indicated that the effective transfer of R&D results to operations was widely viewed as the most serious problem confronting research management. We also cited economic analyses (Mansfield et al. 1971) that indicate the magnitude of the investment that depends, in large measure, on the effectiveness of this transfer. Yet, in spite of the broad agreement about the difficulty of this interface and the strong economic incentive to render it more effective, there is surprisingly little research aimed at a better understanding of the variables upon which it depends. Grayson (1968, p. ii) and Young (1973, p. 31) both report a relative dearth of careful and systematic study. In Young's words, "The bulk of the writing has taken one of two forms: a general prescriptive solution or a specific solution" (p. 31). There is an almost complete lack of definitive, cumulative research; instead, there exist only a few isolated studies at each of several levels of aggregation.[1]

The flow of STI between the laboratory and operations is only one of the variables on which this interface depends, of course. Nonetheless, we take it to be a major variable, and poorly understood. In fact, of all the areas of STI pool and flow that we have examined there is none for which simultaneously the need to understand is higher and the state of knowledge lower. Organizational concerns about proprietary information may be a barrier to research here, but this problem notwithstanding, definitive, cumulative research is a pressing need.

Our assessment of this STI interface problem between R&D and operations is, unfortunately, not a very hopeful one. Given our argument for the centrality of the researchers' informal groups in information pool and flow, this assessment is not surprising. As we will argue in a moment, the difficulty is that precisely those features of the informal STI system that make it so efficient within the R&D laboratory would seem to work against effective interface with operations. This problem, inherent in the laboratory's informal system, is exacerbated by the difficulty of assigning responsibility for an innovation's success or failure once it has been transferred from R&D. Let us examine each of these problems in turn.

A. Informal Groups Exclude As Well As Include

Gatekeepers and intra-organizational liaisons both specialize in the transfer of STI from outside the informal groups and larger informal system they serve--the former from sources outside the parent organization, the latter from corporate sources. Which type of information is the more important to a laboratory effort depends on a number of the variables considered above. The gatekeeper's information would seem the more important: for the development phase, than for the research or design; for the engineer than the scientist; for the corporate than the operating division laboratory; for the more rapidly changing than the more stable R&D mission; for industries with a higher rate of scientific and technical change than slower changing areas; and for discontinuous R&D projects than incremental improvements. The intra-organizational liaison's information, on the other hand, should be more important for the design function than for research or development, and for the opposite of the gatekeeper's in each of the above contrasts. Considering an organization's innovative thrust as a whole, these two information transfer functions seem equally essential to success.

According to the data examined earlier, however, those who play these two roles have quite different "profiles," and vary significantly in the extent to which they are "appreciated" by their colleagues. The gatekeeper is a high producer who is viewed by others as a "key person." He is the technical discussion "star" of his group, as colleagues seek the information he possesses. The liaison, on the other hand, seems to be a "very ordinary" bench level engineer, "just about average" on every performance measure, and is not identified as one frequently sought out by his colleagues for technical discussion. How are we to account for these rather striking differences in light of the apparent equity in the importance of their roles?

First, it should be noted that the gatekeeper is a member of two informal groups; one defined by the intersection of R&D activity, professional identity, and mutual social choice <u>within</u> the organization, and the other by professional identity (and perhaps mutual social choice) <u>outside</u> the organization. It is precisely because of this dual membership--plus his own personal and professional characteristics--that he can perform his STI transfer function. The intraorganizational liaison, on the other hand, would seem to be a member of only one in-house informal group. He maintains contact with, but not membership in, another group, i.e., he is a member of an informal group in R&D and has an outsider's contact with some operating group, or vice versa. Given our thesis concerning the nature of the "cement" that binds STI transfer groups together, this could not really be otherwise. R&D and operating groups are quite different in terms of both the activities in which they are engaged and the professional identities their respective members share. Thus it is unrealistic to expect the same individual to participate fully in both.

As a result of his dual membership, the gatekeeper can bring to each group STI from the other that may prove "facilitating," i.e., information that may prove helpful in the resolution of the problems they are working on. It is for this reason he is so frequently sought out for technical discussion. The liaison who is a member of an informal R&D group and at the same time maintains contact with an operating group, can also bring information to his group--oftentimes information that is vital to the success of the overall innovative effort. It may well be, however, that the information he brings may not be viewed by his colleagues as nearly so "attractive" or potentially useful to their work as that of the gatekeeper. And, in fact, it may not be as "facilitating" in the narrower, technical-solution sense of the term. The STI transferred by the liaison may be more likely to be viewed, not as contributing to a technical solution, but as constraining the problem in ways that make its solution more difficult.

It may well be objected at this point that any professional "worth his salt" will view information that constrains on a par with information that facilitates. One can accept this point, however, and still argue for the cogency of the distinction. Reasonable people--especially those with significantly different professional identities who are engaged in quite different activities--may simply disagree about the desirability or unavoidability of a particular constraint. Add to this the communications handicaps inherent in different coding schema and infrequent contact through under-rewarded intermediaries, and the possibilities for disagreement and misunderstood intentions are increased.

Thus we argue that one of the major reasons for the difficulties encountered in transfers from R&D to operations is to be found in just those features of the informal STI system that make it so efficient <u>within</u> the R&D laboratory. The informal groups are such good information transfer mechanisms because of a cohesiveness born of shared activities and identities. These criteria of membership in the communications network exclude as well as include, however. They not only facilitate the flow of information within the group, but may serve as barriers to information from the outside. The gatekeepers are able to overcome these barriers because the information they bring is from sources with whom they, and those they serve, share at least the professional identity. Because the gatekeepers <u>are</u> members of such source groups, as well as the in-house group, they can not only access the information more fully but also effect such "translation" of it as different coding schemes may require.

The barriers to STI transfer thus seem most acute on the boundary between R&D and operations, for there differences in both professional background and orientation diverge quite markedly. There, also, significant differences in activity are strongly reinforced by organizational structures (at least in the typical situation). Thus liaisons would seem to find the barriers much less permeable than those faced by the gatekeepers. Not only do the R&D and operating groups differ more markedly on both criteria of membership, but also--unlike the gatekeepers--the liaisons cannot mitigate either of these differences by virtue of dual membership.

B. The Matter of Assigning Responsibility

The Visibility of Results

These difficulties in the R&D/operations interface are exacerbated by the problem of assigning responsibility for an innovation's success or failure once it has been transferred from R&D. In short, the question here is the "visibility" of the results of a reseacher's work.[2] The term "visibility" means both the ease with which research results may be assessed, and the manner in which they are assessed. The first of these relates to the clarity or obscurity of organizational goals.

> In an organizational setting where the owner of an organization or his representative can accurately evaluate the findings of a project in terms of organizational goals, he can encourage the researcher who shows high probability of solving such problems. As a consequence, the researcher is motivated to seek solutions to difficult but "relevant" problems in preference to less relevant but easier problems. In seeking a solution to the difficult problems, the researcher at times must abandon traditional methods and thinking (Gordon and Marquis 1966, p. 198).

From the researcher's perspective, the visibility of organizational goals depends in large measure on the ability of the supervisor to perceive and transmit them.

Regardless of the visibility of organizational goals, and thus the ease with which research results may be assessed, research results themselves are not visible until someone actually assesses them. This raises directly the question of the pattern or "style" of R&D management and its influence on innovative behavior. To get at this question Gordon and Marquis divided the research projects examined in their study into three groups.

> 1. Projects in which the project directors either stated that they had no administrative superior or that they did not discuss their research with their administrative superior. (Low visibility of results + freedom.)
>
> 2. Projects in which project directors had freedom to specify their research procedures and they discussed their research with their administrative superior. (High visibility of results + freedom.)
>
> 3. Projects in which the project directors stated that they had an administrative superior with whom they had discussions and who consistently influenced procedures. (High visibility of results + limited freedom.) (Gordon and Marquis 1966, p. 199)

On the hypothesis that both high visibility of research results and research freedom are important to creative activity the second of these three types of authority patterns should be expected to maximize such behavior, while the first and third should minimize it. That proved to be the case: two and one-half times more of the projects rated as most innovative by the independent evaluators were conducted under the ideal authority pattern (type 2) than under either of the non-ideal conditions.

Thus it would seem that creative behavior is more likely to occur where the results of such behavior are visible, i.e., where the organizational criteria for assessing research results are clear <u>and</u> where the supervisor keeps in touch with what the researcher is doing and how his work is going; but where at the same time the reseacher has freedom, i.e., he is not dominated by his superior.

Micro and Macro Assessments During R&D

When we apply the concepts and results of the Gordon and Marquis study to the problems of R&D/operations interface, a number of things became apparent. First organizational objectives--even if highly visible to the researcher--are typically too general to determine which among several technical options is best. They can serve to guide or enhance R&D efforts, but additional criteria are also necessary. Such criteria are provided by the technical orientation and expertise of the R&D management and personnel, the state of the art, "best practice" considerations, etc. The former, or organizational, objectives we shall refer to as the "macro" assessment standard, and the latter as the "micro" standard. The important thing to notice about these two standards is that while macro assessments include considerations of R&D/operations interface, assessments performed in terms of the micro standards typically do not. Before developing the implications of this point we need to introduce one further distinction.

R&D results may be--and in fact are--assessed at various points during the R&D process, and at various points after their transfer to operations. The ease with which macro and micro assessments of research results can be made--and more importantly the impact of such assessments on STI flow--would seem to differ significantly according to the point at which they are made.

Micro assessments of research results during the R&D process are relatively easy to perform. Technical criteria appropriate to the particular R&D activity and the professional group(s) involved are utilized to determine how those responsible for the conduct of a project are doing. Even if the supervisor is not particularly competent in the area, it is usually not all that difficult to get a pretty good reading on the technical quality of the group's work. If such technical assessments are indeed performed at regular intervals they can provide research results with the sort of "visibility" that Gordon and Marquis have shown to be an important factor in the quality of innovative efforts.

Such visibility, arising from periodic micro (or, purely technical) assessments, should also provide an impetus to the STI transfer process. Other things being equal, we should expect to find more active informal systems--and within them more active gatekeepers--in those laboratory settings in which research results are made highly visible by virtue of periodic, and rigorous, technical review.[3] We know of no studies that have addressed this hypothesis, but it seems worthy of empirical test, since it may represent one of the few points at which the formal organization can directly influence the functioning of the informal STI systems.

Turning now to macro assessments of research results during the R&D process, we find a quite different situation. The supervisor bears an unusually heavy and difficult responsibility at this point. In Gordon and Marquis' terms, he must motivate the research group "to seek solutions to difficult but 'relevant' problems in preference to less relevant but easier problems." That is to say, research results that achieve a very high rating on the micro or technical-standards scale might fare poorly or even be unacceptable relative to the macro considerations of organizational goals or constraints. Further, the imposition of these macro considerations--which must be imposed if the potential innovation is to be implemented--may force the researchers to deal with a much more difficult technical task.

In order to perform the macro assessments necessary to insure the compatibility of R&D output and organizational objectives and constraints, the supervisor must himself be a liaison. In at least general terms, for instance, he must understand the limitations on the organization's present productive capabilities, which, if exceeded, will drive up sharply an innovation's implementation costs. Or, to take a different interface example, he must understand enough about the organization's present competitive position in a particular area to guide an innovative effort in ways that will hopefully make it successful in that market. These and other dimensions of macro assessments imply a wealth of STI that seems to be beyond the capacity of a supervisor to handle single-handedly. Either there exist STI liaisons between R&D and the several operating units that have simply not been recognized as yet--as the gatekeeper function was only recently recognized--or this interface is indeed a serious problem.

If supervisors are largely alone in the performance of this STI transfer function, then this fact has implications for the quality of R&D output that go beyond straightforward informational deficiencies. It means that supervisors will be standing virtually alone in imposing macro barriers--considerations of organizational relevance--to many of the highly rated technical solutions that are developed by project groups. The risk here is that the supervisor, perhaps against his better judgment, will be locked into a supervisory "style" that is viewed by those under him as to "meddlesome" or interfering. In Gordon and Marquis' terms he may be forced by circumstances into a "type three" style in which the project results are highly visible and the researcher's freedom is quite limited. As we have seen, this style proved far less conducive to high innovative results than the supervisory approach which coupled high visibility of results with substantially greater independence. Without other effective channels of information about operational "reality," the supervisor would seem to have little choice than to acquire it himself as best he can, and feed it into the R&D process through the mechanism we have called macro assessments.

Micro/Macro Assessments After the Transfer from R&D

After the results of R&D have been transferred to operations, assessments of the innovative effort continue, of course, both during and after implementation. After the transfer, however, the distinction we have been making between micro, or purely technical, assessments and the more macro assessments of organizational relevance comes to be blurred. Indeed, even the visibility of results, at least insofar as assigning responsibility for success or failure is concerned, becomes blurred. After the transfer from R&D, responsibility for the fate of the effort is shared by several organizational units, and thus the claim can always be made that the cause for failure lies elsewhere.

Given this situation, it is difficult to pinpoint a failure by an R&D group to gather the operational information necessary to make their work relevant and useful, as well as technically sound. Without this sort of after-the-fact visibility, there is far less incentive to seek and utilize such information in the course of their work. This should not be taken to mean that R&D personnel are indifferent to the ultimate success or failure of their work. It simply means that the factors in their situation that serve to focus their efforts on the technical dimensions of their work are, in combination, quite strong, and those that would lead them to emphasize the operational dimensions are weak by comparison. It is little wonder, then, that the R&D/operations interface is viewed by many as "the key problem in research management today."

A rather wide range of organizational forms have been experimented with--as alternatives to the typical functional structure--in an effort to overcome the problems inherent in transfers between R&D and operations. Quinn and Mueller (1963, pp. 61-62) have identified a number of these alternative forms:

> Task-Force Groups--These usually are made up of personnel from research, development, marketing, and manufacturing who are often given total responsibility for exploiting a new technology. The composition of the group is heavily weighted toward R&D people at first, but it shifts toward operating people as full-scale operations are approached.
>
> Corporate Development Units--These, having their own marketing staff and flexible pilot-scale facilities, pick up new research technologies and exploit them. The unit can be a profit center, deriving profits from sale of new products. As the products prove profitable, operating groups want to take them on. Thus, development is constantly forced to seek new technologies from research, and operating resistancies are eliminated.
>
> Outside Companies--At times, these are used to entrepreneur new products in specific cases. The research laboratory may take 49 per cent ownership in the new concern formed to exploit the technology. Or it may simply take license revenues. In some cases, large companies have given smaller companies (with special knowledge, facilities, or market access) exclusive rights, under a royalty agreement, to a new technology during a three to five year introductory period. When primary demand has been built up, the larger company has the option of continuing the arrangement or introducing its own branded version of the product.

Staff Groups at Corporate Level--These units serve to coordinate the introduction of new technologies through existing divisional and functional organizations. They are most effective when they either have functional authority over key aspects of line operations or have a budget with which to buy time from line units. Product managers perform this service successfully in some companies.

A Top Executive with Multifunctional Line Authority--This executive can effectively force new technologies into operations in small to medium-sized companies. In a medium-sized consumer products company, the president is also the top technical executive and founding genius. Because of his personal interest and follow-up, new products often move from research to the market in three to six months. He refuses to allow pilot-scale facilities to be built, feeling that they waste time and put less pressure on operating executives than do full-scale facilities.

A Research Group with a Special Budget to Buy Time on Operating Machines--This approach is effectively used in flow process industries (such as paper) where (1) the cost of a pilot facility is prohibitive, or (2) the scale of operation vastly affects technical approaches. There are always problems of scheduling these experiments; but, if an experiment is successful, research has little trouble in demonstrating its value to operations.

Individual Researchers Who Entrepreneur Their Ideas Through Pilot Facilities and into the Market--A pharmaceutical company sets up a profit center for each new product and encourages the researcher, if he has the talent and interest, to follow his idea to commercialization. If successful, he receives a share of the center's profits as additional compensation. Product policy is coordinated by product group managers at corporate level.

Multilevel Committee Responsibility--Such committees have been set up in some companies. In fundamental and early applied research, a research committee coordinates the program. In late applied and early development stages, coordination moves to an R&D committee. In late development, a new product committee takes over program progress. Before pilot scale facilities can be built, the operating committee must approve. A full scale operation requires executive committee approval. Because decisions tend to be slow and conservative under this system, it must normally be supplemented by one of the other organizations described here.

An Entrepreneurial Group at Corporate Level--Used by several of the companies most successfully diversifying through research-produced new products, these groups introduce technologies which are new to the company and which do not logically fit into the organizations of established operating groups. Where they are successful, these entrepreneuring units are headed by a commercially oriented dynamo with a technical background. He has at his disposal a technical group which reduces research ideas to practice, a special budget to build small-scale facilities and underwrite product introduction losses, and a small nucleus of commercially oriented technical men who simultaneously "ride two or three products into the market."

Major difficulties with this appraoch are (1) finding people with the complex of skills and attitudes necessary to entrepreneur new products; (2) replacing these people as they become committed to products they have "ridden into successful division status"; (3) developing the top management attitude toward the risk taking such operations must involve.

Although each of the above forms has proved useful in specific instances, none has been shown to have general applicability. The most suitable form varies from firm to firm and from innovation to innovation.

The risk that an organization runs in adopting one of these alternatives to the typical functional arrangement is that it may weaken or destroy the informal systems which seem to function with such remarkable efficiency in bringing STI into the organization, maintaining it in interrelated "pools" until needed, and transferring it to the appropriate parties. Such informal systems--or so we have argued--find the basis of their cohesion in the combination of shared R&D

activity and similar professional backgrounds and identities. Even if alternative organizational arrangements could create shared activities that occasioned as much group identity as the R&D activity, the other source of group cohesion, a shared professional identity, would--by the very nature of the alternative structures--not be satisfied. Thus we suspect that such alternatives, unless simply used on an occasional, ad hoc basis, would substantially weaken one of the organization's most remarkable and valuable assets in the conduct of R&D--the informal STI system.

* * *

In this Chapter on the interface of R&D and operations we have stressed the difficulties inherent in this interface, and have suggested that the informal systems themselves may, in some measure, be responsible for many of these difficulties. In so doing, we may have inadvertently been more negative than we intended. It seems to be the case, however, that nothing comes without price, and the price for having an effective informal STI system within R&D seems to be difficulties on the R&D/operations interface--difficulties for which we see no easy solution. Whether this price is too high, each organization must decide for itself; if the answer is yes then it should adopt some alternative structure.

Before making a move that may weaken the informal STI system, however, a finding of the Rosenbloom and Wolek (1970) study reported earlier should be considered carefully. It will be recalled that they found the informal system to be so efficient that one-third of time it provided the researcher with the information he needed even before he undertook a search for it. Such efficiency should make an organization seek long and hard for alternatives that will not impair the informal system.

Footnotes

1. In addition to the references cited above, there are a handful of studies at each of two levels of aggregation: (1) at the _interpersonal level_, see Douds and Rubenstein 1966, Morton 1964, and Bean 1968; (2) at the _organizational level_ see also Pessemier 1966, Peterson 1972, Hill and Hlavacek 1972, and Pessemier and Root 1973.

2. For the concept of the "visibility of research results"--and indeed for the basic thrust of the next several paragraphs--we are indebted to Gordon and Marquis (1966). Their study, however, did not concern the R&D/operations interface. Thus responsibility for this new application of the concepts developed by Gordon and Marquis lies with the authors of this study.

3. This is not to say that the results achieved in such settings will also be more innovative, since this depends on other factors as well.

Appendix A

STI Pool and Flow: A Logical Analysis

Given an R&D laboratory setting, one might ask, "Where does the information that proves important to an innovative effort come from?" In the most general terms, the answer is that most of it can ultimately be traced to sources outside the organization, since even the largest R&D operation can generate on its own only a small fraction of the information it requires. This general answer is not very helpful however, since it says nothing about when or how the information enters the organization. To focus on the "when" and "how" of the matter, we might ask about the possible loci of a piece of information that is needed by a researcher in the course of his current work. The following possibilities exist:

1. He already knows it by virtue of his technical training or past experience (In-hand);

2. It is known by some member(s) of a group within the laboratory with whom the researcher has frequent contact (<u>In-group</u>, but not in-hand);

3. It is known by some other member(s) of the organization (<u>In-house</u>, but not in-group);

4. It is known (<u>in existence</u>, but not in-house);

5. It is not yet known (information <u>must be generated</u>).

Each of these possibilities may well occur in the course of the same innovative effort, with quite different implications for formal and informal STI systems.

a. Possibilities 1 and 5: Not Instances of Transfer

In the fifth possibility above, no transfer is possible since the information does not yet exist. The frequency of this occurrence depends on variables in Chapter II. Likewise, the first possibility does not involve a transfer of information, at least not subsequent to the need. The possession of presently needed information typically does imply an earlier transfer--in the course of one's education or previous work experience. From the organizational perspective, the initial employment of the individual was a form of STI transfer--commonly called "on the hoof" transfer--since his general and/or special skills constituted a major reason he was hired. Indeed, "on the hoof" transfer may be a crucial STI flow mechanism in particular instances (Burns 1961, p. 12; Langrish et al. 1972, p. 44, Table 7, p. 79). But in our example in which the transfer is subsequent to the need, the first possibility above, like the fifth, is not an instance of STI flow.

b. Possibility 4: Information Exists, But Not Known In House

With regard to the fourth possibility, in which the information exists but is not known in-house,[1] it may be; published in a professional or trade journal, available through extraorganizational personal contacts, a closely guarded piece of proprientary information of a competitor, a government-held patent or technical report, etc. Many studies have shown that, in aggregate,[2] R&D personnel make little use of the formal literature (see for example Scott and Wilkins 1958, OEEC 1958; Hanson 1964; Averback Corp. 1965; Allen 1966; North American Aviation 1966; Allen 1970). Thus, ignoring for the moment the possibly contrary influence of variables considered in Chapter II, it does not seem highly likely that our researcher will turn first to the literature to meet his need for information. He may get there by an indirect route or as a last resort, but it seems to be an infrequent first move in the typical case (As we saw, gatekeepers and scientists in basic research are the obvious individual exceptions to this generalization).

As for the possibility that our researcher may find the information he needs through an informal contact outside the organization, a number of studies have shown that while--for pre-project activities at least--it may be a frequently used channel in some instances, it is not a very effective one (Allen 1964; Allen 1966; Shilling and Bernard, 1964). In fact, in these studies there was found to be an inverse relation between the use of such extra-organizational personal contacts and the quality of the solutions proposed. In other words, "Better performing groups rely more than poorer performers upon sources within the laboratory, as contrasted with sources outside the lab (Allen 1969).

While such results seem to support our thesis about the centrality of the informal STI system within the laboratory, two points stand out as requiring explanation. First, why did the poorer performing researchers make more frequent use of these external sources in the course of pre-project efforts? Why didn't they, like their better performing counterparts rely more on the informal system within the laboratory? A partial answer to this question lies in the fact that there was also, "...an inverse relation between the size of a lab's technical staff and the extent to which outside sources were used (Allen 1969). This suggests that the in-house pool of information was inadequate in these cases, thus forcing external search. As we argued in Chapter II, one of the variables that perturbs a group's "characteristic" pattern of information flow is the extent to which the technical effort departs from that which the group knows well. The pre-project activities examined in these studies seem to represent substantial discontinuities for those groups who exhibited a heavy reliance on informal external sources.

The second question raised by the results of these particular studies is why did those groups that relied heavily upon external sources perform more poorly? A part of the answer may have to do with the point discussed earlier about the "social reality-testing" function of informal groups. A researcher may feel much freer to "check out" a technical idea with a member of his own group, by asking questions that may be poor ones, than with an outside "expert." Conversely, this closer relationship may permit him to be more probing and critical of an idea offered by a colleague than one offered by an outsider. It is perhaps the absence of the freer interactions characteristic of informal groups that Allen has in mind when he says; "When an engineer resorts to a consultant, he quite likely tends to overestimate the consultant's competence in the area and, as a result, does not exercise sufficient skepticism in assessing the idea" (Allen 1969).

Another part of the answer to this question may involve the notion of "boundary impedance," growing out of the distinctive ways in which an organization may have come to codify and refer to pieces of information with which they deal constantly. The commonality of organizational experiences and perspectives often results in the development of distinctive "coding schema," i.e., short-hand ways of thinking and talking which outsiders may be at something of a loss to understand. Not being privy to this way of coding information will impede communications with an external source and thus reduce that source's effectiveness.

To round out this analysis of the occasions on which the researcher may first seek needed information from an extra-organizational source, let us look at a study that seems to run counter to the results presented above. Hagstrom (1965) found a strong <u>positive</u> correlation between extra-organizational informal communication and productivity for scientists and mathematicians in the <u>university</u> environment (productivity in this case was measured in terms of papers published). While our concern is with STI flow in the <u>industrial</u> sector, this study is important for two reasons. First, it illustrates the fact that some highly interactive--and highly effective--informal groups have memberships that cut across organizational boundaries (see Price 1965; Crane 1972 for discussion of this point in terms of the "invisible college" concept). While productivity was here highly correlated with informal STI transfers external to the formal organization, such transfers were internal to the informal group. Thus the seeming contradiction between the results of this study and those examined above is specious. Here, as before, the role of the informal group is central to the transfer process. The difference is that whereas above the informal group was circumscribed by the organization, here it is not.

This distinction between wholly intra-organizational informal groups and inter-organizational ones has direct implications for the notion of "boundary impedence" discussed above.

> Members of industrial and governmental organizations acquire through common experience, and organizational imposition, shared coding schemes which can be quite different from the schemes held by other members of their discipline i.e. those in other organizations . This is not true for the academic scientists. They generally feel more aligned with scientists in similar research areas than with a particular university or department, and therefore tend to use a system of coding in common with other researchers. In other words, the "invisible college" now becomes the mediator of the coding scheme (Allen 1969, p. 97).

The impedence created by organizational coding schemes in the industrial sector might also serve as a partial explanation for the low frequency of direct use accorded to the formal literature in industrial R&D settings.

The second point to be noted in connection with the Hagstrom study concerns those groups working at the "basic research" end of the R&D activity spectrum. Such groups seem much more likely than others along the R&D activity continuum to utilize extra-organizational information sources--in terms of both informal contacts and the formal literature (Rosenbloom and Wolek 1970, p. 35). In this respect they tend to be much more "academic" than "organizational" in their orientation. Thus R&D personnel with basic research responsibilities are much more likely to participate in informal groups that include extra-organizational members. This, however, does not disturb our basic thesis about the centrality of informal groups in STI transfer. In fact, with the proviso that such groups need not be wholly in-house, it strengthens it.

c. <u>Possibilities 2 and 3: In-Group or In-House</u>

There remain two possible loci from which needed information might be secured; from the researcher's own informal group, or from elsewhere in the organization. We shall consider these two possible sources together on the hypothesis that the latter, or intra-organizational transfers of technical information, are most properly understood as inter-group flows, i.e., as transfers between one group and another within the informal STI system rather than between one individual and another.

One might object to this hypothesis as circuitous and question-begging. Even if the parties to an information transfer do happen to be members of different informal groups, why is it necessary, or even desirable, to think of it as an inter-group transfer? Surely people from different groups within the organization who may have different technical backgrounds, and are working on different tasks can, and do, simply speak for themselves on a technical matter without in any way involving their respective groups. And, of course, this is correct, but it may well also be atypical and thus of less interest from the point of view of understanding the dynamics of STI transfer. It seems reasonable to assume that a technical discussion partner from other than one's own group is typically sought out precisely because he can be expected to reflect the "best practice" or "state of the art" knowledge of that group. If, for instance, the technical problem concerned the smooth interface between one's development work on a project and the design or production work to be conducted later--or the mechanical constraints on the solution of an electronics problem--then one would hope that the information received reflected, somehow, the collective expertise and experience of that professional group, and not simply the views of an isolated individual.

Let us, therefore, assume for the moment that information transfer between members of different groups within the organization are best viewed as intergroup flows rather than simply personal exchanges. Given the hypothesized interdependency of these loci of information, we shall treat them together.

In part, we have structured this preliminary analysis of the researcher's information seeking behavior in terms of the possible loci of such information in order to correct an imbalance that is common in the literature on informal STI systems. The literature tends to emphasize the transfer or "flow" of information to the neglect of the manner in which it is stored or "pooled." It is important to recognize, however, that--like the formal STI systems--the informal systems are mechanisms for storage as well as retrieval. Without the recognition of this "information pool" function, which permits a lag between acquisition and use, it becomes impossible to account for the following apparently contradictory facts:

1. Most STI utilized by an organization was originally generated <u>outside</u> that organization, since no R&D laboratory, not even the largest and most diverse, can generate anew more than a small fraction of the information it needs;

2. Most of the information used by a typical researcher in the course of his work comes to him from sources <u>within</u> his own laboratory.

These facts require for their reconcilliation a distinction between <u>ultimate</u> and <u>immediate</u> sources of STI (Unless it is assumed that--with negligible time lags--information flows into the organization <u>only</u> as it is needed.[3]). This distinction, in turn dictates the existence--and indeed crucial importance--of in-house information pools.

The basic pool of information is the individual researcher's accumulated technical knowledge and experience.

By means of the informal networks that characterize the R&D laboratory, however, these individual stores of information may be aggregated into more comprehensive and diverse pools. How effective such pools are in meeting the information needs that arise depends not only on the size and competence of the group, the richness of its internal communications, and the nature of the activity in which it is engaged, but also on a number of variables to be considered later. In general, however, we would argue that the information pools constituted by the informal networks within the R&D laboratory are typically substantial enough to meet most of the information needs that arise in the course of their members work on most projects. Support for this generalization is presented in Chapter II.

The informal system's information pool is composed of:

1. What each member of the network knows by virtue of his professional training and experience;

2. Information about in-house analysis and experimentation in past organizational endeavors;

3. Information about the organization's operational capabilities and constraints;

4. Accretions of information from sources outside the organization.

The relative importance of each of these sources will vary according to the nature of the R&D activity and other variables considered in Chapter II. In the later phases of the R&D effort, for instance, the researchers' past professional training and experience, along with some measure of analysis and experimentation, may well be adequate, i.e., little input from external sources may be required. In other phases, such as basic research, the competence gained by past training and experience, plus the results of analysis and experimentation seems to be a necessary but not sufficient condition. Quality performance is here strongly dependent upon both extensive flows within the informal network, and a heavy reliance on the formal literature (Hagstrom 1965; Rosenbloom and Wolek 1970).

Information about the analysis and experimentation from past organizational endeavors is probably fairly uniform in its importance across the spectrum of R&D activities. There is probably a substantial unevenness, however, in the extent to which such information is available from sources other than the informal pool. Toward the basic research end of the spectrum there would seem to be an increasing probability that such results, if not in fact published, were at least written up as in-house technical reports. Toward the development end, on the other hand, it seems more likely that the results of analysis and experimentation--expecially negative results--exist only as a part of the informal pool. Much of what is called "how-to" information would seem to fall in this category. We know of no studies that speak directly to this point, but the hypotheses we offer seem consistent with such indirect evidence as exists (See Allen 1969).

As for the importance of that portion of the informal pool that we have characterized as "information about the organization's operational capabilities and constraints," it again depends on the nature of the R&D function (plus certain other variables). Such information would seem to be least important at the "basic research" end of the spectrum, and to increase rapidly in significance as you approach R&D's interface with operations. The reason for this is fairly simple. In the later R&D phases, the work is increasingly sensitive to operational considerations specific to the organization. While information about the opportunities and constraints posed by operational reality may occasionally be available in written form, most of it probably exists only as the "working knowledge" of those experienced in the interface.

The final type of information that we take to be constituent of the informal pool involves all accretions from sources outside the organization. This would include information from both the formal literature and informal contacts. The ways in which such information may come to be a part of the in-house pool have been discussed in Chapter II, as was its relative significance under a range of conditions.

Appendix A

Footnotes

1. Clearly information may exist in-house, e.g., on the shelves of the organization's technical library, without being known in-house. As Allen (1970, p.) has remarked, "The transfer of paper does not guarantee the transfer of information."

2. This statement, like a number of others throughout this Appendix may be less true for certain professional groups engaged in certain R&D activities than for others. It does, however, seem to be a strongly supported generalization about the information seeking behavior of R&D personnel as a total group. We will continue to "flag" such generalizations that may vary in their applicability at lower levels of aggregation by some caveat such as "in aggregate," or "on the whole."

3. This assumption is badly flawed since it requires one to presuppose: 1. that information needs are always sufficiently defined to make external searches possible; 2. that there is always someone at hand who can drop whatever else he is doing and locate the needed information; and 3. that the information stored by outside sources is so efficiently organized and appropriately coded that it may be retrieved with ease. None of these presuppositions is always true.

Appendix B

Summary of Two-Day Workshop on Final Report and Its Action Implications

In addition to seeking to integrate what is known about the R&D laboratory's informal STI system with a range of variables that impinge upon its function, this study also sought:

> To utilize the results achieved in this integrative effort to examine the implications of the nature and function of the laboratory's informal STI system for...
>
> --its interface with formal STI systems and services;
>
> --its interface with the operating units of the laboratory's parent organization or other "clients;"
>
> --the research agenda of scholars concerned with the innovation process, the R&D laboratory, and the pool and flow of STI.

These implications--for those who design and/or operate formal STI systems, those who manage R&D, and scholars who study these processes--have been developed above.

To insure, however, that this integrative effort was as reflective of the state of the art knowledge we could make it, and that its "action" implications were as complete as possible, they were made the focus of an intensive two-day workshop. The invited conferees (see list below), chosen for their demonstrated expertise and experience in one or more of the intersecting elements under study, met with the project group and NSF sponsors at Georgia Tech on March 17-18, 1977.

The major conclusions and recommendations that emerged from this conference are summarized below.

A. <u>Conferees' Critique and Recommendations Concerning the Report's Integrative Treatment of the Laboratory's Informal STI System</u>

1. The Informal Group Concept

There was broad if not total agreement among the conference participants that informal laboratory groups are significant STI pool and flow mechanisms, and that the information-seeking behaviors of most researchers can not be understood apart from consideration of such groups. By way of emphasizing the centrality of such groups to most information transfer instances, one participant argued that, in the short term, the informal system could carry the load if the formal systems suddenly ceased to exist. Though such a conjecture is distorting if taken literally and without further specification, it does serve to balance the contrary assumptions that have led to widespread neglect of the informal system.

Professor Garvey offered a number of important contrasts between formal and informal STI systems in academic science.[1] This generated a lively discussion as to the relevant similarities and differences between the academic and R&D laboratory contexts and the functions of formal and informal systems in each. There was little consensus on these issues, which was to be expected given the complexities of the phenomena involved and the state of the art knowledge. There was agreement, however with Professor Garvey's basic point, that efforts to formalize elements of the informal system should be undertaken with caution. Such formalization of functions previously handled informally usually fails because it eliminates characteristics crucial to their success (Garvey 1976). On the other hand, it is often possible to make changes in the formal STI system that will facilitate the informal system's role in STI pool and flow.

2. The Seven Information-Need Indicators

There was extended discussion of the completeness of this catalog of influences on the nature and function informal laboratory groups in STI pool and flow. Several additional variables were offered as candidates for possible inclusion. For instance, Mr. Saltzer argued the importance of a distinction between government-sponsored and commercially-oriented R&D. In the former case the sponsor may be a substantial STI source, while potential customers in the market-place are often not.

As a second possibility, Dr. Wolek suggested that the adequacy of the in-house STI pool may differ greatly between the R&D effort initiated by the recognition of a scientific or technological opportunity, on the one hand, and a market need on the other. Finally, Dr. Goldhar suggested that STI needs and flow patterns may exhibit systematic differences depending on whether the laboratory's parent organization is a leader or a follower in its industry.

We find it more difficult to assess the potential of these characteristics than those discussed in the body of the report. On the other hand, it would be premature to make a negative assessment of their possible utility. Thus, we recommend that future research designed to test the "information-need indicators" identified earlier be broadened to include these additional candidates.

In the course of this discussion Dr. Carnot Nelson made the observation that what we have called "information-need indicators" or "market segmentation criteria" are analogous to the demographic variables used routinely in the social sciences. That is, many useful correlations have been demonstrated between such demographic variables as age, sex, education, religion, etc. and certain behavioral or attitudinal characteristics. In like manner, we have hypothesized that useful correlations exist between certain "demographic" characteristics of the laboratory, its populace, and environment and the informal pool and flow of STI.

3. The Gatekeeper Concept

It is sometimes the case that, in the long run, the greatest value of a new concept will be found to lie in the new level of questioning which it introduces or permits. Such seems to be the case with the gatekeeper concept. To be sure, its explanatory power is significant, e.g., it accounts for how the many researchers who never or seldom use the formal STI systems are nonetheless served by them. More importantly, however, gatekeepers are the most visible members of the informal systems they serve. Thus their identification has focused attention on the nature and function of such systems.

It was largely in this "value of the questions it raises" tone that the gatekeeper concept was discussed. This was in no sense a denigration of its importance. On the contrary, it reflected the conferees recognition and acceptance of not only its prima facie value, but of its heuristic impact as well. The group pursued this new level of questioning in two ways. On the one hand, beginning with the gatekeeper function as described by Allen and others, the following sorts of questions were raised:

1) In addition to the straightforward "transmission" of information from external sources, to what extent do gatekeepers also "translate" or even "filter" it? What are the implications of these latter possibilities for the laboratory, the formal STI systems, and the quality of particular R&D efforts?

2) How does the informal system reward those who perform the gatekeeper function?

On the other hand, beginning with the characteristics of the informal system, laboratory, and environment in which the gatekeeper is "embedded," the same sort of correlational questions arise as in the case of informal groups, e.g.:

1) Is the gatekeeper function of equal importance across the whole spectrum of R&D activities, or is it more important in some phases than others?

2) Is the gatekeeper role more important in areas of more rapid scientific and/or technological change than in slower changing areas?

Other such "researchable questions" that emerged from the conference are described below.

B. Conferees' Assessment of the Study's "Action Implications"

After a thorough discussion of the laboratory's informal information system, its interface with the formal STI systems on the one hand, and the laboratory's "clients" on the other, the conferees were then asked to draw out the report's action implications for three groups:

1. Designers and/or operators of formal STI systems and services;
2. Managers of R&D laboratories;
3. Academic researchers (and sponsors of such research).

Their major recommendations for each of these groups are summarized below (these recommendations should be taken as additions to those offered in Chapters II, III and IV above).

1. Conferees' Recommendations to the STI Industry

A. Utilize the information need indicators identified in the report--and perhaps those added in the course of this conference--to see if you can identify heavy and light user market segments.

B. Work with the academics in the STI field. They are the industry's research component, and your active cooperation can make their results more useful as well as more rigorous and reliable.

C. In-house information specialists may serve general managers and top executives as well as the researchers in the lab. Technical information is a component of policy decisions as well as research work.

D. Couch the value of the STI services you provide in terms of the indirect as well as direct users. That is, individual users are not only inappropriate market segments, they are inadequate measures of value of your services as well.

2. Conferees' Recommendations to R&D Managers

   A. Be aware that you can, and do, influence the adequacy of the laboratory's in-house information pool by your decisions. That is, informational adequacy is not a constant, but a variable that changes as other elements of the total environment change.

   B. Devise ways to integrate information specialists into your laboratory's formal and informal groups--at least create conditions that may make this possible.

   C. Consider how the information specialist and the computerized storage and retrieval capabilities of the STI industry might be employed to improve the informational interface between R&D and operations.

   D. Utilize the direct/indirect user distinction, instead of the user/non-user one, in assessing the value of the formal STI systems for your laboratory.

   E. Know (anticipate) shifts and surges in your laboratory's need for the formal STI services. Don't wait for your researchers to tell you. They may not do so.

3. Conferee's Recommendations to Scholars Concerned with the STI Process

   A. A high priority should be given to studies of the relationships between laboratory communications patterns and organizational environment and structure.

   B. There is a pressing need to understand better the flow of information between the R&D laboratory and the operational units of the parent organization.

   C. Determination of the reliability of the "information-need indicators" hypothesized in this report is an especially important research agenda item, not only for their short-term practical potential, but also for their potentially integrative effect on the state of the art knowledge.

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Appendix B

Footnote

1. Details of the contrasts offered by Professor Garvey may be found in Garvey and Griffith 1966; Garvey, Lin and Nelson 1970; Garvey and Griffith 1967; and Garvey and Griffith 1972.

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