INDUSTRIAL PERFORMANCE CENTER

Massachusetts Institute of Technology

Cambridge, MA 02139

Organizational Integration in Situations of Uncertainty: A Case Study of MITRE Corporation

Pamela Campos, Richard Lester and Michael Piore

MIT IPC Working Paper 99-006

September 1999

Executive Summary*

Globalization and rapid technological change are creating situations of radical uncertainty for many firms, and are raising new questions about how best to organize economic activity in such conditions. Radical uncertainty creates a demand for greater integration within organizations and between organizations and their environments. Increasingly this integration is provided by network forms of organizing characterized by a reliance on trust, horizontal relationships, and organization around projects. But what, more specifically, are the integration mechanisms used by networked firms in situations of uncertainty?

This report presents the results of a case study of integration mechanisms at MITRE, a Federally Funded Research and Development Center providing systems engineering and advanced development services to the U.S. Department of Defense, the Federal Aviation Administration, and the Internal Revenue Service. The integration mechanisms at MITRE include organizational design, cooperative councils, joint projects, interpretive actors, information technology tools such as an intranet and cooperative work

* This research was sponsored by the MITRE Corporation under a grant to the Industrial Performance Center. We are extremely grateful to MITRE not only for its generous financial support of this project, but also for providing us with superb access to the company and to so many of its outstanding members of staff. Special thanks go to David Lehman and Andrea Weiss for making the project possible and for their invaluable support and encouragement along the way. They and others at MITRE, too numerous to

spaces, and participation in standards development processes. These mechanisms are used to foster both internal and external integration. Analysis of MITRE's integration mechanisms suggests that integration in situations of uncertainty requires not only coordination, but also an ongoing discursive process centered on eliciting project and firm goals. For networked firms such as MITRE, this process, which we term an interpretive process, relies heavily on a strong sense of group or firm identity to provide internal cohesion and a common background.

We find the question of organizational identity to be problematic at MITRE. Identity at MITRE is complicated by the company's FFRDC status. The company must be able to differentiate itself from the government contractor community and from the government itself in order to justify its special status as an FFRDC. One of the dilemmas confronting MITRE today is that the external emphasis on collaboration tends to de-emphasize its uniqueness, while its ability to integrate both internally and externally depends on having a strong sense of identity. While these tensions have always been problematic for MITRE, recent changes in its environment have made this a more pressing problem.

We encountered two very different conceptions of MITRE's identity in the course of our research. The first was of MITRE acting in the nation's interest. The alternate conception was of MITRE as an advanced development information technology firm. While the majority of interviewees strongly identified with the idea of MITRE as a company acting in the nation's interest, this idea manifested itself in different ways. Employees closely tied to client operations have an opportunity to actualize this identity in their contact with and services for clients. Employees who are more focussed on technology development seem to have a harder time making a connection between the idea

mention by name, have been extraordinarily generous with their time and insights. Of course, the contents of this report, including any errors that it may contain, are solely the responsibility of the authors.

of acting in the nation's interest and their own work. The result is an interest in developing technology for use outside of MITRE's usual clients, creating tension within the company about corporate strategy.

The report concludes with a discussion of the practical implications of this research for managerial practice and strategy, followed by a brief consideration of the implications for understanding the nature of the firm. The broader conception of integration that emerges from this research suggests that transactions occurring within and between organizations should be understood not only in terms of exchanges of goods or services, but also as communicative, discursive exchanges.

1. Introduction

Integration is a challenge that pervades a wide range of economic, political, and technological problems today. The need for integration arises within a context of radical uncertainty caused by a convergence of economic forces, including globalization and rapid technological change. Radical uncertainty refers to situations where so little is known about what the future will bring that it is not possible even to identify the range of outcomes that *might* occur. Revolutions in the information and life sciences, economic competition across national and regional boundaries, and competition across formerly well-differentiated industry boundaries all lead to a greater degree of uncertainty. Whether the increase in volatility is an essentially permanent state of affairs or a transitional phase, dealing with it effectively has become a major challenge for a large number of firms.

This volatile environment is reflected in rapidly shifting and ill-defined corporate goals, and in widespread experimentation with new organizational forms. These include networked organizations, virtual corporations, strategic alliances, partnerships, and joint

ventures. The boundaries between and within organizations are becoming increasingly fuzzy.

How can managers, policy makers, and engineers deal with this kind of uncertainty? What organizational forms are likely to perform most effectively in this environment? How can they meet the demand for greater integration in the context of radical uncertainty? What role does information technology play in supporting organizational integration? Does information technology require us to rethink our understanding of integration?

This report address these issues in the context of a year-long case study of the MITRE Corporation, a Federally Funded Research and Development Center (FFRDC) for the Department of Defense, the Federal Aviation Administration, and the Internal Revenue Service. In its role as an FFRDC, MITRE does advanced development and systems integration work on large scale, complex information systems. One motivating factor for undertaking a study of the MITRE Corporation was the company's involvement in the development of new technologies and technical systems. Participation, and especially leadership, in this kind of activity requires managers and engineers to confront and manage a great deal of ambiguity about system applications and goals, as well as uncertainty about the availability of technologies.

The problem of integration under uncertainty is, in a fundamental sense, the problem of MITRE. Most of the company's work entails either integrating technical information and components into complex systems involving multiple technologies, or providing advice to its sponsors as to how such systems should be designed and implemented. MITRE also plays an integrating role in a much larger sense, bridging the organizational divide between government, industry, and research communities. The company operates at the crossroads between different branches of the armed services,

between different technical programs within individual services, and between the operational and acquisition communities within the defense complex. MITRE's ability to accomplish these external integration tasks hinges on its ability to utilize and capitalize on the wide range of knowledge available within the company – a function that requires a high degree of internal integration.

Many theorists conceive of integration as an essentially mechanical task – as the last and in many ways least interesting stage in the problem-solving process. The various components to be integrated, whether technical or organizational, are seen as parts that can be put together like the pieces of a jigsaw puzzle. But as markets become more capricious and unpredictable, and as firms are forced to contend with radical uncertainty, this view of integration is becoming less and less useful. The manager starts out without really knowing what the problem is that he or she is trying to solve. And without knowing the 'whole', it is unclear how to break it up into a series of component parts that can be assigned to different organizational sub-units. Indeed, it isn't even clear what those sub-divisions should be. Under these circumstances, the process of integration necessarily takes on an open-ended and even creative aspect. An ongoing research program at the MIT Industrial Performance Center is focusing on this aspect of integration, and seeks to develop a framework useful for describing and managing it.

Our study of MITRE is part of this larger research program. As a pure systems integrator (which is actually enjoined from undertaking 'routine' production or service delivery activities), MITRE provides an opportunity to focus without distraction on the organizational processes that are at the core of our research.

This report demonstrates that network organizations can facilitate the integration needed in situations of uncertainty. Network organizations take two forms – networks of firms and networks within organizations. They are characterized by frequent transactions,

a reliance on trust, and are often organized around projects. We argue that organizing as a network requires a strong sense of identity to provide internal cohesion and prevent cooptation by other organizations. This report will describe a number of integration mechanisms at MITRE, including organizational design, strategic planning, integrative councils and projects, and information technology.

The rest of the report is organized as follows. Chapter 2 describes the research methodology of the study, while Chapter 3 lays the theoretical foundation for understanding the connections between uncertainty, integration, and networks. Chapter 4 provides background information on the MITRE Corporation. Chapter 5 presents a case of one particular technology, CORBA, to demonstrate the nature and range of MITRE's work. Chapters 6 and 7 discuss the integration mechanisms uncovered by this research at MITRE and their strengths and weaknesses. Chapter 8 presents a discussion of the integration mechanisms in light of the theoretical material covered in Chapter 3. Chapter 9 discusses the firm's problems dealing with organizational identity, a key aspect of organizational culture. Finally, Chapter 10 concludes with practical and theoretical implications of the research. Readers whose main interest is in the practical implications of this research may wish to skip the intermediate chapters and focus on Chapters 6-10. Chapters 9 and 10 include certain specific recommendations for consideration by MITRE managers.

2. Methods

This report is part of a larger research project at the Industrial Performance Center examining new approaches to organizational integration. The core finding of this research, described in (Piore et al. 1994, 1995, 1997a, 1997b, Lester et al., 1998), is that a broad range of economic processes, especially those concerned with the generation of new products and services, can be usefully categorized as either analytical or interpretive. Each type of activity requires very different kinds of skills: different ways of working together, different forms of managerial control and authority, and more generally different ways of thinking about the economy. The objective of the larger research project is to develop insights into these two basic categories of economic activity, the contrasts between them, and the ways in which they can be combined successfully in business organizations. Previous research includes a series of case studies on the organization of design and product development in the cellular phone, fashion apparel, medical device, and automobile industries.

MITRE was selected as a case for two reasons. As a Federally Funded Research and Development Center (FFRDC), MITRE is not permitted to undertake "routine

production or service delivery activities." The firm's position as a 'pure' systems integration company provides an opportunity to focus without distraction on the organizational processes that are at the core of the larger research project. In addition, the company's role as a systems engineer to the Department of Defense requires it to deal frequently with situations of radical uncertainty – situations in which effective organizational integration is likely to be both important and problematic.

2.1 Methodology

The project was sponsored by the MITRE Corporation. In the discussions prior to initiating the research project, MITRE executives cited innovation, knowledge sharing, and understanding the firm's unique value to its customers as major managerial challenges for the corporation.

The initial research plan was to do a preliminary round of interviews at MITRE and then select one or two of the company's projects for closer study. However, at the end of our first round of interviews we decided to continue interviewing broadly, as the breadth of projects at MITRE made representative selection difficult, if not impossible.

After an initial interview with the sponsoring executives, a search for business articles on the company, and a review of MITRE's extensive online information, we began interviews. Our initial list of contacts came from the sponsoring executives, but was quickly broadened by suggestions from the initial interviewees. We interviewed 43 MITRE employees. All held managerial or engineering positions with the company, and ranged in seniority from 6 months to over 30 years. Table 1 shows the distribution of interviews by organizational center. Most of the interviews were conducted in person, five were conducted by video conference, and one was conducted by phone.

Table 1: Distribution of Interviews

Organization	*Number of Interviews*
WC3	13
Air Force Center	10
CIIS	16
CAASD	1
Corporate	4

As with much theory-building research, we conducted open-ended interviews. After contacting interviewees, we began each session by introducing ourselves and the research topic broadly, and then asked the interviewee to describe a bit about themselves and their position. This usually led to a series of stories, prompted only by our stated interest in "management in situations of uncertainty." In general, we interrupted only for clarification. Interviews were taped and later transcribed.

We met with the research sponsors formally on two occasions. The first meeting occurred midway through the field work. We presented our findings to date, which focussed on integration problems at MITRE and discussed potential projects to focus on. The second formal meeting came after completing the first draft of chapters 3 and 5-9 of this report.

2.2 Biases

There is at least one bias in the report that should be noted. To the extent that people were telling us stories, rather than describing current events in their work lives, they were telling us about experiences that had happened in the past. In retrospect, this is hardly surprising – it's very hard to tell a story if you don't know how it ends! Weick (1995) describes this as retrospective sensemaking, suggesting that "people can know what they are doing only after they have done it" (pg. 24) Weick suggests, and we concur, that when a story is told, the way it is told will be influenced by current events. We also would suggest that the selection of stories people chose to tell us were reflective of current organizational concerns. For this reason, we believe our analysis is still relevant to MITRE today; our initial discussions with executives at the company support this. However, the reader should keep the bias towards historical events in mind. This is particularly true when reading chapter 6, the CORBA case study, which describes events that occurred as many as five years ago.

This bias manifests itself in another way. A number of recent managerial initiatives have begun to address some of the problems discussed in this report. The foremost among those that we are aware of are the changes to the MITRE Technology Program, the establishment of the Technology Transfer Office, and the recent study and restructuring of the technology centers. While the tech center study was mentioned in our interviews, the creation of the Technology Transfer Office took place after our fieldwork had ended, and changes to the Technology Program were mentioned in only a few interviews. Because we were unable to gather comprehensive information about these initiatives, our understanding of how they work and their effectiveness is necessarily limited.

3. Uncertainty, Networks, and Integration: Theoretical Background

Specialization and coordination, the division of labor and integration are opposing poles that are studied in economics, management science, and organization theory. These issues have received considerable attention recently due to advances in theories of industrial organization, a renewed interest in economic institutionalism and transaction cost economics, and an increase in interactions between sociologists and economists.

This chapter provides the theoretical foundations for examining integration at MITRE. We begin by exploring the concept of uncertainty and then examine organizational integration from both an economist's and a sociologist's perspective. Next, we define and discuss networked corporations and technology-mediated integration, and conclude by suggesting a new definition for integration.

3.1 Understanding uncertainty

While uncertainty is a commonplace word, in the social sciences it is used in different ways by different authors, so we will begin by clarifying what we mean by

uncertainty. In his development of transaction cost economics, Oliver Williamson bases his discussion of uncertainty on that of Koopmans, who distinguishes between primary and secondary uncertainty. Primary uncertainty refers to situations of state-contingent uncertainty, while secondary uncertainty denotes a lack of state-related communication between decision makers. (Koopmans, 1957 cited in Williamson, 1985) To this, Williamson adds the assumption of guile on the part of both parties, creating the possibility of "strategic nondisclosure, disguise, or distortion of information." (Williamson, 1985, pg. 57) Williamson also discusses the role of strategic planning in decision making. He suggests that contracting parties may form their plans based in part on expectations about the other party's plans, leading to an additional degree of uncertainty. Both Koopmans and Williamson discuss situations where there is a change in state. Williamson's notion of uncertainty due to strategic planning – what he calls behavioral uncertainty – assumes that both parties have in mind a clear notion of what their preferences and goals are, and what a range of possible end states may be.

It is at this point – the notion of known states, preferences, and goals – that our differences with this line of argument arise. Neither Williamson nor Koopmans allows for the possibility of complete uncertainty about the range of possible states, or about actors' goals. Williamson assumes, as do most economists, that each player has clear goals in mind at the beginning of an economic interaction.

Frank Knight's classic *Risk, Uncertainty and Profit* is often cited as providing a distinction between risk and uncertainty. He states:

> "The practical difference between the two categories, risk and uncertainty, is that in the former the distribution of the outcome in a group of instances is known (either through calculation *a priori* or from statistics of past experiences), while in the case of uncertainty this is not true, the reason being in general that it is impossible to form a group of instances, because the situation dealt with is in a high degree unique." (pg. 233)

Knight's definition of uncertainty is often altered slightly, changing the emphasis on the different elements of uncertainty. For instance, Jon Elster, referring to Knight's definition, claims:

> "Risk is defined as a situation in which numerical probabilities can be attached to the various possible outcomes of each course of action, uncertainty as a situation in which this is not possible." (Elster, 1986, pg. 5)

This description of Knight's definition is lacking. Knight suggests that it is "impossible" to form a group of instances – meaning it is not possible to place instances in any category at all. If categories cannot be formed, we can hardly be expected to formulate guesses about the possibilities of outcomes, as some rational choice theorists suggest. (Elster, 1986)

Our notion of radical uncertainty rests on Knight's original definition. We refer to situations where the actor has no knowledge about what the instances, categories or outcomes might be. (Piore et al., 1995) It is this type of uncertainty – radical uncertainty – that characterizes many of MITRE's systems integration tasks, as well as the tasks of many other firms in the market today.

The relationship between uncertainty – radical or otherwise – and organizational integration is a subject addressed by many researchers. Most researchers argue that, in situations of uncertainty, organizations expand the boundaries of the firm and enclose more transactions within hierarchical relationships. (Podolny, 1994, Williamson, 1975, Chandler, 1977) The next section addresses this issues directly.

3.2 Economic and Sociological Approaches to Integration

3.2.1 The Economist's View

For economists, the word 'integration' has two slightly different meanings. The first refers to the process of coordinating activity within a firm; the second refers to the state of bringing transactions within the boundaries of a firm via vertical or horizontal integration.

Historically, the problem of integration arose with the division of labor. Adam Smith's story of visiting the pin factory demonstrates both the benefits of specialization through division of labor and the consequent need for integration. Smith describes visiting a pin factory where each step of the pin manufacturing process was carried out by a different person. (Smith, 1976, pg. 8) One person drew the wire, another straightened the wire, the next person sharpened the point, another attached the head of the pin, and the final person packed the pins in a box. Smith describes his amazement at the productivity of the entire factory. Dividing the tasks among a group of men allowed the factory to produce far more pins in total than if each man had done every step himself. Workers developed great skill at their particular task, both saving time by remaining with one task and increasing their output by developing special tools for each step. The resulting gains in productivity form the basic argument for the division of labor. The cost of this style of production is that someone must coordinate the work of each pin specialist. On their own, individual workers do not produce a useful product. Someone – either a manager or the efforts of the workers together – must coordinate the speed of the work, placement of tools, and type and amount of wire.

Milgrom and Roberts describe this problem succinctly:

> A fundamental observation about the economic world is that people can produce more if they cooperate, specializing in their productive activities

> and then transacting with one another to acquire the actual goods and services they desire. The problem of organization then arises because when people are specialized producers who need to trade, their decisions and actions need to be coordinated to achieve these gains of cooperation, and the people must be motivated to carry out their parts of the cooperative activity. (pg. 25)

From this perspective, the problem of integration is nothing more than coordination – ensuring that the right actions take place at the right time by the right people.

Economists also refer to integration as bringing actions within the boundaries of the firm, i.e., vertical or horizontal integration. Integrating, in this sense, is the act of acquiring firms or expanding firm activities into the market. This is the most frequent way that the word is used by economists – as an alternative to transactions or activities that take place in the marketplace. (Coase, 1988) Implicit in the idea of vertical or horizontal integration is the notion that hierarchical rules and managerial action will provide necessary coordination. In this way the two senses of the word – integration as coordination activity and integration as the expansion of a firm into the marketplace – converge.

In their theory of economic governance structures, transaction cost economists address the relation between uncertainty and organizational form. Transaction cost economics is based on Coase's suggestion that firms can reduce the transaction costs of certain actions. (By transaction costs, Coase means the costs of discovering prices and negotiating contracts.) A firm's boundaries will expand to the point where the marginal cost of coordinating economic activity within the firm is equal to the marginal cost of the same transaction in the marketplace. (Coase, 1937) Williamson builds on this theory by introducing two behavioral assumptions: bounded rationality and opportunistic behavior. (Williamson, 1985)

Williamson discusses three forms of economic organization – markets, hierarchies, and hybrids. In a market, prices provide coordination in a decentralized manner by providing a limited amount of information. (Hayek, 1945) Markets provide strong incentives for agents to respond to change and are mediated by the use of classical contracts. (Williamson, 1991) Hierarchies are characterized by the use of rules and fiat to provide coordination. In a hierarchy, incentives tend to be weak but the existence of a central control structure provides effective response to changes requiring internal cooperation. Hybrids, which Williamson uses to describe more networked organizations, fall somewhere between markets and hierarchies. They are characterized by incentive structures and levels of administrative control that fall somewhere between that of markets and that of hierarchies. Relational contracts, which are more flexible and allow for negotiation after the contract is signed, are used to support coordination. They are effective at responding to change that requires both single-party adaptation and cooperation between parties, but are not as resilient or responsive as markets are, and don't foster cooperation as efficiently as hierarchies. (Williamson, 1991)

Williamson's theory characterizes economic governance structures on three dimensions: asset specificity, uncertainty, and frequency of transaction. His argument relies on all three dimensions, with the greatest emphasis placed on asset specificity. (Williamson, 1989) Williamson argues that transaction costs are lower within the boundaries of the firm in situations of asset specificity, bounded rationality, and uncertainty. In Williamson's formulation, firm size expands until the costs of error and rigidity within a hierarchy (the internal transaction costs) are equal to the cost of transactions within the market place. He suggests that governance structures will be determined by the number of interactions, degree of asset specificity, and degree of uncertainty. (Williamson, 1985)

Uncertainty plays an important role in determining governance structures in Williamson's model. Without uncertainty in economic situations, the question of governance would be moot, as any future changes could be anticipated in a contract. Hierarchies are only preferable to markets in repeated interactions with asset specificity. (Williamson, 1985) As uncertainty increases, integration becomes a more preferable governance mechanism. Williamson suggests that hybrid forms of organizations are the most vulnerable to uncertainty. In Williamson's model the hybrid has neither the quick, unilateral decision making seen in a market setting nor the fiat seen in a hierarchy to provide timely responses to external changes. Williamson sees the hybrid model as requiring mutual consent between parties to respond to change, a time consuming process placing hybrid organizations in a weaker position than markets or hierarchies. (Williamson, 1989)

The discussion of governance structures addresses directly the questions of integration. Williamson's framework is, among, other things, a theory for both describing and suggesting when firms should be more integrated – both in the sense of internalizing economic transactions and in the sense of the type of coordination (relational or fiat) within the firm. However, this discussion follows the line of our previous discussion about integration – it neglects the problem of goal setting. Williamson adopts the neoclassical assumption that firms and individuals have established clear preferences and goals when they enter into an interaction or transaction.

Our discussion of economic approaches to integration has drawn heavily on Williamson, but other flavors of the theory of the firm (agency theory, property rights theory, and the firm as a nexus of contracts) have the same problem as transaction cost economics – no discussion of goal setting. (Alchian and Demsetz, 1972, Hart, 1989, Jensen and Meckling, 1976, Gibbons, 1998)

Economists conceive of the problem of integration as a situation where people want to exchange goods with a specific price, quality, and quantity. But in fact, the market involves decisions about what to make and how to make it. "Where in the market" a firm or job seeker is going, what the goal's of their actions are, and what services a firm is trying to provide are all questions as crucial as coordinating these actions. Sociologists provide a slightly more complex approach to this problem

3.2.2 The Sociologist's View

Sociologists deal with integration in a slightly more complex way. We will take Lawrence and Lorsch's discussion of integration as a basis for our discussion. Lawrence and Lorsch developed the idea of contingency theory in their 1967 book *Organization and Environment.* Their premise was twofold: 1) organizational structure is impacted by the environment, and 2) organizations are systems with different subparts that interact to influence the effectiveness of the organization as a whole. Lawrence and Lorsch focus on companies in three different industries – plastics, food, and containers. The study looked at the relationship between organizational sub-units and three aspects of the environment – the market, scientific knowledge, and the techno-economic (or production technology) environment. These sectors of the environment were assumed to correlate with organizational sub-units – sales, production, and applied and basic research. They suggested that dynamic environments require differentiated organizations, that differentiation must be balanced with integration, and that integration devices must match the demands of the environment. In general, the authors find empirical evidence to support this case:

> "We have found that the state of differentiation in the effective organization was consistent with the diversity of the parts of the environment, while the state of integration achieved was consistent with the environmental demand for interdependence. … The more diverse the

> environment, and the more differentiated the organization, the more elaborate the integration devices." (Lawrence and Lorsch, 1967, pg. 157)

Lawrence and Lorsch's argument is based on a specific connotation of differentiation. That is, differentiation within an organization means that the sub-units of a firm – sales, production, and research – will have different goals, different time and interpersonal orientations, and different formality of structure. In other words, in addition to playing a specialized role by focusing on a particular task, these divisions are understood to have different world views. A unit's goals and time orientation depend on the function of the organization: sales will have goals related to monthly or quarterly sales, while research will have goals related to innovation or patents. Interpersonal orientation and formality of structure are dependent on the amount of uncertainty found in an industry's market, scientific knowledge base, or production technologies. Increased uncertainty in these areas leads to less formal structures. Highly certain or highly uncertain environments will lead to task oriented interpersonal relations, while a relationship orientation will be seen in other settings.

Lawrence and Lorsch see conflict between sub-units as a natural consequence of differentiation; integration is seen as the process and state of resolving those conflicts. The authors define integration as "the quality of the state of collaboration that exists among departments that are required to achieve unity of effort by the demands of the environment" (ibid., pg. 11). In other words, different environments demand different types of integration. In fact, the authors find that all environments demand integration, but the hierarchical level at which integration occurs depends on the certainty of the environment. In uncertain environments greater information is needed to resolve conflicts. Because this information resides at lower levels of the hierarchy, conflict should be resolved there. This creates a demand for a different set of integration mechanisms than in certain situations.

Despite their distinction between mechanistic and organic organizations, and their discussion of different interpersonal styles, Lawrence and Lorsch present an essentially mechanistic discussion of integration. Lawrence and Lorsch rely on Burns and Stalker's findings that organizations in stable industries are more mechanistic – they rely on rules and make decisions at a higher level of hierarchy. Organizations in dynamic industries are found to be more organic, with wider spans of control, less formal procedures, and decision making at lower levels of the organization. Because Lawrence and Lorsch presume a clear mapping between external environmental sectors and internal organizational sub-units, they assume that each sub-unit's set of goals will be determined by its environment.

While this may be true of many organizations, it does little to help us understand how innovative organizations in situations of radical uncertainty can formulate the common goals necessary to develop a new product or process. If the organization is defining a new technical or market environment, or acting in a situation of radical and turbulent change, environmental signals may be impossible to discern or may be changing too quickly to be of use. In addition, it is difficult to transfer Lawrence and Lorsch's findings to organizations that are organized by project or technology rather than environmental sector.

It is worth noting that Lawrence and Lorsch's notion of integration does not require a convergence of world view. They claim that one of the most effective ways of resolving conflict is through confrontation and problem solving. This requires a limited amount of communication – agreement on the problem and eventually agreement on how to solve the problem. What matters in the end is that the conflict is resolved, but Lawrence and Lorsch are vague about how this occurs. In fact, Lawrence and Lorsch suggest that conflicting views are necessary not only because they reflect adequate sub-

unit differentiation but also because conflict, in their view, is necessary in a dynamic environment.

In a network corporation, the problem is not so much how to resolve conflict, which could be achieved through a number of mechanisms, but how to enable the transfer of knowledge and temporary convergence of world views, achieved through goal setting processes, about a particular problem. Integration for networks should not refer to conflict resolution but instead to the ability to easily access the right resource in a timely manner and to come to a consensus about the best ways to communicate. Differentiation may take place in a network setting, but it is found within smaller groups, not the large sub-units in Lawrence and Lorsch's model. The integration problem in a network setting is a broader issues centering on identifying processes for discovering a common goal.

One other perspective on integration that deserves mention here is Iansiti and Clark (1994) who build on the core competence/dynamic capabilities literature (Teece et al., 1997, Teece, 1994). Iansiti and Clark argue that external and internal integration capabilities are important requirements for a firm to develop its dynamic capabilities. The dynamic capabilities literature suggests that firms must be able to respond to external change quickly and flexibly utilizing core competencies effectively. (Teece, 1994). Iansiti and Clark, in a study of the automotive and computer industries, find that:

> "The capacity for integration, as we have defined it, is not only a function of the communication of information between individuals or of the effective coordination of activities between organizational sub-units. The essence of integration is the generation, fusion and accumulation of knowledge: the capacity to merge new knowledge about the impact of possibilities with deep accumulated knowledge of the complex existing capability base of the organization." (pg. 602)

Iansiti and Clark's discussion of knowledge anticipates our discussion of *technology-mediated integration* below. Note, though, that while this perspective sees integration as a task much larger than mere coordination, Iansiti and Clark do no more to address the problem of goal setting processes than any of the other perspectives we have discussed so far.

Podolny (1994) and Shane (1999) discuss mechanisms other than hierarchical integration that organizations use to deal with uncertainty. Podolny shows that investment banks utilize firm reputation and previous experience in deciding whom to work with on uncertain deals. Shane provides a similar argument in his discussion of reputation and social networks in the venture capital industry. In these two studies, external social relationships provide the information necessary for a firm to respond to uncertain environments.

This discussion of what economic governance structures will arise in uncertain situations leads directly to our next topic. Network organizations are seen to occur, according to network theorists, in situations of uncertainty because they convey a relatively greater amount of information.

3.3 Networked Organizations

There is a strong link between network organizations and situations of uncertainty. Baker states that "network (or organic) structures are better suited to complex, rapidly changing, and turbulent environments than hierarchical (or mechanistic) structures, which do better in stable, simple, routine environments." (Baker, 1992, pg. 405) Podolny and Page emphasize the "adaptability of this form to unanticipated environmental changes." (pg. 12) Powell describes networks as "light on their feet" –

perhaps less reliable, but better suited to respond to change. He states that "the open-ended quality of networks is most useful when resources are variable and the environment uncertain." (Powell, 1990, pg. 322) Networks often provide many more avenues for formal and informal communication than hierarchies and markets. Jay Galbraith points out the importance of information in situations of uncertainty:

> "the greater the task uncertainty, the greater the amount of information that must be processed among decision makers during task execution in order to achieve a given level of performance." (Galbraith, 1977, pg. 36 quoted in Scott, 1998, pg. 97)

For Galbraith, hierarchical mechanisms such as rules and schedules as providing only a limited amount of information; liaisons, taskforces, project teams, and matrix organizations provide more complex representations of information in Galbraith's view. The need for increased information makes networks an ideal organizational structure in situations of uncertainty.

Networks are also described as good at learning. Podolny and Page state that "they preserve greater diversity of search routines than hierarchies and they convey richer, more complex information than the market." (Podolny and Page, 1998, pg. 7). Powell suggests that "one of the key advantages of network arrangements is their ability to disseminate and interpret new information. … Kaneko and Imai (1987) emphasize this dynamic property of networks, noting that they are particularly adept at generating new interpretations; as a result of these new accounts, novel linkages are often formed." (Powell, 1990, pg. 325)[1] The ability of networks to preserve and generate routines provides them with an advantage in situations of frequent environmental change.

[1] The discussion of learning and routines comes out of the evolutionary economics literature. For more on this, see (Nelson and Winter, 1992) and (Cohen and Sproull, 1996)

What exactly do we mean by network organization? Any organization, or even any social relation, can be viewed as a network. Network analysis has gained much prominence in sociology recently, focussing on individual, group and organizational relations.[2] Generally these studies focus on particular aspects of relationships, such as time shared, emotional intensity, and reciprocal services.[3] In general, the literature focuses on networks characterized by a reliance on trust, frequent transactions, shared property rights, the use of relational contracts, tasks that are projects not functions, and an authority based on knowledge not on skill. (Powell, 1990, Podolny and Page, 1998, Baker, 1992)

The business literature includes studies of both networks of organizations (Saxenian, 1994) and individual organizations structured as networks (Baker, 1992). In the first instance, the focus is on joint ventures, strategic alliances, franchises, outsourcing, research consortia, and other multi-organizational relationships. In the second instance the focus is on firms that have intentionally removed most levels of the hierarchy, organize projects by teams or small groups, and emphasize work relations that cross whatever formal boundaries exist.

While we will address the notion of MITRE as a firm operating within a network of other organizations, our focus will be on MITRE as a networked organization. Baker's technical description is helpful in understanding this type of organization: "intergroup relations in a network organization are associated with heterogeneity – opportunities for contact – not with ingroup biases." (Baker, 1992, pg. 401) In other words, relationships are not limited to groups working on similar projects or technologies.

This definition provides a description of what we mean by a network organization, but it also suggests how integration can be understood in a network

[2] See (Emirbayer and Goodwin, 1994) for a review and analysis of this research.
[3] See for instance, (Granovetter, 1973).

organization. Baker describes integration as "the degree of coordination (or, in a broader sense, interaction) among organizational units, however differentiated." (ibid., pg. 400) He states that a network organization "is a social network that is *integrated* across formal boundaries."(ibid., pg. 398) Thus the emphasis is on the extent to which groups and individuals reach outside of their workgroup to collaborate with other groups, regardless of their position within the firm.

Three forces impact integration in a network – task characteristics, organizational characteristics, and environmental factors. Unique projects are particularly important for our purposes: "The production of unique products, for example, creates regular and frequent cross-group interaction because the mix of experts (e.g. product specialists) and client managers changes from deal to deal… Whenever products or projects are unique, require input from various experts, and must be solved creatively, an integrated organization is more effective." (ibid., pg. 402, citing Mintzberg, 1979) Baker cites two other aspects of integration in network organizations that are important for our purposes. First, he suggests that a highly differentiated organization can induce integration since no one team will be able to work alone. Conversely, "An intensified need for frequent communication and interaction across formal boundaries can be created by vague roles and responsibilities." (ibid., pg. 404) In other words, integration within networks can be fostered by the use of both focussed teams and vague responsibilities.

Baker's discussion allows us to understand organizations, as we will argue in the MITRE case, as networks, even in the presence of a formal hierarchical structure. While MITRE's formal structure is hierarchical, we will see that the managerial and strategic focus is to encourage cooperation across group boundaries as much as possible. However, Baker's discussion does no more to address the question of goals than Lawrence and Lorsch do.

In his survey of the literature on networks, Marshall Van Alstyne directly addresses the question of goals:

> "a network as an organization presupposes a unifying purpose and thus the need for a sense of identity useful in bounding and marshaling the resources, agents, and actions necessary for concluding the strategy and goals of purpose. Without common purpose, agents cannot discern either the efficacy or desirability of association or know whether actions are directed towards cooperative gains. (Van Alstyne, 1997)

While he doesn't discuss goals directly, Powell also notes the importance of identity and unity within networks:

> Networks should be most common in work settings in which participants have some kind of common background – be it ethnic, geographic, ideological, or professional. The more homogenous the group, the greater the trust, hence the easier it is to sustain network-like arrangements." (Powell, 1990, pg. 326)

Not all theorists agree that networks rely on cohesion or common goals. In fact, Castells claims that a network enterprise is "that specific form of enterprise whose system of means is constituted by the intersection of segments of autonomous systems of goals." (Castells, 1996, pg. 171) But even Castells admits that the performance of a network will depend on "the extent to which there is sharing of interests between the network's goals and the goals of its components." (ibid)

So it seems clear that network forms of organizing require some degree of internal cohesion. However, it is still not clear how that cohesion – either cultural or goal related – is established.

3.4 Integration and Goal Setting, and Identity

So far our discussion has centered on integration; we will now turn briefly to a discussion of goals in organizations. Aldrich and Marsden describe the importance of goals in our understanding of organizations:

> Goal orientation and deliberate design of activity systems are, however, often cited as distinctive features discriminating between organizations and other collectivities. Organizations are purposive systems, and to an observer, members of organizations behave as if their organizations have goals. Concerted collective action toward an apparent common purpose distinguishes organizations from social units such as informal groups, friendship circles, and audiences or mass publics" (Aldrich and Marsden, 1988, pg. 362)

Goals may serve different purposes in organizations. The various theoretical schools for understanding organizations conceive of goals in different ways, but each captures a different aspect of the roles that goals play. Goals can guide decision making and action, serve to motivate organizational members, or play a symbolic role with entities in the organization's environment such as public, clients, or governments. (Scott, 1998, chap. 11) In addition to these roles, a goal may be created after the fact to rationalize organizational action. (Weick, 1979)

The question of how goals are formed depends in part on one's theoretical perspective. This discussion is based on acceptance of the idea that organizations are influenced by their environments, that internal organizational sections influence goals, and that goals change as they are discussed, developed, and enacted.

Cyert and March suggest that organizational goals are formed by a negotiation process among members of an organization's "dominant coalition." The members of the dominant coalition are determined by their ability to successfully deal with uncertainty,

their substitutability to the organization, and their centrality in the organization. (Hickson, 1971, cited in Scott, 1998) As environmental uncertainty increases, more units of the organization gain entry to the dominant coalition. (Thompson, 1967 cited in Scott, 1998) Changes in the dominant coalition which result from environmental changes, lead to changes in organizational goals. (Fligstein, 1990 and Perrow, 1961) The negotiation process within the dominant coalition leads to the creation of organizational goals that reflect different internal interests, but don't reflect the goals of the organization per se.

3.4.1 Goals and Identity

A number of writers discuss the importance of vision, identity, mission and culture in organizations. Fransman (1998) discusses the idea of vision to explain the success that some firms have in utilizing knowledge to respond to external change. Collins and Porras (1994) argue that vision, not technology or charismatic leadership, leads to long term corporate success. In his discussion of organizational culture, Schein addresses the importance of identity and mission. Schein's discussion of goals is intimately tied to his notion of mission. He sees mission as a crucial concept for any organization:

> "Every new group or organization must develop a shared concept of its ultimate survival problem, from which it usually derives its most basic sense of core mission, primary task, or reason to be." pg. 53

> "one of the most central elements of any culture will be the assumptions the members of the organization share about their identity and ultimate mission or functions. These assumptions are not necessarily conscious but one can bring them to the surface by probing the organization's strategic decisions." pg. 56

Schein sees the existence of common goals as a high priority for organizational survival and success. He goes as far as suggesting that without a mission, organizational debates about goal setting and strategy will lead to dissolution. His understanding of how

goals are developed pulls from the dominant coalition model, but introduces negotiations about organizational goals:

> "Internal debates start among members for whom the priorities among the different functions are different, forcing the organization to confront what collectively it has assumed to be at the top of this hierarchy. If no such overarching priority is found, the group may splinter and even dissolve. On the other hand, if the debate leads to an affirmation of what the group's ultimate mission and identity are, a strong cultural element has been formed, one that will carry forward through the beliefs and assumptions of senior management." pg. 54-55

Schein does not believe that a common mission necessarily leads to common goals for all organizational members. In fact, he explicitly recognizes the variety of goals within organizations, and emphasizes the need for discourse about the connection between mission and goals.

> "Consensus on the core mission does not automatically guarantee that the members of the group will have common goals. The mission is often understood but not well articulated. To achieve consensus on goals, the group needs a common language and shared assumptions about the basic logical operations by which one moves from something as abstract or general as a sense of mission to the concrete goals of designing, manufacturing, and selling an actual good or service within specified and agreed upon cost and time constraints… Mission and strategy can be rather timeless, while goals must be formulated for what to do next year, next month, and tomorrow. Goals concretize the mission and facilitate the decisions on means. In that process goal formulation also often reveals unsolved issues or lack of consensus around deeper issues." pg. 56

For Schein, the process of developing a common language and shared assumptions is integral to managing internal integration. Implicit in his argument is the suggestion that culture is formed, in part, via organizational discussion about goals. In addition to these processes, defining group boundaries, distributing power, developing norms of friendship,

defining rewards and punishment, and developing ideology are also essential elements of the integration process.

3.4.2 Culture and Identity

Schein's discussion of mission and goals is part of a much larger examination of culture in organizations. Schein's definition of culture has three components. The first is shared understanding among members of the culture about a range of topics – ways of interacting, group norms, espoused values and philosophy, skills, mental models, and root metaphors or integrating symbols. The second element that of structural stability among members in the organization, and the final aspect is a "larger paradigm or gestalt that ties together the various elements." (ibid., pg. 10) Managers have a great deal influence, though not total control, over organizational culture. In fact, a large portion of his book is dedicated to case studies and discussion of the ways that management can influence culture to achieve organizational goals. A major part of organizational leadership is seen to be management of culture. Conflict within the organization over cultural issues can lead to performance difficulties for the organization, although in a turbulent environment, so degree of conflict can be helpful as a source of adaptation or learning. (ibid., pg. 68)

Kunda (1992) examines the question of managerial culture in much greater detail. He suggests that as society has become more bureaucratized, managers have tried to gain more control over the innards of a person – control over self, values, and attention. The focus on corporate culture as a managerial tool emphasizes this – that corporations can explicitly attempt to manage their culture with the goal of creating greater identity between their employees and the organization's goals. This control over identity can be used both internally and externally. In a study of corporate sponsorship of museums,

Amy Ninetto shows that corporate identity has both external and internal uses. A company's identity can be used to communicate with its customers and suppliers as well as to communicate with employees internally.

3.4.3 Interpretive Processes

> "A common language and common conceptual categories are clearly necessary for any other kind of consensus to be established and for any communication to occur at all." (Schein, 1992, pg. 75)

What is particularly interesting about Schein is the emphasis he places on the process of identifying organizational mission and goals. His attention to the development of common language and shared assumptions reflects an approach to organizational action and theory seen in research by Michael Piore, Richard Lester, and Kamal Malek at the Industrial Performance Center at MIT. This interpretive approach to product development captures much of what we refer to as a "discursive process of goal setting."

What characterizes a discursive process? Understanding what we mean by the term 'discursive' requires a dip into literary and linguistic theory. There we see two ways of understanding interaction – interpretive and analytic approaches. Previous research characterizes this distinction, as well as the distinction between pragmatic and hermeneutic interpretation, and discusses its application to management. We summarize this research briefly with particular attention to identity and integration.

Our definition of discursive action relies in part on Charles Taylor's idea of dialogical action. (Taylor, 1993) Taylor states that the "notion of coordination fails to

capture the way in which some actions require and sustain an integrated agent." (ibid., pg. 51) He suggests a different category of action –dialogical action – to describe social actions. "An action is dialogical … when it is effected by an integrated nonindividual agent. This means that for those involved in it, its identity as this kind of action essentially depends on the agency being shared. These actions are constituted as such by a shared understanding among those who make up the common agent." (ibid., pg. 52) Taylor suggests that an individual's identity with respect to a larger group is realized through dialogical action:

> "a great deal of human action happens only insofar as the agent understands and constitutes him or herself as an integral part of a 'we.' Much of our understanding of self, society, and world is carried in practices which consist of dialogical action… This means that our identity is never defined simply in terms of our individual properties. It also places us in some social space." (ibid)

The suggestion is that the portion of our identity that extends beyond our selves is formed – 'carried' in Taylor's words – through dialogical action.

Taylor's notion of dialogical action incorporates the ideas of shared context and shared agency. Our discussion makes two modifications to this idea. The first is to emphasize that parties only enough of a common background to enable conversation; they need not share occupational or social backgrounds. The second is to add an element of change through time. As one participates in dialogical actions, each party's ideas about the action in progress begin to change, and this changed context than impacts future interactions.

The idea of interpretation relies on a world view that is ambiguous and contingent. Categories used in conversation or projects are understood to be socially constructed rather than reflections of a fundamental or natural division. Practices and interactions are

understood to occur in time, developing and changing as interactions take place. All parties to an interaction are understood to appeal to a background, or habitus, or common beliefs, experiences, and skills, that cannot be explicitly described. (Bourdieu, 1977). Malek (forthcoming) makes a distinction between pragmatic and hermeneutic processes of interpretation. In the pragmatic mode of interpretation, there is a particular topic or purpose to the conversation that grounds the interpretation occurring between the parties. In the hermeneutic process of interpretation, there is no notion of a dialogue as a purposive act.

Interpretation might be seen as different individuals with different world views engaged in an ongoing process. This process may be conversational or may be centered on doing a project, identifying a goal, and accomplishing a task; or it may not have a particular purpose at all. Within this process, as the parties spend more time talking, passing ideas back and forth, the categories that they use to analyze and understand a situation shift slightly, as do their understandings of values and goals. Neither person needs to have had a particular world view or concept before the conversation begins. Clarification and change that occurs within the discursive process may reflect elicitation of tacit knowledge, or may reflect the construction of new knowledge as a result of interaction between the two individuals.

Interpretive approaches to management are seen at three levels of analysis: 1) individuals acting in an "interpretive" manner as border-crossers, interpreters, or 'cocktail hostesses;' 2) groups or councils as locales for interpretive discourse; and 3) organizations acting to "interpret" the needs of the market with respect to new, as-yet-unconceived-of actors. In addition to the level of analysis, Piore et al. address the question of *when* in a product or organizational life cycle interpretive approaches are most likely to arise. One

suggestion is that interpretive approaches are particularly useful at the beginning of a product life cycle when there is a great deal of uncertainty about what the product will be, who the consumers are, and how the product will be used. Interpretation at this stage might occur between designer and potential consumer, between designer and engineer, and between the firm and the market more generally, or might occur at all three of these levels.

Another point at which interpretation is seen is in the interaction between different firms within the same industry. The fashion case study (Piore et al., 1997b) sees particular individuals acting as interlocutors or interpreters between different firms. These individuals hold a central position within networks of firms, but their role goes beyond merely acting as a gatekeeper or router of information. In the process of visiting one firm and moving on to another firm, they reinterpret the developments and designs of the individual firms, forming trends that other firms in the network themselves reinterpret. Yet another place that interpretive action is seen is the model of a manager as orchestra conductor or cocktail hostess, passing information from one part of the conversation to another part, ensuring that "the right people" talk to each other about "the right things at the right time."

Two examples of 'market' interpretation are found in the fashion world (Piore et al., 1997b) and in medical devices. (Piore et al., 1997a) The first was an iterative process of developing a medical sensing technology. While the technology was developed initially to monitor heart action, a lengthy process of product development led to the creation of a product for monitoring consciousness during surgery – a demand that had not existed prior to the introduction of the new sensing device. Interpretation, here, occurred between the medical devices firm, which did not realize its technology might be used to monitor patient consciousness, and professional anesthesiologists, who did not realize patient

consciousness needed to be monitored.[4] The second is the interaction between Levi's and the marketplace during the development of baggy jeans. Levi's had initially introduced baggy jeans after noticing a "ghetto" trend to wear baggy clothes. After their sales started to fall, they initiated a major marketing campaign to push the baggy look. While sales of baggy jeans picked up again, Levi's was not able to differentiate the impact of their marketing campaign from street fashion trends.

3.5 Technology Mediated Integration

Information technology is an important topic to consider in understanding organizational integration. Supporting integration is a common use of information technology. While IT used to be seen as a "backoffice" tool, used to support accounting and production divisions of a company, the use of IT has become a major strategic issue for mid- and large- size companies, regardless of their product area. In addition, the IT industry has provided many of the recent models for network corporations (Saxenian, 1994). A particular reason for our focus on the role of IT in organizational integration is its importance to MITRE. Information technology is both the major technical domain at MITRE and a major tool for creating integration within the company.

[4] Anesthesia has three effects on a patient - paralysis, pain relief, and amnesia. On rare occasions, a patient will only experience paralysis and pain relief- leaving them unable to notify surgeons that they are in fact conscious throughout surgery. The medical device discussed here allows the anesthesiologist to ensure that patient is not conscious during surgery.

The IT industry, including semiconductor, computer manufacturers, network, and software firms, deals with some of the most rapidly changing technology on the market. The demand for technical and organizational, integration, is extremely high. In part because of this, some of the more innovative ideas about how to provide and achieve integration come out of this business. While engineering standards organizations have been in existence since at least 1918,[5] the importance of open standards has gained the general public's attention only recently with the advent of the World Wide Web.[6] Previously arcane organizations have come to hold great power in shaping the future of the technical marketplace, as evidenced in the current debate over managing domain names on the Internet. (US Department of Commerce, 1998) Finally, ideas which gained currency in the IT world – such as constructivism and emergence, are reflected in integration mechanisms such as discursive processes and standards processes, and support new goals of fostering decentralized integration.

The first aspect of information technology that concerns us is the impact on transaction costs between and within firms. One common suggestion about IT is that it will lower transaction costs between firms, favoring markets over hierarchical forms of organizing, and possibly leading to disintermediation in the marketplace. (Malone et al. 1987, Ciborra, 1993) The idea is that networks, databases, and user-accessible interfaces, as well as newer technologies such as agents, natural language processing, and voice recognition, reduce the cost of finding, collecting, sorting, and viewing information. Ciborra states that "The information system of a business organization can be transactionally defined as the network of information flows that are needed to create, set up, control and maintain the organization's constituent contracts." (Ciborra, 1993, pg. 116)

[5] The American National Standards Institute was founded in 1918. (See web.ansi.org/public/about.html)
[6] For a discussion of standards in the IT Industry see (Kahin and Abbate, 1995)

Malone et al. suggest that IT should generally increase the use of markets for economic activity because of reduced coordination costs. They also suggest that IT should be helpful for conveying information about complex products. Following Williamson, they see hierarchies as used in situations of high asset specificity and complex product descriptions. In their initial formulation, IT is used to transfer information in the product development process, and to coordinate action in product distribution, particularly through the use of just-in-time delivery services. Their "electronic integration effect" is the increased use of IT to provide tighter coupling between and within organizations – relying, mostly, on shared or linked databases.

Bailey (1998) suggests that the impact of IT is somewhat more complex than this, at least with regard to disintermediation. He shows that intermediaries still play an influential role in selling goods online, particularly with respect to pricing and aggregation, and that pricing strategies are more complicated than would be expected from a simple transaction cost model.

In addition to its impact on transaction costs, IT supports discursive processes within firms. Like any technology, IT both influences and reflects the environment in which it is used. A number of theorists discuss this loose relationship between technology and structure, recognizing that "technology is not only strongly shaped by social and political processes but also embodies crucial social assumptions in the so-called technical system." (Scott, 1990, pg. 125) Coyne describes what he calls a pragmatic view of technology when he states that "We are shaped by our technologies as much as we fashion them." (Coyne, 1995, pg. 7)

We suggest that the interaction between information technology and organizational form can best be described as structurational. By structuration we refer to the reflexive relationship between technology, human action, and environmental institutions. In plainer

words, people choose what to do based on what they know and believe. Their choices, particularly about technology, influence what they will know and believe in the future. The result is a (messy) cycle through time of acting freely within constraints, changing the constraints, and acting freely within the new constraints.[7]

This structurational relationship is particularly powerful when dealing with communication technologies. In Orlikowski's discussion of *interpretive flexibility* of technologies, she refers to the "degree to which users of a technology are engaged in its constitution (physically and/or socially) during development or use." (Orlikowski, 1992, pg. 409) Communication technologies, and particularly information technologies, are extremely flexible by this definition. Not only does MITRE test its technologies internally, but even fully developed technologies, such as email, databases, and web-based tools, provide users with a huge range of customization possibilities. The fact that these technologies are used for communication, and they are easily adapted to user needs creates a reflexive pathway between technology and structure that is of much higher frequency than for other technologies.

The ability of IT to influence the nature of organizational integration is quite clear. Winograd and Flores suggest that computers may be effective as tools to manage the networks of conversation between different people engaged in productive activity. They state "In most work environments the coordination of action is of central importance. The conversational dimension permeates every realm of coordinated activity, whether it be computer programming, medical care, or selling shoes." (Winograd and Flores, 1986, pg. 158) Winograd and Flores see IT as a way of allowing speech acts to take place via computer, monitoring completion of tasks, keeping track of temporal relations, providing a way to view the network of communications, and automating recurrences of

[7] See Giddens (1984) for a discussion of structuration and Orlikowski (1992) for a discussion of structuration applied to technology.

propositional content and functions. The explosion of intranets and business applications provided over the Internet demonstrate the viability of this approach.

Computer objects – databases, models, documents, and programs – can directly influence integrative discussion. Carlile describes the important of computer-related boundary objects between different sub-units within an organization. He suggests that "objects" that are conceptually flexible, such as easily modified databases, etc., make more effective boundary objects. (Carlile, 1999)

But our reflexive pathway truly does go both ways – the use of technologies influences the way firms deal with and think about integration. Information Technology is changing our idea of integration, in part because much IT now is used to support and create organizational integration. IT is forcing different conceptions of integration to come together. The technology itself doesn't force a particular idea, but the technology does force consideration that there is an idea there. IT, particularly in the context of relative ease of design and implementation, changes with the desires of firm managers, consultants, and users – in other words, the role that technology plays is endogenous to our understanding of how the organization works.

3.6 Reexamining integration

This chapter has presented a number of ways of understanding integration in situations of uncertainty – situations where so little is known about future outcomes that it is not possible to even create potential categories to describe these outcomes. Before introducing our own discussion of integration in these circumstances, we will recap these different perspectives.

Williamson predicts that we will see greater integration (via hierarchy) in situations of uncertainty. In his discussion of hybrid organizations, which are adept at responding to both coordinated and individual change, Williamson emphasizes the inability of hybrid organizations to provide the quick responses needed in uncertain situations because of the time-consuming negotiations required by relational contracting. The other theorists we discussed see a different relationship between integration and uncertainty. Lawrence and Lorsch suggest that we will see less formal structure in situations of uncertainty. Perrow states the same principle slightly differently:

> "when faced with a high degree of uncertainty about what would sell and an inability to immediately shape and define the market, firms had to forgo the economics of vertical integration and centralization, and decentralize and contract out for services." (Perrow, 1986, pg. 184)

Baker and Podolny suggest that network organizations provide the adaptability needed in uncertain situations.

The economists' discussion of integration is largely about coordination, while sociologists address the problem of connections between internal structure and external environment. Our discussion of integration adds to these ideas by introducing the problem of goal-setting processes to the subject of integration. In addition to determining what mechanisms to use to get different actors to work together, firms and individuals within a marketplace face the problem of developing goals and strategies for achieving those goals. Economists deal with misalignment of goals but don't deal with the process of identifying goals. The sociological conceptions we have examined discuss goal-setting mechanisms and establish a link between goals and organizational culture, but we still do not have a coherent idea of how organizations establish goals in situations of uncertainty.

Imagine that Adam Smith's pin factory manager is trying to do the same task for a far more complex product. Recall our brief discussion of the medical device designed initially to measure heart signals and eventually used to assess patient consciousness. Suddenly the integration task requires far more than just coordination. What is the purpose of the new product? How will it be used and who will use it?[8] These questions arise much more frequently in an environment of rapid innovation. Integration then involves a set of complex tasks that go beyond just coordinating action.

We suggest that integration in situations of uncertainty requires not just coordination, but an ongoing, discursive process centered on eliciting project and firm goals. Integration does involve the act of coordinating different pieces of a system, but it also involves creating a common mindset among individuals within an organization. It is an interpretive process focussed around both the need to provide coordination and the need to identify goals. Integration involves the development of a common language, the ability to define common goals, and the creation of a common understanding and coordination of activities necessary to achieve that goal. A crucial part of the background needed to foster discursive processes is a sense of identity. The sense of identity is both relied on and changed during interpretive processes. The state of integration can be determined in part based on the ability of a firm's sub-units to cooperate easily.

The goal-setting process is a discursive one. Like any linguistic process, it relies on a common background that changes even while the discussion is taking place. This

[8] Uncertainty of the type seen in the medical device study is extremely common in the World Wide Web domain. Web start ups often change their business plans radically in their first months of existence. One site started out as a financial information site and changed, over a period of a few months, into a discussion site about the online art community.

suggests that integration is a process, not a state. It also indicates that integration requires knowledge sharing and communicative exchanges that create opportunities to define and identify goals.

Integration is a larger issue than just determining firm structure and boundaries. In addition to the question of benefits of specialization vs. costs of integration, firms must integrate disparate kinds of knowledge. Integration must cross technical and operational boundaries, disciplinary or experiential domains merging different social and thought worlds.

This is not to say that a clear description of goals is needed before collective action within companies or between organizations, can proceed. Our suggestion is only that successful integration between different parts of a company, or between firms engaged in joint projects requires an ongoing dialog about the goals of the interaction.

When we reframe the question of integration to include both the process of coordination and the process of goal setting, the range of appropriate mechanisms for fostering integration is widened. Suddenly, rather than just bringing transactions within a firm's boundaries, coordination and goal setting involves collaboration between firms on projects and products, entry of third parties such as standards organizations to help facilitate goal setting, and the use of councils to create goal setting forums.

MITRE is a good case study of integration mechanisms because it is a firm that cannot integrate in the ways that we often think about integration – by acquiring other firms or by engaging in joint ventures. Instead, it has developed a range of alternative mechanisms for integrating – we characterize many of these mechanisms as interpretive in nature. MITRE demonstrates many types of integration, including cooperation with clients and suppliers (engineering firms that supply technology), crossing internal

boundaries, and participating in the strategic planning of other organizations. We will examine these mechanisms in detail, but first some background about MITRE is in order.

4. Background on MITRE

MITRE's role as a Federally Funded Research and Development center can be understood at two levels. The first is the successful implementation of individual projects; the second, transcending these projects, is a more general and ongoing function of integrating across services, programs, user and acquisition communities, and military and technical communities. It is this second function that identifies MITRE uniquely within the defense community, and MITRE's ability to survive and prosper depends on the degree to which it can sustain and strengthen its identity and performance in this area.

Work at MITRE is organized around projects. This makes MITRE very different from the manufacturing or service organizations which are the subject of most of the management literature, where the focus is on the production of a continuous stream of output. As production in this classic sense of the term has become increasingly automated, and even in traditional manufacturing and services firms the emphasis has shifted to the development of new products, project organizations have been recognized as a distinct type. These organizations are seen as prototypical of the post-industrial age into which we are moving. The recent emphasis in the management literature on clear

mission statements and a focus on core competencies is largely an outgrowth of this trend. But in the literature there is still relatively little recognition of distinctions among projects or project organizations. MITRE as a project organization is clearly very different from the research and development divisions of an automobile company seeking to shorten the product cycle or even organizations in industries where projects have been the predominant form of work from time immemorial such as law, banking or construction firms.

The difficulty of characterizing its projects creates a variety of issues for MITRE, but foremost among them is what can be termed an "identity problem". While a strong sense emerged in our interviews that MITRE has a distinct culture, or personality – a sense shared not only by us but by the company respondents as well – it is extremely difficult to pin this down and say exactly what this culture is. Hence it is difficult to manage the evolution of the company over time, as the emphasis in the management literature on mission statements and core competencies suggests one should. Indicative of this problem is the emphasis that MITRE's own historians place on discrete projects; rather than attempt to characterize the company and its evolution over time, the company's official history simply describes a prototypical project in each époque. (Dyer and Dennis, 1998) We believe that the key to better integration at MITRE is to clarify and interpret the company's identity. To do so one needs to comprehend the underlying nature of the company's projects – what binds them together and makes it appropriate that they all be placed in one organization with a shared managerial structure and drawing upon a common pool of human resources.

This chapter provides a brief history of MITRE, a description of its role as a federally funded research and development center, a description of the firm's mission and organizational structure, and concludes with a discussion of recent changes in MITRE's environment.

4.1 A Brief History of MITRE

MITRE was established in 1958. Its original purpose was to serve as the systems engineer to the United States Air Force for the implementation of SAGE (Semi-Automatic Ground Environment), a ground-based air defense system designed to protect the United States against an over-the-pole attack by the Soviet Union. MIT's Lincoln Laboratory had done much of the original engineering work on SAGE, developing the networks, software, and computer memory needed to track multiple targets[9]. As the development work was completed, the Department of Defense looked for a company to act as systems engineer for the project, overseeing integration of the radar, weapons, and command and control system. DOD rules precluded individual companies from participating in both oversight and the more profitable manufacturing function. As a result, no suitable contractor could be found for the systems engineer role and MIT was reluctant to have Lincoln Laboratory participate in such an operations-oriented task. DOD thus asked MIT and Lincoln Laboratory to create an independent, not-for-profit corporation called MITRE, whose original staff consisted largely of ex-Lincoln employees.

At the time that MITRE was formed, systems engineering was still a relatively new discipline. The firm's purpose was to develop detailed objectives for large-scale, complex systems and their components, to make systematic trade-offs between conflicting system goals, and to create the technical specifications to ensure that the system worked.

[9] Much pioneering work in the computer science field was done to support this system, including the creation of the first graphical displays, core memory, and real-time machines. For a history of the SAGE project, see (Hughes, 1998 or Jacobs, 1986)

The system engineer's role is similar in many ways to that of a prime contractor in the aviation industry or a general contractor in the construction industry. The difference is that in the case of military contracts there is often *also* a prime contractor who bears final responsibility for the product. But because of the risks associated with monopsony in military procurement, the government hires a third party (a) to ensure the quality and capability of the purchased system and (b) to ensure that the system works as a whole and is designed to the best possible capability, rather than being designed to take advantage of technology that the prime contractor favors. As we shall see, MITRE's role has taken on additional dimensions over the years, but the basic systems engineering function remains a core capability of the company.

MITRE today remains an independent, not-for-profit corporation, with current operating revenues of just under $500 million. The company has about 4000 employees; approximately two thirds are members of the technical and professional staff. Most of MITRE's business still originates from the Federal government, more specifically from the DOD and the intelligence community. The company's other large sponsor is the Federal Aviation Administration.

In the defense domain, the U.S. Air Force remains MITRE's leading source of contracts. The largest single client, accounting for about 40% of its total work, is the Air Force Electronic Systems Center (ESC) at Hanscom Air Force Base in Bedford, MA. (ESC's precursor was MITRE's original client for the SAGE system.) Other national security clients include the other services, the Joint Staff, the Combatant Commands, and several intelligence agencies.

The majority of MITRE's employees are located in Bedford, MA and Washington, D.C. The remainder are housed on or near the military bases that MITRE is

serving and, occasionally, in the field with users of MITRE systems. MITRE has staff at about 50-60 sites around the world.

4.2 MITRE's Federally Funded Research and Development Centers

MITRE is one of a number of special non-profit organizations created since the end of the Second World War to provide specialized technical support to the Federal government. The term of art for these organizations has changed over the years, as have the particular contractual structures within which they operate, but the basic function has remained the same. These organizations meet government demand for specialized technical inputs that cannot be as effectively provided by either permanent government employees or for-profit contractors. The current incarnation of this class of organizations is the Federally Funded Research and Development Center (FFRDC). Each FFRDC has a major government client, and FFRDC activities are generally confined to a particular set of technical areas or goals.

Today there are almost 40 FFRDCs, serving the Department of Defense, the Department of Energy, and several other Federal agencies. Universities or other non-profit institutions administer the majority of these FFRDCs. MITRE operates three FFRDCs: the Command, Control, Communications, and Intelligence (C^3I) FFRDC for the Defense Department; the Center for Advanced Aviation System Development (CAASD) for the Federal Aviation Administration; and the Tax Modernization Center, for the Internal Revenue Service.[10] The research described in this report focuses primarily on the DOD

[10] DOD FFRDCs are of three types: systems engineering (of which the MITRE C^3I Center), research and development, and studies and analysis. CAASD is a research and development center. The Tax Modernization Center is a new FFRDC and the only IRS FFRDC, so does not yet fall into any category.

FFRDC, which currently accounts for the majority of MITRE's funding, staff, and projects.

The special character of FFRDCs as intermediary institutions between government and the private sector is reflected in descriptions of MITRE that stress its detailed knowledge of both the defense and technical domains and its objectivity as a non-profit entity without commercial ties to industry or potential conflicts of interest. As an official history of the company states:

> MITRE's unique capabilities include not only a very high level of technical competence combined with what one admiring customer calls 'profound knowledge' of the systems and organizations into which new technology must be inserted, but also, equally essential, an impartial and unbiased perspective in evaluating technological choices. (Dyer and Dennis, 1998, p. 4)

The rationale for creating FFRDCs (and for the MITRE FFRDC specifically) is that these capabilities could not be assembled any other way. It is unlikely that the government itself could assemble such a team, given civil service salaries and hiring restrictions. It is more likely that a private contractor could collect such expertise, but the role of trusted advisor and agent requires privileged access both to sensitive government planning information and to proprietary commercial information that could give a private contractor a significant commercial advantage over its competitors. The FFRDC role of 'honest broker' helps to ensure that the government's technical interests are advanced and protected.

A key attribute of the FFRDC structure is to help provide continuity to the government's technical decision-making – a particularly important feature for military

---

However, its work could be characterized as systems integration of very large scale software systems. (Personal communication with Peter Sharfman on August 6, 1999.)

systems, which may remain technically active over long periods. Maintaining uninterrupted technical support over the life of such systems is of considerable value to the military which, because of its own fairly high rates of personnel turnover, has a relatively unreliable institutional memory. It would be difficult for the government to enter into a long-term relationship with a private contractor without conferring unfair competitive advantage.

The privileged role conferred upon FFRDCs brings with it some significant constraints – FFRDCs are limited in the amount and type of work that they can do. They are not permitted to compete against industrial contractors for government business, they cannot manufacture products or provide 'routine' services, and they are not allowed to undertake work that is not consistent with their mission and capabilities. In addition, the total number of employees and the total budget is capped by Congress.

Some of these constraints also apply to the organization administering the FFRDC, and MITRE's status as an FFRDC has sometimes been problematic. For-profit government contractors such as BDM and SAIC[11] complain that defense FFRDCs such as MITRE compete in areas beyond those legally prescribed. These contractors argue that FFRDCs take unfair advantage of their special relationship with sponsors to obtain non-FFRDC work. (Mintz, 1995, Sugawara, 1989) In the 1980s and early 1990s, as MITRE took on more non-defense work in the environmental and social services areas, public pressure around these issues increased. Congressional hearings on the status of FFRDCs in 1996, prompted in part by contractor lobbying, were strongly critical of FFRDCs. (House, 1996) Anticipating criticism from Congress and DOD misgivings about its diversification, MITRE decided to spin off almost all of its non-FFRDC businesses into an independent non-profit corporation, Mitretek Systems. (Black, 1995, Day 1995, Day, 1996) Mitretek subsequently created a for-profit subsidiary, Concept Five, focusing on

commercial enterprise integration software whose technical roots lay in earlier work done by MITRE itself. (Krebs, 1999) The issue of diversification at MITRE is closely related to the problem of integration that is the focus of this research, and we will return to it later in this report.

4.2.1 Mission and Organization of the C^3I FFRDC

4.2.1.1 MITRE's mission

MITRE's C^3I FFRDC is formally designated as a 'systems engineering' FFRDC. Unlike 'research and development' FFRDCs such as Lincoln Laboratory, MITRE's special skills lie not in a particular technology but in the ability to create robust, reliable systems that involve multiple technologies. The term systems integration has many interpretations, and in the course of our interviews at MITRE we found many different types of projects, including prototype creation, source selection, systems engineering, and systems enhancement, technical management, and system design. MITRE itself describes systems integration as the creation of performance specifications, including those affecting operations, interfaces (between technical systems, and between technical systems and people), functions, reliability, and maintainability. (MITRE, 1990) In the process of creating these specifications, MITRE might undertake a risk assessment and discuss alternative technical approaches with contractors and users. Additional tasks might include developing strategies for technology insertion (adding a new technology to an existing system) and modernization. MITRE develops new technical approaches to problems such as communication between different modeling and simulation programs, the effective use of military GPS signals, information security tools, and tools for remote collaboration. MITRE does not market these technologies – they are either used on a

[11] BDM and SAIC are for-profit government contracting companies.

one-time basis or are transferred to a contractor or to a standards organization for market development.

In addition to the tasks described above, performed in the context of specific projects, MITRE's charter with the DOD requires the firm to assist "the DOD to accomplish its C4ISR[12] mission." (MITRE, 1998a) This responsibility is particularly important for understanding the company's identity. MITRE is expected to choose its projects and actions in a manner that supports the DOD in creating an integrated military command and control system. In the process, it draws upon an "end-to-end understanding of the C4ISR mission area with emphasis on systems acquisition (including technical analysis support to source selection), integration of commercial and military technologies, system of systems functions, C4ISR architectures, and interoperability." (MITRE, 1998a) It is particularly important to note that, while MITRE's charter creates a responsibility to support the DOD C4ISR mission, no funds or projects are dedicated solely to this purpose; DOD expects this mission to be met through the vehicle of more specific, focused projects.

This broad responsibility is one aspect of MITRE's larger integration mission – its efforts to provide not just technical integration services but to assist the federal government in the use of technology in the nation's interest. This larger mission sometimes extends beyond even the limits of the DOD, FAA, and IRS. For instance, the company has recently been advocating the importance of 'critical infrastructure protection' as a means to combat a major vulnerability of the United States.[13]

[12] Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance

[13] The control systems for many water, energy, and telecommunications networks are not systematically tested against computer-based intrusion.

In pursuing these missions, MITRE's activities cover a broad spectrum, from technology strategy and planning to research, prototyping, systems engineering and architecture definition. On occasion, MITRE personnel are also involved in fielding and maintaining MITRE developed prototypes.[14]

4.2.1.2 MITRE's organizational structure

The C^3I FFRDC is made up of three centers: the Center for Integrated Intelligence Systems (CIIS), the Washington Command, Control, and Communication Center (WC3), and the Center for Air Force Command and Control Systems, referred to here as the Air Force Center. Each center is further divided into directorates, and each directorate is divided into divisions.

The work of the centers is organized around projects. The projects may arise in a number of ways. In some cases, a client has a particular need and approaches MITRE to respond to that need. In other cases, MITRE may already be working on a project when it becomes clear that there are other areas within that project where MITRE's services might be useful. In addition, MITRE also funds internal research, both basic and project oriented, in an effort to anticipate their clients' future technical needs.

The projects range widely in size and duration, from small projects involving only a few people for a few weeks to "superprojects" such as Airborne Warning and Control System (AWACS) or Joint Surveillance Target Attack Radar System (Joint STARS), which extend over many years and can involve hundreds of employees. The larger projects tend to be broken down into smaller pieces involving perhaps 5 – 15 people.

[14] Examples of this include implementation of advanced network systems during the Gulf War and support of one-of-a-kind unified wargame simulations.

Other work – including most of the work in the WC3 – is organized into relatively small, separate projects. Finally, some MITRE work is best understood as small scale consulting work. Much of the work done by the CIIS is of this sort, and tends to be focused on information systems. Examples include developing software to integrate machine translation and intelligence information systems.

Project teams are generally put together by the project manager. This person may be an employee's boss if the unit is not part of a matrix organization. Generally the majority of the team is comprised of staff from within the same directorate or division. However, 'soft-shelling', or borrowing employees from other parts of the company, is fairly common. Generally, soft-shelled employees are identified based on previous working experiences or word of mouth.[15]

The organization of work within the C^3I varies across the three centers. Two years ago, the Air Force Center changed to a fully matrixed organization, while the CIIS and WC3 are a mix of matrix and client-based structures. The CIIS and WC3 also contain "tech centers," groups of 15-200 people that focus on a particular type of technology. Employees who are not in tech centers are organized into client-based divisions and directorates.

Because it is a fully matrixed organization, the Air Force Center does not have technical centers; all employees within this system are organized based on their technical expertise. Project managers, who often have a long-standing relationship with a particular client, form project teams from the technical specialties within the Air Force Center and occasionally from the CIIS and WC3.

[15] The development of MITRE's intranet with sophisticated search and publication tools is an effort to extend soft-shelling beyond the circle of personal contacts.

For many fields (e.g., software and networking) the categorization by technical skill is straightforward; but in some cases, notably systems engineering and project management, the commonality between employees is less clear.

The distinction between systems engineering/project management work and more specialized technical work is an important one for understanding integration problems at MITRE. While the distinction is more evident within the Air Force center, it exists within all three DOD centers. In general, employees at MITRE develop along one of two pathways. Along the first path they continue to develop their technical skills, becoming experts in a technical area and perhaps advancing to lead specialty technical groups or tech centers. The second path involves broadening one's skills, developing both systems engineering knowledge and importantly, military domain knowledge about the operational needs of a particular client. About 45% of MITRE's employees fall within the first category, sitting with tech centers. (MITRE, 1999b) The remaining technical staff have more of an operational emphasis in their skill base.

These two career pathways are not completely divorced from one another. It is not unusual for someone to gain systems engineering skills and then return at a later date to a more technical capacity within MITRE. But the more common pathway is for a technical specialist to take more of a leadership role within projects, gaining greater knowledge of a domain and a set of clients over time. The division between these two types of roles, and the larger distinction between the technical and operational domains that it derives from, is a critical factor in understanding the barriers to integration at MITRE. We will return to this issue later in this report.

4.3 Recent Changes in MITRE's Environment

During the past ten years MITRE's operating environment has been transformed to an extraordinary degree, with major consequences for the kind of work the company is required to carry out.

The end of the Cold War brought about far-reaching changes in the nation's military doctrine and strategy. For the armed forces there is greater emphasis today on limited engagements and peace-keeping operations. Cooperative engagements in which U.S. forces work with other forces under the auspices of NATO or the United Nations have become much more common, and this has increased the importance of achieving high levels of operational coordination – and hence technical interoperability – between different national forces.

At the same time, a major change in warfighting doctrine – often referred to as a 'Revolution in Military Affairs' – has elevated the improvement of command and control capabilities to the highest priority for military planners. The C4ISR[16] mission area is moving from being 'a useful but ancillary adjunct to weapons systems to an emphasis on becoming the heart of the joint vision.' As the Secretary of Defense stated in the most recent Quadrennial Defense Review, '[a]t the heart of the joint vision is information superiority – the ability to collect and distribute to US forces throughout the battlefield an uninterrupted flow of information, while denying the enemy's ability to do the same." The DOD is thus putting progressively greater reliance on information and communications technologies, and has identified the integration of systems across defense platforms and across services as one of its highest priorities.

The third important development is the very rapid introduction of new networking technologies and cheaper computing power in the civilian domain. The use of these technologies has meant that, to a much greater degree than in the past, military

needs can be met with civilian technologies, opening up new opportunities for efficiency and cost reduction.

Taken together, these factors – the emphasis on operational collaboration, on technical interoperability, and on the use of commercial systems – have had important consequences for MITRE. At the most general level, they have obviously made MITRE's roles as a system integrator and as an integrator of the defense and commercial industries more germane. More specifically, there have been several significant changes in both work tasks and work processes: an increase in attention to IT work, increased attention on prototyping, emphasis on organizational integration tools and collaboration, and an increased pace of work.

4.3.1 Focus on IT

There has been a much greater emphasis on IT systems in MITRE's work, particularly on the 'softer' side of information technologies – networking, communications, and software technologies, and relatively less on hardware development (e.g., radio, radar, and chip design.)

4.3.2 Prototyping

A consequence of the increased emphasis on IT work has been a change in the way that MITRE deals with prototyping. MITRE has been building prototypes since it was founded, but the emphasis now is on software, not hardware, prototypes. Throughout this research, we tried to ascertain whether the increased attention to

[16] Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance

information technology work had made prototyping activities more important. We were curious about whether integrating software systems required more reliance on prototyping than integrating radar and sensing systems.[17] The responses to this question varied widely, and we were not able to reach a definite conclusion. Virtually everyone at MITRE agreed that in order to stay 'at the top of its game' in the range of technologies its clients are using, MITRE needs to build prototypes. Hands-on experience is crucial for understanding details and costs of the technology and for learning how to make tradeoffs between technology, cost, and compatibility with legacy systems.

But the importance of prototypes beyond this role is unclear. Symbolically, at least, prototypes are seen by some in the organization as an alternative to systems acquisition oversight work. Some managers and engineers we spoke to seemed to think that MITRE's future lay in developing new prototypes and transferring them to the marketplace. Some groups seemed to identify themselves clearly as prototype groups, suggesting that prototypes are the "future of this company." Others saw prototypes as giving MITRE more entry into and credibility within the academic and technical communities. One web-oriented manager expressed the concern that a lack of attention to prototyping was threatening the survival of MITRE as an IT company:

> I don't know, I have serious doubts whether MITRE's going to make it. I just look at the other companies that are in this field and, for example I think it was Stanford did a study recently, they looked at the number of innovative companies – 3M, Microsoft – went through a set of companies that were very much information technology focused and found out that a core trait of all these organizations was constant prototyping. You know, just prototyping, trying things out… a lot of things won't work out but you'll get some gems along the way that become your next products. And the mean time to produce a prototype was 5 days in these organizations.

[17] MITRE's work has always involved both hardware and software systems. Radar systems, of course, involve elements of communication and control that are crucial in the modern command and control systems MITRE architects. Our questions were about a major change in emphasis, not about a change of type.

> So that's where we should be in providing guidance to our customers, because we don't have the luxury of focusing on a particular technology segment. We've got to cover a much wider segment, and that means we have to be trying these things out a lot faster than we are now. So. I don't know, it will be an interesting next couple years.

Others clearly disagreed with this view. An executive within the company thought this perspective was somewhat misguided. He emphasized that governments deliver services, not products, and that MITRE's role is to support the delivery of those services by doing systems engineering. From this perspective, one role of prototypes is to contribute to the government's evolutionary acquisition process.[18] An engineer who had been with MITRE since its founding, while certainly not opposed to prototyping, took a more instrumental view. To paraphrase: young people always want to be building things, not overseeing how they are built. To deal with this, you let them build some new stuff, but mix in a little bit of oversight work with it. As people become more senior, one of those new ideas may actually make sense for a particular project – then you return to the junior guy and say "hey, you've been trying to sell this idea for ages. Now you've sold it and have the chance to turn it into reality – are you going to take it?" In this way, the youthful desire to build prototypes is channeled into a more mature, and necessary, focus on MITRE's *real* work – systems acquisition.[19]

Others, including some of those who believe that MITRE does have an important prototyping function, note that regardless of the technology (i.e., whether it is hardware or software), MITRE lacks the experience (in manufacturing and productizing its prototypes) necessary to bring those products to market. As one technical director put it:

---

[18] For a description of how prototype field experiments are used in the spiral development process, see (Boutelle and Grasso, 1998)

[19] Note that even the suggestion that MITRE's *real* work is systems acquisition is controversial. A more common perspective on "MITRE's *real* work" would be systems architecture, integration, and evolutionary acquisition.

> You have the same problems with hardware and software. If we built a little gidget, a hardware gidget, which we could do for instance in our VLSI lab, we built this thing and we could actually get that out and demo it around and actually have it go out into the field as an operational prototype. Same for software. Both systems would suffer from the same thing. No attention to productization, no attention to fulfillment, you know all the stuff that has to do with helping the vendor make it work, and frankly no experience in this company with providing the maintenance tail, the support tail that those products require.

Some executives argued that MITRE was struggling with too many 'operational prototypes' – prototyped systems that the client had fielded and was now looking to MITRE to support. They were concerned that this was making MITRE vulnerable to criticism from for-profit systems integrators claiming that MITRE was unfairly infringing on their markets.[20]

In sum, it is clear that there has been a shift in the character of prototyping activity at MITRE as the company has placed more emphasis on software and networking. But whether or not the role of prototyping has fundamentally changed is less clear, although hands-on experience will continue to be important for the company's systems engineering work. As we were completing this research, MITRE publicly released the source code to its Collaborative Virtual Workspace package, a very successful "prototype" that has been used by numerous intelligence and military clients (and whose designer has since taken up a research position at Microsoft.) It is possible that in an era of open source software, MITRE's ability to transfer its prototypes into the marketplace will become greater than ever, making the company a source of technologies. The risk will be the potential for complaints from for-profit systems integrators who see MITRE and its work as a threat.

[20] In March, 1999, after our field work had concluded, MITRE created a technology transfer office in part to avoid this problem by ensuring that MITRE-developed technologies were quickly transferred to the private sector. In addition, MITRE executives mentioned efforts to manage customer expectations, increasing their awareness of the need to find commercial support for any MITRE prototypes used on an ongoing basis.

4.3.3 Organizational integration tools

MITRE's increased work on information systems has brought with it a more explicit focus on the organizational structures and processes of its clients. In the military domain as in the business world, information systems design and organizational design are very closely coupled. One manifestation of this relationship at MITRE has been an increasing emphasis on the development of software tools to support organizational integration, in particular collaboration and knowledge management tools. An example of this type of technology is the Collaborative Virtual Workspace, an online office automation environment that supports distributed teams. MITRE's development of this tool was stimulated by the needs of military units spread over many time zones to work together continuously:

> We've got forces in Korea that need to talk to forces back in Hawaii at Pacific Command who need to talk to people in the Pentagon and, guess what, they sleep at different times … nonetheless they have to get together.

MITRE frequently uses its own internal organization as a test-bed for the development of these tools. Like many software organizations, it has a policy of 'eating our own dogfood.' In this way the company's work for its clients on organizational integration has become closely connected to efforts to strengthen its internal integration processes. A good example of this is MITRE's intranet, the MITRE Information Infrastructure. MITRE first started developing intranets for an intelligence client that had originally approached MITRE looking for an "CompuServe-type system." Over a period of six months, MITRE worked with the client to develop a more appropriate web-based system, using the test and development phases of this work to create its own intranet using DNS servers, a client-server approach, and web style guides.

Another example is the Organization Wide Learning, or OWL project. MITRE engineers developed a set of macros to track the use of commands within Microsoft Word by individual users. By creating an instrumented environment and then tracking usage statistics, the team developed a 'recommender' system that informs a user about who else within the company has expertise on the tasks they are working on. Recommender systems promise to give MITRE and its clients a method for locating and sharing knowledge within networks that is more systematic and more widely accessible than personal experience. In fact, at least one MITRE-developed recommender system have become operational both within MITRE and its clients.

4.3.4 Emphasis on collaboration

Beyond the development of particular software tools, we found evidence of increased attention to collaborative processes at MITRE, both internally and in interactions with clients. Its relationship with its largest client, the Air Force, reflects this trend. A passage in an official history of the company describes this evolving relationship:

> In 1997 the Air Force ESC reorganized to emphasize functional C2 [command and control] components and their integration and set up the new Chief Architect's Office. At the same time, MITRE set up a parallel organization and provided staff to the new office. The Air Force also established a new central organization, the Air and Space C2 Agency, at Langley Air Force Base, to lead the integration effort across all major commands, and MITRE serves as the liaison between the new organization and ESC. The result of these changes, says Lt. Gen. Ronald T. Kadish, commander of ESC, is a new, more interdependent relationship evolving between the Air Force and the company: "We're moving from a model in which we oversee our contractor to a technical partnership to accomplish this integration task." Kadish also credits MITRE's assistance in developing a range of management innovations, such as architecture councils and other integration activities, to address the extremely difficult

> technical and organizational challenges of making the new C2 systems come to life. (Dyer and Dennis, 1998, pgs. 172-173)

Using somewhat different language, one interviewee at MITRE's Air Force Center made a parallel observation, suggesting that the company's interactions with the other services were similarly evolving:

> MITRE has changed from somebody who was focused primarily on the Air Force – getting requirements on the table, getting a definition of work put together, getting the Air Force to put that definition of work out and then harassing the contractor to make sure he delivers – to what I think is a model of senior level consultants. You have a good set of people that understand the technology in detail so that when something really breaks we can go in an advise them on how to fix it. It's gone from a company that's had its focus primarily on the Air Force and the Electronic Systems Command out here at Hanscom to a company that does that across the DOD for the Army, Air Force and Navy.

Our interviews also highlighted the growing attention to collaboration within MITRE's internal organization. According to one manager in the CIIS:

> One of the things that we put a lot of emphasis on is collaboration. Taking lessons learned from one project and making them available on other projects. We tend to have people not working on just one project because we find that the tech transfer and their own education benefits from having them on at least two projects.

And another interviewee affirmed that

> MITRE is seeing more reaching out, explicitly espousing collaboration as a value. They have created the infrastructure and informal relationships for this. The informal stuff is the most important.

4.3.5 Increased pace of work

The final major change that emerged from our interviews was an increase in the tempo of work at MITRE. Interviewees perceived rapid increases in both the pace of technological change and the speed of acquisition activities. The AWACS program office, for example, has decreased its upgrade cycle from a decade to 18 months:

> [T]ime frames have gone from 18 years maybe, 10, 20 years, to 18 months. Literally within a couple of years, so we've had this shocking shift from you might say 4th gear into 1st gear and we're told to go at the same speed. So the engines are highly strained principally because of that, in part because of that time window shortening. People have said basically, we will go to market within 18 months.

At the same time, product cycles in the commercial domain are getting shorter, and this too affects MITRE's system integration work. As one web engineer put it:

> I think our job 5 or 10 years ago was a heck of a lot easier because projects were longer. We could kind of study something from 20 different angles so we really understood every little nuance about it, make some recommendations and you know I think [MITRE's] culture and the way it's grown up is very good at that – being able to take an application or a set of technologies and spend some time really understanding . . . and trying to come up with the best recommendation. But now you're dealing with so much uncertainty with technologies that are coming out that seem promising but they are buggy as all get out, do you recommend using them, do you recommend waiting on them, and the answers are different depending on what technologies you look at, what instant in time you look at them and I think as an organization we're trying to adjust to that increase in tempo.

Finally, even the speed of military engagements is much faster than in the past. Decision support systems that enabled decisions to be made in minutes now must enable those same decisions in seconds. A technical director described the problem this way:

> The world has changed, now we don't have time, things have gotten a lot quicker, we used to see something and shoot at it in a matter of 3 minutes. Now we have 20 seconds, maybe 30 seconds. So how do you build a system that gets the information to a human or set of human decision makers in 5 seconds as opposed to a minute?

Collectively these changes – increased work in information technology and organizational integration tools, increased emphasis on collaboration, faster pace of work, and a shift to building software rather than hardware prototypes – define MITRE's new work environment. The pace of MITRE's work, military engagements, and changes in technology all contribute to increased uncertainty in a work area that was never clearly defined. Most of these changes contribute directly to a greater emphasis on integration. In particular, the focus on organizational integration tools, collaboration, and a faster pace of work make integration within the company and between the company and its clients and suppliers a more important issue.

5. CORBA: A Brief Case Study

A case study of one technology at MITRE, CORBA (Common Object Request Broker Architecture) illustrates many of the roles played by the company. While this story reflects events that happened approximately 5 years ago, it ties together several key issues that are critical to an understanding of integration processes: the question of MITRE's identity, the division between technical and operational domains at MITRE, the relation between the tech centers and project work, and integration both within the company and across company boundaries to other organizations, including both contractors and private and military standards organizations.

CORBA is an architecture and set of standards for communication between different types of software systems, particularly in the client-server environment. It is a component architecture that enables pieces of programs, called objects, to communicate with one another regardless of what programming language they were written in or what operating system is being used. CORBA also determines how computers can share access to data and services. CORBA was developed by an industry consortium known as the

Object Management Group, and is used for distributed computing, enterprise computing, and collaboration software.[21]

Initially, CORBA was not designed to support real-time applications. In the software industry, 'real-time' refers to software that supports functions that must be completed according to a strict schedule. Unlike other services provided by a computer, such as processing text, some functions, such as command and control systems for controlling the movement of a robotic arm or the switching processes on a fast network router, must be processed immediately. However, most processors are designed to split their attention between different demands on the computer system – for instance, graphics demands might be met briefly, followed by a demand for calculations from a spreadsheet, followed by demands from input devices such as a mouse or keyboard. For most of these operations, it doesn't matter if the processor delays service for a split second. In contrast, real-time demands require prompt attention from the processor in order to be effective. In a network of computers, ensuring this kind of access requires changes in the protocols that computers use to communicate with each other. In its initial design, the CORBA standard did not include the rules necessary to support real-time applications.

Tech Center vs. Project perspectives

Our story centers on a senior MITRE systems engineer who had been working on Airborne Warning and Control Systems (AWACS) for some time. MITRE was the systems engineer for a series of AWACS modernization projects. The Air Force was upgrading the AWACS radar system, including the computers and displays used inside the airplane, which were built on heavy, energy-intensive mainframe computers. MITRE's AWACS program manager requested that a software technical center within

[21] Software Engineering Institute's Software Technology Review, www.sei.cmu.edu/str/descriptions/corba_body.html, accessed on 5/12/99

MITRE develop proposals to "migrate legacy real-time applications… into modern architectures." When the technical center seemed unable to present realistic solutions, the AWACS program manager asked this senior MITRE engineer to review the technical center's research efforts in greater detail. As the engineer describes it:

> So [MITRE's AWACS program manager] started talking to me about what was wrong with these guys – why can't they say anything real. And he asked me to take a look at it. And at the time I was not a research guy and I really had a bad taste in my mouth for the research program over here in general. But when I started looking at it I saw that at the worker level there were some good ideas but it just wasn't percolating up through the project and being made into recommendations. One of these ideas . . . was that you can make extensions to CORBA that would make it run in real-time and that using a CORBA-based architecture . . . could be an aid to migrating legacy systems.

Once the basic idea of making real-time extensions to CORBA had been identified, considerable work was required to convert it into a proof of concept model, and from there into a prototype which could be tested in the AWACS system. After MITRE established proof of concept and showed that CORBA could indeed be used to support real-time work, the company attempted to pass the technology on to both Lockheed Martin and Boeing, contractors on the AWACS project:

> We got Lockheed Martin interested. Lockheed Martin was on contract to build the computers and some of the software infrastructure for the new AWACS. And we tried to get Boeing convinced. Boeing it turned out was hard to convince because they wanted to do this thing they called open system architecture, which was translating everything into Ada '83.

Boeing's Ada '83 architecture suffered from one serious limitation: the entire software system would have to be recompiled and retested if any future changes, such as

the addition of a new type of sensor, were made to the AWACS system. Because of this inflexibility, MITRE was able to persuade the AWACS System Program Office (SPO) that it should continue to develop and test the real-time CORBA idea, and MITRE subsequently completed the prototyping and initial testing of the real-time system.

> Well when we proposed doing that people said "you'll never make that work." And then we got it working and then we prototyped it [real-time extensions to CORBA] here at MITRE and it seemed to work. We built a higher fidelity prototype at Boeing and it seemed to work. We did a system demonstration with live data on the ground and it worked. And last week unless they canceled the flight again it was supposed to be airborne on TS3 test airplane for the first time. So we're actually beginning to fly this architecture and at the end of the year we're going to start deploying it to the fleet where you've got all of the legacy functions still being done on the old mainframe but some functions gradually being migrated here. And the plan is as money becomes available we're going to migrate functions out of here and into those and eventually take out this computer and this computer which take up a lot of weight and power and heat load.

> It's pretty much all based on this MOIE [Mission Oriented Investigation and Experimentation] research which was misguided and misdirected until I started complaining about it. But it's been good and it turns out that to make it work the Lockheed Martin guys started building a real-time version of CORBA based on the requirements that came out of the MITRE MOIE.

Working with standards organizations

While Lockheed Martin continued development of the real-time CORBA system for AWACS, MITRE became involved with the Object Management Group (OMG), an industrial consortium, on CORBA issues. MITRE had in fact had a longstanding relationship with the OMG, working with them on previous occasions on security issues. A former AWACS engineer, who was doing research on real-time systems at MITRE, approached OMG about working on a real-time CORBA standard. This engineer

subsequently became the chair of the OMG real-time special interest group, the body that organized the real-time standard development process.

Proposal development for OMG standards is generally done in unofficial meetings, and because MITRE was anxious to participate in this process, it accepted an invitation from Sun to join their proposal team. As an FFRDC, MITRE's participation on one team and not the others could have created an impression of bias. To avoid this, MITRE agreed to join the Sun team on a non-exclusionary basis. With Sun's reluctant agreement, MITRE approached the other proposal teams, including the Lockheed Martin team, about participating in their development process. However, none of the other teams were interested in having MITRE participate.

> So we go to all the secret proposal meetings because in between OMG meetings the people who have actually proposed … try to figure out what they really want the standard to be. Since we joined one of the teams we can go to those meetings and we've been taking advantage of that. So we clearly expect to have the OMG real-time version of CORBA meet the needs of AWACS.

In addition to participating in the standards process, MITRE was also active in promoting the use of the Lockheed Martin CORBA product across the Electronic Systems Center. In fact, Lockheed Martin's real-time CORBA system has been used by a number of Air Force systems, including Regional Sector Air Operations Center, Theatre Battle Management Control Systems, the AWACS radar processors, and Joint STARS. Encouraging the use of this technology required efforts not just from the owner of the technology (i.e., Lockheed Martin), but also by the MITRE team that did the testing and prototyping:

> So in general I kind of feel like a marketing guy for Lockheed Martin sometimes. We've managed to get the concept of migrating legacy systems into new architectures using CORBA and real-time CORBA to work. … when they [others] find out that CORBA doesn't perform well enough for them, doesn't meet the real-time requirements, we manage to find solutions

> that they can use using these real-time extensions of CORBA. And we're working to get them [these solutions] into OMG.

Integrating internally to support external integration

At the same time that MITRE was developing and pushing the real-time CORBA solution for AWACS, other parts of MITRE were assisting the Defense Intelligence Systems Agency (DISA) in its efforts to develop a software architecture and infrastructure to ensure interoperability between military command, control, and communication systems at reduced cost. The major focus of this effort consisted in developing the Defense Information Infrastructure Common Operating Environment (DIICOE). The DIICOE includes a kernel of operating system, security, printing, and installation extensions as well as common support applications such as databases, messaging, and network management. One goal of the DIICOE is to enable collaboration between computer systems in the different services. Still another MITRE project in support of software architecture efforts at the Electronic Systems Center entailed determining whether Air Force programs, including AWACS, would have difficulty migrating to the DIICOE due to their real-time needs. The afore-mentioned AWACS system engineer was asked to address this question:

> We got all the programs that thought they couldn't migrate to COE based on real-time requirements to come and start talking about what those requirements were and what it would take to meet them. And what we concluded was that they were right – the DIICOE did not address the requirements they had. But you didn't have to stretch it very far…
>
> Well then they decided what to do was to go out and I think there were other forces at play here … I think the Navy had been seen as being more proactive and the AF was not playing and not doing a good job and not contributing and sort of being trumped by the Navy and being told to do what the Navy told them to do so the AF wanted something they could do so that that wouldn't happen. So they've kind of picked up on this real-

> time COE as something they can champion – they can say "this is one of our initiatives" and stuff like that. In a sense they're looking for something to grab on to and champion. And this came along at the right time. And it turned out that Col. Payling [Director of the Air Force DII Infrastructure programs] who's now retired thought it was kind of cool stuff. …and Col. Payling and I took an instant liking to each other so – a lot of things just happened to fall in place at the right time.
>
> And so we went to DISA. We got a real-time working group started up and we've been trying to talk about how we're going to build real-time DIICOE for a year now. … We started laying out all these different work program things that didn't sound like a DISA technical working group kind of work – didn't sound like just requirements gathering. It sounded like a program office. So we proposed that there should be a program office responsible for integrating real-time DIICOE … we've given a contract to Boeing to start doing some integration work.
>
> And the thing that I think is exciting about it is that it's all falling out of the AWACS work and the MITRE MOIE work and stuff like that. Turns out the MITRE MOIE worked with Victor Wolf at the University of Rhode Island – we've got a longstanding collaboration with his group. Navy hired Victor to do some consulting on real-time CORBA for them several years ago. Not surprisingly the Navy's getting very consistent advice on real-time CORBA as what the Air Force was getting because Victor's group and our group tend to put their heads together. We've worked comparing notes on specific projects but pretty much on the same sheet of music with what we thought about CORBA and how to make it real-time.

There are many elements of this story that will be developed over the course of this report: the inter-service politics around DIICOE, MITRE's efforts to transfer real-time CORBA ideas to Lockheed Martin and to see that technology developed into a standard at the OMG, and the transfer of real-time CORBA between different Air Force Projects within the ESC and across service boundaries to the Navy. The story demonstrates the breadth of MITRE's involvement on different AWACS projects, and with different military projects from ESC and defense agencies such as DISA. The story

also shows how MITRE has tried to get ideas important to the defense sector into the commercial industry through the OMG standard.

Another issue highlighted by the case is the relationship between the technical centers and domain, or military engineers. On the one hand, the AWACS systems engineer did not initially perceive the tech centers as being helpful, and the AWACS program manager was dissatisfied with the tech center's initial recommendations. On the other hand, partly because the AWACS systems engineer was comfortable dealing with both military needs and the technical issues around real-time CORBA, an idea that was developed within MITRE was successfully implemented in a number of Air Force projects and also extended into the private sector via the OMG.

An interesting footnote to this story is that the AWACS systems engineer has since become a department leader within the Air Force Center's new matrix organization. This is significant because, as a manager in the resource part of the Air Force center, this engineer is now responsible for the development and utilization of a set of technologies – in essence, he has changed from being a military domain specialist to being a technology advocate within MITRE.

6. Mechanisms for Integration at MITRE

Integration, both internal and external, is central to MITRE's mission. Recent changes in the company's environment have increased its importance. Much of our research at MITRE focused on understanding the processes and mechanisms used by MITRE to accomplish its integration tasks. In this section we report our findings. The discussion is divided into two parts, according to whether the integration processes are internally or externally oriented.

6.1 Internal Integration

We observed several mechanisms for fostering integration within and between the three centers that make up the DOD FFRDC. We group these mechanisms into the following broad categories:

- organizational design
- creation of specific offices tasked with promoting integration
- Ad hoc efforts, including the efforts of individual center directors, project leaders and other managerial personnel

6.1.1 Organizational design

The DOD FFRDC is organized into three centers, each with divisions and departments. The centers are divided according to customer type – Air Force Center, Center for Integrated Intelligence Systems (CIIS), and Washington Command, Control, and Communications Center (WC3), a catch-all for Army, Navy, DOD agency, and Joint Staff work. Within these centers, some divisions are defined by their major customers (e.g. W070, Battlefield Systems, works almost exclusively for the Army) and others are defined by their technology focus (e.g. G20 is Information Security). This basic organizational dichotomy between customer-based and technology-based groups emerged early in MITRE's life. We shall see that it is significant for understanding the problems and opportunities the company faces today.

6.1.1.1 Technical Centers[22]

Historically, MITRE organizational structure has been determined by its projects. (Dyer and Dennis, 1998, MITRE, 1979) As large-scale projects such as AWACS grew, project divisions within MITRE grew as well. This provided some advantages for MITRE's clients (e.g., a level of continuity that could not be matched by military or civil service staff). However, MITRE's ability to coordinate within and across customer domains and its ability to take full advantage of the technical expertise within the company were constrained. Throughout the 60's and 70's, MITRE experimented with various ways of distributing its highly technical knowledge resources across the organization. But 'stovepiping,' the association of people and divisions with particular projects focused entirely on narrow, project-defined goals, persisted and technical

[22] In some MITRE internal documents, the resource divisions of the Air Force Center are considered technical centers. Because the Air Force Center is a matrix organization, we did not consider these divisions technical centers. Our discussion of technical centers focuses on the CIIS and WC3.

expertise tended to get "stuck" within project divisions. In the mid 1980s, Barry Horowitz and Charles Zraket created the first *technical centers* (tech centers) with the purpose of sharing expertise across projects and breaking down the barriers between stovepiped systems.

Tech centers work for multiple internal clients across the company. They manage relatively few projects; their employees are usually "soft-shelled" or loaned out to other divisions with closer ties to clients. Tech center employees may work on two or more projects for very different clients. On average employees in tech centers have slightly fewer years of experience and less education than those in the rest of MITRE. (Tech centers have a higher proportion of Ph.D.'s than the rest of the company, but the smaller proportion of master's degrees in the tech centers lowers the average educational level below the rest of the company.) (MITRE, 1999b) The idea is to create an environment where technical information can be shared readily by people working on similar technologies, even if the domain or military problem on which they are working is very different, and to centralize scarce technical skills so that all projects have access to them. The directors of the tech centers shuttle human resources towards the projects where they are likely to have the greatest impact. The tech centers tend to get a higher than average percentage of MITRE's internal research funds, and tech center directors suggested that the concentration of expertise within tech centers makes MITRE a more appealing place to work for engineers interested in research, boosting both hiring and retention.

The tech centers have been effective integrating mechanisms for MITRE, but our interviews, as well as the results of a recent internal study on tech centers (MITRE, 1999b), suggest that the company is struggling to define their future role. They raise administrative costs and can create morale problems in the operational divisions. For instance, in a division with a tech center directorate and client oriented directorates, the

tech center tends to receive a larger share of corporate resources and managerial attention. One technical director described this as an "orphan child" problem. Moreover, as MITRE's work has become increasingly focused on information technology and software, technical centers have developed in different parts of the company with skills that are not clearly differentiated from one another. The clearest example of this is the Advanced Information Technology Group within the CIIS and the Information Systems and Technology division within WC3, the two largest tech centers in the company. The expertise at the two tech centers differs somewhat, but there is considerable overlap in skills (e.g., information management, networking, component software, and software architecture), and it is not clear that the company gains from having them as separate centers. Indeed, the fact that two such similar units exist in CIIS and WC3 is an indication that barriers between the two centers persist, although there is clearly considerable communication between them. Another difficulty faced by the information technology centers is that they can quickly become obsolete, as formerly specialized skills – for example, Java coding – rapidly expand into the general engineering environment and become readily available from a variety of sources. The conclusions of the recent internal study on tech centers indicated the need for better collaboration mechanisms between centers, as well as the need to link tech centers to the firm's corporate strategy.

6.1.1.2 Matrix Structures

The technical centers represent a partial move towards a matrix-structure organization, but one center has moved to an entirely matrixed structure. In 1997 the Air Force Center changed from being a project-based organization with some technical centers to a fully matrixed organization. Within the matrix, all employees are categorized by their technical skill, while each project is categorized by its function within the Air Force's

command and control system. The reorganization of the Air Force Center was conducted in association with a reorganization of its leading client, the Electronic Systems Center (ESC) at Hanscom Air Force Base. The basic objective in both cases was to achieve better integration of the command and control systems across the Air Force.

One senior manager in the Air Force Center described the rationale for the adoption of a matrix structure:

> [In the past] We thought that by having a core set of people who worked AWACS for the long term … we were gaining a certain continuity, a certain domain knowledge, a corporate memory … that stayed on that job. They knew the operational mission that AWACS flew, they had a relationship with the AWACS operators, they understood the problems that they faced when they went up in the air to do their jobs – the non-technical aspects but the knowledge you need to know to understand where technology should be applied in order to improve that system.
>
> It worked – I mean we operated that way for quite some time. What were some of the disadvantages that we found by doing that? Well, probably the biggest disadvantage is that we wound up building stove pipe systems … you do a good job of building an AWACS airplane, but when you got into issues of "well how does that fit within the bigger context of what the Air Force or the other services are trying to do with surveillance or with command and control," the people working on AWACS had a certain set of blinders on – they were optimizing AWACS. They didn't necessarily know enough or have the incentive to worry about anything outside of that particular system.
>
> We felt that by mixing these people up, at least in one dimension of their life, in the resource [technical] dimension, we would start removing some of the blinders. At least within their resource organization they would start talking to each other and saying "Oh you're doing that on Joint STARS? Well, you know, we're doing that in a little bit different way on AWACS – I wonder, why we shouldn't do it the same way?"

Employees in the Air Force Center are now grouped into one of 5 major divisions based on their technical expertise: information technology, networking and

communication, sensors and enabling technology, systems engineering, and program engineering. Program engineering is the division that contains all of the program managers for the Air Force Center. These are engineers with significant expertise in project management and long term relationships with ESC programs. Systems engineers are more junior general engineers who have developed skills beyond their initial engineering discipline.

The part of the matrix structure that has given MITRE the most difficulty is the systems engineering division. Some of the groups in this division appear to have developed a distinctive identity – for instance, the architects have created a clear idea of the tasks that they do. However, other groups are less successful at identifying unique contributions, particularly when compared with the program manager group. Since leadership for projects is found within the program manager division, the systems engineering division is left without a clear way to establish its added value.

The other dimension of the matrix consists of projects that are grouped together in four "pillars": communications, situation awareness, planning and execution, and "platform." The pillar categories roughly match the grouping of projects within the ESC.[23] Each pillar has an executive director, a set of project directors responsible for major customers, and project leaders responsible for each project. The project directors are each responsible for fostering integration and cooperation between the projects they oversee. The "platform" pillar represents projects whose purpose is to foster interoperability between and across the projects in the other pillars and is discussed further below.

[23] By this means MITRE also hopes to insulate itself from future large scale organizational changes within ESC. A major reorganization at ESC would only require a change in the pillars at the AF center, not a major change in the technical groupings of engineers.

The new structure has changed the way technical resources are allocated among the projects. Previously, program managers had responsibility both for achieving project goals and for ensuring the high performance and satisfaction of their employees. With the shift to the matrix structure, many of these program managers have been moved into the program engineering division where they have responsibility for project goals but not for particular employees. Division and department (resource) managers are now responsible for ensuring that all employees have sufficient coverage (i.e. projects to work on), gain appropriately varied experience, and enhance and fully utilize their skills. Resource managers, who balance project needs with their employees' workloads and expertise, now oversee the hiring of specialists into projects.

One impact of this has been to break down the longstanding barriers between different projects. Program managers can no longer bury an engineer with a particularly unusual skill within a project.[24] In addition, all types of engineers are expected to gain from closer proximity to their technical peers within MITRE. One potential disadvantage of the matrix structure is the loss of continuity that MITRE has historically provided to military projects. Often MITRE staff are the only people to stay with a project for more than a few years. While project managers are expected to stay with a project for a longer period of time, providing continuity, the matrix structure creates greater turnover among the technical staff and this has led to some tension between project leaders and resource managers.

Thus the matrix structure tries to foster integration on two levels – by placing similar engineers together, the hope is that casual conversation and light managerial intervention will lead to shared use of technical solutions within different ESC projects.

At the same time, by grouping together projects with similar functions in the pillars, program managers are given the task of ensuring appropriate integration and sharing between those projects.

The platform pillar deserves special note. Platform projects might be thought of as "meta-integration" projects. They represent a concerted effort by both MITRE and ESC to ensure better integration between the various projects that make up the Air Force's command and control system. As an Air Force Center manager explained:

> [I]f the mechanism of putting the AWACS and the Joint Stars person in the same resource organization isn't enough … than you've got this platform organization whose charter is to put in place a formal set of processes and controls and cooperative architecture councils and a variety of mechanisms that we're trying to create … to make sure that things are being optimized globally as opposed to locally in the way that we're trying to create the command and control system for our customer.

In other words, in addition to the work of project leaders in supporting cross-project integration, pillar projects have an explicit goal of ensuring interoperability between Air Force command and control systems.

The new structure within the Air Force center does seem to have led to a significant increase in cooperation and effective management of human resources. As one manager describes it:

> We went from divisions of 200-250 people where you built up your own infrastructure, you built up your own resources, you built up your own programs, and heaven forbid there is any cooperation across divisions. I'd rather kill than support. I'd rather build my own than see somebody else build. … I'll take this piece and build this and you'll build that, there's a lot of duplication. If I've got somebody good I'll keep them in my program

[24] Note that breaking down these barriers was also a reason for creating the tech centers.

> as opposed to sharing them with a more important program. That's what died. . . . .[Now] I've got a bunch of people who are running the projects business, then I've got a bunch of people providing resources.

Another manager, who had been with MITRE for over 30 years, suggested the matrix structure led to more appropriate use of engineers' skills:

> The Air Force Center structure is very different now [after the reorganization]. Programs are globally optimized rather than locally optimized... The old structure focused on the project, not on internal skills development. In the old systems we focused more on getting people covered than on the right skill match.

A few interviewees, particularly those who had been "soft-shelling" employees before the reorganization, described themselves as "What reorg?" people, suggesting that the structural change hadn't influenced them much. But most people reported an increased emphasis on collaboration and integration between systems within the Air Force center. One person even cited the reorganization and subsequent focus on collaboration as the motivating factor for his return to the Air Force center from elsewhere in MITRE.

One difficulty associated with the matrix reorganization concerns the role of the resource leaders – the department managers within the new, technically based divisions.

> One of the concerns we've had over and over again is when you go into a resource organization, how do you motivate the people? What level of cohesion do you have? If you're project oriented, fine. You have a project or product and that's your focus and you understand. But when you do resource, how do you provide that same motivation, that same focus?

MITRE has tried to deal with this by encouraging department managers to act as evangelists for the type of technology they represent.

> I took a technology focus and said "hey, your job is look across the company for applications for that technology, look back to the research community in terms of where you can get money to support that technology growth. And try to influence the technology along the lines we think are appropriate for our customer base. And to try to educate our customers in terms of what that technology can do for them. And my emphasis isn't just on the pure technology, it's advanced applications of technology.

These efforts have not been entirely successful. While some department managers value this marketing task personally, they don't see it as something for which MITRE rewards or encourages them. Some department heads see these activities as "unofficial" activities they do because of their own interests, not as tasks they on which they will be evaluated and rewarded, or even as tasks that senior management expects them to do. Once department leader expressed this sentiment:

> A section leader is supposed to run a department-sized group of people and he's supposed to be concerned with making sure people are trained, making sure people have resources to do their job, and making sure people have jobs to do, things like that. And they're not supposed to really contribute to projects. In fact originally we were told that you were not allowed to contribute to projects at all – well that seems kind of severe.

Ironically, the department head quoted above was identified by his superiors as an example of an effective technical evangelist. A similar situation arose in the case of another manager in the Air Force Center, whose efforts were praised by a senior officer:

> He and his people work in a technical niche but he's got a good understanding of his own technology and related technologies. He's got a good understanding of what we're trying to do with this integrated command and control system and he's created for himself and his people a vision for where their technology might fit or should be tried to fit in order to realize this command and control integration vision. And so he's got a view that says "here are the kind of things that we really ought to be pushing that not only please us as technologists and they're fun to work on, but they're also making a valuable contribution to what the company as

> a whole is trying to do for its customer." ... [B]ased on that vision he goes off and he pushes with the project leaders to inject that vision into their projects, and he's successful at that.

Neither of these managers perceived their efforts to push technical agendas as running counter to the company's goals, but neither did they say that these efforts were particularly strongly supported, pointing out that the structure of the Air Force Center requires them to focus on human resource management. There is a clear opportunity here for MITRE senior management to hold up these employees as positive examples, and to close the perceived gap between what these employees are actually doing and the goals and strategy of the company.

6.1.2 The Creation of Integration Offices and Councils

Two examples of specific entities created to foster intraorganizational integration at MITRE are the systems engineering group, which supports all Air Force Center projects related to the Combat Air Force System Program Office (CAFSPO), and the cross-company Defense Information Infrastructure (DII) Council.

MITRE's organizational structure uses a variety of categories to group like with like. The three major centers within the DOD FFRDC are grouped by major customer, and within two of these centers activities are grouped by specific customer. The company also uses technology categories to group activities within the tech centers. But inevitably there are crosscutting themes that are not captured by the organizational structure – project themes such as work on the Defense Information Infrastructure (DII), or functional themes such as collaboration tools. There are also internal managerial categories, such as the use of information technology, where broad input from across the organization is desirable. MITRE has responded to the need for coordination on such topics by creating councils of managers from across the company that meet regularly to

discuss them. Examples include the DII Council, the Collaboration Council, and the 'I Team.'

6.1.2.1 MITRE's DII Council

The Defense Information Infrastructure Council is a good example of a 'discursive' approach to integration. The council consists of six senior level managers from across the three centers. It meets on a biweekly basis to discuss issues related to MITRE's work on the Defense Information Infrastructure, and particularly on the Defense Information Infrastructure Common Operating Environment (DIICOE). DIICOE is a software architecture and set of standards developed and managed by the Defense Intelligence Systems Agency (DISA) with the goal of creating interoperability between Navy, Army, and Air Force command and control systems. All military command and control systems are now required to be DIICOE compliant.

MITRE supports work related to the DIICOE in a variety of ways. In addition to supporting DISA's efforts to define the DIICOE, many of MITRE's Army, Navy, and Air Force projects have DIICOE-related components. Supporting various organizations, which are often at cross purposes, that all have an interest in the DIICOE has created problems for the company. At the same time that MITRE was assisting DISA in creating the DIICOE, other MITRE project managers were recommending to their clients that DIICOE compatibility not be emphasized. Some of the latter felt that achieving DIICOE compatibility might directly inhibit a project's chances of success. DIICOE standards, developed by committee with representation from all three services but often led by individuals from one service, have not always been compatible with existing systems. The lack of support for real-time systems, discussed in the CORBA case study above, is one example of this. In addition, the fact that DIICOE standards have been mandated without

provisions for funds to meet the standards creates financial pressure within the military project offices.

Initially, there was no effort within MITRE to coordinate DIICOE related recommendations. Eventually, senior military leadership became aware of MITRE's conflicting advice and confronted MITRE about what its position on the DIICOE was, and how the company was coordinating the development of DIICOE recommendations internally. MITRE created the DII Council to serve as a mechanism for avoiding these problems in the future. The Council tries to anticipate these conflicts and to provide a forum in which MITRE as a whole can resolve inconsistencies and arrive at coherent positions regarding the DIICOE. The council has no particular responsibilities, and does not approve or oversee projects. The meetings often involve a presentation from the technical staff on a particular issue, followed by discussion about work that should involve cross-company collaboration. Its role is solely to provide a forum for discussion of DII-related issues. The council's activities, in addition to managerial efforts across DIICOE-related projects, have resolved the tensions around DIICOE-related recommendations.

6.1.2.2 CAFSPO Systems Engineering Group

The Combat Air Force Command and Control Systems Group (CAFC2) in the Air Force Center includes 12 major air defense and planning programs. This group is part of the pillar structure of the Air Force Center – CAFC2 is an umbrella organization for projects that deal with Air Force planning and execution tasks. Within CAFC2, there is a systems engineering group formed to foster integration between the 12 CAFC2 programs. All of these programs support the Combat Air Force System Program Office (CAFSPO) in ESC, and together make up the majority of the work the CAFSPO manages. The goal

of the Systems Engineering Group is to find common problems and common technical solutions among the CAFSPO projects, to increase interoperability, and to decrease design, development, and maintenance costs for the projects. The system engineering group is staffed by engineers with previous experience on CAFSPO projects, so they are both "domain literate" and technically experienced. Their task is to seek out common requirements and functional similarities, and to analyze implemented code. They do this by analyzing formal specifications and design documents, attending design reviews, and having monthly meetings with project managers. According to an Air Force Center manager:

> I have taken people out of these line functions and created a group that's trying to break down the barriers from an engineering point of view and a design point of view so that we can look at reuse and we can look at component sharing, information flows and information flow analysis from an operations view. But also as well as from an implementation point of view. In my mind without that life would go on and we would see haphazard integration and haphazard relationships develop under these line functions. But that group up there is a facilitator to make that happen – to say, wait a minute what you're doing is the same as what you're doing, and to effect change.

The main task of the Systems Engineering group is the "domain engineering activity…. functional decomposition, structured analysis, functional analysis." The goal is to identify within different technical systems a "least common denominator". For example, an air defense system and an air tracking system might have similar requirements and software implementations. The systems engineering group's task would be to locate and identify those similarities and make recommendations to the relevant program managers about reusing code between the two projects.

Because of its focus on software components and the code reuse, the Systems Engineering group has a type of knowledge that is particularly useful for other MITRE

integration projects – in particular, the DIICOE. While the Chief Architect's Office[25] in ESC is the official connection between the Air Force and DISA's oversight group for the DIICOE, the Systems Engineering group is informally involved in reviewing and suggesting changes to the DIICOE. CAFSPO leadership has come to rely on the systems engineering group more heavily than the Chief Architect's Office for this purpose. The CAFSPO Program Executive Officer has gone so far as to name one member of the Systems Engineering group as the CAFSPO liaison to DIICOE headquarters in DISA. In effect, the Systems Engineering group has become an alternate communication channel between Air Force programs and the DIICOE efforts in Washington. Engineering group members are also involved in the councils and working groups formed by the Chief Architect's Office.

6.1.3 Ad hoc efforts

In addition to the formal integration mechanisms discussed above, informal integration efforts are an important source of collaboration and cooperation within the firm. Previous work experience is a large source of cooperative efforts. "Soft-shelling", or sharing employees across divisions, is another informal mechanism for sharing knowledge and experience within the company. We observed a variety of informal integration efforts that resulted from work contacts within the organization, including efforts to integrate CORBA and Java into large scale systems. MITRE's investments in information technology – both old and new technologies – have had an impact in this area. Many engineers mentioned internal listservs as a useful source of information and an effective way to find expertise within the company. The MITRE Information Infrastructure, or MII, which includes sophisticated search and publishing capabilities, is another mechanism that supports information integration.

[25] See discussion of the Chief Architect's Office below.

6.2 Integration Across Boundaries

The integration mechanisms discussed in the previous section were designed to overcome barriers within MITRE's own organization. Next we consider the ways in which MITRE reaches across its corporate boundaries into other domains, including both the armed forces and various civilian communities (academic, commercial computing and software, military contractors, etc.), in order to accomplish its system integration mission. Through its work in private and government standards efforts, as well as through its long-term involvement in projects, MITRE fosters cooperation and coordination within the military domain, within the civilian/technical domain, and between the two domains. These efforts frequently transcend MITRE's own relationships with its clients or collaborators, and one way to understand MITRE's special FFRDC role is as a facilitator of integration processes and mechanisms within and between the organizations – both military and civilian – with which it works. One manager we spoke with reflected on his experiences with his Army clients in this regard:

> I think fundamentally the organizational barriers that exist within the Army are still there, there are formal mechanisms that certainly exist that bring these folks together, but we have certainly facilitated not only dialogue but much more than that. We've identified points of intersection and we have worked to try to integrate work programs, and I think we've had many successes in those areas, and they have been much appreciated, and there's been payback for MITRE. As a result we've become, certain sponsors have embraced us more so than they would have if we did not have this integrating role.

At times these integration activities even expand beyond the DOD, as in the company's efforts to raise awareness of the need for critical infrastructure protection. An information technology manager described MITRE's activities in this area:

> We at MITRE are pulling together a bunch of industrial groups, like the power providers, like the water distributors, like the communications, telecommunications infrastructure providers, together with their government counterparts, in particular those associated with making sure that the public has access and use to those … MITRE, actually, has a key role in helping to do a whole bunch of things, including just getting those people to talk to one another…. most people weren't several years ago worried about people attacking our infrastructure. What if I'm a high school student in Iran and I want to shut off your power . . . . what if I was really nefarious and I wanted to shut off the power to all of the people over 80 years old. Well such an attack is not at all inconceivable, because records associated with all of the information is actually on line, much of the power grid is actually digitally accessible, increasingly via satellite, very vulnerable. People haven't thought yet about how to attack that. The point there is that MITRE has a role, a more societal role as well, in some cases, or can have one, where we have this natural tendency to bridge industry, academia and the government. And the critical infrastructure protection is a good example or that.

In some situations, integration of this type is a natural part of the projects MITRE is paid to do; in other situations these activities fall under the category of MITRE's mission to act in the nation's interest. During our research, we observed a variety of mechanisms for facilitating external integration, including collocation, strategic planning, specific projects focused on integration, and participation in standards organizations and technical communities.

6.2.1 Collocation and Field Testing

Many of MITRE's divisions have people working in the field or collocated with sponsors. (MITRE has staff at about 60 sites around the world.) These employees belong to a MITRE directorate but spend the majority of their time working on-site with military personnel. MITRE's on-site personnel are located both at military acquisition centers and at operational command centers, working with users. They include engineers,

senior scientists, and deputy department heads. These staff may be influenced at least as much by the needs of the military program they are working for as by MITRE's organizational demands, and they provide the key link between MITRE and the system users. One manager described the integrating role that collocated employees play:

> [This structure] happens to provide an organizational system that is primed for integration because you literally have people sitting at customer sites, listening in the meetings where the general says "darn it my operators, we're killing our own men and women, how can we stop that?" They [MITRE's collocated employees] know that's important, so they run back to the technical guys in the center and say "hey, can you guys help us do this?" And we say "no no no you can't do that because if you're going to decide when they're going to be able to shoot, that means you're going to have to do things in 5 seconds as opposed to 2 minutes, there's no way you can do that today." And then the [field] guys are saying "oh ok, when can we do it?" And the technical guys are saying "well you know, the object management group is working on real-time systems, you know they're beginning to come into the field but they're really not going to be here for another 5 years in hardened, robust, commercial, deployable form." … Then the systems guy, the third piece of the equation, the guy who's working on the program, says "oh, well, guess what, we're doing a block upgrade in 3 years. Now we can't buy it, but boy if we could spec it –"

Thus the field representative plays a crucial role in providing integration between users, MITRE project offices, and engineers developing and testing systems. The tasks performed by on-site personnel can vary from program strategy activities and task leadership to designing, building, and testing prototypes. The off-site personnel are usually part of an internal MITRE team, which provides them with structured opportunities to pass information back to technical and project staff at MITRE. Over time, this relationship can lead to a better understanding of both the military domain and the best way to apply technical skills to military problems.

The Air Force Operations department, a small unit in the Air Force Center's program engineering division, has a handful of employees who are collocated with systems users – warfighters, command and control centers, and logistics centers. These employees serve a dual role – to transfer operational knowledge back to systems designers at MITRE, and to educate users about the range of technical options in order to prepare them for systems in the pipeline. A senior Air Force Center manager described their work:

> In forming this organization, one of the things we wanted to do was to build better operational awareness among the staff across the entire [Air Force] center – so that people had a better understanding of how systems are used within the military, how they use the systems when they fight wars, or how they use the systems in their logistics planning activities. So we wanted to get a focus on building operational knowledge and we established a section of D300 [program engineering], what we call Air Force Ops, made up of a few people here in Bedford but for the most part it's people who are assigned to work at sites in various places around the country and a couple oversees. In those site locations they work very closely with the using organization, the warfighter, as opposed to the acquisition part of the Air Force. So they give us a better insight into what the users really need and how they really use the system and then we take that insight that those people have and . . . use that to build the awareness across the center, the operational awareness.

So collocation introduces two different types of knowledge into MITRE – operational knowledge about how systems are currently being used and program knowledge about expectations of future needs.

Collocation-based integration between MITRE and its military clients can occur at both the engineering and the executive levels. When we asked one engineer whether his location on site with an intelligence client gave him advantages in identifying opportunities for new projects or technologies, his initial reaction was to describe himself as "plugged into the bowels of this place", with little opportunity for strategic action. However, he then described a casual conversation with the client about the need to

quickly translate documents from foreign languages into English. The engineer was familiar with MITRE's efforts to develop machine translation software. He suggested to both the client and to MITRE's machine translation team that MITRE might have the capability to solve the client's translation problems. MITRE eventually developed a prototype that converted intelligence information into a format that machine translation software can read. Despite being "plugged into the bowels", therefore, the engineer was able to influence the course of a technical project for the client. Senior technical staff are also sometimes located at sites; their influence in selecting and shaping projects will be discussed in the next section.

In addition to the semi-permanent on-site stationing of MITRE employees, some projects involve fieldwork (to test a prototype or perhaps to discuss user requirements) of limited duration that provides valuable, if limited, feedback to MITRE about operational needs. Fieldwork provides opportunities to build cohesion between employees working on a project, particularly between MITRE and military or technical staff who otherwise have limited opportunity for extended, face-to-face contact. One form of fieldwork that demonstrates the opportunities for interorganizational integration particularly well is benchmark testing. For example, MITRE has organized benchmark tests of network intrusion detection systems. Builders of intrusion detection system from both the military and the private sector were invited to participate in a benchmarking session arranged by MITRE in which different systems could be tested in a contained environment. A security manager described the benchmarking process and MITRE's motivations for participating:

> So we had 7 intrusion detection system vendors, with their system and 6 different platform targets, some with flaws in them and some with no known flaws. And we had a red team that just ran scripts Arpanet or Internet scripts against the system and we'd watch, we had an intrusion

> detection team that watched the products and saw what they reported. Then we also did surgically designed scripts, and the intrusion detection systems, some of them, almost all of the them were pretty good at getting well known flaws, some of them stronger in one aspect than another. … And part of our hidden agenda was to make the marketplace better because all of these people would see what the others could do, and our other hidden agenda was to find out how the analysts did their intrusion checking, the red teaming.

Companies participated largely so they could see how their own systems stood up against the average. But by hosting the meeting, MITRE learned how the companies designed and tested their systems

6.2.2 Strategic Planning

Another means by which MITRE fosters integration is to participate in strategic planning for its clients. In the case of the Air Force Center, this took place at a very senior level when Hal Sorenson, the Air Force Center general manager, and Lt. General Kadish, in charge of ESC, worked together to develop an improved organizational structure for ESC. This collaboration led not only to the major and parallel reorganizations of the ESC and the Air Force Center, but also to a specific project to create a unified information architecture for all of the Air Force's command and control systems. Responsibility for this project was assigned to a new Chief Architect's Office, located at the Hanscom Air Force Base and staffed entirely by MITRE employees. (We discuss this initiative in more detail below.)

MITRE also plays a key role in strategic planning activities at the Army's CECOM (analogous to ESC within the Army) and at DISA's Joint Project Office, though neither have gone through reorganizations comparable to that of ESC.

6.2.3 Integration Projects

The most formal of MITRE's cross-boundary integration mechanisms are projects that have the explicit goal of promoting closer integration between or within organizations. One example is the Chief Architect's Office in the Electronic Systems Center (ESC) and Hanscom Air Force Base. Another is a Joint Project Office created by the Defense Department to facilitate the transfer of new technologies developed within the Defense Advanced Research Projects Agency (DARPA) into operational form at the Defense Information Systems Agency (DISA.)

The purpose of the Chief Architect's Office (CAO) is to create a general information technology framework for the entire Air Force:

> The Chief Architects' Office is responsible for the architectural oversight of all ESC programs. The mission of the CAO is to establish and evolve the Architectural Framework for the infrastructure and mission applications that make up an operationally flexible Air Force Integrated C2 [Command and Control] System as an integral and compliant part of the joint Defense Information Infrastructure (DII). … After a year of operation, the MITRE CAO has assumed the role as "the" prime integrating organizational element in the reorganized ESC." (MITRE, 1998b)

The Chief Architect's Office is developing systems and technical architecture for Air Force command and control systems. While other divisions of the ESC are responsible for particular functional or technical aspects of Air Force Command and Control systems, the Chief Architect's Office is responsible for making sure all systems

are interoperable, meet command requirements, and utilize the DIICOE framework. The architectural tasks of the Chief Architect's Office mean that it must integrate programmatic knowledge at both the Air Force and the DOD level with knowledge about particular technologies.

The ESC has essentially handed all responsibility for DIICOE relations to MITRE. One indication of the extent of MITRE's responsibilities is that one of the MITRE employees working in the Chief Architect's Office has been named the official Air Force representative to DISA's DIICOE council – every other member of the council is either an officer or a civilian employee of the DOD. The Chief Architect's Office staff member manages a multidirectional information flow. On the one hand, it is collecting and filtering information about programmatic needs and passing it on to DISA's chief engineer for the COE. At the same time, Chief Architect's Office staff attend as many COE design reviews as possible to stay abreast of possible changes within the COE that might impact Air Force programs. The Chief Architect's Office staff member acts as a filter in passing information between the Air Force and DISA. She also facilitates the creation of Technical Working Groups to develop the detailed aspects of the DIICOE. The Chief Architect's Office is also tasked with helping System Program Offices (SPO's) determine reasonable costs for making changes to current contracts involving the COE.

Another example of a project with an explicit purpose of fostering integration is the DARPA-DISA Joint Program Office (JPO.) The Department of Defense created a Joint Project Office to facilitate the transfer of new technologies developed within DARPA into operational form at DISA. In addition to providing support to both DISA and DARPA, MITRE provides systems integration services to the DARPA-DISA JPO. MITRE's support of the DARPA-DISA JPO serves two purposes – to support technology transition from DARPA to the armed services via DISA, and also to create better order within the projects that MITRE does for DARPA. For accounting and historical reasons, MITRE's work for DARPA was not centrally coordinated, and

consequently no one person at either DARPA or MITRE was aware of all of the projects being carried out on DARPA's behalf. Among the risks created by such a situation is that projects are only tangentially related to MITRE's mission will be initiated. There is evidence that at least one project that might have been more appropriately carried out by a private contractor was undertaken during this period. The establishment of the JPO office in conjunction with creating an internal point person for DARPA work has increased the amount of internal coordination at MITRE, and provided better integration with both DARPA and DISA.

6.2.4 Participation in Standards Processes

MITRE's participation in standard-setting activities is an important mechanism for influencing the direction of technical activity in both the military and the commercial spheres. The CORBA case study presented earlier demonstrated MITRE's participation in two standards development efforts – the Object Management Group's real-time CORBA standard, and the DIICOE real-time standards. In both cases MITRE's participation in technical working groups and leadership positions in the standards organizations enabled it to push for a version that included the elements needed to use real-time CORBA in a military command and control setting such as AWACS.

Another example of MITRE's activity in the standards community is its work in developing the High Level Architecture (HLA,) an architecture used to enable war games simulations involving multiple services or even nations. The HLA is essentially a set of rules describing all the components of a simulation and the ways those components can interact. MITRE worked with both government and industry standards groups such as

the Object Management Group and the World Wide Web Consortium to develop a standard useful for both commercial and military purposes.

6.2.5 Tech Centers and Resource Management

MITRE's technical centers, as well as the technology-focused resource groups in the Air Force Center, use a variety of different integrating mechanisms to create ties with both the academic and commercial engineering spheres. Tech centers are expected to follow developments in both domains. As one tech center director put it:

> Their job, if they do it well, is to track where things are occurring in industry. So if I don't know who's doing the latest information summarization technology in the world, I've not done my job. If I can't say talk to Oracle, Microsoft, British Telecom, and by the way talk to the folks out at Mead because the Lexis/Nexis folks have a new service and it uses summarization – if I can't say that off the top of my head or know who to talk to… to get that answer then I haven't done my job. ... [B]asically you and your team, your distributed team, really have to know what's going on. You have to have your pulse into industry and into academia.

Tech center personnel do this by, for example, attending conferences, where they can scope out the booths and demos of other organizations. They also participate in standards organizations, where they work closely with other companies and academic experts to define new standards, and act as beta testers for new technologies, allowing them to gain a greater understanding of technologies that are still in the pipeline.

6.2.6 Ad hoc efforts

MITRE tries to foster integration between different parts of the military community. One example is MITRE's efforts to integrate war game simulations across different services. The Aggregate Level Simulation Protocol (ALSP) is a MITRE protocol to enable war game simulations from different services to work together effectively. ALSP is a precursor to the High Level Architecture (HLA) discussed previously. Because this is a one-of-a-kind product (the military only needs to coordinate its war games once), MITRE has been acting as the systems engineer on the project in the field. However, a new software system to integrate war games, called JSIMS, is under development by TRW. The project office for JSIMS has not been participating in or attending any of the ALSP test events. But as a result, the new simulation project is losing the opportunity to learn from ALSP experience. MITRE has only limited direct involvement in JSIMS with only a few people working on the project. While there is excellent communication between MITRE's ALSP and JSIMS employees, the JSIMS project office has not been interested in participating in lessons learned from ALSP. MITRE's senior management has made an effort to encourage greater cooperation between the two projects to ensure the transfer of lessons learned from ALSP older project to JSIMS, but has not had much success.

MITRE also fosters interorganizational integration in a much more casual or instrumental way. To facilitate integration within the technical community, MITRE management encourages its employees to participate in professional societies and conferences. Where there is a close match between MITRE interests and engineering demands, the company will sponsor engineering conferences, such as the Association for Computing Machinery Conference on Computer Supported Cooperative Work. In addition, when particular technical needs arise, MITRE funds applied research to develop solutions and works with standards organizations such as the Open Management Group to ensure that these solutions are put to use in the context of current standards efforts. Finally, senior managers engage in ongoing conversations with major technology

companies, such as Sun, Microsoft, Boeing, and Lockheed Martin. Their goal is to influence the internal research and development as well as product development efforts to reflect the needs of MITRE's clients.

6.2.7 Managerial Efforts

There are a number of integration mechanisms mentioned to us by senior management that did not come up in our interviews. We state them here for completeness, although our understanding of how they work and their effectiveness is necessarily limited.

The MITRE Technology Program (MTP) has a number of devices to provide integration vertically and horizontally within the company. The first is that the chief engineers of each organizational center, as well as of ISIS, MITRE's internal IT services division, identify technical topics of interest to their centers. Ten percent of the MTP's funds is distributed to chief engineers to use for "innovation grants" – small grants provided at the discretion of the chief engineer for developing an idea for future application to the MSR and MOIE pools of money. Twice a year formal proposals are collected and evaluated for potential impact on direct funded programs, academic community, standards and vendor organizations, and MITRE operations. In addition, each center has a Technology Integrator, often an associate technical director of a center, whose role is to develop a business strategy for each center to guide MTP funding, to assist Principal Investigators in arguing the business case for their research, and to identify technology gaps that their center might address. The MTP also created Technology Area Teams that are responsible for keeping abreast of academic and industrial research and practice in particular technical areas, as well as monitoring MITRE's capabilities in those areas. The Technology Area teams provide assessments of these areas to the corporate Engineering Council and share their findings internally via the

MII. Finally, Technology Exchange Meetings provide a time and place where engineers dealing a single thematic issues can share research and project results.

7. Integration Problems: Where MITRE Falters

7.1 Ceiling constraints are not the major problem

An important managerial consideration at MITRE is the ceiling constraint – the budget and headcount limits that are determined by Congressional mandate each year. Virtually every manager and engineer we talked with brought up this issue. The ceiling constraint certainly has a significant bearing on the company's organizational effectiveness, and might be thought of as the cost to MITRE of having its particular institutional form – the FFRDC. But while 'ceiling', as many people at MITRE refer to it, certainly creates issues that would not exist for other organizations, managers seem to find ways around the constraint. In fact, one senior manager pointed out that the constraints on MITRE's work created by the ceiling allow the company to focus on high quality work. When 'ceiling' does create problems, these have more to do with underlying issues of collaboration or identity than the ceiling constraint per se.

One example of how the ceiling problem manifests itself is a project in which staff members from two different centers were involved. The client asked the staff from one center to increase their pace of their work, which would have required one center to use a

disproportionate share of the project's ceiling allocation. The client had initially promised that it would find additional ceiling allocation, but after the first center increased its activity on the project, the client was unable to deliver on its promise. The client asked that the second center cease work on the project to enable the first center's staff to continue to work. Then the representatives of the second center became protective of their ceiling allocation and suggested that the first center had intentionally used more than its share of the ceiling allocation in order to force the second center off the project. In the end, the MITRE project manager resolved the issue by telling the client that MITRE would not be able to change the staffing, and the first center's employees stopped working on the project.

In a different organizational setting, this problem might have been resolved by increasing the budget for the project or creating a different project for the second center's underutilized staff. While it is true that the ceiling constraint denies MITRE this option, it is too simplistic to blame this failure on the ceiling constraint alone. If both centers had had a stronger sense of collaboration and had valued project performance over their ceiling allocation, the tension might have been avoided. While the second center would have been required to give up a portion of its work, the trust created with the client and with the first center might have led to higher quality work with the client in the future, enhancing opportunities for both centers.

7.2 Sharing knowledge internally and externally

Sharing knowledge is a challenge at MITRE at a number of levels. The transfer of knowledge between groups within the organization, particularly technical and project groups, and the transfer of knowledge from MITRE to its military clients and to the engineering marketplace is a difficult task.

At the most basic level, knowledge transfer within MITRE is hindered because of the confined scope of activity of many of the company's engineers. All of the engineering staff we spoke with, including the more senior engineers, had a limited scope of work relative to the range of projects, technologies, and work descriptions at MITRE as a whole. Often this scope was defined by the limits of the department or division in which the employee worked. On a number of occasions, an engineer described his or her position as unique in some way: in relation to the technology used, or the amount of time spent offsite, or the stage of technology development. Then they proceeded to describe a situation very similar to a story we had heard in a previous interview. Similarly, MITRE's library staff is reportedly regularly approached by engineers looking for what they describe as 'esoteric' information that has actually been recently requested by someone else. While many of these engineers engage in soft-shell work on a regular basis and seem to have a good understanding of the diversity of the company as a whole, the very idea of diversity seems to translate into the notion that their own work is unique.

The problem with this attitude is that it limits the company's ability to take full advantage of the range of technical and project experiences within the organization. If an employee believes that only his immediate neighbors in the company will find his work experiences useful, there is little incentive to participate in knowledge-sharing efforts such as posting publications on MITRE's intranet or seeking out others within the company who might be dealing with similar issues.

While MITRE's division directors have a broader understanding of projects and technologies within the company, in the past this has not always translated into greater coordination or knowledge sharing between similar projects. A good example is the lack of coordination between DIICOE related activities at MITRE discussed above. MITRE has responded to this particular challenge by creating the DII Council. But the fact that this

council was created only under pressure points to the difficulty of fostering internal knowledge transfer.

Knowledge sharing between technical and project-oriented staff is another problematic area for MITRE. The walls between these two domains were illustrated in the CORBA case study presented earlier in this report. The senior AWACS engineer in that story recounted his frustration that the tech centers rarely had answers to the questions he deemed relevant. He reported wanting to know the average time from beta testing to fielding for flight-based programs, only to discover that not only did the tech center he approached not know the answer, but they did not consider it a "fun and interesting" question. Given this divergence of perspectives, it is perhaps not surprising that the real-time ideas that *were* percolating in this tech center did not reach the project managers until the project engineer actively inquired at lower levels of the tech center organization.

Some of these same tensions persist in the matrix structure of the Air Force Center. Project staff have a clear incentive to retain the same technical staffers for the duration of their project. The more experience an engineer gains in a particular domain area, the more useful to that project he or she becomes. However, by staying with one project, an engineer may not develop the breadth of technical skills necessary to be useful on the next project. The result is a constant tension between the project manager's desire for increased domain knowledge and the engineer's desire for increased technical knowledge. Resource managers in the Air Force Center struggle to get project leaders to accept different personnel over the lifecycle of a project, since the change in personnel may hinder progress on the project.

7.3 Transferring technology to the marketplace

In its role as an FFRDC, MITRE develops prototypes using a number of different technologies, including both software and hardware systems. One of MITRE's unofficial tasks is to transfer this technology to the marketplace where it can be generally available to DOD and commercial clients. Unfortunately, MITRE has limited means to do this. MITRE cannot directly manufacture any products, and many of its prototypes are not far beyond the "proof of concept" stage of development. MITRE's focus on projects limits its ability to spend resources finding an appropriate company to develop and sell its technology.

The increased use of commercial off-the-shelf (COTS) technology in government systems has reduced the opportunities for MITRE to transfer technology to contractors in the acquisition process.[26] The current model for technology transfer relies much more heavily on standards organizations, sharing knowledge at conferences, and transferring technology directly to the marketplace. But more than one engineer described difficulty in giving away technology to the marketplace. Part of the problem is that MITRE does not want to favor one company over another, as this would jeopardize its position as a disinterested advisor to the government. But some engineers and managers seemed to suggest that companies were not interested in using any technology that was being given away.

There are some exceptions to this. Some of MITRE's prototypes have been so successful that its clients have demanded their equivalent from private contractors. The Collaborative Virtual Workspace (CVW) is one example of this. According to its developers, CVW has been used widely enough within the military and intelligence

[26] In the past, MITRE transferred technology "by working side by side with contractors, or providing technology to contractors at the sponsors direction." (MITRE, 1999a)

community that it has raised the level of expectation for collaborative technologies. Private software developers have complained that they have difficulty selling their technologies because they don't meet the standard set by CVW. While this is not a case of direct technology transfer, it does indicate that MITRE's prototypes have increased the level of services provided in the collaborative technology marketplace. The advent of open source software may provide MITRE with new opportunities for technology transfer. In fact, MITRE recently made the source code for CVW publicly available for download.

The creation, in March 1999, of MITRE's first formal technology transfer office may resolve some of these difficulties. In addition to facilitating provision of open source or freeware code, the office will participate in efforts to establish industry standards and consider low-fee licensing where it is appropriate for both the sponsor and for MITRE. Aside from concerns about creating an apparent conflict of interest, there are no legal barriers preventing MITRE from licensing its technology.

7.4 Defining customer needs: opportunities for interpretive action

Another challenge for MITRE has to do with the definition of customer needs. This process typically takes place in several stages, with clients stating their needs, MITRE suggesting technical possibilities, clients adjusting their need statements, and MITRE changing its technical suggestions in response.

One complicating factor is the lack of technical expertise on the part of military officers involved in the acquisition process. The officers generally have short assignments, and cannot reasonably be expected to have the breadth of current technical knowledge needed to make sophisticated design decisions about, say, command and control systems.

Their view of future needs tends to be constrained by the possibilities of the technologies they are already familiar with. Often this means that they will approach MITRE with a specific technology in mind when in fact the functional need they have might be better met by a different technology.[27] One engineer mentioned an intelligence client who approached MITRE about finding silent, high quality color printers. When MITRE began to explore how these printers were to be used, it turned out that the printouts were to be scanned into another computer system in the same room. What the client really needed was a fast, robust network connection between two computer systems, not a quiet printer.

Another example concerned the development of handheld computing devices used by field medical staff to track patient information. Previously the clients had used a clipboard system, and in initial design discussions described an electronic version of their current system as the goal. As the client began to test the prototype and explore new possibilities, such as networked connections to a database that routes patients to different hospitals, both MITRE and the client saw a host of new ways of using and designing the system. This led to a longer but productive design period, involving repeated iterations of development and field testing.

A notable approach to dealing with this recurring issue is the appointment of a handful of staff within the Air Force Center whose role is to monitor the users of systems designed by MITRE and to prime those users to understand the range of new technologies available, so that future conversations about product definition and specifications can start at a more sophisticated level. We believe that this type of 'interpretive' role may be particularly important to MITRE's future success as a system integrator, and suggest that MITRE may want to consider extending it to other Centers.

[27] One interviewee described this as "paving the cow path"

8. Analysis of Integration Mechanisms at MITRE

We now have an understanding of the integration mechanisms that MITRE uses internally and externally, as well as the problems it encounters in integration. The next task is to return to the questions raised in Chapter 3. Does the empirical evidence from the study of MITRE support the contention that integration requires something beyond coordination? If so, are the mechanisms that are used discursive and centered on the problem of setting goals? Is the claim that MITRE is a network organization correct? This chapter addresses these questions.

The first question is whether MITRE is in fact an organization dealing with radical uncertainty. This issue has already been addressed in chapters 2 and 4, but we will summarize the issue again here. As an FFRDC, MITRE's role is to help develop and integrate new military command and control, air traffic control, and tax modernization systems. These require an intimate knowledge of rapidly changing networking, database, communications, and information processing technologies, as well as a close understanding of the military, aviation, and tax domains. While MITRE's customers are relatively stable, the technologies in question are changing rapidly. These technological changes enable new organizational processes, creating further uncertainty. The result is an

environment of radical uncertainty – systems and projects that are so uncertain that it is difficult, if not impossible, to characterize at the outset what the final result will be.

The next question is whether MITRE fits our earlier description of network organizations. Recall Baker's definition of a network organization as one where intergroup relations are heterogeneous and not associated with ingroup bias. Reliance on trust, frequent transactions, tasks organized by project, and knowledge based authority are other characteristics of network organizations. (Powell, 1990, Podolny and Page, 1998, Baker, 1992) Many of these descriptions are true of MITRE. Internally, work at MITRE is organized by projects. The practice of soft-shelling spreads knowledge throughout the company and encourages cross-company collaboration. Externally, MITRE's status as an FFRDC fosters a strong sense of trust between company and governmental clients – MITRE has long-standing relationships with the same clients, such as the Electronic Systems Center, over many years. While relational contracting, per se, is not used within the DOD FFRDC, MITRE's FAA FFRDC does use negotiated annual outcomes as the basis for its contract with the FAA. Other characteristics of network organizations, such as shared property rights, are not apparent at MITRE.

MITRE fits our definition of network organization in both senses – as a firm organized as a network and as a firm operating within a network. Internally, project work is characterized by the use of resources from across the firm in a shared, trusting manner. Externally, MITRE has long-standing relationships with clients, and frequent interaction with standards organizations and technology companies. This description, however, needs to be qualified by the limitations on internal networking seen at MITRE. While the firm is striving to foster relationships that cross internal borders, internal boundaries still exist. Problems around the DIICOE projects and tech centers suggest that the recent increase in collaboration has not yet advanced to the degree desired by company executives. In addition, MITRE has not decentralized many of its administrative

functions, such as hiring and purchasing. One interviewee summarized the tensions within the company around these issues:

> MITRE is very much struggling with this centralized vs. decentralized way of running the organization. Do you allow your departments to run as autonomous business units or do you try to provide some central level of consistency in terms of how business is done? And its kind of, it's a tough area for MITRE because MITRE's charter as an FFRDC has to run a tighter ship than a commercial company. We get audited, we get threatened with audits, just to make sure since we're a non-profit, federally funded, that we're spending the money in very reasonable ways that can be accounted for.

Administrative centralization aside, MITRE's professional work is characterized by networking across boundaries, while operating as a firm within a network of government agencies and private companies.

8.1 Goals and Interpretation in MITRE's Work

In the previous chapter we discussed two good examples of interpretation of a clients need. The first was a client asking for a printer when in fact what was needed was a network. The second was an electronic tablet to support health care personnel in the field. Both of these cases called for interpretation on the part of MITRE. In fact, what was needed was a discussion of the goals of the project. Did the first client really wish to print images, or was the goal to transfer images easily from one computer user to another? Did the health care unit want to digitize its current organizational system or was there room for improvement in the operational systems? Both of these cases fit the structuration model introduced in chapter three. Both clients came to MITRE with a particular goal in mind. After revisiting both the problem and potential technical

solutions, the initial goal changed. In the first case this interaction was fairly simple – the result led to reframing the need from a printer to a network. In the second case the interaction was more complex, with numerous iterations between field and lab, and major changes in the operational use of MITRE's prototype.

In MITRE's uncertain environment, the goals of a project may not be clear at the outset and, even when the goals are clear, it may be that the appropriate technologies are changing so quickly that the appropriate solution is difficult to develop. While it would seem that the military's hierarchical structure would lend itself easily to the process of goal setting, very often the interaction between MITRE and its clients is a complicated dialog about what exactly the purpose of a system is. Indeed, even when goals are clearly stated at a strategic level, it can be exceedingly difficult to translate those goals into guidelines for operational development. This translation process itself involves goal setting. We saw an excellent example of this in the difficulties around the DIICOE standards. While the DOD has a clear interest in creating interoperability between service information systems, at the level of an individual program, implementing these standards created conflicts due to lack of funding. Making a decisions about how and when to support the DIICOE within a command and control system requires an examination of the goals of the system – is it more important for a battlefield command and control system to provide new functionality to commanders, or to provide interoperability with strategic control systems?

The processes used to address the questions are inherently conversational. They require a common understanding of existing technical and operational systems. MITRE's role as a "trusted advisor" to the government creates a sense of shared agency between MITRE employees and military clients. The process of addressing these issues involves

changes to both parties' understanding of both the problem and potential solutions. These characteristics are exactly what we defined as a discursive process in chapter 3 – common background, shared agency, and change in understanding of context.

The examples above demonstrate external integration – integration relationships between MITRE and its clients. But the same principles hold when examining integration within the company. To draw on the DIICOE example once again, the problem was that DIICOE related projects were neither sufficiently aware of each other nor of a corporate position on the utility of the DIICOE. Left without internal guidance, each project advised its client in the interest only of that client, neglecting MITRE's larger mission of supporting the DOD's efforts to build a unified command and control system.

8.2 Mechanisms to support discursive processes

A closer look at the integration mechanisms described in chapter 6 shows that virtually every mechanism used by MITRE actively supports the discursive processes we are describing. All of these mechanisms encourage repeated interactions involving a significant degree of information and knowledge sharing, with the goal of changing the way all parties understand a problem.

The clearest example of discursive integration mechanisms at MITRE is the integration councils used to foster internal integration within the company. The DII Council, I Team, and Collaboration council are all examples of discursive integration mechanisms. These councils function as locales for fostering conversation between parties with a common interest. These councils might be seen as pragmatic in Malek's sense – they exist to foster conversation around a particular topic, such as DII related activities, information systems within MITRE, or collaboration technologies and applications. They

define general topic areas and have broad mission statements, but usually don't have explicit coordination tasks. The DII Council, for instance, was formed in response to a particular problem within the corporation, but was expected only to foster greater cooperation and discussion between DIICOE related projects, not to develop a statement about MITRE's position on the use of DIICOE within projects. Collocation and field activities, external integration mechanisms, also have a strong discursive element. The repeated interactions between MITRE and its clients on a daily basis foster greater integration across firm boundaries.

These mechanisms are based on a handful of different principles. The idea behind matrix organizations, the tech centers, and collocation is to place like employees together, both physically and organizationally, in the hopes that proximity and shared management will create an environment conducive to knowledge sharing and discussion about common problems. Integration projects and teams such as the Chief Architect's Office and the systems engineering group within the CAFSPO program designate individuals or small groups as interlocutors – individuals tasked to foster conversation among MITRE employees about connections between different projects. Finally, councils such as the DII Council and integration meetings organized by MITRE's DARPA office create a place in time where engineers can share knowledge about similar projects.

There are two caveats to our discussion here. The first is that, in addition to encouraging discursive interactions about project and firm goals, many of these mechanisms also promote coordination within the firm. The Chief Architect's Office, for instance, ensures that Electronic Systems Center programs submit relevant information regarding DIICOE requirements to DISA, and resource managers within the Air Force Center matrix ensure that employees are working on a manageable number of contracts at any given time. These coordination tasks are what would be expected in any mid-size corporation. The emphasis placed here on discursive processes is not meant to diminish

the importance of coordination within an organization, but only to establish that discursive processes are, in fact, an important aspect of integration.

The second caveat is that, while these mechanisms *foster* discursive processes, they do not create them. Fundamentally, it is individual behavior, and not organizational mechanisms, that creates the interpretive interaction between organizations. If the MITRE employees did not value collaboration and interaction with colleagues and clients, it is extremely unlikely that any of the mechanisms would be successful in providing fostering integration. We will return to this issue in chapter 9 when we discuss corporate identity.

8.3 Technology-Mediated Integration: MII and CVW

Two particular technologies at MITRE stand out as supporting organizational integration. The MITRE Information Infrastructure (MII), mentioned above, was developed in parallel with a project for a client that needed an intranet system. The MII has continued to evolve as web-based tools for finding expertise and internal publications have been developed and an increasing amount of programmatic information is published. One major goal of the MII is to extend the practice of soft-shelling between centers beyond the exchanges that occur because of word of mouth recommendations. While some individuals are heavy users of the MII, using its publishing capabilities to transfer documents to colleagues, only a few interviewees mentioned the MII as a tool for finding

and accessing corporate knowledge, although most people made use of its administrative capabilities such as scheduling meetings.

The Collaborative Virtual Workspace (CVW) is another system designed to support integration. CVW is a groupware package that supports audio, video, text, and document sharing services in a customizable and secure environment. CVW is used both internally at MITRE and by a number of governmental clients, who have been reluctant to stop using the prototypes developed by MITRE. While those that use CVW regularly praise its utility, our interviews suggested that the application has not gained widespread use throughout the company.

Both of these tools encourage discursive processes. The MII provides an internal location to broadcast information as well as tools for sharing documents, models and plans with anyone in the company. The CVW directly supports discursive processes through its text, audio, and video services. However, neither tool has achieved its full potential as an integration mechanism.

There are a number of reasons that these two technologies have had only a limited impact. The first is the common problem of creating trust online. While MITRE has a generally collaborative and open culture, people seemed more willing to share information with those they had personal contact with. In addition, the posting and document transfer capabilities on the MII were seen by some as tantamount to publishing a document internally, and people may not be willing to 'polish' their documents to a publishable standard without clear knowledge that the document will be used.

Understanding the limited use of CVW is bit different. CVW tends to be used within groups – either everyone within a work group uses it or no one uses it. Because of its persistent text capabilities, it serves as a very useful tool for geographically distributed teams. Groups that are collocated did not seem to have the same need for a collaborative workspace.

9. MITRE's Identity

"It's a company that's struggling, struggling as it always has, with what its purpose is."

In our analysis of integration mechanisms at MITRE, we conclude with the observation that it is individual behavior, not integration mechanisms, that creates the discursive processes necessary for integration. An important part of the definition of a discursive process is a reliance on a shared background. This chapter deals with shared background and mission at MITRE – in essence, MITRE's identity.

Identity at MITRE is complicated by the company's FFRDC status. The company must be able to differentiate itself from the government contractor community and from the government itself in order to justify its special status as an FFRDC. The dilemma confronted by MITRE today is that the external emphasis on collaboration tends to *de*-emphasize its uniqueness, while its ability to integrate internally and externally depends on having a strong sense of identity. While these tensions have always been problematic for MITRE, the changes in its environment have made this a more pressing problem.

This dilemma is illustrated by the problem of prototyping discussed earlier in the report. The creation of prototypes does not in and of itself compromise MITRE's unique status as a military-technical integrator. But to the degree that MITRE-created prototypes – especially in the IT domain – are today more likely to enter the commercial marketplace, its special standing may be challenged.[28]

More generally, the increased emphasis on organizational integration across the military establishment and between the military and commercial domains is breaking down some of the boundaries between the collaborating organizations, including MITRE. The risk to MITRE is that as its organizational boundaries – both those that separate it from its clients and those that separate it from the contractors – become blurred, its ability to differentiate itself may be adversely affected. This is problematic not only for MITRE's survival as an FFRDC, but also because its ability to establish and maintain close ties simultaneously with industry, academia, and the military hinges on its unique role and institutional standing. In the long run, unless MITRE can clearly differentiate itself from the institutions – military and commercial – with which it deals, it risks being absorbed by them.

The question of organizational identity is also important in fostering integration within MITRE. We have previously commented on several problems of internal coordination – between the technical centers and the projects, between project managers and engineers, and between similar projects that are organizationally isolated from each other. In all of these cases, a lack of awareness of the connection between individual project goals and the larger goals and identity of the company contributes to the internal barriers to cooperation. This is particularly true of the tensions between domain-focussed

[28] The establishment of a technology transfer office with responsibility for managing the transfer of MITRE technologies may alleviate this problem somewhat.

and technically focussed employees, who have less of a common background on which to rely.

9.1 MITRE as an FFRDC

"MITRE's charter is to act in the national interest"

In the course of our research we encountered two very different conceptions of MITRE's identity. The first focussed on MITRE as an FFRDC acting in the nation's interest; the second focussed on MITRE as an advanced development information technology company.

Many interviewees focused on MITRE's role as a systems integration FFRDC as the key to understanding MITRE's identity:

> We try to help the Air Force identify their communications requirements so they can take it back to their own groups and help argue for a system that meets their requirements.
>
> MITRE is a company that acts as an interpreter between government and contractors, via its oversight work.
>
> We have a party line that says that one of the strengths MITRE brings to the table is an integrating role for our customers. And that's integration across service boundaries, across program boundaries within a service, across the user to the technical communities, across the operator to the acquisition communities. ... And across a lot of different technologies to try to pull them all together into systems that need them all.

> We play an integrating role between services, programs, user to technology community, user to acquisition community, between different technologies.

Over time, MITRE's role as an FFRDC has changed as it has taken on an ever broader conception of acting in the nation's interest. Starting with the expansion of SAGE technology into the civil aviation domain, MITRE has put its technical knowledge to use in areas beyond its military projects. MITRE's charter currently refers to an integration role that goes beyond any particular project. This role is laid out in its sponsoring agreements:

> "While serving the immediate needs of the many individual programs it supports, the C3I FFRDC directs its work program towards achieving DOD's vision of an integrated C4ISR[29] capability based upon a system of systems that supports joint U.S. and multinational military operations." (MITRE, 1998a)

This role, which is inherently vague and undefined, is not attached to any particular program. It is a task that only an institution like an FFRDC – with close, ongoing ties to both the technical and military communities – could do. Though tight budget and staff limits mean that in practice MITRE is constrained for the most part to working on specifically contracted projects, and has few explicit resources to allocate to other activities, the FFRDC charter recognizes that MITRE in principle has the opportunity – and the obligation – to work towards a larger goal, namely an integrated military command and control structure for the DOD.

---

[29] Command, Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance

MITRE's work in support of the nation's interest goes beyond the military and aviation domain. The company has a history of expanding beyond its DOD and FAA activities into other domains – a history that was brought at least temporarily to a halt with the spin-off of Mitretek. More recently the creation of a new FFRDC to support the Internal Revenue Service can be seen as another effort to utilize MITRE's technical knowledge in the nation's interest. Another example is the company's efforts to raise awareness of the need for critical infrastructure protection.

The conception of MITRE as serving the national interest is clearly a key identifying issue within the organization. A number of employees – both engineers and managers – specifically mentioned this aspect of their work as being important to them. But the implications of this vary across the organization. For MITRE employees who operate primarily within the military domain, their opportunity to contribute to the national interest is relatively well defined, and the channels through which they can exercise their initiative and ingenuity in support of this goal are fairly clear. They need 'only' join up with other program managers or systems engineers and find ways of contributing to the larger integration goal of the C3I FFRDC.

But for the technical specialists the situation is a little different. It is more difficult for them to take a leadership position beyond the particular projects they are working on. Because they are dealing with tools and techniques rather than domain problems, they are more likely to generate ideas that find application beyond MITRE's military, aviation, and tax projects – for example, ideas in support of critical infrastructure protection or information security. But, short of the formation of new FFRDCs within MITRE, there are few opportunities to develop these ideas,

This is not to suggest that the technical staff at MITRE contribute less to MITRE's corporate goals or to the national interest than do military domain staff.

Indeed, it is possible to exaggerate the significance of this distinction, since some individuals hold both types of positions over the course of their careers at MITRE. But it is clear that MITRE's technical staff have ideas and a desire to contribute that are currently constricted within the organization. The alternative vision of MITRE as a firm that develops advanced information technology can be understood as a manifestation of this problem.

9.2 MITRE as an IT company

A second view of MITRE's identity emphasized the company's role as a developer of advanced technology. During our interviews we frequently heard phrases like "sustaining our position", "remaining competitive", "becoming an information technology company" – all suggesting a view of MITRE competing within the information technology marketplace. For example:

> I think the thing that we're going through right now as a company is probably most significant because the company says it wants to become an information technology organization, which means you have to be very nimble and fleet of foot and all of that and we're definitely not there.

Senior management at MITRE has pushed the idea of becoming an IT company, but there are several different interpretations of what this means. Senior managers, in discussing the future development of MITRE in the IT domain, emphasize the company's focus on the practice of using information technologies to support governmental needs. Some hardware engineers have resisted the idea that MITRE would become more of an IT company on the grounds that such a development would leave little room for their skills and capabilities, although MITRE managers emphasize the role of both hardware and software in this context. Finally, there are also individuals who seem to think about the future of MITRE as a player in IT applications outside of just governmental applications.

One manager discussed at length his interest in using MITRE's information security expertise to expand into the infrastructure protection market. While this manager is discussing the critical infrastructure domain, his emphasis on expanding beyond the military market, developing technologies for sale, and creating growth opportunities within the firm exemplify the idea of MITRE as an information technology company.

> Interviewee: I view [this site] as being in a stronghold position to address other sponsors. I'm not sure if you're familiar with some work MITRE's doing in critical infrastructure protection which is basically security protection – I view MITRE … as being a stronghold for taking that kind of work into the New York City arena where you have the center of banking, you have the center of industry, you have many centers that need and require critical infrastructure protection. So I would view it a strategic goal of this site to expand beyond just the Army.
>
> Interviewer: But all the things you just mentioned are civilian applications.
>
> How does that fit within MITRE as an FFRDC?
>
> Interviewee: What it is, MITRE as an FFRDC would not perform that. But once again the DOD FFRDC supports the Department of Defense. The MITRE corporation which is the corporation which operates the FFRDC, has had approval in the past to address areas of core competency that this corporation holds that are of public service and interest, and critical infrastructure protection is one of those areas. Although not a DOD supported activity, it is one that has been approved by our prime sponsor as one that MITRE can and should pursue because of our special capabilities and because it serves the public's interest.
>
> Interviewer: Ok, so if you were successful, if we were talking a year from now and you were successful in moving into critical infrastructure protection for the banking industry, how would you go about staffing that? Would MITRE have to set up another division outside of the FFRDC in order to staff that and would that work be influenced or limited by MITRE's ceiling?
>
> Interviewee: Ah, there are some very good questions there. I think that I would not try to segregate. One of the reasons I would want to do this, is

> one of the issues I believe we as a corporation have is because we are constrained in growth. Congressionally, we are constrained in offering opportunity. And that becomes problematic in retaining key skills. So this is an outlet in many ways to be able to track and retain key skills within this organization and afford them opportunity for growth. So what I would like to do is use that outlet to ensure that there is some cross fertilization going on in what the commercial world's doing with the DOD world and to be able to attract what I would call the top talent in those areas by offering them not only the challenge of a tough work program but career growth opportunities through real exhibited growth in the organization.

This interchange demonstrates a number of topics that bear on the identity issue – the scope of MITRE's work, its responsibility and opportunity to carry out non-DOD work, the opportunity to emphasize technology development, and the need to provide opportunities for technical staff in order to retain them.

Many of the issues discussed previously, such as concern over extensive prototyping within the company and a lack of attention to military problems by the technical centers, can be seen as the natural result of a strong desire, at least within the technical side of the company, to push MITRE's work into the information technology marketplace.

The basic difficulty is that the technical staff does not clearly see the relationship between its project-level tasks and the larger mission and identity of the company. This problem has two distinct roots (and consequently two potential solutions), one better understood than the other. The more familiar source of the problem is MITRE's difficulty in applying its technical expertise to new domains of practice. One might say that the constraints on MITRE's expansion into such new domains limit its capacity to express the technical aspects of its identity. The other source of the problem is that MITRE, as a project-based organization, lacks a vocabulary for discussing its larger integration mission even within its accepted domains of activity (e.g.. DOD command and control systems), and that *this* aspect of its identity is not well articulated. This second

deficit once again poses particular difficulties for MITRE's technical specialists, who are further removed than the military domain staff from an understanding of the integration possibilities in the military area. One important task for senior management will be to lead conversations within MITRE aimed at developing a new vocabulary to describe the company's larger, ongoing integration mission.

9.3 Analysis

MITRE has a strong sense of culture. The notion of using technology to act in the nation's interest pervades the company. It seems to be part of what attracts people to MITRE and keeps them there. The problem is that many employees do not have a clear sense of the connection between their own work and identity and the corporate identity. The result is that most employees focus on the connection between their work and the group level – they see themselves as MITRE tech center people, or as MITRE project people. What is lacking at MITRE is not a culture, per se, but effective management of the culture.

Because culture is not being "managed" and MITRE is working in a rapidly changing environment, different ideas about company goals are beginning to form. While this is potentially a source of new ideas about MITRE, the risk in this situation is that the networks within the organization will begin to fragment. We saw some evidence of this in the difficulty in facilitating cooperation across centers and different ideas about what MITRE's future should be, including what the role of prototypes should be. Externally, the danger is that the firm will be coopted by the organizations with which it creates close relationships, as we saw in the case of the DIICOE.

MITRE has recognized this problem, at least in some areas. The recent tech center study (MITRE, 1999b) concluded that the company needed to create better connections between tech center objectives and MITRE's strategic vision.

MITRE managers must shape the firm's identity both internally and externally. The substance of MITRE's identity is the same internally as it is externally – using technology to act in the nation's interest. However, MITRE's identity serves a different purpose in the external environment than within the company. Externally, MITRE should focus on its identity as an unbiased systems integration firm with a larger purpose of helping the nation use technology. This aspect of MITRE's identity allows firm employees to gain access to standards groups, research parks, firms, and clients that it might not reach otherwise, and to retain its FFRDC status. Internally, MITRE needs to focus on its "actions in the nation's interest" to motivate its employees to share knowledge and expertise with other employees. MITRE needs its identity to motivate employees to integrate internally, but it needs to provide clearer connections between this mission and both technical and project work.

MITRE's conflict over identity does not imply that the company is failing at providing integration services, or that it is not meeting its standards as an FFRDC. However, more attention to this issue might provide opportunities both to strengthen integration performance and to create a satisfying environment for employees.

10. Conclusions

10.1 Practical Implications

MITRE employees have a hard time describing to themselves, to clients, and to the public exactly what it is that the company does. We have argued that these problems of identity are consequential – that they complicate MITRE's ability to perform its external integration functions successfully, and that they make it harder for MITRE's internal resources to be shared effectively across the organization. We have further argued that MITRE's need for a stronger sense of identity is, if anything, becoming more acute because of changes in its strategic and technological environment.

How might MITRE respond to these identity problems? As reported in the previous section, research at the company revealed two alternative visions of MITRE among its employees – an FFRDC acting in the national interest, and an advanced information technology development company. These are to a large extent opposing visions, and one way to think about MITRE's options is to pose the following choice: the company can try to clarify its identity either by looking for ways to integrate these

two views more effectively, or by deliberately cultivating each aspect separately – in other words, by intentionally fostering a dual identity.

In the former case, there are several possibilities for action. MITRE could foster greater interaction between the military and technical domains within the company by creating career pathways that encourage transfer between these two areas, and by creating positions that more explicitly bridge the two. Alternatively, the company could encourage both managers and engineers to spend part of their careers at MITRE working with intelligence clients or in other areas where collaborative approaches are strongly valued. Promoting interchange between different parts of the company in these ways would help to develop the common language needed to cross the boundary between military and technically oriented work.

A complementary approach would be to develop a clearer language to help internal discussions of MITRE's broader integration function, as well as metrics or assessment mechanisms that would link this broader role to MITRE's technology development work. The company could go beyond this and introduce new institutional mechanisms to support this role. In fact, MITRE has limited mechanisms to do this. The first is the use of MSR and MOIE money to support internal research efforts that support the company's broader integration function. The second is the time of its administrative employees, particular senior executives and division directors, who are paid out of overhead and thus able to use their time with somewhat more discretion. Third, by actively selecting projects that create opportunities for broader integration within the military community, MITRE can at least meet its DOD integration goals. However, these mechanisms do not create opportunities for all MITRE employees, particularly technical employees, to both participate in and be rewarded for contributing to the company's broader integration function. Changes made to the MITRE Technology Program reflect an initial recognition of the problems discussed here. The outcomes

measurement used to assess the MITRE Technology Program and CAASD might provide models for developing such metrics.

The alternative to trying to synthesize these two views of MITRE would be to explicitly cultivate each one separately. Because this would mean placing greater emphasis on MITRE's role as an advanced IT development company, it would necessarily involve more significant organizational changes, and would immediately raise a number of questions about the appropriate range of activities for FFRDCs, a long unresolved issue in federal research funding debates.

In this regard, MITRE might strengthen mechanisms that would allow its technologies to be licensed to other companies for commercial development, or even to be "mined" by another company specifically focused on commercial technology development. Alternatively, MITRE could encourage its technology centers to focus on prototypes and technology development with the hope that some of these technologies could be spun off into private companies with no formal ties to MITRE. A formal review process would be needed to determine whether a spin-off would be consistent with MITRE's other responsibilities and its status as an FFRDC. Each case would need to be judged on its own merits, and one possibility would be to establish a standing review board, comprising MITRE, DOD, and commercial representatives, which would review spin-off opportunities on a case-by-case basis.

10.2 Theoretical Implications

10.2.1 Redefining Integration

Integration requires more than just coordination. We have suggested that integration in situations of uncertainty requires not just coordination, but an ongoing, discursive process centered on eliciting project and firm goals. The discursive process of forming goals may be the most important part of the integration task in situations of uncertainty.

10.2.2 Networks, Integration, and Uncertainty

We have argued that integration in situations of uncertainty is facilitated by networked organizations. Network forms of organizing are used both internally within firms and between firms in a marketplace. Uncertainty creates a demand for integration because of the need for great amounts of information to be passed quickly. Network forms of organization provide this capacity, as their greater density of information transfer ensures that not only is information passed through the entire organization, but that a greater level of detail is communicated. In situations of uncertainty, integration is fostered by working within a network, which provides more access to social capital and a larger scope of information about possible events.

Most ties within network organizations are a result of previous work or social experiences. Information technology applications such as groupware, Notes, intranets, etc., are an attempt to provide technology-mediated mechanisms for forming new ties

within and across organizations without having to rely on the particular individuals one has worked or played with before. A common problem with these systems is the development of sufficient trust to support their use for that purpose.

The relationship between identity and goal-setting discursive processes fits the structuration model described in Chapter 3 and, consistent with this model, is somewhat circular. When individuals engage in the goal-setting discursive processes we have described, they rely in part on a preexisting understanding of their firm's goals. As they continue working, and talking, with people from other parts of the firm, or from other organizations, their sense of their firm's goals and identity changes. This new understanding then becomes the background for their next interaction. If a firm does not have strong internal practices to reinforce a particular identity, the firm risks internal disintegration, as different sub-units identify themselves more strongly with their respective clients. If a networked firm is to create cohesion and internal integration, particularly in an environment of substantial collaboration with other firms and institutions, the firm needs to foster a strong sense of identity – an overarching (though possibly quite vague) goal about what the purpose or *raison d'être* of the firm is. However, the new ideas about the firm's identity that are created within discursive goal-setting processes allow it to adjust and respond to environmental change. Firms like MITRE can be well integrated with clients and suppliers by using techniques that allow them both to coordinate and to establish goals.

The current discussion of core competencies (Teece et al., 1994, 1997), fits into this argument. Identifying core competencies requires a firm to identify the set of skills and abilities that it has developed most fully. These competencies, in conjunction with the mission of the organization, form the identity of the company. This identity in turn provides the cohesion necessary for a networked firm to remain effectively integrated.

An interpretive approach to understanding integration may help to resolve some of the fundamental questions about why we have firms, how the boundaries of firms are determined, and under what circumstances internal organization will outperform markets. Specifically, it promises to shed light on two important issues: understanding the boundaries of the firm, and understanding the differences between firms, networks, and hierarchies.

One suggestion for future research is to explore extensions of the transaction cost model that would incorporate the idea of discursive exchange into economic transactions. Examining economic transactions as discursive exchanges, as well as exchanges of goods, services, or funds, might lead to a better explanation of why transaction costs are lower in firms. By acting as a locale for creating common languages and norms, firms may enable more effective discursive exchanges, thereby lowering transaction costs.

11. References

Alchian, Armen and H. Demsetz. (1972), "Production, Information Costs, and Economic Organization," *American Economic Review*, 62 (December), pgs. 777-795.

Aldrich, Howard E. and Peter V. Marsden. (1988), "Environments and Organizations" in *Handbook of Sociology*, ed. by Neil J. Smelser, Sage Publications, London.

Astely, W. Graham and Andrew H. Van de Ven. (1983), "Central Perspectives and Debates in Organization Theory," *Administrative Science Quarterly*, 28, pgs. 245-273.

Bailey, Joseph P. (1998) *Intermediation and Electronic Markets: Aggregation and Pricing in Internet Commerce*, Ph.D. thesis, Technology, Management, and Policy Program, MIT, Cambridge, MA.

Baker, Wayne. (1992), "The Network Organization in Theory and Practice," in *Networks and Organizations: Structure, Form and Action*, ed. Nitin Nohria and Robert G. Eccles, Harvard Business School Press, Boston, MA.

Barley, Stephen R. (1988), "Technology, Power, and the Social Organization of Work," *Research in the Sociology of Organizations*, 31, pgs. 33-80.

Black, Chris. (1995), "Shakeup Expected at MITRE; Firm to be split into 2; US Defense cuts cited," *Boston Globe*, September 12, 1995, Economy section, pg. 37.

Bourdieu, Pierre. (1977), *Outline of a Theory of Practice*, Cambridge University Press, Cambridge, UK.

Boutelle, Steven and Alfred Grasso. (1998), "A Case Study: The Central Technical Support Facility," *Army RD&A*, March-April 1998, pgs. 30-33.

Burns, Tom and G.M. Stalker. (1961) *The Management of Innovation*, Tavistock Publications, London.

Burrell, Gibson and Gareth Morgan. (1979), *Sociological Paradigms and Organizational Analysis*, Heinemann, Portsmouth, NH.

Carlile, Paul R. (1998) "From Transfer to Transformation: Working through Knowledge Boundaries in Product Development," unpublished manuscript, Massachusetts Institute of Technology.

Castells, Manuel. (1996), *The Rise of the Network Society*, Blackwell Publishers, Oxford, UK

Ciborra, Claudio U. (1993), *Teams, Markets, and Systems: Business Innovation and Information Technology*, Cambridge University Press, New York.

Coase, Ronald H. (1937) "The Nature of the Firm" in *Economica*, November, pgs. 386 - 405.

Coase, Ronald H. (1988) "The Nature of the Firm" in *Journal of Law, Economics and Organization*, 4, pgs. 3-47.

Cohen, Michael D. and Lee S. Sproull, ed. (1996) *Organizational Learning*, Sage Publications, London.

Collins, James C. and Jerry I. Porras. (1994) *Built to Last: Successful Habits of Visionary Companies*, HarperCollins, New York.

Coyne, Richard. (1995) *Designing Information Technology in the Postmodern Age: From Method to Metaphor*, MIT Press, Cambridge, MA.

Cyert, Richard M. and James G. March. (1963), *A Behavioral Theory of the Firm*, Prentice Hall, Englewood Cliffs, NJ.

Day, Kathleen. (1995), "MITRE Weighs Severing Nonmilitary Unit," *Washington Post*, September 22, 1995, Financial section, pg. C3.

Day, Kathleen. (1996), "The Think Tank That Went Out for a Spin; MITRE Splits in Two to Answer Concerns That It Has an Unfair Edge in Government Work," *Washington Post*, February 23, 1996, Financial section, pg. B1.

Dyer, Davis and Mitchell Aaron Dennis. (1998), *Architects of Information Advantage*, MITRE Corporation, Bedford, MA.

Chandler, Alfred D. (1977), *The Visible Hand: The Managerial Revolution in American Business*, Belknap Press, Cambridge, MA.

Elster, Jon. (1986), Introduction to *Rational Choice*, ed. Jon Elster, New York University Press, New York.

Emirbayer, Mustafa and Jeff Goodwin. (1994) "Network Analysis, Culture, and the Problem of Agency" in *American Journal of Sociology*, 99(6), pgs. 1411-1454.

Fligstein, Neil. (1990), *The Transformation of Corporate Control*, Harvard University Press, Cambridge, MA.

Fransman, Martin. (1994), "Information, Knowledge, Vision and Theories of the Firm," *Industrial and Corporate Change*, 3(3), pgs. 713-757.
Galbraith, Jay R. (1977), *Organization Design*, Addison-Wesley, Reading, MA.

Gibbons, Robert. (1998), "Game Theory and Garbage Cans: An Introduction to the Economics of Internal Organization" in *Debating Rationality: Nonrational Aspects of Organizational Decision Making*, ed. Robert Stern and Jennifer Halpern, Cornell University Press, Ithaca, NY.

Giddens, Anthony. (1984), *The Constitution of Society: Outline of the Theory of Structuration*, University of California Press, Berkeley.

Granovetter, Mark S. (1973) "The Strength of Weak Ties", in *American Journal of Sociology*, 78(6), pgs. 1360-1380.

Hart, Oliver. (1989), "An Economist's Perspective on the Theory of the Firm," *Columbia Law Review*, 89, pgs. 1756-1774.

Hayek, Frederich, A. (1945), "The Use of Knowledge in Society", *American Economic Review*, 35 (4), pgs. 519-530.

Hickson, David J., C.R. Hinings, C.A. Lee, R.E. Schneck, and J.M. Pennings. (1971), "A Strategic Contingencies Theory of Intraorganizational Power," *Administrative Science Quarterly*, 16, pgs. 216-229.

Hughes, Thomas P. (1998), *Rescuing Prometheus*, Pantheon Books, New York.

Iansiti, Marco and Clark, Kim B. (1994), "Integration and Dynamic Capability: Evidence from Product Development in Automobiles and Mainframe Computers," *Industrial and Corporate Change*, 3(3), pg. 557-605.

Jacobs, John F. (1985), *The SAGE Air Defense System: A Personal History*, MITRE Corporation, Bedford, MA.

Kahin, Brian and Janet Abbette, ed. (1995) *Standards Policy for Information Infrastructure*, MIT Press, Cambridge, MA.

Kaneko, I and K. Imai. (1987), "A Network View of the Firm," paper presented at the First Hitotsubashi-Stanford Conference.

Knight, Frank. (1921), *Risk, Uncertainty, and Profit*, Harper and Row, New York.

Koopmans, Tjalling. (1957), *Three Essays on the Sate of Economic Science*. McGraw Hill, New York.

Krebs, Brian. (1999), "Growing a New Generation; Concept Five Has Branched Off from its MITRE Roots to Commercial Systems," *Washington Post*, March 1, 1999, Financial section, pg. F5.

Kunda, Gideon. (1992), *Engineering Culture: Control and Commitment in a High-Tech Corporation*, Temple University Press, Philadelphia.

Jensen, Michael and William Meckling, (1979), "Theory of the Firm: Managerial Behavior, Agency Costs, and Capital Structure," *Journal of Financial Economics*, 3(October), pgs. 305-360.

Lawrence, Paul R. and Jay W. Lorsch. (1967), *Organization and Environment: Managing Differentiation and Integration*, Harvard Business School Press, Boston, Massachusetts.

Lester, Richard K, Michael J. Piore, and Kamal Malek. (1998) "Interpretive Management: What General Managers Can Learn from Design," *Harvard Business Review*, March-April, pgs. 86-96.

Malek, Kamal. (forthcoming), *Analytical, Pragmatic and Hermeneutic Practices in Product Development: Some Evidence from the Automobile Industry*, Ph.D. thesis in Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA.

Malone, Thomas W., Joanne Yates, and Robert I. Benjamin. (1987), "Electronic Markets and Electronic Hierarchies," *Communications of the ACM*, 30(6), June, pgs. 484-497.

Martínez Vela, Carlos Andrés. (1998), *The Challenge of Integration in the Research University*, S.M. Thesis, Technology and Policy Program, Massachusetts Institute of Technology, Cambridge, MA.

Milgrom, Paul and John Roberts. (1992), *Economics, Organization, and Management*, Prentice Hall, Englewood Cliffs, New Jersey.

Mintz, John. (1995), "Nonprofit Think Thanks Vie to Keep Federal Contracts; For-Profit Groups Argue for Open Bidding," *Washington Post*, February 8, 1995, pg. C2.

MITRE. (1979), *MITRE: The First Twenty Years*, MITRE Corporation, Bedford, MA.

MITRE. (1990), *MITRE and AWACS: A Systems Engineering Approach*, MITRE Corporation, Bedford, MA.

MITRE. (1998a) *DOD Sponsoring Agreement with the MITRE Corporation*, MITRE intranet, accessed June 29, 1998.

MITRE. (1998b), *Annual program award nomination - Chief Architect's Office*, MITRE intranet, provided July 25, 1998.
MITRE. (1999a), *Maintaining and Increasing MITRE's Impact: The MITRE Technology Transfer Office*, briefing provided by David Lehman, June, 1999.

MITRE. (1999b), *Technical Center Assessment: Interim Results: Status Briefing to I-Team*, MITRE Intranet, provided July 2, 1999.

Nelson, Richard R. and Sidney G. Winter. (1982), *An Evolutionary Theory of Economic Change*, Belknap Press of Harvard University Press, Cambridge, MA.

Ninetto, Amy. (1998), "Culture Sells: Cézanne and Corporate Identity," *Cultural Anthropology*, 13(2), pgs. 256-282.

Orlikowski, Wanda and Baroudi, Jack J. (1991), "Studying Information Technology in Organizations: Research Approaches and Assumptions," *Information Systems Research*, 1(1), pgs. 43-69.

Orlikowski, Wanda. (1992) "The Duality of Technology: Rethinking the Concept of Technology in Organizations," *Organization Science*, 3(3), August 1992, pgs. 398-427.

Perrow, Charles. (1961), "The Analysis of Goals in Complex Organizations," *American Sociological Review*, 26, pgs. 854-866.

Perrow, Charles. (1986), *Complex Organizations: A Critical Essay*, third edition, McGraw-Hill, Inc., New York.

Piore, Michael J., Richard K. Lester, Kamal M. Malek. (1995), "Case Studies in the Organization of Product Development: The Cellular Telephone Equipment Industry", Industrial Performance Center Working Paper, MIT, Cambridge, MA

----------. (1997a), "The Division of Labor, Coordination, and Integration: Case Studies in the Organization of Product Design: Medical Instruments", Industrial Performance Center Working Paper, MIT, Cambridge, MA

----------. (1997b), "The Division of Labor, Coordination, and Integration: Case Studies in the Organization of Product Design in the Blue Jeans Industry", Industrial Performance Center Working Paper, MIT, Cambridge, MA

Piore, Michael J., Richard K. Lester, Fred Kofman, and Kamal M. Malek. (1994), "The Organization of Product Development" in *Industrial and Corporate Change*, 3(2), pgs. 405-434.

Podolny, Joel M. (1994), "Market Uncertainty and the Social Character of Economic Exchange," *Administrative Science Quarterly*, 39, pgs. 458-483.

Podolny, Joel M. and Karen L. Page (1998), "Formal Organizations - Network Forms of Organizations" in *Annual Review of Sociology*, 24, pg. 57-76

Powell, Walter W. (1990), "Neither Market nor Hierarchy: Network Forms of Organization" in *Research in Organizational Behavior*, JAI Press, vol. 12., pgs. 295 - 336.

Saxenian, AnnaLee. (1994). *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Harvard University Press, Cambridge, MA.

Schein, Edgar H. (1992), *Organizational Culture and Leadership*, second edition, Jossey-Bass, San Francisco.

Scott, W. Richard. (1990), "Technology and Structure: An Organizational Level Perspective," in P. Goodman, L. Sproull and Associates, *Technology and Organizations*, San Francisco: Jossey-Bass, pgs. 109-143.

Scott, W. Richard. (1998), *Organizations: Rational, Natural, and Open Systems*, Fourth ed., Prentice Hall, Upper Saddle River, New Jersey.

Shane, Scott and Daniel Cable. (1998), "Social Relationships and the Financing of New Ventures," MIT Entrepreneurship Working Paper, Cambridge, MA.

Smith, Adam, 1976. *The Wealth of Nations*. University of Chicago Press.

Sugawara, Sandra. (1989), "The Mighty Voice of MITRE; Federally Funded Think Tank Has Its Critics," *Washington Post*, Financial Section, August 20, 1989, pg. H1.

Taylor, Charles. (1993). "To Follow a Rule…" in *Bourdieu: Critical Perspectives*, ed. Craig Calhoun, Edward LiPuma, and Moishe Postone, University of Chicago Press, Chicago.

Teece, David and Gary Pisano. (1994) "The Dynamic Capabilities of Firms: an Introduction," *Industrial and Corporate Change*, 3(3), pgs. 537-557.

Teece, David J., Gary Pisano and Amy Shuen. (1997), "Dynamic Capabilities and Strategic Management," *Strategic Management Journal*, 18(7), pgs. 509-533.

Tesch, Renata. (1990), *Qualitative Research: Analysis Types and Software Tools*, Falmer Press, New York.

U.S. House. (1996), Committee on National Security, Subcommittee on Military Research and Development, *Hearings on National Defense Authorization Act for FY97: H.R. 3230 and Oversight of Previously Authorized Programs. Title II: Research, Development, Test, and Evaluation*, 104th Cong., 2nd sess.

U.S. Department of Commerce. National Telecommunications and Information Administration (1998), *A Proposal to Improve Technical Management of Internet Names and Addresses*, www.ntia.doc.gov/ntiahome/domainname/dnsdrft.htm, accessed August 4, 1999.

Thompson, James D. (1967), *Organizations in Action*, McGraw-Hill, New York.

Weick, Karl E. (1979), *The Social Psychology of Organizing*, Random House, New York.

Weick, Karl E. (1995), *Sensemaking in Organizations*, Sage Publications, Thousand Oaks, California.

Williamson, Oliver E. (1975), *Markets and Hierarchies: Analysis and Antitrust Implications*, Free Press, New York.

Williamson, Oliver E. (1985), *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting*, Free Press, New York.

Williamson, Oliver E. (1989) "Transaction Cost Economics" in *Handbook of Industrial Organization, Volume 1*, Ed. by Richard Schmalensee and R.D. Willig, Elsevier Science, New York.

Williamson, Oliver E. (1991). "Comparative Economic Organization: The Analysis of Discrete Structural Alternatives" in *Administrative Science Quarterly*, 36, pgs. 269-296

Williamson, Oliver E. (1996), *Mechanisms of Governance*, Oxford University Press, New York.

Winograd, Terry and Flores, Fernando. (1986) *Understanding Computers and Cognition,* Ablex Publishing Company, Norwood, NJ.

Van Alstyne, Marshall. (1997) “The State of Network Organization: A Survey in Three Frameworks” in *Journal of Organizational Computing*, 7(3), accessed at ccs.mit.edu/papers/CCSWP192/CCSWP192.html