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The Role of the Information Intermediary in the Diffusion of Aerospace Knowledge

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SUMMARY

With its contribution to trade, its coupling with national security, and its symbolism of U.S. technological strength, the U.S. aerospace industry holds a unique position in the nation's industrial structure. However, the U.S. aerospace industry is experiencing profound changes created by a combination of domestic actions and circumstances such as airline deregulation. Other changes result from external trends such as emerging foreign competition. These circumstances intensify the need to understand the production, transfer, and utilization of knowledge as a precursor to the rapid diffusion of technology. This article presents a conceptual framework for understanding the diffusion of aerospace knowledge. The framework focuses on the information channels and members of the social system associated with the aerospace knowledge diffusion process, placing particular emphasis on aerospace librarians as information intermediaries.

INTRODUCTION

The ability of aerospace engineers and scientists to identify, acquire, and utilize scientific and technical information (STI) is of paramount importance to the efficiency of the research and development (R&D) process. Testimony to the central role of STI in the R&D process is found in numerous studies (14). These studies show, among other things, that aerospace engineers and scientists devote more time, on the average, to the communication of technical information than to any other scientific or technical activity (28). A number of studies have found strong relationships between the communication of STI and technical performance at both the individual (3,19,31,) and the group level (11,32,34). Therefore, we concur with Fischer's (14) conclusion that the "role of scientific and technical communication is thus central to the success of the innovation process, in general, and the management of R&D activities, in particular."

In terms of empirically derived data, very little is known about the diffusion of knowledge in the aerospace industry both in terms of the channels used to communicate the ideas and the information-gathering habits and practices of the members of the social system (i.e., aerospace engineers and scientists). Most of the channel studies, such as the work by Gilmore, et al., (17) and Archer (5), have been concerned with the transfer of aerospace technology to non-aerospace industries.

Most of the studies involving aerospace engineers and scientists, such as the work by McCullough, et al., (25) and Monge, et al., (27), have been limited to the use of NASA STI products and services and have not been concerned with information-gathering habits and practices. Although researchers such as Davis (12) and Spretnak (35) have investigated the importance of technical communications to engineers, it is not possible to determine from the published results if the study participants included aerospace engineers and scientists. It is likely that an understanding of the process by which aerospace knowledge is communicated through certain channels over time among the members of the social system would contribute to increasing productivity, stimulating innovation, and improving and maintaining the professional competence of U.S. aerospace engineers and scientists.

OVERVIEW OF THE FEDERAL AEROSPACE KNOWLEDGE DIFFUSION PROCESS

Figure 1 presents a model that depicts the transfer of federally funded aerospace R&D vis-à-vis the U.S. government technical report as being composed of two parts: the **informal** that relies on collegial contacts and the **formal** that relies on surrogates, information products, and information intermediaries to complete the "producer to user" transfer process. The producers are NASA and the DOD and their contractors and grantees. Producers depend upon surrogates and information intermediaries to complete the knowledge transfer process. When U.S. government technical reports are published, the initial or primary distribution is made to libraries and technical information centers. Copies are sent to surrogates for secondary and subsequent distribution. A limited number are set aside to be used by the author for the "scientist-to-scientist" exchange of information at the individual level.

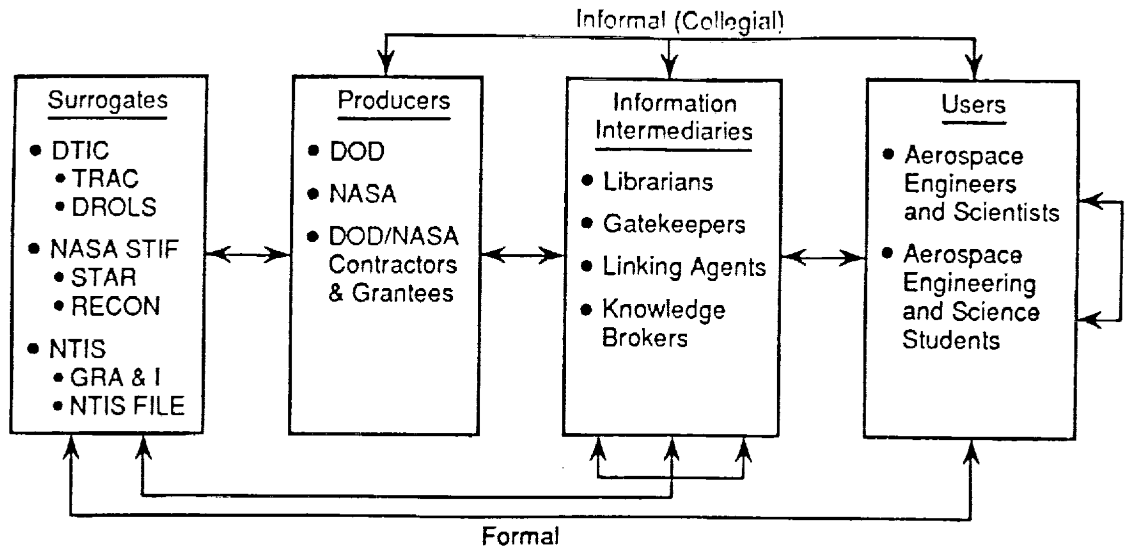

Figure 1. A Model Depicting the Transfer of Federally Funded Aerospace R&D.

Surrogates serve as technical report repositories or clearinghouses for the producers and include the Defense Technical Information Center (DTIC), the NASA Scientific and Technical Information Facility (NASA STIF), and the National Technical Information Service (NTIS). These surrogates have created a variety of technical report announcement journals such as TRAC (Technical Report Announcement Circular) and STAR (Scientific and Technical Aerospace Reports) and computerized retrieval systems such as DROLS (Defense RDT&E On Line System) and RECON (REmote CONsole) that permit online access to technical report databases.

Information intermediaries are, in large part, librarians and technical information specialists in academia, government, and industry. Those representing the producers serve as what McGowan and Loveless (26) describe as "knowledge brokers" or "linking agents." Information intermediaries connected with users act, according to Allen (2), as "technological entrepreneurs" or "gatekeepers." The more "active" the intermediary, the more effective the transfer process becomes (18). Active intermediaries take information from one place and move it to another, often face-to-face. Passive information intermediaries, on the other hand, "simply array information for the taking, relying on the initiative of the user to request or search out the information that may be needed" (13).

Problems With the Federal STI System

According to Ballard and his colleagues (6), the problem with the total Federal STI system is "that the present system for transferring the results of federally-funded STI is passive, fragmented, and unfocused." Effective knowledge transfer is hindered by the fact that the Federal government "has no coherent or systematically designed approach to transferring the results of federally-funded R&D to the user" (6). In their study of issues and options in Federal STI, Bikson and her colleagues (8) found that many of the interviewees believed "dissemination activities were afterthoughts, undertaken without serious commitment by Federal agencies whose primary concerns were with [knowledge] production and not with knowledge transfer; [therefore,] much of what has been learned about [STI] and knowledge transfer has not been incorporated into federally-supported information transfer activities."

The problem with the **informal** part of the system is that knowledge users can learn from collegial contacts only what those contacts happen to know. Ample evidence supports the claim that no one researcher can know about or keep up with all of the research in his/her area(s) of interest. Like other members of the scientific community, aerospace engineers and scientists are faced with the problem of too much information to know about, to keep up with, and to screen -- information that is becoming more interdisciplinary in nature and more international in scope.

Two problems exist with the **formal** part of the system. First, the **formal** part of the system employs one-way source-to-user transmission. The problem with this kind of transmission is that such formal one-way "supply side" transfer procedures do not seem to be responsive to the user context (8). Rather, these efforts appear to start with an information system into which the users' requirements are retrofit (1). The consensus of the findings from the empirical research is that interactive, two-way communications are required for effective information transfer (8).

Second, the **formal** part relies heavily on information intermediaries to complete the knowledge transfer process. However, a strong methodological base for measuring or assessing the effectiveness of the information intermediary is lacking (7). Empirical findings on the effectiveness of information intermediaries and the role(s) they play in knowledge transfer are sparse and inconclusive. In most studies, the value placed on and the use made of the information intermediary and information organization have been the criteria used in determining the intermediary's role in transferring the results of federally funded aerospace R&D. In addition, the impact of information intermediaries is likely to be strongly conditional and limited to a specific institutional context.

In a study conducted for the U.S. Department of Energy, King and his colleagues (22), using a value added approach, investigated the contributions information intermediaries and organizations make to the value of information. First, they assume that information is a necessary commodity for conducting R&D. Second, they estimated that, were information unavailable from libraries\technical information centers, information substitutes would be more expensive and potentially less effective. Hypothetically, if information were not readily available, less actual information use would occur and less value would be derived from information seeking, thereby increasing the fundamental cost of R&D.

Federal policymakers may well ask if information intermediaries promote the effective transfer or diffusion of knowledge. Specific to this study, they may ask if information intermediaries promote the effective transfer or diffusion of federally funded aerospace R&D from producers to users. It is generally assumed that information intermediaries play a significant role in the knowledge diffusion process; however, their role in and contributions to the knowledge diffusion infrastructure are poorly understood.

Influence on Information-Seeking Behavior and Use

The nature of science and technology and the differences between engineers and scientists influence their information-seeking habits, practices, needs, and preferences and have significant implications for planning information services for these two groups (36). Taylor (37), quoting Brinberg (9) stresses that fundamental differences exist between engineers and scientists: "unlike scientists, the goal of the engineer is to produce or design a product, process, or system; not to publish and make original contributions to the literature. Engineers, unlike scientists, work within time constraints; they are not interested in theory, source data, and guides to the literature nearly so much as they are in reliable answers to specific questions. Engineers prefer informal sources of information, especially conversations with individuals **within** their organization. Finally, engineers tend to minimize loss rather than maximize gain when seeking information."

Anthony, et al., (4) suggest that engineers may have psychological traits that predispose them to solving problems alone or with the help of colleagues rather than finding answers in the literature. They further state that "engineers like to solve their own problems. They draw on past experiences, use the trial and error method, and ask colleagues known to be efficient and reliable instead of searching or having someone search the literature for them. They are highly independent and self-reliant without being positively anti-social."

According to Allen (2), "engineers read less than scientists, they use literature and libraries less, and seldom use information services which are directly oriented to them. They are more likely to use specific forms of literature such as handbooks, standards, specifications, and technical reports." What an engineer usually wants, according to Cairns and Compton (10), "is a specific answer, in terms and format that are intelligible to him -- not a collection of documents that he must sift, evaluate, and translate before he can apply them."

Young and Harriot (38) report that the "engineer's search for information seems to be more based on a need for specific problem solving than around a search for general opportunity. When they use the library it is more in a personal-search mode, generally not involving the professional (but nontechnical) librarian." Young and Harriot (38) conclude, conclude that "when engineers need technical information, they usually use the most accessible sources rather than searching for the highest quality sources. These accessible sources are respected colleagues, vendors, a familiar but possibly outdated text, and internal company [technical] report. He [the engineer] prefers informal information networks to the more formal search of publicly available and catalogued information."

Finally, engineers do tend to minimize loss rather than maximize gain when seeking information. Gerstberger and Allen (16), in their study of engineers and choice of an information channel, note

> Engineers, in selecting among information channels, act in a manner which is intended not to maximize gain, but, rather, to minimize loss. The loss to be minimized is the cost in terms of effort, either physical or psychological, which must be expended in order to gain access to an information channel.

Their behavior appears to follow a "law of least effort" (39). According to this law, individuals, when choosing among several paths to a goal, will base their decision upon the single criterion of "least average rate of probable work." According to Gerstberger and Allen (16), engineers appear to be governed or influenced by a principle closely related to this law. They attempt to minimize effort in terms of work required to gain access to an information channel/source. Gerstberger and Allen (16) reached the following conclusions:

> 1. Accessibility is the single most important determinant of the overall extent to which an information channel/source is used by an engineer.
>
> 2. Both accessibility and perceived technical quality influence the choice of the first source.
>
> 3. Perception of accessibility is influenced by experience. The more experience engineers have with an information channel/source, the more accessible they perceive it to be.

Rosenberg's (29) findings also support the conclusions by Gerstberger and Allen (16) that accessibility almost exclusively determines the frequency of use of information channels. Rosenberg (29) concluded that researchers minimize the cost of obtaining information while sacrificing the quality of the information received.

In his study of the Factors Related to the Use of Technical Information in Engineering Problem Solving, Kaufman (21) reported that the engineers in his study rated **technical quality** or **reliability** followed by **relevance** as the criteria used in choosing the most useful information source. However, **accessibility** appears to be the criteria used most often for choosing an information source **even if that source** proved to be the least useful.

Use of Libraries and Library Services

The process by which engineers solve technical problems affects their use of libraries and library services. The results of Shuchman's (33) study, which are supported by the findings of several engineering information use studies, confirm this position. The steps the engineers in Shuchman's (33) study followed in solving technical problems appear below.

HOW ENGINEERS SOLVE TECHNICAL PROBLEMS

Steps in Solving Technical Problems	Percent of Cases
1. Consulted personal store of technical information	93
2. Informal discussion with colleagues	87
3. Discussed problem with supervisor	61
4. Consulted internal technical reports	50
5. Consulted key person in firm who usually knows new information	38
6. Consulted library sources (e.g., technical journals, conference proceedings)	35
7. Consulted outside consultant	33
8. Used electronic databases	20
9. Consulted librarian/technical information specialist	14
10. No pattern in problem-solving	5

Herner (20) found that engineers at Johns Hopkins University considered their personal knowledge and informal discussions with colleagues and with experts within their organization to be most useful when faced with solving a technical problem. Rosenbloom and Wolek (30) found that engineers favored the use of interpersonal communications (e.g., discussions with colleagues within their organization) when faced with the need to solve a technical problem. These findings are supported by Kremer (24) and Kaufman (21). Only after they have exhausted their personal store of information and have consulted their colleagues do engineers turn to another information source, such as a library.

In Shuchman's study (33), libraries ranked sixth as the information source engineers used in solving a technical problem. The fact that librarians and technical information specialists ranked ninth as the information source engineers used in solving a technical problem supports the hypothesis that engineers tend to assume personal responsibility for fulfilling their information needs. This statement is supported by Shuchman's finding that engineers inher study attempted to find the information themselves in the library before soliciting the help of a librarian or technical information specialist.

Allen (2) corroborated these findings, noting that although the library is an important source of information, rarely do engineers make full use of its potential. He too reported that engineers prefer to search for library information themselves, only in "rare" instances seeking the services of a librarian or technical information specialist.

Other studies suggest several reasons why engineers do not seek technical information in libraries. Apart from engineers' "personal" and "informally" directed approach to fulfilling their technical information needs, Frohman (12), quoted by Allen (2), states that the extent of library use is related inversely to the distance separating the user from the library. Allen (2) summarized his discussion of library use by observing that "the value seen in using the library simply does not seem great enough to overcome the effort involved in either traveling to it or using it once the person is there."

Information on the use of electronic bibliographic databases by engineers is limited. Those engineers who participated in Shuchman's (33) study made little use of on-line databases. In the steps used in solving a technical problem, databases ranked eighth, just before librarians and technical information specialists. Kaufman (21) found that approximately five percent of the engineers in his study used on-line databases when searching for the solution to a technical problem. Engineers in Kaufman's (21) study indicated that "accessibility" was the single most important criterion for determining the use of an on-line database. Furthermore, when the engineers in Kaufman's (21) study did use on-line databases, they did so most frequently to define or redefine the technical problem and continued to use the databases for the duration of the attempt to solve the technical problem.

As shown in the chart that follows, aerospace engineers and scientists use a variety of information sources when solving a technical problem (28). They use, in decreasing order of frequency, the following sources.

SOURCES USED BY AEROSPACE ENGINEERS AND SCIENTISTS TO SOLVE TECHNICAL PROBLEMS

Sources	Percent of Cases
1. Personal knowledge	88.7
2. Informal discussion with colleagues	77.2
3. Discussions with experts within the organization	69.5
4. Discussions with supervisor	45.1
5. Textbooks	39.6
6. Technical reports	35.4
7. Journals and conference/meeting papers	35.2
8. Handbooks and standards	34.5
9. Government technical reports	33.5
10. Discussions with experts outside of the organization	25.5
11. Librarians/technical information specialists	14.1
12. Technical information sources such as on-line databases	8.2

In an attempt to validate the findings, the sources used by the aerospace engineers (28) were compared with the steps used by the engineers in Shuchman's (33) study of Information Transfer in Engineering. With minor exceptions, the aerospace engineers and scientists sought information from sources similar to the sources used by engineers in Shuchman's (33) study. Both groups begin with what Allen (2) calls an "informal search for information followed by the use of formal information sources." Having completed these steps, engineers turn to librarians and library services for assistance.

NASA/DOD AEROSPACE KNOWLEDGE DIFFUSION RESEARCH PROJECT

The **NASA/DOD Aerospace Knowledge Diffusion Research Project** is a cooperative effort that is sponsored by NASA, Office of Aeronautics, Exploration and Technology (OAET) and the DOD, Office of the Assistant Secretary of the Air Force, Deputy for Scientific and Technical Information. The research project is a joint effort of the Indiana University, Center for Survey Research and the NASA Langley Research Center. As scholarly inquiry, the project has both an immediate and a long term purpose. In the first instance, it provides a practical and pragmatic basis for understanding how the results of NASA/DOD research diffuse into the aerospace R&D process. Over the long term, it will provide an empirical basis for understanding the aerospace knowledge diffusion process itself and its implications at the individual, organizational, national, and international levels.

Despite the vast amount of scientific and technical information (STI) available to potential users, several major barriers to effective knowledge diffusion exist. First, the very low level of support for knowledge transfer in comparison to knowledge production suggests that dissemination efforts are not viewed as an important component of the R&D process. Second, there are mounting reports from users about difficulties in getting appropriate information in forms useful for problem solving and decision making. Third, rapid advances in many areas of S&T knowledge can be fully exploited only if they are quickly translated into further research and application. Although the United States dominates basic R&D, foreign competitors may be better able to apply the results. Fourth, current mechanisms are often inadequate to help the user assess the quality of available information. Fifth, the characteristics of actual usage behavior are not sufficiently taken into account in making available useful and easily retrieved information.

These deficiencies must be remedied if the results of NASA/DOD funded R&D are to be successfully applied to innovation, problem solving, and productivity. Only by maximizing the R&D process can the United States maintain its international competitive edge in aerospace. The **NASA/DOD Aerospace Knowledge Diffusion Research Project** will provide descriptive and analytical data regarding the flow of STI at the individual, organizational, national, and international levels. It will examine both the channels used to communicate information and the social system of the aerospace knowledge diffusion process. The results of the project should provide useful information to R&D managers, information managers, and others concerned with improving access to and utilization of STI.

Project Assumptions

1. Rapid diffusion of technology and technological developments requires an understanding of the aerospace knowledge diffusion process.

2. Knowledge production, transfer, and utilization are equally important components of the aerospace knowledge diffusion process.

3. Understanding the channels; the information products involved in the production, transfer, and utilization of aerospace information; and the information-seeking habits, practices, and preferences of aerospace engineers and scientists is necessary to understanding aerospace knowledge diffusion.

4. The knowledge derived from federally funded aerospace R&D is indispensable in maintaining the vitality and international competitiveness of the U.S. aerospace industry and essential to maintaining and improving the professional competency of U.S. aerospace engineers and scientists.

5. The U.S. government technical report plays an important, but as yet undefined, role in the transfer and utilization of knowledge derived from federally funded aerospace R&D.

6. Librarians, as information intermediaries, play an important, but as yet undefined, role in the transfer and utilization of knowledge derived from federally funded aerospace R&D.

Project Objectives

1. Understanding the aerospace knowledge diffusion process at the individual, organizational, and national levels, placing particular emphasis on the diffusion of federally funded aerospace STI.

2. Understanding the international aerospace knowledge diffusion process at the individual and organizational levels, placing particular emphasis on the systems used to diffuse the results of government funded aerospace STI.

3. Understanding the roles played by the NASA/DOD technical reports and aerospace librarians in the transfer and utilization of knowledge derived from federally funded aerospace R&D.

4. Achieving recognition and acceptance within NASA and the DOD and throughout the aerospace community that STI is a valuable strategic resource for innovation, problem solving and productivity.

5. Providing results that can be used to optimize the effectiveness and efficiency of the Federal STI aerospace transfer system and exchange mechanism.

The Role of Aerospace Librarians In Knowledge Transfer

How do librarians as information intermediaries promote/facilitate the transfer of federally funded aerospace knowledge? Several approaches will be used to make this determination. In **Phase 1**, a random sample of U.S. aerospace engineers and scientists who are members of the American Institute of Aeronautics and Astronautics (AIAA) were surveyed to determine their information-seeking habits and preferences. The questionnaires sent to the sample covered a range of information-seeking and use activities including use of aerospace libraries and library services. The questions covered such factors as relative use and importance of the library, distance from the user, reasons for not using the library, use of electronic databases, and the use of library in problem solving.

Phase 2 includes a survey of approximately 325 U.S. aerospace libraries in government and industry. Questionnaires covered a variety of topics such as NASA/DOD technical reports, use of print and online databases, use of information technology, marketing strategies, services provided, and a variety of questions concerning the role of information intermediaries in knowledge transfer. **Phase 3** includes a survey of approximately 70 U.S. academic aerospace/engineering libraries. Topics covered were similar to those covered in **Phase 2**. In addition, aerospace faculty and undergraduate students were also surveyed to determine their information-seeking habits and practices. Faculty and students were asked a number of questions regarding their use of libraries and library services. **Phase 4** involves a survey of non-U.S. aerospace engineers and scientists, information intermediaries, faculty, and students. Topics covered are similar to those covered in **Phases 1, 2, and 3**. The non-U.S. data will permit the comparison of systems to determine similarities and differences. Having completed these phases, we can begin to develop an empirical basis for understanding the aerospace knowledge diffusion process itself; its implications at the individual, organizational, national, and international levels; and the role that the information intermediary plays in the transfer of federally funded aerospace STI.

CONCLUDING REMARKS

Although the U.S. aerospace industry continues to be the leading positive contributor to the balance of trade among all merchandise industries, it is experiencing significant changes whose implications may not be well understood.[1] Increasing U.S. collaboration with foreign producers will result in a more international manufacturing environment,

[1] "Aerospace" includes aeronautics, space science, space technology, and related fields.

altering the current structure of the aerospace industry. International alliances will result in a more rapid diffusion of technology, increasing pressure on U.S. aerospace companies to push forward with new technological developments and to take steps designed to maximize the inclusion of recent technological developments into the R&D process.

To remain a world leader in aerospace, the U.S. must take the steps necessary to improve and maintain the professional competency of U.S. aerospace engineers and scientists and to enhance innovation and productivity as well as to maximize the inclusion of recent technological developments into the R&D process. How well these objectives are met, and at what cost, depends on a variety of factors, but largely on the ability of U.S. aerospace engineers and scientists to acquire and process the results of NASA/DOD funded aerospace R&D. Furthermore, it is likely that an understanding of the process by which STI in the aerospace industry is communicated through certain channels over time among the members of the social system will contribute to increasing productivity, stimulating innovation, and improving and maintaining the professional competence of U.S. aerospace engineers and scientists.

The knowledge diffusion process is complex. A myriad of factors influence the conception, initiation, and operation of the process. A wide range of commonly recognized elements and influences are implicit in the process. Even if all the practical and theoretical elements of the knowledge diffusion process were understood, the success of the "diffusion" of knowledge would not necessarily be assured. One determinant of success is the presents of an "active" knowledge diffusion mechanism which involves the participation of "linking agents" who can assist the potential knowledge user in identifying information requirements/needs, identify knowledge that can meet those needs, and indirectly promote communication between the knowledge producers and users. Defining the role that information intermediaries play in the transfer and utilization of aerospace R&D may contribute to increased effectiveness and efficiency in the Federal STI aerospace knowledge transfer system and exchange mechanism.

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