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Paper Twelve:

The Diffusion of Federally Funded Aerospace Research and Development (R&D) and the Information Seeking Behavior of U.S. Aerospace Engineers and Scientists

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THE DIFFUSION OF FEDERALLY FUNDED AEROSPACE RESEARCH AND DEVELOPMENT (R&D) AND THE INFORMATION-SEEKING BEHAVIOR OF U.S. AEROSPACE ENGINEERS AND SCIENTISTS

Thomas E. Pinelli, John M. Kennedy, and Rebecca O. Barclay

INTRODUCTION

The diffusion of knowledge resulting from federally funded aerospace research and development (R&D) is indispensable in maintaining the vitality and international competitiveness of the U.S. aerospace industry. This knowledge is understood to be central to innovation and its management and crucial to the technical performance of aerospace engineers and scientists. However, little is known about the diffusion of federally funded R&D and the aerospace knowledge diffusion process itself. Whereas knowledge resulting from federally funded aerospace R&D is understood to be a valuable strategic resource for innovation, problem solving, and productivity, linkages between the various sectors of the R&D infrastructure are weak, poorly defined, and, in some cases, simply not understood. It is assumed, however, that the ability of engineers and scientists to identify, acquire, and utilize this knowledge is of paramount importance to the efficiency of aerospace R&D. Understanding knowledge diffusion, therefore, is a precursor to the rapid diffusion of federally funded aerospace R&D and to maximizing the aerospace R&D process. Both, however, require an understanding of the information-seeking behavior of U.S. aerospace engineers and scientists. As Menzel (1966) states

> The way in which [aerospace] engineers and scientists make use of scientific and technical information (STI), the demands they make on STI systems, and the satisfaction achieved by their efforts are among the items of knowledge which are necessary for the wise planning of [aerospace] STI systems and policy.

In this paper, the diffusion of federally funded aerospace R&D is explored from the perspective of the information-seeking behavior of U.S. aerospace engineers and scientists. The following three assumptions frame this exploration: (1) knowledge production, transfer, and utilization are equally important components of the aerospace R&D process; (2) the diffusion of knowledge resulting from federally funded aerospace R&D is indispensable for the U.S. to remain a world leader in aerospace; and (3) U.S. government technical reports, produced by NASA and DoD, play an important, but as yet undefined, role in the diffusion of federally funded aerospace R&D. A conceptual model for federally funded aerospace knowledge diffusion, one that emphasizes U.S. government technical reports, is presented. Data regarding three research questions concerning the information-seeking behavior of U.S. aerospace engineers and scientists are also presented.

BACKGROUND

To remain a world leader in aerospace, the U.S. must improve and maintain the professional competency of its engineers and scientists, increase the R&D knowledge base, increase productivity, and maximize the integration of recent technology 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 federally funded R&D. 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. (1967) and Archer (1962), have been concerned with the transfer of aerospace technology to non-aerospace industries.

Related Work

Most of the studies involving aerospace engineers and scientists, such as the work by McCullough, et al. (1982) and Monge, et al. (1979), 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 (1975) and Spretnak (1982) 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 STI in the aerospace industry 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.

Aerospace Knowledge Diffusion Research

We have organized a research project to study aerospace knowledge diffusion. Sponsored by NASA and the Department of Defense (DoD), the *NASA/DoD Aerospace Knowledge Diffusion Research Project* is being conducted by researchers at the NASA Langley Research Center, the Indiana University Center for Survey Research, and Rensselaer Polytechnic Institute (RPI). This research is endorsed by several aerospace professional technical societies including the American Institute for Aeronautics and Astronautics (AIAA) and the Royal Aeronautical Society (RAeS). In addition, it has been sanctioned by the Advisory Group for Aerospace Research and Development (AGARD) Technical Information Panel and the AIAA Technical Information Committee.

This four-phase project is providing descriptive and analytical data regarding the diffusion of knowledge at the individual, organizational, national, and international levels. It is examining both the channels used to communicate and the social system of the aerospace knowledge diffusion process. Phase 1 investigates the information-seeking behavior of U.S. aerospace engineers and scientists and places particular emphasis on their use of federally funded aerospace R&D. Phase 2 examines the industry-government interface and places special emphasis on the role of the information intermediary in the knowledge diffusion process. Phase 3 concerns the academic-government interface and places specific emphasis on the information intermediary-faculty-student. Phase 4 explores the information-seeking behavior of non-U.S. aerospace engineers and scientists from Brazil, India, Israel, Japan, Portugal, Spain, the Soviet Union, and other Western European nations.

As scholarly inquiry, our research has both immediate and a long term purposes. 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 provides an empirical basis for understanding the aerospace knowledge diffusion process itself and its implications at the individual, organizational, national, and international levels. The results of the project should provide useful information to R&D managers, information managers, and others concerned with improving access to, the quality of, and the utilization of federally funded aerospace STI. (Pinelli, Kennedy, and Barclay, 1991).

THE DIFFUSION OF FEDERALLY FUNDED R&D

Federal involvement in stimulating technological innovation is a recent phenomena in American government. With the possible exceptions of aerospace and agriculture, attempts by the Federal government to stimulate technological innovation have been largely unsuccessful.

Three Models

Three approaches or models have dominated the "transfer" of federally funded R&D (Ballard, et al. 1989; Williams and Gibson, 1990). While variations of the three approaches have been tried, Federal R&D transfer and diffusion activities continue to be driven by a "supply-side" model.

The **appropriability model** emphasizes the production of knowledge by the Federal government and competitive market pressures to promote the use of knowledge. Deliberate transfer mechanism and intervention by information intermediaries are viewed as unnecessary. Appropriability emphasizes the supply (production) of knowledge in sufficient quantity to attract potential users. Good technologies, according to this model, sell themselves.

The **dissemination model** emphasizes the need to transfer information to potential users and embraces the belief that the production of quality knowledge is not sufficient to ensure its fullest use. Linkage mechanisms such as information intermediaries are needed to identify useful knowledge and to transfer it to potential users. This model assumes that if these linkage mechanisms are available to link potential users with knowledge producers, then better opportunities exist for users to determine what knowledge is available, acquire it, and apply it to their needs. While the dissemination approach facilitates access, it is a passive structure that does not take users into consideration except when they enter the system and request assistance.

The **knowledge diffusion model** mandates an active process that stresses intervention and reliance on interpersonal communications as a means of identifying and removing interpersonal barriers between users and producers. This approach also emphasizes the link between producers, transfer agents, and users and seeks to develop user-oriented mechanisms (e.g., products and services) specifically tailored to the needs and circumstances of the user.

Federal Aerospace Knowledge Diffusion

A model depicting the transfer of federally funded aerospace R&D through U.S. government technical reports appears in figure 1. The model is 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 (i.e., NASA) 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.

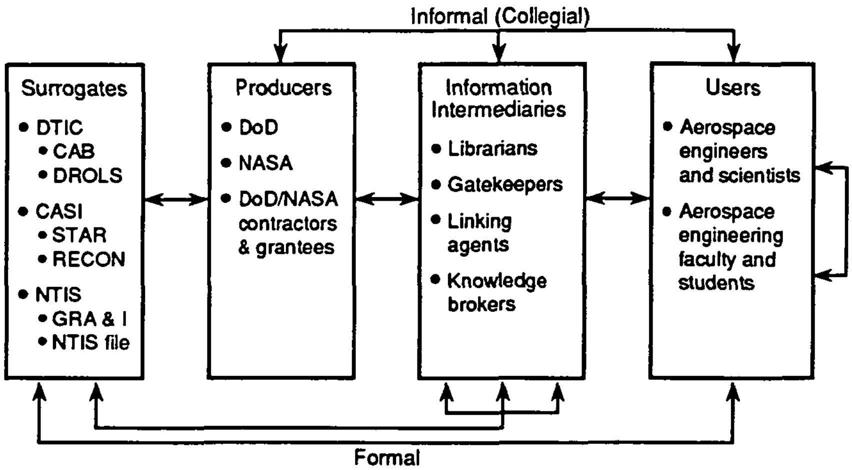

Figure 1. A Model Depicting the Diffusion of Federally Funded Aerospace R&D.

Surrogates serve as technical report repositories or clearinghouses for the producers and include the Defense Technical Information Center (DTIC), the NASA Center for Aero Space Information (CASI), and the National Technical Information Service (NTIS). These surrogates have created a variety of technical report announcement journals such as CAB (Current Awareness Bibliographies) and STAR (Scientific and Technical Aerospace Reports) and computerized retrieval systems such as DROLS (Defense RDT&E Online 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 (1981) describe as "knowledge brokers" or "linking agents." Information intermediaries connected with users act, according to Allen (1977), as "technological entrepreneurs" or "gatekeepers." The more "active" the intermediary, the more effective the transfer process becomes (Goldhor and Lund, 1983). 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" (Eveland, 1987).

The overall 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 the Federal government "has no coherent or systematically designed approach to transferring the results of federally funded R&D to the user" (Ballard, et al. 1986). In their study of issues and options in Federal STI, Bikson and her colleagues (1984) 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 specific 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 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. To compound this problem, information itself 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 (Bikson, et al. 1984). Rather, these efforts appear to start with an information system into which the users' requirements are retrofit (Adam, 1975). The consensus of the findings from the empirical research is that interactive, two-way communications are required for effective information transfer (Bikson, et al. 1984).

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 (Beyer and Trice, 1982). In addition, empirical findings on the effectiveness of information intermediaries and the role(s) they play in knowledge transfer are sparse and inconclusive. The impact of information intermediaries is likely to be strongly conditional and limited to a specific institutional context.

Furthermore, according to Roberts and Frohman (1978), most Federal approaches to knowledge utilization have been ineffective in stimulating the diffusion of technological innovation. They claim that the numerous Federal STI programs are "highest in frequency and expense yet lowest in impact" and that Federal "information dissemination activities have led to little documented knowledge utilization." Roberts and Frohman also note that "governmental programs start to encourage utilization of knowledge only after the R&D results have been generated" rather than during the idea development phase of the innovation process.

David (1986), Mowery (1983), and Mowery and Rosenberg (1979) conclude that successful [Federal] technological innovation rests more with the transfer and utilization of knowledge than with its production. In a critique of Federal innovation policy, David (1986) states that "innovation has become our cherished child, doted upon by all concerned with competitiveness; whereas diffusion has fallen into the woeful role of Cinderella."

INFORMATION-SEEKING BEHAVIOR OF U.S. AEROSPACE ENGINEERS AND SCIENTISTS

The following three research questions were formulated for this paper:

1. Is there a difference between the information-seeking behavior of U.S. engineers in general and U.S. aerospace engineers and scientists?

2. Is there a difference between the information-seeking behavior of U.S. aerospace engineers and U.S. aerospace scientists?
3. Is there a difference between the information sources used by U.S. aerospace engineers and scientists in problem solving and those used to find out about U.S. government technical reports?

Methodology

The data reported herein were collected from U.S. aerospace engineers and scientists belonging to the AIAA. The AIAA is a professional research society and the characteristics of its members reflect a research orientation. Over 31 percent of the respondents hold a doctorate and an additional 39 percent have earned masters degrees. Most of the respondents are managers, researchers, or academics. Only 28 percent reported their principal job activity as "design or development." The vast majority of the respondents reported that they were educated and work as engineers. Following Vincenti's (1990) statement that "engineering implies a knowledge-producing activity embedded within a larger problem-solving activity," we expect that those surveyed will be especially involved in "seeking and using" information.

The data used to answer the research questions were obtained through the use of self administered questionnaires. The data were derived from three surveys (samples) of the AIAA membership. Sample 1 was used to undertake a pilot (exploratory) study that was conducted between July and September 1988. Approximately 2,000 individuals, randomly selected from the 1988 AIAA membership list, were sent questionnaires and 606 usable responses were received (30 percent response rate) by the established cutoff date. The results of the pilot study (study 1) are documented in NASA Technical Memorandum 101534 (Pinelli, et al. 1989).

Two random samples were used to select 3,298 (Study 2) and 1,795 (Study 3) persons from the 1989 AIAA membership list. Overall, 2,016 U.S. aerospace engineers and scientists responded to the second study and 975 responded to the third study. The adjusted response rate (corrected for sample problems) for studies 2 and 3 was about 70 percent. Studies 2 and 3 were conducted during the the summer and fall of 1989. The results of study 2 are documented in NASA Technical Memorandum 102774 (Pinelli, 1991). The results of study 3 are being documented but have not been published as of this date.

Research Question 1

Our review of the literature reveals certain general characteristics about the information-seeking behavior of engineers (Pinelli, 1991). They are not interested in guides to the literature nearly so much as they are in reliable answers to specific questions. They prefer informal sources of information, especially conversations with individuals **within** their organization. Engineers may have psychological traits that predispose them to solve problems alone or with the help of colleagues rather than seeking answers in the literature. "Engineers like to solve their own problems by drawing on past experiences, using the trial and error method, and asking colleagues known to be efficient and reliable instead of searching or having someone search the literature for them" (Anthony, East, and Slater, 1970). According to Allen (1977), engineers seldom use information services which are directly oriented to them. When they use a library, it is more in a personal search mode, generally not involving the professional (but "non-technical") librarian.

To answer Question 1, we compared selected results of Shuchman's (1981) study with selected results from Study 1 (Pinelli, et al. 1989). The comparison appears in table 1. Shuchman's (1981) study is a broad-based investigation of information transfer in engineering. The respondents represented 14 industries and the following major disciplines: civil, electrical, mechanical, industrial, chemical and environmental, and aeronautical. Seven percent, or 93 respondents, were aeronautical engineers. The engineers in Shuchman's study, regardless of discipline, displayed a strong preference for informal sources of information. Further, these engineers rarely found all the information they needed for solving technical problems in one source; the major difficulty engineers encountered in finding the information they needed to do their job was identifying a specific piece of missing data and then learning who had it.

Table 1. Information Sources Used by U.S. Aerospace Engineers and Scientists to Solve Technical Problems

	Percent of Respondents	
Sources	U.S. Engineers	U.S. Aerospace Engineers and Scientists
Personal store	93	88
A coworker in my organization	87	79
My supervisor	61	50
Library search	50	68
Colleague outside my organization	33	56
Database search	20	53
Librarian in my organization	14	36

Sources U.S. Engineers–Shuchman (1981)
U.S. Aerospace Engineer and Scientists–Pinelli, et al. (1989)

In terms of information sources and problem solving, Shuchman (1981) reports that engineers first consult their personal store of information, followed in order by informal discussions with co-workers, and discussions with supervisors. Next they search the library. If they fail to obtain the needed information, they contact a "key" person in the organization who usually knows where the needed information may be located. Having failed to that point, they search or have a database searched and/or seek the assistance of the organization's librarian. Based on these findings, Shuchman concluded that librarians are used by a small proportion of the engineering profession.

Using Shuchman's list of information sources, our survey respondents were asked to indicate those sources used to solve technical problems. Although the amount of use appears higher for U.S. aerospace engineers and scientists, their responses, which appear in table 1, compare favorably with Shuchman's findings. Like the engineers in Shuchman's study, the U.S. aerospace engineers and scientists in our study display a preference for using their personal store of STI, especially that which they keep in the office; personal contacts; and informal sources of information. Engineers in general and U.S. aerospace engineers and scientists in particular begin with an informal search for information followed by what Allen (1977) calls "an informal personal search for information followed by the use of formal information sources. Having completed these steps engineers turn to librarians and library services for assistance." Based on these focused but admittedly limited data, we find *no difference* between the information-seeking behavior of engineers in general and U.S. aerospace engineers and scientists. While the pattern is the same, the amount of use is greater among our sample.

Research Question 2

The nature of science and technology and differences between engineers and scientists influence their information-seeking behavior. Evidence exists to support the belief that differences between science and technology and scientists and engineers directly influence information-seeking habits, practices, and preferences. The results of a study conducted by the System Development Corporation (1966) determined that "an individual differs systematically from others in his use of STI" for a variety of reasons. Chief among these are five institutional variables—type of researcher, engineer or scientist; type of discipline, basic or applied; stage of project, task, or problem completeness; the kind of organization, fundamentally thought of as academia, government, and industry; and the years of professional work experience."

To answer Question 2, the U.S. aerospace engineers and scientists in study 2 were asked to describe briefly the most important technical project, task, or problem they had worked on in the past six months. Respondents were given a list of nine information sources and were asked to identify the steps followed (sources used) in looking for the information needed to complete the project, task, or to solve the problem.

Survey participants were instructed to enter "1" beside the first step, "2" beside the second, and so forth. Weighted average rankings were calculated to determine the actual steps followed (sequence in which information sources were used) by survey respondents to acquire the information needed or used to complete their most important technical project, task, or problem in the past six months. The steps followed in the search for information were examined from the standpoint of educational preparation as either an engineer or scientist (table 2).

In terms of project and task completion and problem solving, the U.S. aerospace engineers and scientists in our study are a relatively homogeneous group. With few exceptions, the steps used to acquire information are fairly uniform for both engineers and scientists. Both begin their search for information using their personal store of knowledge followed by discussions with colleagues. The library, however, was used third most often by both groups (n = 942 for engineers and n = 146 for scientists) but they tend to use it later in the process presumably in a self-directed manner. The librarian, distinct from the library, is the last step taken in the overall information strategy. Based on these data, we find *no difference* between the information-seeking behavior of U.S. aerospace engineers and U.S. aerospace scientists.

Research Question 3

To the extent that a generalization can be formed, U.S. engineers in general and the U.S. aerospace engineers and scientists in our studies appear to be a relatively homogeneous group in terms of their information-seeking behavior. Their search strategy begins with an

Table 2. Order of Information Sources Used by U.S. Engineers and Scientists to Complete Their Most Important Technical Project, Task, or Problem

Engineers (n = 1627)			Scientists (n = 235)		
Steps followed	n	Weighted avg. rank[a]	Steps followed	n	Weighted avg. rank[a]
Used personal store of technical information	1212	7.51	Used personal store of technical information	180	7.33
Discussed problem with a colleague in my organization	1098	7.15	Discussed problem with a colleague in my organization	161	7.03
Discussed problem with a key person in the organization	839	6.86	Discussed problem with a key person in the organization	106	6.73
Discussed problem with my supervisor	709	6.74	Intentionally searched library resources	146	6.57
Intentionally searched library resources	942	6.06	Discussed problem with my supervisor	82	6.38
Discussed problem with a colleague outside the organization	769	6.02	Searched data base or had data base searched	109	6.35
Searched data base or had data base searched	739	6.01	Discussed problem with a colleague outside the organization	105	6.19
Asked a librarian in the organization	499	5.29	Asked a librarian in the organization	73	5.15
Asked a librarian outside the organization	336	3.99	Asked a librarian outside the organization	49	4.64

[a]Highest number indicates step was used first; lowest number indicates step was used last.

examination of their personal store of knowledge and includes information kept in the office or work place. Discussions with coworkers is the next phase of the strategy, followed by a personal search of formal information products and services in the library or technical information center. If they fail to obtain needed information, at this point they turn to the librarian or technical information specialist.

We found nothing in the literature that led us to conclude that their approach to finding out about U.S. government technical reports would be different. They would check their personal store or collection; talk with coworkers; go to the library and look for themselves; and, if all else fails, ask a librarian or technical information specialist.

To answer Question 3, we asked survey respondents in study 2 if they used U.S. government technical reports to complete their technical project, task, or problem. Next, we asked the approximately 65 percent who did use them how they found out about these reports. We compared the responses to this question (Study 1) with the responses to the question (Study 2) concerning the sources used in problem solving. The data used in making the comparison appear in table 3.

In completing their most important technical project, task, or problem, the U.S. aerospace engineers and scientists in our studies used their personal store of technical information first, followed by discussions with a coworker or key individuals. Next, they searched the library or a database and last, asked a librarian. The sources used by U. S. aerospace engineers and scientists to find out about U.S. government technical reports were very similar to those used to solve technical problems. Based on these data, we find *no difference* between the information sources used by U.S. aerospace engineers and scientists in problem solving and those used to find out about U.S. government technical reports used in problem solving.

A TEST OF THE AEROSPACE KNOWLEDGE DIFFUSION MODEL

We attempted to test our model (figure 1) and gauge the amount of "proactivity" on the part of librarians and technical information specialists in linking U.S. aerospace engineers and scientists with the results of federally funded aerospace R&D contained in U.S. government technical reports. We measured "proactivity" by attempting to determine the extent to which the librarians or technical information specialists took the initiative to "link" users to DoD/NASA/technical reports.

In testing our model, we asked survey respondents in Study 3 two questions: how they find out about DoD and NASA technical reports and how they physically obtain them? Responses to the question of "how do you find out about DoD and NASA technical reports," appear in figure 2. Responses to the question regarding "how do you physically obtain DoD and NASA technical reports" appear in figure 3.

Table 3. Sources Used by U.S. Aerospace Engineers and Scientists to Solve Technical Problems and to Find Out About U.S. Government Technical Reports

Sources	Percent of Respondents: Problem Solving	Percent of Respondents: U.S. Government Technical Reports
Personal store	88.1	83.1
A coworker in my organization	78.8	57.7
Library search	68.4	49.7
Colleague outside my organization	55.6	49.9
Database search	53.3	30.5
My supervisor	49.7	22.8
Librarian in my organization	36.1	27.1

Sources: Problem Solving—Pinelli, et al. (1989)
U.S. Government Technical Reports—Pinelli (1991)

Finding Out About DoD and NASA Technical Reports

Survey respondents who indicated that they used DoD and NASA technical reports were asked to select from a list the various means by which they find out about these reports. For presentation and discussion, we grouped the choices into the following three categories: **Producer**, which includes announcement journals such as STAR; **User**, which includes colleagues and coworkers; and **Intermediary**, which includes interaction with a librarian or technical information specialist.

In the aggregate, there was little difference in how U.S. aerospace engineers and scientists find out about DoD and NASA technical reports. **User** methods, dominate the question of "awareness" with "cited in a publication" and "referred by a colleague" being the frequent choices. **Intermediary** methods ranked second with "database search" being the frequent choice. **Producer** methods ranked third with announcement journals such as STAR and CAB being the frequent choice.

Physically Obtaining DoD and NASA Technical Reports

Survey respondents were asked how they physically obtained copies of DoD and NASA technical reports. Their responses were grouped into the following three categories. **Producer**, including sent by author; **User**, including obtained from a colleague; and **Intermediary**, including routed to me by my library.

Overall, **User** methods dominate the question of "physical access" with "requested/ordered from my library" being the frequent choice (see figure 3). **Producer** methods ranked second with "sent by DoD/NASA" being the frequent choice. **Intermediary** methods were third with "requested/ordered from NTIS" being the frequent choice.

In our test of the model (figure 1), we attempted to ascertain a measure of "proactivity" for aerospace librarians and information specialists by determining their role in linking U.S. aerospace engineers and scientists with DoD and NASA technical reports. Our design is admittedly crude. Our findings lead us to the following preliminary conclusions: (1) the success of the system for transferring the results of federally funded aerospace R&D via the U.S. government technical report depends in large part on the "proactivity" of the user, (2) the data support our earlier statement regarding the "passive" nature of the formal part of the system, and (3) although aerospace librarians and technical information specialists play an important "linking" role in the "producer-to-user" transfer process, their measure of "proactivity" is rather weak. On the other hand, we must also restate that a strong methodological base for measuring or assessing the "proactivity of the information intermediary" is needed before such a statement can be made with confidence and certainty.

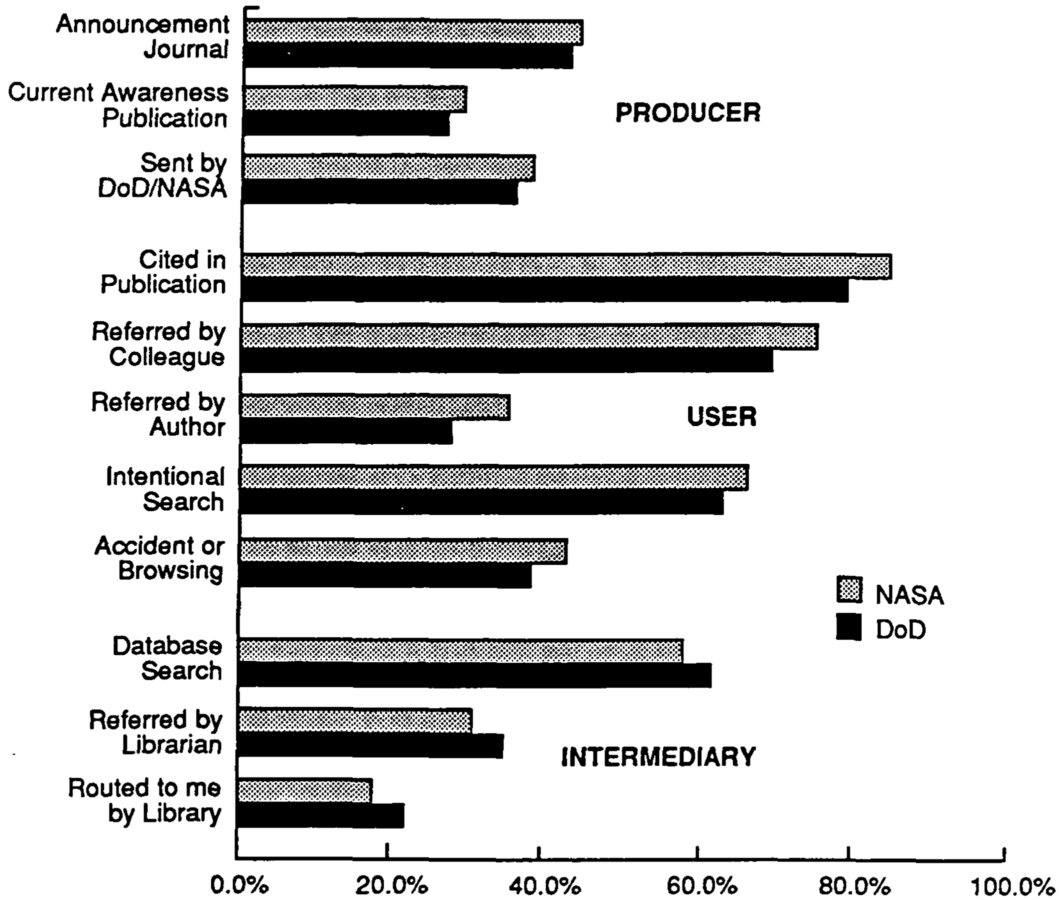

Figure 2. How U.S. Aerospace Engineers and Scientists Find Out About DoD and NASA Technical Reports.

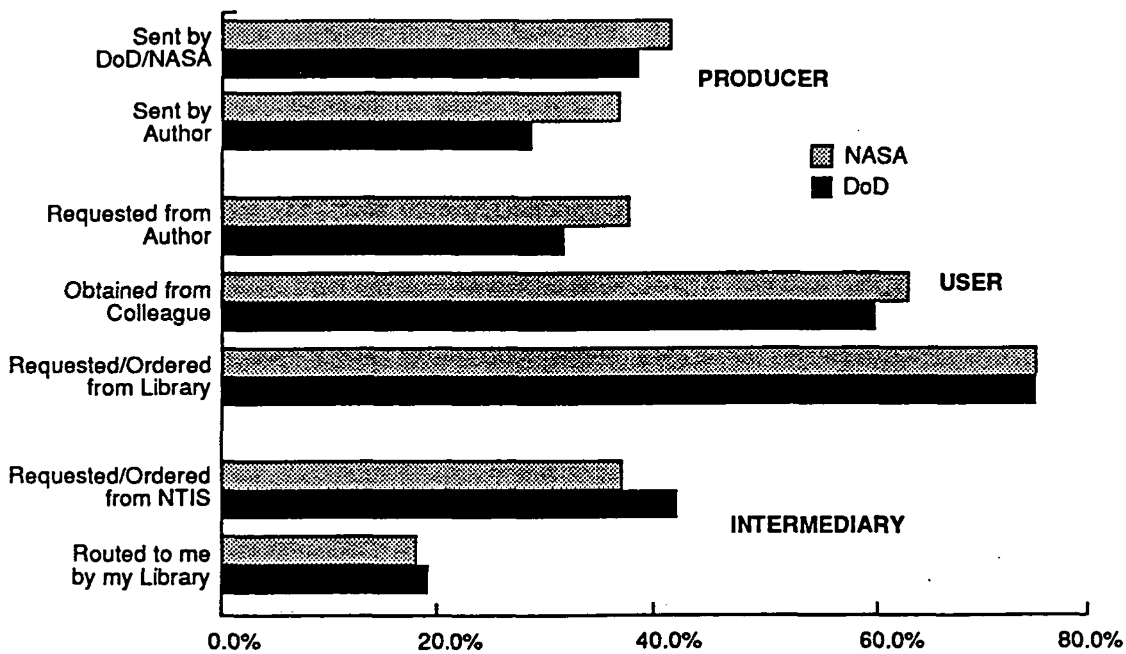

Figure 3. How U.S. Aerospace Engineers and Scientists Physically Obtain DoD and NASA Technical Reports.

CONCLUDING REMARKS

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 and international circumstances. Some features of these changes result from domestic actions and circumstances such as airline deregulation, while others result from external trends and events such as emerging foreign competition. Consequently, while the implications of these changes are of national importance, they are not well understood.

Certain factors, events, and trends are changing the nature of the U.S. aerospace industry and the commercial aviation sector in particular. The continuation of the domestic airlines' traditional role in launching new aircraft is uncertain due to economic deregulation and the deteriorating financial performance of domestic airlines. Worldwide, the manufacture of aircraft is becoming an attractive industry and many foreign companies enjoy a special supportive (financial) relationship with their governments. Domestic air travel is projected to grow less rapidly than in foreign markets, so export sales will become increasingly important. Countries are demanding a participatory role in manufacturing as the price of entry into their markets. Simultaneously, U.S. producers are seeking to spread risks and to develop additional capital. Thus, increasing U.S. collaboration with foreign producers results in a more international manufacturing environment. The changing composition of the industry will foster an increasing flow of U.S. aerospace trade. At the same time, international industrial alliances will result in a more rapid diffusion of technology, increasing pressure on the U.S. aerospace industry to push forward with new technological developments.

The importance of the U.S. aerospace industry to the American economy is illustrated in the following commentary offered by the Aerospace Industries Association (1990).

> Last year U.S. aerospace exports totaled nearly $32 billion. Imports of similar goods were approximately $10 billion for a positive sectoral trade balance of $22 billion. This was a net improvement of $4 billion over 1988. In fact, the U.S. sectoral trade balance in aerospace products has improved every year since 1984. The contrast to other U.S. manufacturing industries is striking. The trade trend for high-tech U.S. industries, such as computers and automobiles, has been steadily negative. For such industries, the goal is reversing these persistent negative trends; for U.S. aerospace, the goal is to maintain its positive trade balance.

In spite of its importance to the U.S. economy and the balance of trade, very little is known about aerospace knowledge diffusion, both in terms of the channels used to communicate the ideas and the information-gathering habits and practices of the members of the aerospace social system.

"Judged against almost any criterion of performance–growth in output, exports, productivity, or innovation–the U.S. aerospace industry, in particular the commercial aviation sector, must be considered a star performer in the American economy" (Mowery and Rosenberg, 1982). "Total factor productivity in this [the commercial aviation sector] industry has grown more rapidly than in virtually any other U.S. industry during the postwar period" (Mowery and Rosenberg, 1982).

In 1989, the U.S. aerospace industry was the leading positive contributor to the balance of trade among all merchandise industries, including agriculture (U.S. Department of Commerce, 1990). Along with this performance record, the U.S. aerospace industry, in particular the commercial aviation sector, presents important anomalies in structure and conduct that make it worthy of investigation from the standpoint of enhancing innovation and productivity and understanding the innovation process. These anomalies include the factors that influence the rate and direction of innovation, the diffusion of federally funded aerospace R&D, and Federal involvement in supporting civilian R&D.

Therefore, it is likely that an understanding of the process by which aerospace STI is communicated through certain channels over time among the members of the aerospace social system would contribute to stimulating technological innovation, maximizing the R&D process, increasing R&D productivity, and maintaining the professional competence of U.S. aerospace engineers and scientists. Allen (1966), citing Herner (1959), states

> Perhaps the most important and least considered factor in the design of [aerospace] S&T information systems is the user of such systems. Regardless of what other parameters are considered in the [design and] development of such systems, it is necessary to consider its potential use and mode of use by the persons or groups for whom it is intended; it is necessary either to fashion the system to suit the user's information needs, habits, and preferences or to fashion the user to meet the needs, habits, and practices of the system. Both approaches are possible. However, the [design and] development of any [aerospace] S&T information system should serve the user.

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