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THE RELATIONSHIP BETWEEN TECHNOLOGY POLICY AND SCIENTIFIC AND TECHNICAL INFORMATION WITHIN THE U.S. AND JAPANESE AEROSPACE INDUSTRIES

by
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ABSTRACT

Government technology policy has nurtured the growth of the aerospace industry which is vital to both the U.S. and Japanese economies. Japanese technology policy differs significantly from U.S. technology policy, however, particularly with respect to the production, transfer, and use of scientific and technical information (STI). In this paper, we discuss the unique position of the aerospace industry in the U.S and Japan, U.S. and Japanese aerospace policy, and the role of STI in the process of aerospace innovation. The information-seeking behaviors of U.S. and Japanese aerospace engineers and scientists are compared. The authors advocate the development of innovation-adoption technology and STI policy goals for U.S. aerospace and the inclusion of an aerospace knowledge diffusion transfer system with an "active" component for scanning and acquiring foreign aerospace technology and STI.

INTRODUCTION

With its contribution to trade, its coupling with national security, and its symbolism of technological strength, the aerospace industry occupies a unique position in the industrial structures of the United States and Japan and plays critical but different roles in the economies of both nations. In the U.S. and Japan, government policy has influenced innovation in the aerospace industry, particularly in the commercial aviation sector, with its demand for military and civilian aircraft and through direct support of research. In both nations, government has played a major role in the production, transfer, and use of scientific and technical information (STI) resulting from aerospace research and development (R&D). This paper focuses on the aerospace industry in the U.S. and Japan and the role of STI in the process of aerospace innovation. It calls for a coordinated set of technology policy goals and an active STI diffusion oriented system that scans, acquires, and transfers foreign STI for domestic users.

U.S. Aerospace in Perspective

The U.S. government has a long history of providing national leadership and significant financial support for the development of aerospace research and technology (R&T). In fact, the U.S. aerospace industry, in particular the commercial aviation sector, is unique among manufacturing industries in that a government research organization, the National Advisory Committee for Aeronautics (NACA), subsequently the National Aeronautics and Space Administration (NASA), has for many years conducted and funded research on airframe and propulsion technologies. The commercial aviation sector has also benefitted from considerable investment in terms of research and procurement by the Department of Defense. "Although not intended to support innovation in any but military airframe and propulsion technologies, this investment has, nonetheless, yielded indirect, but very important, technological spillovers to the commercial aircraft industry" (Mowery, 1985, p. 17). A critical element of the U.S. economy, the U.S. aerospace industry is a national and global leader. Aerospace produces the largest trade surplus of any U.S. industry ($26 billion in 1990), which significantly reduces the nation's merchandise trade deficit (U.S. Department of Commerce, 1992, p. 25-1).

U.S. aerospace policy assumes a positive relationship between U.S. preeminence in both military and civil aviation and effective U.S. aerospace R&T programs. In 1982, the Keyworth study was undertaken to examine the appropriateness and effectiveness of U.S. aeronautical R&T policies and the U.S. government's role in support of aeronautical R&T. The study concluded that superiority in aeronautics is a unique and vital asset to U.S. national security and that U.S. aeronautical R&T is a clearly established government responsibility. The study also concluded that unclassified but critical dual-use technology was not being adequately controlled and that the results of non-U.S. aeronautical R&T were not being purposefully collected and diffused within U.S. government and industry (Office of Science and Technology Policy, 1982, p. VII-89).

Japanese Aerospace in Perspective

In Japan, aerospace enjoys considerable public support because of its technological linkages with a wide range of high-value-added industries. Japanese industry and government have targeted aerospace as one of three key technologies for the next century. Japan's initial effort to develop an indigenous aerospace industry suffered losses "four times its capitalization and when it wound down in the early 1970's, the planners retreated from their independent approach to consider less ambitious strategies for commercial aviation" (Samuels and Whipple, 1989, p. 277-8). Government and industry subsequently allied themselves as junior partners with leading Western aerospace producers, and Japanese subsidies for commercial jet engine development soon equaled those for computer research and exceeded those for energy and telecommunications. By 1990, the Japanese Ministry of International Trade and Industry (MITI) had actively supported a decade of commercial collaboration with Western aerospace firms in an attempt to transform commercial aerospace into the next Japanese export success story (Samuels and Whipple, 1989, p. 275). As with other industries, Japan has emphasized the acquisition, development, and use of aerospace technology to improve its national economic performance. The Japanese aerospace industry has excelled in adapting foreign technology and expertise in contrast to the "not-invented-here" (NIH) syndrome found in the U.S.

Policy Considerations

Can government involvement in the aerospace industry serve as a useful model for stimulating non-defense technological innovation? It is generally accepted that investing in national security should result in products and processes having commercial application. Engineers and scientists outside of the defense community would learn of these discoveries and would adopt them to produce marketable goods. However, few technologies proceed effortlessly from defense conception to commercial application. The technology process requires substantial additional investment and attention (Alic et al., 1992, p. 9). Frequently, programs for technology transfer ignore (1) the relationship between knowledge production, transfer, and utilization as equally important components of the innovation process and (2) the limitations of organizations engaged in technological innovation to exploit extramural research. Both U.S. and Japanese policies in the aerospace industries have not only supported precommercial research in military and civilian aircraft technologies, but they have also played a major role in supporting the diffusion of the results of such research.

These policies exhibit a fundamental difference, however. U.S. government programs encourage the utilization of knowledge only after the R&D results have been generated rather than during the idea development phase of the innovation process (Roberts and Frohman, 1978, p. 9). This concept of "spin off" is illustrated in figure 1. Spin-off emphasizes revolutionary developments that create new markets, rather than the processes of incremental improvements and rapid response on which commercial competitiveness demands. The spin-off paradigm portrays knowledge diffusion as easy and nearly automatic; it assumes that borrowers can recognize and

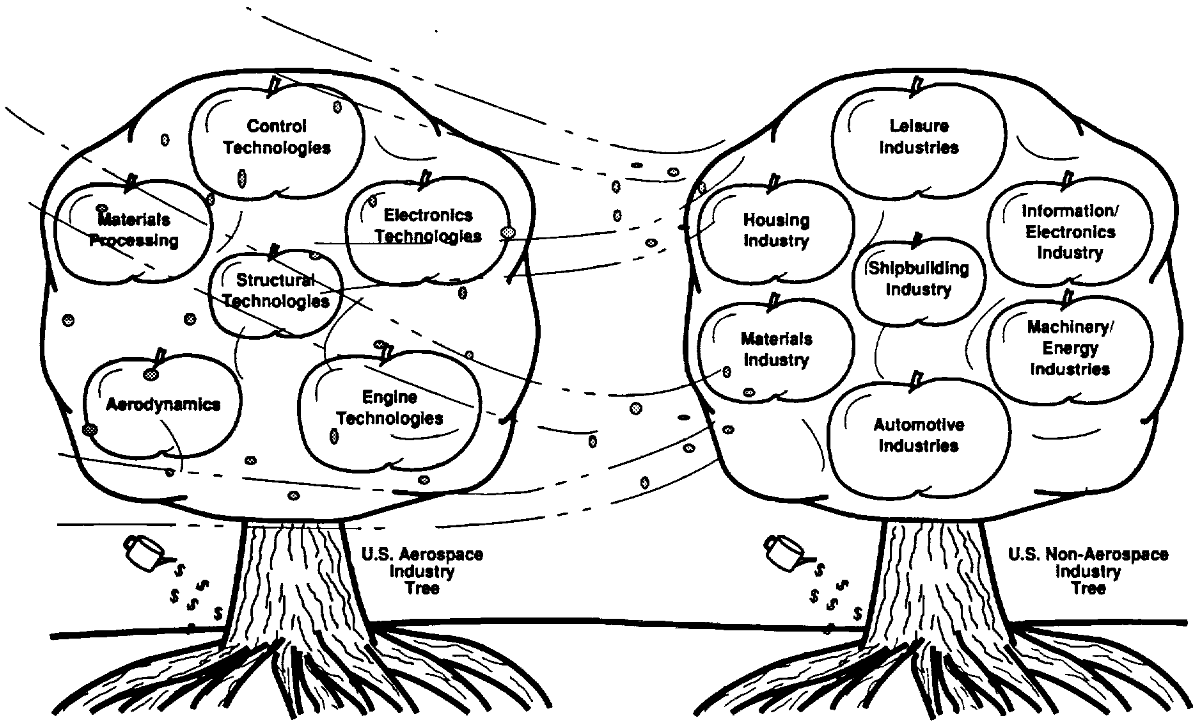

Figure 1. U.S. Technology Spin-Off Model

apply potentially useful technology from government funded R&D and apply it with minimal effort to any number of non-defense industries (Alic, et al., 1992, p. 9).

Japanese government programs, in contrast, do not wait until the R&D results have been generated. Technology transfer programs in Japan, as illustrated in figure 2, "spin on" or extend the application of technologies originally developed for commercial purposes (Samuels and Whipple, 1989, p. 276). Technological development is valued for its ability to elevate the fundamental capacities of the economy. Consequently, the know-how that enabled production in a particular technology is "diffused aggressively throughout the Japanese economy" (Friedman and Samuels, 1992, p. 4). This know-how is obtained by acquiring foreign STI through licensing, joint ventures, and direct purchase of foreign high technology companies. Although Japan's private sector conducts most technology acquisition activities, the Japanese government actively encourages and facilitates the transfer of STI (Chaney and Grimes, 1991, p. 3).

MODELS FOR THE TRANSFER OF STI

Three models or approaches have dominated the "transfer" of STI arising from government funded R&D (Ballard, et al., 1989; Williams and Gibson, 1990). While variations of the models or approaches have been tried in a number of disciplines, a "supply-side" dissemination model is used to transfer aerospace STI in the U.S. and, to a lesser extent, in Japan.

The Appropriability Model

The **appropriability model** emphasizes the production of government funded knowledge that would not otherwise be produced by the private sector and competitive market pressures to promote the use of that knowledge. This model emphasizes the production of basic research as the driving force behind technological development and economic growth and assumes

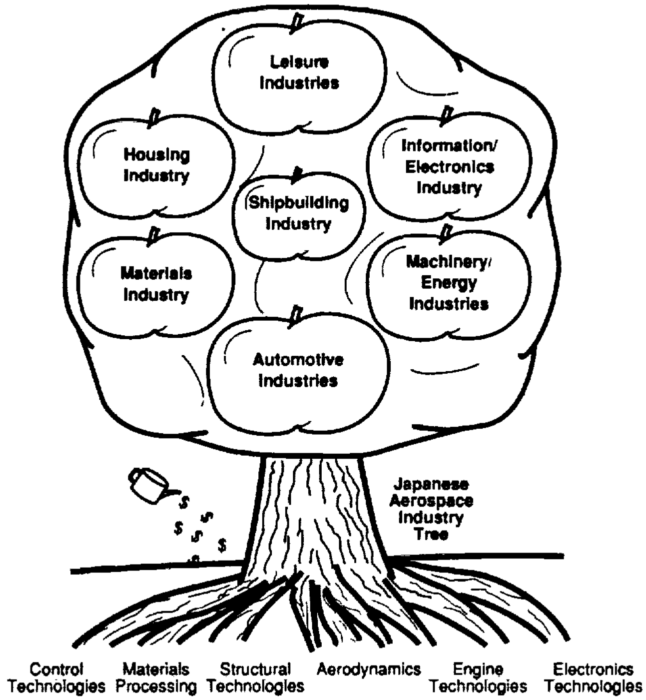

Figure 2. Japanese Technology Spin-On Model

that government funded R&D will be rapidly assimilated by the private sector. Deliberate transfer mechanisms 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 and offer clear policy recommendations regarding government priorities for improving technological development and economic growth. This model incorrectly assumes that the results of government funded R&D will be acquired and used by the private sector, ignores the fact that most basic research is irrelevant to technological innovation, and dismisses the process of technological innovation within the firm.

The Dissemination Model

The **dissemination model** emphasizes the need to transfer information to potential users and embraces the belief that the production of government funded 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 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. The strength of this model rests with the recognition that STI transfer and use are critical elements of the process of technological innovation. Its weakness lies with the fact that it is passive, for it does not take users into consideration except when they enter the system and request assistance; however, user requirements are seldom known or considered in the design of information products and services. This model employs one-way, source-to-user transfer procedures that are seldom responsive in the user context. In this model, the role of information technology is expanded to emphasize information and retrieval, but retrieval is accomplished by intermediaries who are required to have more familiarity with the activities of the knowledge producers than the potential users have.

The Knowledge Diffusion Model

The **knowledge diffusion model** is grounded in theory and practice associated with the diffusion of innovation and planned change research and the clinical models of social research and mental health. Knowledge diffusion emphasizes "active" intervention as opposed to dissemination and access; stresses intervention and reliance on interpersonal communications as a means of identifying and removing interpersonal barriers between users and producers; and assumes that knowledge production, transfer, and use are equally important components of the R&D process. 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. It makes the assumption that the results of government funded R&D will be under utilized unless they are relevant to users and ongoing relationships are developed among users and producers. This model uses proactive information intermediaries and information technology to enhance both formal and informal communication among all participants in the innovation process. It purposefully collects, analyzes, and diffuses foreign STI. It encourages the user oriented development and evaluation of STI products and services.

The STI Aerospace Dissemination Model: An Analysis and Critique

As we envision it, the Aerospace STI Dissemination 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. Producers include government laboratories, the aerospace industry, and universities. (The more collegial the relationships between government laboratories, the aerospace industry, and universities, the greater the effectiveness of the STI Aerospace Dissemination Model.)

Surrogates serve as repositories or clearinghouses for the producers. In the U.S. they include the Defense Technical Information Center (DTIC), the NASA Center for Aero Space Information (CASI), and the National Technical Information Service (NTIS). In Japan they include the Japan Information Center of Science and Technology (JICST), the National Center for Science Information System (NACSIS), and to a lesser extent, the National Space Development Agency which operates the Aerospace Information Reference System (AIRS).

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) call "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 (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, p. 4).

The major problem with the STI Aerospace Dissemination Model is that it lacks a "coherent or systematically designed approach to transferring the results of R&D to the user" (Ballard, et al., 1986, p. 2-3). Approaches to STI transfer may vary considerably and may change significantly over time. These variations reflect fundamental differences between organizations (e.g, government and industry), the interpretation of their missions, and budgetary opportunities and constraints. For example, in their study of issues and options in U.S. government STI policy, Bikson and her colleagues found that many interviewees considered dissemination activities "afterthoughts, undertaken without serious commitment by agencies whose primary concerns were with [knowledge] production and not with knowledge transfer;" therefore, "much of what has been learned about knowledge transfer has not been incorporated into [formal] STI transfer activities" (Bikson, Quint, and Johnson, 1984, p. 22).

The specific problem with the **informal** part of STI Aerospace Dissemination Model 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. Two problems exist with the **formal** part of the model. It employs one-way, source-to-user transmission, but one-way, "supply-side" transfer procedures do not seem to be responsive to the user context (Bikson, Quint, and Johnson, 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, Quint, and Johnson, 1984).

The **formal** part of the model also relies heavily on information intermediaries to complete the knowledge transfer process, but a strong methodological base for measuring or assessing the effectiveness of the information intermediary is lacking (Kitchen and Associates, 1989). The impact of information intermediaries is likely to be strongly conditional and limited to a specific institutional context. To date, empirical findings on the effectiveness of information intermediaries and the role(s) they play in knowledge transfer are sparse and inconclusive (Beyer and Trice, 1982).

The **formal** part of the STI Aerospace Dissemination Model is ineffective because aerospace STI is not organized and structured according to problem relevance. More to the point, putting aerospace STI to use frequently requires transferring it in a use context that is quite different from the context in which it was produced or originally packaged. This problem is complicated by the fact that aerospace STI is organized along traditional disciplinary lines as are subject matter indexes, abstracts, and key words. This organizational scheme makes multidisciplinary retrieval extremely difficult for users and (typically non-technical) information intermediaries alike. The **formal** part of the model becomes even less effective when the user's environment is not well aligned with the standard disciplinary taxonomies (Bikson, Quint, and Johnson, 1984).

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

Rapidly changing patterns of international cooperation and collaboration and innovative technological and managerial changes are combining to influence the production, transfer, and use of STI in the workplace. To contribute to our understanding of information-seeking behavior at the international level, an exploratory study was conducted that investigated the information-seeking behavior of aerospace engineers and scientists in Japan and the United States (U.S.).

The data reported herein were collected through self-administered questionnaires undertaken as a Phase 4 activity of the *NASA/DoD Aerospace Knowledge Diffusion Research Project.* The Japanese/U.S. study included the following objectives:

1. To solicit the opinions of aerospace engineers and scientists regarding the importance to their profession of effectively communicating STI,
2. To determine the types of STI products produced and used by aerospace engineers and scientists,
3. To determine the use and importance of computer and information technology to them, and
4. To determine the sources of STI used in problem solving.

Background

Aerospace engineering exhibits particular characteristics which make it an excellent platform for studying information-seeking behavior in the international workplace. The aerospace industry is becoming more international in scope and increasingly collaborative in nature, thus creating a multinational manufacturing environment. International industrial alliances will result in a more rapid diffusion of technology in order to enhance innovation and increase productivity. Aerospace producers will feel growing pressure to push forward with new technological developments, to maximize the inclusion of those developments into the R&D process, and to maintain and improve the professional competency of aerospace engineers and scientists. Meeting these objectives at a reasonable cost depends on a variety of factors, but largely on the ability of aerospace engineers and scientists to acquire, process, and communicate STI. Studies have shown that access to STI can increase productivity and innovation and help aerospace engineers and scientists maintain and improve their professional skills. These same studies demonstrate, however, that little is known about how aerospace engineers and scientists find and use STI or how aerospace knowledge is diffused. To learn more about this process, researchers at the NASA Langley Research Center, the Indiana University Center for Survey Research, Rensselaer Polytechnic Institute, and institutions in selected countries are studying aerospace knowledge diffusion. These studies comprise the *NASA/DoD Aerospace Knowledge Diffusion Research Project.*

Phase 1 of the project 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 and U.S. government technical reports. Phase 2 examines the industry-government interface and emphasizes the role of information intermediaries in the aerospace knowledge diffusion process. Phase 3 concerns the academic-government interface and focuses on the relationships between and among the information intermediary, faculty, and students. Phase 4 explores patterns of technical communications among non-U.S. aerospace engineers and scientists in selected countries (Pinelli, Kennedy, and Barclay, 1991). The Project fact sheet is Appendix A. A list of *NASA/DoD Aerospace Knowledge Diffusion Research Project* publications appears in Appendix B.

The Japanese exploratory study is particularly interesting for two reasons. First, Japanese culture is perhaps as different from that of the U.S. as the culture of any other developed nation; hence, it has the potential to provide us with instructive contrasts and insights into the influence of language and culture on information-seeking behavior. Second, very few studies specifically concerned with the information-seeking behavior of Japanese engineers and scientists have been conducted. The bulk of the literature on Japanese information-seeking focuses on interpersonal and business communication rather than on the communication of STI. (For a discussion of the importance of language and culture on STI in Japan, see Kohl et al., 1993.)

Research Design and Methodology

A list of approximately 50 U.S. and 13 Japanese aerospace engineers and scientists served as the sample frame for the exploratory study. All of these engineers and scientists were working in the fields of cryogenics, magnetic suspension, and adaptive walls. We sent multiple questionnaires to the members of the sample and asked that each recipient distribute the survey to colleagues. We received 63 U.S. and 96 Japanese responses by the established cut off date.

Demographic Information About the Survey Respondents

Survey respondents were asked to provide information regarding their professional duties, organizational affiliation, years of professional work experience, education, gender, and whether English was their first (native) language. These demographic findings appear in table 1.

Table 1. Demographic Findings
[N=96;N=63]

	Japanese		U.S.	
	%	(n)	%	(n)
Professional Duties				
Design/development	27	(26)	14	(9)
Administration/management	2	(2)	27	(17)
Research	40	(38)	35	(22)
Other	31	(30)	24	(15)
Organizational Affiliation				
Academic	36	(34)	24	(15)
Government	26	(25)	41	(26)
Industry	37	(35)	24	(15)
Other	1	(1)	11	(7)
Professional Work Experience				
1 - 9 years	26	(25)	8	(8)
10 - 19 years	35	(34)	15	(9)
20 or more years	39	(37)	39	(48)
Education				
Bachelor's degree or less	22	(21)	18	(11)
Graduate degree	78	(74)	82	(52)
Educational Preparation				
Engineer	91	(87)	87	(55)
Scientist	8	(8)	13	(8)
Other	1	(1)	0	(0)
Current Duties				
Engineer	91	(87)	68	(42)
Scientist	6	(6)	10	(6)
Other	3	(3)	22	(14)
English (native) language	0	(100)	89	(55)
Member of a Professional/ Technical Society	87	(83)	87	(56)
Gender				
Female	1	(1)	2	(1)
Male	99	(95)	98	(62)

A comparison of the two groups reveals that they are similar in education, educational preparation, and gender. They differ in professional duties, organizational affiliation, years of professional work experience, and current duties. We speculate that differences in organizational affiliation and professional duties may account for some variations in the responses of the two groups. However, we took these differences into account in our analysis of the data and in the discussion which follows.

Importance of and Time Spent Communicating STI

Approximately 97% of the Japanese respondents and 95% of the U.S. respondents indicated the ability to communicate STI effectively is important. (Importance was measured on a 5-point scale with a 1 = very unimportant and 5 = very important; percentages = combined "4" and "5" responses. According to Hall (1976), Japan (unlike the U.S.) is a high-context society, in which information is widely and freely shared. Even the typical Japanese office arrangement, in which dozens of workers share a common workspace, with desks arranged in groups and separated only by low dividers (Haas and Funk, 1989, p. 364), would seem to encourage communication. Hence we might expect Japanese aerospace engineers and scientists to spend more time communicating STI than their American counterparts.

However, when subjects were asked how many hours per week they spend communicating STI, the median for Japanese respondents was 5 hours, compared to 10 hours for the Americans. (table 2.) We believe the explanation for this apparent contradiction to be that the Japanese rely more on oral communication than on written communication. Because it takes less time to communicate orally than in writing, it is not surprising that the mean for the Japanese was lower.

The claim that the Japanese rely more on oral communication and less on written communication than Americans do is supported by several sources. For example, in their ethnographic study of Japanese technical communication, Haas and Funk (1989) found that "shared information is primarily spoken rather than written." They also noted "work groups met formally as often as twice a day," and that "matters of office procedure, upcoming deadlines, even notices of social events, which might be conveyed in memos in the U.S. were announced publicly at departmental meetings" (pp. 364-365). Similarly, Cutler (1988) observes that "it is difficult to track research activities in Japan because there are no paper trails, no intermediate publication points" (p. 45).

Table 2. Median Number of Hours Spent Each Week by Japanese and U.S. Aerospace Engineers and Scientists Communicating Scientific and Technical Information

	Japanese	U.S.
Communicating With Others	5.00 hours/week	10.00 hours/week
Working With Communications Received From Others	10.00 hours/week	10.00 hours/week
Percent of Work Week Devoted to Technical Communications*	37.5%	50%

*Based on a 40-hour work week

Approximately 38% of the Japanese respondents and 42% of the U.S. respondents indicated that the amount of time they spent communicating STI had increased over the past 5 years (table 3). Forty-seven percent of the Japanese respondents and 45% of the U.S. respondents indicated that the amount of time they spent communicating STI had stayed the same over the past 5 years. Fifteen percent of the Japanese respondents and 13% of the U.S. respondents indicated that the amount of time they spent communicating STI had decreased over the past 5 years.

Table 3. Changes in the Past 5 Years in the Amount of Time Spent Communicating Scientific and Technical Information by Japanese and U.S. Aerospace Engineers and Scientists

	Japanese		U.S.	
	%	(n)	%	(n)
Increased	38	(36)	42	(26)
Stayed the Same	47	(45)	45	(28)
Decreased	15	(15)	13	(8)

As they have advanced professionally, 48% of the Japanese respondents have increased the amount of time they spend communicating STI. Likewise, 56% of the U.S. respondents indicated that, as they have advanced professionally, they have increased the amount of time they spend communicating STI (table 4).

Table 4. Changes in the Amount of Time Spent Communicating Scientific and Technical Information as a Part of Professional Advancement by Japanese and U.S. Aerospace Engineers and Scientists

	Japanese		U.S.	
	%	(n)	%	(n)
Increased	48	(46)	56	(35)
Stayed the Same	34	(32)	25	(16)
Decreased	18	(17)	19	(12)

Scientific and Technical Information Products Produced

When survey participants were asked how many times they wrote or prepared various types of STI products, their responses further confirmed the Japanese emphasis on oral communication. For example, the Japanese respondents produce far fewer memos (the most common form of internal written communication) than their American counterparts (table 5). As Funk (1988) observed, in Japan "projects...are set up quickly, without paperwork or written requisitions. Employees from one department frequently visit other departments in order to coordinate their activities" (p. 58).

Table 5 also shows that the Japanese produce fewer letters, audiovisual materials, and technical talks/presentations than the U.S. respondents. They produce more of certain scholarly or research-based types of publications such as abstracts, in-house technical reports, and journal articles, and they write the same number of conference/meeting papers and technical proposals as their U.S. counterparts. However, these latter types of documents are written less frequently than the others, and the low numbers that are involved make these median figures less meaningful. Thus, although the Japanese do not use written communication at least as often as U.S. aerospace engineers and scientists do to document and report their research, it seems clear that they rely on informal oral communication for many kinds of information that are communicated in writing in the U.S.

Scientific and Technical Information Products Used

We also asked subjects how many hours per week they spend working with STI received from others. For this question, the medians for the Japanese and the Americans were the same: 10 hours per week (table 2). However, when asked about how many times they had used particular types of STI during the past six months, the Japanese reported using far fewer memos, letters, and audiovisual materials, but more abstracts, conference/meeting papers, journal articles, technical manuals, computer program documentation, drawings/specifications, and AGARD (Advisory Group for Aerospace Research and Development) reports (table 6).

Table 5. Median Number of STI Products Produced in the Past Six Months by Japanese and U.S. Aerospace Engineers and Scientists

	Japanese	U.S.
Letters	5	10
Memos	1	6
Audiovisual Materials	0	4
Technical Talks/Presentations	2	3
Conference/Meeting Papers	1	1
Technical Proposals	1	1
Abstracts	2	1
In-house Technical Reports	2	1
Journal Articles	1	0
Drawings/Specifications	0	0
AGARD Technical Reports	0	0
Computer Program Documentation	0	0
Technical Manuals	0	0
Trade/Promotional Literature	0	0
U.S. Government Technical Reports	0	0

Because the different subgroups of the survey participants undoubtedly use and produce different types of STI in varying quantities and proportions, we also analyzed the responses of the university professors, administrators, and R&D engineers separately. Although the specific U.S.-Japanese ratios varied slightly, the pattern was consistent: the Japanese are able to spend more time producing and working with STI that is the most essential to research, and they "have much less work-related 'mail' to sort through every day than their American counterparts" (Haas and Funk 1989, p. 365). We suspect that the two phenomena are related.

Use and Importance of Computer and Information Technology

Survey participants were asked about their use of computer technology to prepare STI. About 86% of the Japanese respondents use computer technology to prepare STI. Almost all (98%) of the U.S. respondents use computer technology to prepare STI. About 24% of the Japanese respondents and about 37% of the U.S. respondents "always" use computer technology to prepare STI. A majority of both groups (99% and 98%) indicated that computer technology had increased their ability to communicate STI. About 52% of the Japanese respondents and 69% of the U.S. respondents stated that computer technology had increased their ability to communicate STI "a lot".

From a prepared list, survey respondents were asked to indicate which computer software they used to prepare written STI (table 7). Word processing software was used most frequently by

Table 6. Median Number of STI Products Used in the Past
Six Months by Japanese and U.S. Aerospace Engineers and Scientists

	Japanese	U.S.
Letters	5	10
Memos	1	10
Trade/Promotional Literature	2	4
Technical Proposals	2	3
Audiovisual Materials	2	5
U.S. Government Technical Reports	2	5
Technical Talks/Presentations	5	8
Journal Articles	6	6
Technical Manuals	2	2
In-house Technical Reports	6	5
Abstracts	10	6
Conference/Meeting Papers	10	7
Drawings/Specifications	5	3
AGARD Technical Reports	3	2
Computer Program Documentation	5	2

both groups. Overall, the U.S. respondents made greater use of computer software for preparing written technical communications than did their Japanese counterparts; however, the Japanese respondents made greater use of word processing software than did their U.S. counterparts.

Table 7. Use of Computer Software by Japanese and
U.S. Aerospace Engineers and Scientists to
Communicate Written Scientific and Technical Communications

	Japanese		U.S.	
Software	%	(n)	%	(n)
Word Processing	99	(90)	95	(55)
Outliners and Prompters	9	(7)	14	(7)
Grammar and Style Checkers	24	(20)	26	(14)
Spelling Checkers	62	(53)	74	(42)
Thesaurus	13	(11)	37	(20)
Business Graphics	28	(24)	31	(16)
Scientific Graphics	63	(56)	79	(45)
Desktop Publishing	28	(24)	30	(16)

Survey respondents were also given a list of information technologies and were asked, "How do you view your use of the following information technologies in communicating STI?" Their choices included "already use it"; "don't use it, but may in the future"; and "don't use it and doubt if I will". The Japanese and U.S. aerospace engineers and scientists who participated in this study use a variety of information technologies. The percentages of "I already use it" responses ranged from a high of 88% (FAX/TELEX) to a low of 5% (teleconferencing) for Japanese respondents. Similarly, the U.S. responses ranged from a high of 97% (FAX or TELEX) to a low of 5% (laser disk/video disk/CD-ROM).

Table 8. Use, Nonuse, and Potential Use of Information Technologies by Japanese and U.S. Aerospace Engineers and Scientists

Information Technologies	Already Use It		Don't Use It, But May in Future		Don't Use It and Doubt If Will	
	Japan %	U.S. %	Japan %	U.S. %	Japan %	U.S. %
Audio Tapes and Cassettes	28	24	43	37	29	40
Motion Picture Film	21	30	43	23	36	47
Videotape	74	56	25	34	1	10
Desktop/Electronic Publishing	27	32	64	52	9	17
Computer Cassettes/Cartridge Tapes	26	32	37	35	37	33
Electronic Mail	33	54	59	30	8	16
Electronic Bulletin Boards	22	16	66	54	12	30
FAX or TELEX	88	97	9	2	3	1
Electronic Data Bases	42	39	55	53	3	8
Video Conferencing	5	23	67	60	28	17
Teleconferencing	5	54	50	39	46	7
Micrographics and Microforms	57	22	31	43	12	35
Laser Disk/Video Disk/CD-ROM	17	5	80	75	3	20
Electronic Networks	36	38	60	44	4	18

A list, in descending order, follows of the information technologies most frequently used.

Japanese

FAX or TELEX	88%
Videotape	74%
Micrographics and Microfilm	57%
Electronic Data Bases	42%
Electronic Networks	36%

U.S.

FAX or TELEX	97%
Videotape	56%
*Electronic Mail	54%
*Teleconferencing	54%
Electronic Data Bases	39%
Electronic Networks	38%

*indicates tie

A list, in descending order, follows of the information technologies "that are not currently being used but may be used in the future."

Japanese

Laser Disk/Video Disk/ CD-ROM	80%
Videoconferencing	67%
Electronic Bulletin Boards	66%
Desktop/Electronic Publishing	64%
Electronic Networks	60%

U.S.

Laser Disk/Video Disk/ CD-ROM	75%
Videoconferencing	60%
Electronic Bulletin Boards	54%
Electronic Data Bases	53%
Desktop/Electronic Publishing	52%

Use of STI in Problem Solving

From a list of sources of STI, survey respondents were asked to indicate which sources they routinely used in problem-solving (table 9). Sources of STI used for problem-solving by Japanese and U.S. aerospace engineers and scientists in this survey exhibit a number of interesting similarities and differences. Both groups of respondents rely heavily on collegial (informal) sources of STI (discussions with others), which confirms the oral tradition of technology (as opposed to science) and, in the case of Japanese language traditions, reliance on the spoken word. Both groups also rely on formal and informal printed products (journal articles and technical reports). The Japanese respondents reported a greater use of on-line information (60%) than did the U.S. respondents (37%); however, they reported less frequent use of personal collections of STI (79%) than did their U.S. counterparts (95%). Only 21% of the Japanese respondents consulted a librarian or technical information specialist whereas 86% of the U.S. respondents consulted such an individual in the search for STI.

Table 9. Sources of STI Used by Japanese and U.S. Aerospace Engineers and Scientists in Problem-Solving

	Japanese		U.S.	
	%	(n)	%	(n)
Informal Discussions With Colleagues	98	(93)	100	(61)
Discussions With Supervisors	73	(68)	66	(38)
Discussions With Experts In Organization	89	(84)	100	(62)
Discussions With Experts Outside Organization	70	(66)	89	(54)
U.S. Government Technical Reports	47	(44)	90	(54)
Other Technical Reports	92	(86)	92	(56)
Professional Journals	96	(91)	90	(56)
Conference/Meeting Papers	72	(68)	95	(58)
Textbooks	93	(87)	92	(56)
Handbooks And Standards	82	(76)	64	(37)
On-line Sources Of STI	60	(54)	37	(21)
Librarians/Technical Information Specialists	21	(19)	86	(53)
Personal Store Of STI	79	(73)	95	(59)

Discussion

Given the limited purposes of this exploratory study, the overall response rates, and the research designs, no claims are made regarding the extent to which the attributes of the respondents in the studies accurately reflect the attributes of the populations being studied. A much more rigorous research design and methodology would be needed before any claims could be made. Nevertheless, the findings of the studies do permit the formulation of the following general statements regarding the production, transfer, and use of STI by the aerospace engineers and scientists who participated in the two studies:

1. The ability to communicate STI effectively is important to Japanese and U.S. aerospace scientists and engineers.

2. As the Japanese and U.S. aerospace engineers and scientists in these studies have advanced professionally, the amount of time they spend producing and working with STI products has

increased for more than one-third of the Japanese respondents (42%) and the U.S. respondents (38%).

3. The Japanese and U.S. aerospace engineers and scientists in these studies display great similarities in their reported use and anticipated use of information technology, particularly electronic-network-related technologies.
4. Both the Japanese and U.S. aerospace engineers and scientists in these studies make use of oral sources of STI within and outside their organizations. The Japanese respondents do not appear to rely on librarians and technical information specialists to the extent that their U.S. counterparts do; however, they do make greater use of on-line sources of STI than do their U.S. counterparts.

Despite the limitations of this investigation, these findings contribute to our knowledge and understanding of the production, transfer, and use of STI by aerospace engineers and scientists at the national and international levels. The findings reinforce some of the conventional wisdom regarding the nature and importance of STI and the amount of time engineers and scientists devote to its production, transfer, and use. The findings hold implications for technology and STI policy development and point out a need for additional research.

U.S. TECHNOLOGY POLICY AND THE DIFFUSION OF STI

Critics, such as Tornatsky and Fleischer (1990) suggest that the "United States has no coherent innovation or technology policy. The United States does, however, have many programs and numerous policies which cut across political jurisdictions and the idiosyncratic missions and mandates of single agencies which are more or less responsive to a series of shifting political alliances and imperatives"(p. 241). Phillips (1992, p. 104) argues that existing national technology policy is vague, confusing, politicized, and frequently ineffective because it is usually driven by special interests rather than by strategic intent. With the globalization of technology, the continued loss by U.S. high technology industries of world market shares, and the end of the Cold War, political strategists and public policy planners are slowly beginning to conclude that the U.S. could benefit from a coherent, coordinated technology policy. George Fisher, CEO of Motorola, recently described the U.S.'s primary rivals as no longer military ones. Fisher told a Chicago audience, " 'They are those who pursue economic, industry, and technology policies designed to expand their shares of global markets. U.S. policies [economic, trade, and technology] must reflect this reality if we are to remain a world leader and a role model' " (Phillips, 1992, p. 107). A review of U.S. and Japanese aerospace policy illustrates and reinforces Fisher's point.

U.S. and Japanese Aerospace Policy in Retrospect

Despite the expenditure of billions of dollars more on military and defense R&D in the U.S. than in Japan, Japanese manufacturers now exhibit defense production capabilities that match or exceed U.S. capabilities in many areas. This type of growth has occurred, Friedman and Samuels (1992) argue, because the Japanese view of technology and national security differs considerably from comparable American beliefs. In their paper, "How to Succeed Without Really Flying: The Japanese Aircraft Industry and Japan's Technology Ideology," Friedman and Samuels (1992, p. 3-5) make the following points.

- Both the U.S. and Japan have vigorously attempted to foster indigenous defense technologies but have employed very different ideologies and approaches to achieve this objective.
- U.S. technology strategy (policy) has focused on making public outlays to specialized defense laboratories and commercial firms and, while many "spin-offs" have occurred, no special effort has been made to marry commercial and defense industry capabilities.

Indeed, U.S. strategy has actually impeded effective exchanges of commercial and defense technology.

- Japan, in contrast, has made little distinction between military and civilian technology, focusing instead on the following 3 principles: (1) obtaining and indigenzing foreign civilian and military design, development, and manufacturing capabilities; (2) diffusing these capabilities as widely as possible through the economy; and (3) nurturing and sustaining the prime and subcontractors to which commercial and military technologies could be diffused and from which indigenous development could be generated.
- To the Japanese, differences between domestic capabilities and foreign dependence were not as crucial as nurturing the more fundamental ability to design and make things. What matters most is aggressively diffusing the know-how that enables production throughout the Japanese economy as a matter of security (economic) ideology, national (technology) policy, and private practice. As part of the process, defense technology became valued as much for its ability to elevate the fundamental capacities of the economy as for its capability to produce military hardware.
- Unlike U.S. defense production, Japanese defense production is simply one of many technology linkages that firms maintain within the domestic economy. Japan's defense contractors are less specialized than their American counterparts and more readily combine defense and commercial production in a wider range of industrial undertakings. As a consequence, defense and commercial technologies interdiffuse—they "spin-on" and "spin-off" to each other with comparative ease in Japan.

U.S. Technology Policy and STI

Although there is growing recognition that the U.S. should establish a consistent and coherent technology policy, there does not yet appear to be a political consensus as to its form and substance. In a recent trip to San Jose, California, President Clinton outlined his "supply-side" approach to technology policy which involves the use of tax breaks and "peace dividend" money from scaled-back defense spending to help create more high technology jobs. The key points of the President's policy include a permanent extension of the R&D tax credit, government support of new computer and communications technology, increased funding of the national (federal) laboratories, increased funding for the Environmental Protection Agency (EPA) for private-industry development of environmental technology, and federal grants to industry-led research project among groups of companies, a tentative first step toward the kind of European government involvement that produced the Airbus ("Clinton Fleshes Out..." February 23, 1993, p. B9).

Implicit in Mr. Clinton's policy is the idea that U.S. technology policy should look like that of its chief competitors, namely Japan and Germany. Both of these countries have developed and implemented long term strategic plans for economic competitiveness that benefit their companies (and their nation) in global competition. But those who urge that U.S. technology policy should look more like that of Japan and Germany overlook the profound reasons why the U.S. economic and political system differs so much from those of its economic competitors: (1) an individualistic, free-market culture that does not lend itself to national strategizing or statist planning and (2) what may be history's greatest collection of special interests, both in the financial capital of New York and the political capital of Washington, DC (Phillips, 1992, p. 110).

These differences notwithstanding, the call is becoming louder for an articulated U.S. technology policy that is based on competition in a global economy (Raloff, 1992; Burton, 1992; "Innovation: The Machinery..." and "American Technology Policy..."; and "Industrial Policy..."). A review of recent articles demonstrates the following points of agreement.

- The U.S. must develop and implement a coordinated and holistic approach to technological innovation and economic competitiveness.
- The current "supply-side" approach to technology policy, which is product, not process, oriented, encourages innovation and emphasizes the production of knowledge but not its transfer and use. [N.B., Mowery (1983) and others believe that the failure of previous U.S. attempts to stimulate non-defense R&D stems from the application of an inappropriate theoretical economic framework, one that ignores or does not account for the effective transmission and utilization of complex research results. In particular, attempts to transfer the results of "mission-agency" produced R&D overlook the ability and limitations of organizations engaged in non-defense R&D to exploit extramural research, thus ignoring the relationship between knowledge production, transfer, and utilization as equally important components of the innovation process.]
- The trickle-down benefits associated with the funding of basic research and mission-oriented (defense) R&D provide an inadequate basis for developing U.S. technology policy.
- In other words, the current approach will simply not restore the U.S. to a more competitive footing with its economic rivals who are adopting what Branscomb (1991) calls "diffusion-oriented" or "capability-enhancing" policies that increase the power to absorb and employ new technologies productively. Before U.S. technology policymakers can adopt such policies, however, they must discontinue relying on a rather passive, dissemination-oriented approach to the transfer of government funded STI.

Policymakers generally agree that STI derived from government funded R&D can be used to enhance technological innovation and economic competitiveness. Studies show a positive relationship between government funded STI and successful innovation, technical performance, and increased productivity. However, as Solomon and Tornatzky (1986) point out, "While STI, its transfer and utilization, is crucial to innovation [and competitiveness], linkages between [the] various sectors of the technology infrastructure are weak and/or poorly defined" (p. 43). Defining and understanding these linkages is critical for formulating U.S. technology policy that would recognize the inherent relationship between technological innovation and STI resulting from government funded R&D. As Ballard, et al., (1986) have noted though, the U.S. lacks a coherent or systematically designed approach for transferring the results of government funded R&D to users.

Policy instruments such as the Stevenson-Wydler Technology Innovation Act of 1980 (P.L. 96-480), the Federal Technology Transfer Act of 1986 (P.L. 99-502), the Japanese Technical Literature Act of 1986 (P.L. 99-382), and Executive Order (E.O.) 12591, "Facilitating Access to Science and Technology" (April 10, 1987), the High Performance Computing Act of 1991 (P.L. 102-194), and Office of Management and Budget (OMB) Circular A-130 have shaped the legislative and regulatory environment for Federal STI policy. Excluding A-130, the intent of these instruments is to (1) develop a predominant position for the U.S. in international markets by facilitating technology transfer from government laboratories and (2) provide the inducements for Federal engineers and scientists to nurture the transfer process. In addition, some of these instruments provide a mechanism for the collection and dissemination of foreign (i.e., Japanese) STI in the U.S. The High Performance Computing Act, for example, emphasizes linking government, industry, and academia for distributed access to high-performance computing and communications (HPCC) although little emphasis is placed on the role of HPCC technologies in the transfer and utilization of government funded STI and technology transfer in general.

The intent of A-130, which concerns the management of information as a resource, includes Federal STI. According to OMB, STI conforms to a standard information life cycle and does not exhibit any unique characteristics calling for the development and implementation of a separate information policy framework. Attempts by OMB to regulate STI with a single policy instrument fail recognize the linkages between Federal technology policy and federally funded STI; thus, from a policy standpoint, A-130 negates attempts by the Congress to promote innovation and competitiveness (Hernon and Pinelli, 1991).

The Globalization of Technology and STI

The past 20 years have witnessed the propensity of technology and STI to cross national boundaries, a phenomenon that observers such as Vernon (1987) have labeled "the globalization of technology." This boundary-spanning propensity of technology and STI is due mainly to improvements in communications and transportation and the fact that developed and developing nations are spending more on R&D. The globalization of technology illustrates the growing interdependence of science and technology systems, requires both countries and organizations involved in innovation to construct strategies for exploiting extramural research, and places increasing pressure on countries and organizations to develop strategies and systems for scanning and acquiring foreign technology and STI. The Japanese have been notably successful in developing strategies for acquiring foreign technology and STI to increase the international reach of their R&D organizations. The U.S has been much slower, however, in recognizing both the growing interdependence of science and technology systems and the need to develop strategies and systems for scanning and acquiring foreign technology and STI. The dissemination-oriented approach used to transfer government funded STI, as presently constituted, remains much too passive to be used for scanning and acquiring foreign technology and STI.

CONCLUDING COMMENTS

In closing, we take the position that U.S. technology and STI policy must be closely coordinated and that the present passive dissemination-oriented approach to the transfer of government funded STI should be replaced with an active knowledge diffusion oriented system. Further, this system must have an "intelligence" component for scanning and acquiring foreign technology and STI and for matching these acquisitions with domestic needs and activities. (In the absence of cooperative domestic and foreign research projects and the outright purchase of foreign R&D, scanning—identifying and acquiring useful technology and STI on a global scale and diffusing them domestically—has the advantage of preserving economies of scale in R&D, providing control over domestic technology and STI, while placing the lowest demand on financial and human resources.) The intelligence component of the knowledge diffusion system would be used to identify foreign technologies and STI that could accelerate the development and production of new products and services. It would also be used to assess the strength and strategies of key technologies and foreign competitors, to help benchmark domestic and foreign technology, and to help overcome the "not invented here" (NIH) syndrome, which is not an easy task under the best of conditions.

The U.S. government and firms have historically taken a dim view of allocating funds for scanning activities in particular and STI programs in general. Witness the very low level of support for knowledge transfer and utilization in comparison to knowledge production by the U.S. government and the fact that such activities, even the most modest, are often most vulnerable to cost-cutting efforts by both management and R&D organizations. In the final analysis, the NIH syndrome and the mistaken belief that other nations only build on U.S. science and technology rather than serve as potential contributors to it will significantly challenge attempts to initiate both a knowledge diffusion system for transferring government funded STI and any attempts to include a component for a scanning and acquiring foreign technology and STI and for matching these acquisitions with domestic needs. We remain convinced, however, that an active knowledge diffusion system that has a scanning component offers the best hope for maintaining U.S. preeminence in aerospace and restoring it to a preeminent position in other high technology arenas.

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Appendix A

AEROSPACE KNOWLEDGE DIFFUSION RESEARCH PROJECT

Fact Sheet

A research study is investigating the production, transfer, and use of scientific and technical information (STI) in aerospace, a community which is becoming more interdisciplinary in nature and more international in scope. Sponsored by the National Aeronautics and Space Administration, the Aerospace Knowledge Diffusion Research Project is being conducted by the Indiana University Center for Survey Research, the NASA Langley Research Center, and RPI with the cooperation of the AGARD and AIAA technical information panels.

This 4-phase 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 STI 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. Phases 1 and 4 investigate the information-seeking habits and practices of U.S. and non-U.S. aerospace engineers and scientists and place particular emphasis on their use of government funded aerospace STI. Phase 2 examines the industry-government interface and places particular emphasis on the role of the information intermediary in the knowledge diffusion process. Phase 3 concerns the academic-government interface and places particular emphasis on the information intermediary-faculty-student interface.

Empirically, little is known about the production, transfer, and use of aerospace STI in general and about the information-seeking behavior of aerospace engineers and scientists in particular. Less is known about the effectiveness of information intermediaries and the role(s) they play in knowledge diffusion. It is generally assumed that information intermediaries play a significant role in the aerospace knowledge diffusion process. However, a strong methodological base for measuring or assessing their effectiveness is lacking.

The ability of aerospace engineers and scientists to identify, acquire, and utilize STI is of paramount importance to the efficiency of the R&D process. An understanding of the process by which aerospace STI is communicated through certain channels over time among members of the social system would contribute to increasing productivity, stimulating innovation, and improving and maintaining the professional competence of aerospace engineers and scientists.

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Appendix B

NASA/DoD AEROSPACE KNOWLEDGE DIFFUSION RESEARCH PROJECT PUBLICATIONS

REPORTS

Report No.

1 PART 1 Pinelli, Thomas E.; Myron Glassman; Walter E. Oliu; and Rebecca O. Barclay. **Technical Communications in Aerospace: Results of Phase 1 Pilot Study.** Washington, DC: National Aeronautics and Space Administration. NASA TM-101534. February 1989. 106 p. (Available from NTIS 89N26772.)

1 PART 2 Pinelli, Thomas E.; Myron Glassman; Walter E. Oliu; and Rebecca O. Barclay. **Technical Communications in Aerospace: Results of a Phase 1 Pilot Study.** Washington, DC: National Aeronautics and Space Administration. NASA TM-101534. February 1989. 83 p. (Available from NTIS 89N26773.)

2 Pinelli, Thomas E.; Myron Glassman; Walter E. Oliu; and Rebecca O. Barclay. **Technical Communication in Aerospace: Results of Phase 1 Pilot Study -- An Analysis of Managers' and Nonmanagers' Responses.** Washington, DC: National Aeronautics and Space Administration. NASA TM-101625. August 1989. 58 p. (Available from NTIS 90N11647.)

3 Pinelli, Thomas E.; Myron Glassman; Walter E. Oliu; and Rebecca O. Barclay. **Technical Communication in Aerospace: Results of Phase 1 Pilot Study -- An Analysis of Profit Managers' and Nonprofit Managers' Responses.** Washington, DC: National Aeronautics and Space Administration. NASA TM-101626. October 1989. 71 p. (Available from NTIS 90N15848.)

4 Pinelli, Thomas E.; John M. Kennedy; and Terry F. White. **Summary Report to Phase 1 Respondents.** Washington, DC: National Aeronautics and Space Administration. NASA TM-102772. January 1991. 8 p. (Available from NTIS 91N17835.)

5 Pinelli, Thomas E.; John M. Kennedy; and Terry F. White. **Summary Report to Phase 1 Respondents Including Frequency Distributions.** Washington, DC: National Aeronautics and Space Administration. NASA TM-102773. January 1991. 53 p. (Available from NTIS 91N20988.)

6 Pinelli, Thomas E. **The Relationship Between the Use of U.S. Government Technical Reports by U.S. Aerospace Engineers and Scientists and Selected Institutional and Sociometric Variables.** Washington, DC: National Aeronautics and Space Administration. NASA TM-102774. January 1991. 350 p. (Available from NTIS 91N18898.)

7 Pinelli, Thomas E.; John M. Kennedy; and Terry F. White. **Summary Report to Phase 2 Respondents Including Frequency Distributions.** Washington, DC: National Aeronautics and Space Administration. NASA TM-104063. March 1991. 42 p. (Available from NTIS 91N22931.)

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