A Comparison of the Information-Seeking Behaviors of Three Groups of US Aerospace Engineers

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Abstract

To understand the transfer of scientific and technical information (STI) in aerospace, it is necessary to understand the characteristics and behaviors of those who create and use STI. In this paper, we analyze the similarities and differences in the scientific and technical information-seeking behaviors of three groups of US aerospace engineers and scientists. We describe some of their demographic characteristics and their duties and responsibilities as a method of understanding their STI use patterns. There is considerable diversity among aerospace engineers in their use of STI. In general, engineers engaged in research use more STI than those who are in design/development and manufacturing/production. Research engineers also use different standards to determine the STI sources and products that they will use.

The Aerospace Knowledge Diffusion Research Project

This paper presents some data from a five-year Project whose primary aim is to provide an understanding of the information environment in which US aerospace engineers and scientists work and the factors that influence their use of STI (Pinelli, et al., 1993b, Kennedy, et al., 1994). From this Project, we hope to understand the impact of federal policies and practices on aerospace knowledge diffusion and to contribute to improvements in the transfer of aerospace research knowledge produced through federally funded research. The Project attempts to understand the users and uses of information at the individual, organizational, national, and international levels in the aerospace industry. The Project focuses on the methods used by aerospace engineers and scientists to gather, evaluate, use, and communicate STI.

The Project has four phases. Phase 1 examines the production and use of aerospace information by US aerospace engineers and scientists. Phase 2 examines how information intermediaries (principally librarians and technical information specialists) in the aerospace industry evaluate and disseminate technical information. Phase 3 looks at aerospace engineering in US academic settings, to include students, faculty, and information specialists.

Phase 4 examines the international dimensions of aerospace STI. A variety of surveys of aerospace engineers and students in western Europe and in Asia were conducted in this Phase. This paper reports data collected as a Phase 1 activity.

Federal Research and the US Aerospace Industry

The US aerospace industry is a critical component of the national economy. Over the past 20 years, it has consistently been a net exporting industry (second only to agriculture) and has contributed significantly to minimizing the balance of payments deficits with other industrialized nations. The industry is a leader in advanced technologies. Most importantly, the aerospace industry provides well-paid and highly-skilled jobs, the types of jobs most important for industrial and employment growth. Overall, the success of the aerospace industry is critical to the health of the US economy.

The aerospace industry differs from other US industries in that it is heavily influenced by federal policies and programs. The US aerospace industry has been described as a "sheltered" culture (Derian, 1990), as opposed to an "exposed" culture, because the federal government plays a key role in the innovation and diffusion process. The aerospace industry has benefited from a variety of federal policies. For example, the federal government has supported the aerospace industry by providing essential research and development (R&D) activities needed to develop new civilian aircraft. In addition, the US government is a dominant purchaser of aircraft, primarily for the Department of Defense (DoD). The major US aircraft manufacturers produce both military and civilian aircraft. The design and development of defense aircraft have supported both technology transfers from defense to civilian aircraft and the establishment of production facilities that are used to build civilian aircraft. In general, the design of civilian aircraft has benefited more from federal R&D for military aircraft than vice versa.

Sound economic and policy objectives are met through government-funded aerospace R&D. Langford (1989) notes that the government should fund R&D when negative economic incentives to the private sector result from the research. This problem often occurs in aerospace because research costs associated with the development of new technologies are too expensive to benefit any one firm. When the federal government (usually NASA) conducts research, it provides public benefits that cannot be allocated equitably by the private sector. This research serves to stimulate the private sector and provide cost-efficient public benefits (Langford, 1989).

In the US, aerospace companies have traditionally benefited from the R&D activities conducted by NASA and the DoD. As the NASA aeronautics and the DoD budgets decrease, these changes will impact the development of new aerospace technology. The number of new purchases and orders for aircraft will also decrease. For the US aerospace industry to maintain competitiveness, more rapid dissemination of federally funded STI to the US aerospace industry will be critical. The US federal government supports the aircraft industry through support of aerospace R&D, but unlike the direct financial support provided by other governments, there is no guarantee that the R&D will be utilized by US civilian aircraft producers.

The Role of STI in Aerospace R&D

Success in the civilian aerospace industry requires that firms take significant risks during aircraft development. Many years elapse from the first plans for a new aircraft until the new aircraft is delivered to an airline. During the design, development, and production phases, the aircraft designers continually test their designs as well as incorporate new information (i.e., technologies) available from internal and external sources. The availability of both positive and negative research results are critical during development. For example, if NASA conducted research that demonstrated that a design change would cause a particular problem, it may not be necessary for the aircraft designer to do similar research.

The complexity and uncertainty in aircraft development, along with the competitive nature of the marketplace, produce demands on aircraft designers to include as much innovative R&D as possible in the aircraft. Other research from this Project indicates that, as the complexity and uncertainty associated with a task or project increases, the need for STI produced external to the organization increases (Pinelli, et al., 1993a). Engineers must balance the need to incorporate innovative new technology with the possibility that it may have unforeseen consequences. Increased access to STI can reduce the possibility of error in these decisions and allow the aircraft to come to market more quickly and efficiently.

During the development period, research within and outside the organization is conducted. We assume aircraft designers will have access to internal research. Ideally, a designer will have access to all public information relevant to the aircraft system that s/he is designing. There is some question about how well engineers can access externally-generated research. Federal policies support a system in which federally funded aerospace STI is assumed to be available, but the effectiveness of the dissemination in reaching the appropriate aircraft designers has not been determined.

The federal government attempts to disseminate aerospace STI through a variety of sources and products. For example, most non-classified technical reports produced from federally funded R&D are publicly available through the National Technical Information Service. NASA regularly holds conferences on various areas of technology, and NASA personnel regularly participate in professional organization activities, such as AIAA meetings. NASA also supports various STI dissemination products such as STAR. The federal STI dissemination strategy is based on the assumption that the adequate documentation, cataloging, and availability of materials will provide adequate access to STI. The system appears to provide sufficient documentation and cataloging of all relevant federally funded aerospace STI, but previous research conducted from this Project clearly indicates that the use of the dissemination system is problematic (Pinelli, et al., 1994). The problems of disseminating federally funded R&D are well-known and documented. (Averch, 1984; Mowery, 1983; Bikson, et al., 1984; Tornatzky and Fleischer, 1990.)

While aerospace (aeronautical) engineering is a relatively new engineering profession, as with many engineering disciplines, its training focus has changed over time from a primarily hands-on orientation to a more theoretical approach. The 1955 Griner report (Grayson, 1993) oriented engineering education towards increased training in the sciences and reduced the emphasis on the training of hands-on engineering skills in the undergraduate education curriculum. The more "science" model of engineering education created a need for additional training in using STI resources as part of the engineers' skills training.

Aerospace engineering also developed while two conflicting forces were happening that affected engineering. First, during this century, engineering evolved into a more professional occupation - -similar to medicine and law. Increasing numbers of engineers were academically trained, especially at the technical and the land-grant universities. At the same time, large bureaucratic organizations such as the major aerospace firms were employing larger numbers of engineers. These organizations attempted to constrain the professional activities of engineers by treating them as technical rather than professional employees (Zussman,1985; Whalley, 1986; Meiskins and Smith, 1993). As a result, during the first half of this century a "revolt of the engineers" (Layton, 1971) occurred. Engineers became more oriented towards their profession than their employers. Both changes, along with the recent changes in academic curriculum, contributed to an increased recognition by engineers that the ability to use STI was essential to their professional careers, perhaps more so than hands-on training, because it made them less reliant on their employers.

The development of the US aerospace industry created the need for multiple types of engineers to perform a variety of engineering tasks that range from basic science through engineering science to design and development and to manufacturing/production engineering. Each contributes to the aerospace industry, and each is assumed to produce and use STI in different ways. We expected differences among the groups in the types of STI used, the sources used to find STI, and the amount of STI needed to perform their duties. These differences are important to the understanding of the aerospace STI dissemination system.

Description of the Survey Procedures and the Samples

In this paper, we report on surveys of three groups of aerospace engineers and scientists -- the members of the AIAA, subscribers to *Aerospace Engineering* provided by the Society of Automotive Engineers (SAE) Aerospace Division, and subscribers to *Manufacturing Engineering* whose SIC code indicated they were employed in aerospace. The Society of Manufacturing Engineers (SME) provided the latter list.

This Project conducted five surveys of AIAA members. Most of the AIAA data in this paper were collected in two surveys conducted during 1988 and 1989 (n=2016 and 975). Phase 1 of the Project also included four SAE surveys. The data for this paper were collected in a survey conducted in 1991 (n=946). The SME survey was conducted during the summer of 1994 (n=465). The adjusted response rates for the AIAA and the SAE surveys were about 70%. The SME survey response rate was much lower (43%) because: 1) we were not able to target aerospace engineers, and 2) there were dramatic employment changes occurring in the aerospace industry that affected mail distributions and mailing lists during the past summer.

Each group selected for the Phase 1 surveys was assumed to represent different types of engineers and scientists involved in different aspects of aerospace R&D. We assumed that multiple groups would provide a comprehensive scan of aerospace engineers and help us to determine how STI use differed by job activities and organizations. The groups we selected contain the range of engineers and scientists in aerospace, but we do not assume that the combination of all groups is a fully representative sample of US aerospace engineers and scientists because: 1) there is likely some overlap in the groups, and 2) some aerospace engineers may not be included in any groups.

The AIAA sample consisted primarily of aerospace engineers and scientists involved in aerospace engineering research. Most AIAA members considered themselves to be research engineers, scientists, or technical research managers (Pinelli, 1991). We categorize this group as generally more oriented to research in aerospace engineering or, as Vincenti (1990) would classify their activities, engineering science. The SAE sample consisted of engineers primarily involved in design and development. We considered this group intermediate in the product development process between the AIAA and the SME. The SME group represented engineers we expected would perform duties most closely tied to the manufacturing/production processes. Overall, the three groups represent the range of activities of US engineers in aerospace research, design, and production.

Characteristics of US Aerospace Engineers and Scientists

In each group, a majority of respondents identified themselves as engineers when asked questions such as: "In your present job, do you consider yourself primarily as an engineer, a scientist, or something else?" About two-thirds of the AIAA and SME samples self-identified as engineers and about 90% of the SAE sample considered themselves engineers (Table 1). A substantial portion of the AIAA and SME samples classified themselves as "other." An examination of the written responses indicates that among the AIAA group most "other" responses were given by managers.

Table 1: Current Status, Training, and Duties of US Aerospace Engineers and Scientists.

	AIAA %	SAE %	SME %
Current			
Engineer	68	90	71
Scientist	8	3	1
Other	24	7	28
Training			
Engineer	83	91	73
Scientist	12	7	3
Other	5	2	24
Duties			
Research	17	7	3
Management	38	15	14
Design/Development	28	60	16
Manufacturing/Production	1	12	51
Teaching	10	1	--
Other	6	5	16

Table 1 also indicates a variety of career paths in aerospace. The SAE sample appears to be the most consistent between training and duties. About 90% of the SAE sample were trained as engineers. The proportion of AIAA members who were trained as engineers (83%) is substantially larger than the proportion who are currently identify themselves as engineers

(68%). Among the SME sample, about 28% identified their training as "other." An analysis of the written responses indicates that most were trained in business or in various technologies.

We selected a range of aerospace engineering groups because we expected each group might have different attitudes towards STI and possibly use STI differently. We were also interested in managers because we thought they set the tone for the use of STI in their organizations. If they need less STI, or if they are less favorable towards the use of STI, their attitudes and behaviors could affect the use of STI by engineers under their supervision in their organizations.

Each group differed in primary daily activities and duties. A substantial proportion of the AIAA sample are involved in management, research, and teaching.[1] Most of the SAE sample are employed in what might be considered as typical engineering work - - almost three-fourths consider design/development or manufacturing/production as their primary work activities. Over 50% of the SME sample list manufacturing or production as their primary current duties.

Other demographic characteristics of each sample indicate additional diversity among US aerospace engineers. About 70% of the AIAA members have earned masters or doctorates. The SAE and SME samples are composed primarily of persons with bachelor degrees. About 50% of the AIAA members have been employed in aerospace for more than 20 years, but only 40% and 30% of SAE and SME respectively were employed in aerospace as long. There were few academics in the SAE and SME lists.

Demographic characteristics reflect the various professional locations of aerospace engineers. Engineers with advanced degrees, and who work in research are likely to use more STI than other types of engineers. Design/development and manufacturing/production engineers need and use STI, but their requirements differ by amount and type from those of research engineers. The data from the various Phase 1 surveys allow us to feel comfortable in assuming we captured a broad range of aerospace engineering occupations and duties. We believe that, in terms of the generation, production, dissemination, and use of aerospace STI, the various groups probably represent the diversity of aerospace STI users. These data allow us to comprehensively assess the STI use patterns among aerospace engineers.

Aerospace engineering operates in an information-intensive environment. To do their work, aerospace engineers require substantial amounts of information. For the most part, aerospace engineering does not involve substantial amounts of "hands-on" work. Rather, aerospace engineers spend substantial time researching, designing, and making products and systems. To do so, they continually use and create STI. A clear recognition of the patterns of STI use is important to the continued competitiveness of the US aerospace industry.

The Use of STI by US Aerospace Engineers

In general, aerospace engineers and scientists spend a significant amount of professional work time on STI activities. We broadly define STI to include formal literature, such as technical reports and journal articles, and informal information, such as memoranda, letters, and telephone conversations. The AIAA respondents reported that they averaged about 14 hours per week communicating technical information to others and about 13 hours per week working with technical communications from others (Pinelli, et al., 1989). The SAE

[1] Teaching implies some research or scholarly activities.

respondents reported 19 and 15 hours respectively for these activities (Pinelli, et al., 1994). Overall, US aerospace engineers in all settings and work responsibilities spend a significant portion, and probably a majority of their work week, using and producing technical information. Our findings are in substantial agreement with previous research that found engineering to be information-intensive (Rosenbloom and Wolek, 1970; Allen, 1977; Kremer, 1980; Shuchman, 1981; and Kaufman, 1963).

The daily workplace activities of US aerospace engineers and scientists is filled with formal and informal information gathering. The formal STI use activities include searching the open literature, visiting libraries, and searching databases. The informal strategies include discussions with colleagues (both inside and outside their organizations) and with managers. In addition, from the descriptions of their daily work activities, we conclude that much STI is passed semi-formally in meetings and through such products as technical memoranda, letters, and product specifications (Pinelli, et al., 1992).

In our surveys, we asked aerospace engineers and scientists to report the steps they took when they needed information while working on their most important project or task over the past six months (Table 2). Among the AIAA members, their strategies were to: 1) search their personal stores of information; 2) discuss problems with colleagues or key persons within the organization; 3) search library and data resources; 4) discuss with colleagues outside the organization; and 5) ask a librarian. The SAE and SME respondents used their personal stores of STI and spoke with co-workers as their first steps. Then they spoke with colleagues outside the organization, used their organization's library, and asked a librarian.

Table 2: Information Sources Used to Complete Most Important Technical Project, Task, or Problem.

Sources	AIAA %	SAE %	SME %
Used personal store of technical information	93	91	88
Discussed problem with colleague(s) in my organization	78	90	90
Discussed problem with colleague(s) outside my organization	70	73	73
Used literature resources in my organization's library	68	64	52
Searched electronic database	63	---	34
Asked a librarian	48	43	30

These findings generally support the results of Allen (1977) but allow us to understand information-seeking behavior more fully. Engineers are reputed to be "social" researchers (i.e., they gather information from colleagues both inside and outside their organizations). While that finding appears to be descriptive, the data also indicate that they first go to their easily available sources (i.e., their own stores of information). Within their personal stores of technical information, they make decisions about quality, reliability, and relevance to the task (Pinelli, 1991). If they find what they believe is the needed information in their personal stores, there is some indication that they will cease looking. If their information is not complete or up-to-date, then they are not using the best available information.

Another finding that indicates the restricted nature of aerospace engineers' STI search is the reliance on colleagues inside the organization. Obviously, they are more accessible, but there is no indication that internal colleagues have the best information. In another study that we conducted in the Project (Pinelli, et al., 1992), we found that the primary reason for contacting a colleague was that the information is relevant. A much smaller proportion reported that the technical quality of the STI was the reason for asking a colleague. These data (and others from the Project) indicate that the engineers value information with high technical quality, but there is little indication that they make efforts to track down the best information. They appear to use what's easily available from their personal stores and then ask colleagues. Only when these sources do not provide useful materials do they enter the formal STI dissemination system.

Information Sources

In this section, we examine the use of selected sources of information by aerospace engineers. In particular, we focus on two sources of professional open literature (i.e., journal articles and conference papers), one source of somewhat proprietary nature (i.e., in-house technical reports), and one source that indicates the use of federally funded aerospace STI (i.e., NASA technical reports).

Table 3: Number of Times an Information Product Was Used in a Six-Month Period (means).

Information Products	AIAA	SAE	SME
Conference/Meeting Papers	12.0	4.1	8.5
Journal Articles	14.7	6.9	7.6
In-House Technical Reports	20.3	9.7	12.8
NASA Technical Reports	8.5	2.4	1.9

The survey respondents were asked to indicate the number of times in a 6-month period they used each information product while performing their professional duties (Table 3). In-house technical reports are used more often than the other three information products by members of all three groups. The AIAA members are the heaviest consumers of these information sources, which may reflect a more research-focused orientation in their work. The SME sample appears to use more information than the SAE sample. Neither the SAE nor the SME samples used many NASA technical reports.

The survey participants were also asked to rate the importance of the information products in performing their professional duties (Table 4). Importance was measured on a 1 to 5 point scale, with "1" being the lowest possible importance and "5" being the highest possible importance. Of the four information products, in-house technical reports received the highest importance rating by all respondents. NASA technical reports received the lowest importance ratings (i.e., they were the least important source of technical information among the four sources). Overall, the data from Tables 3 and 4 indicate that engineers prefer the most readily-available information (in-house technical reports) and they do not use much federally funded STI in the form of NASA technical reports that are not published elsewhere in the open literature.

Table 4: Importance of Technical Information Products in Performing Professional Duties (means).

Information Products	AIAA	SAE	SME
Conference/Meeting Papers	3.53	2.54	2.94
Journal Articles	3.52	2.65	3.03
In-House Technical Reports	3.84	3.28	3.70
NASA Technical Reports	3.31	2.57	2.07

We asked the survey participants to indicate the extent to which their use of the selected technical information products was influenced by seven factors (Table 5). The AIAA members tended to use STI products based on accessibility, technical quality, and relevance. The SAE and SME samples appeared to base their decisions on technical quality, comprehensiveness, and relevance. The SAE and SME samples generally assigned higher ratings to the products than did the AIAA members. The data in Table 5 indicate that research engineers and managers use and evaluate STI products differently from design/development and production/manufacturing engineers.

Table 5: Influence of Seven Factors on the Use of Selected Technical Information Products (means).

	Conference/ Meeting Papers	Journal Articles	In-House Technical Reports	NASA Technical Reports
AIAA				
Accessibility	3.79	3.88	4.01	3.89
Ease of Use	3.43	3.51	3.61	3.45
Expense	2.50	2.64	2.50	2.55
Familiarity	3.56	3.58	3.78	3.59
Technical Quality	3.74	4.03	3.77	3.54
Comprehensiveness	3.38	3.59	3.51	3.43
Relevance	3.97	3.87	4.15	3.94
SAE				
Accessibility	3.58	3.61	3.61	3.54
Ease of Use	3.71	3.74	3.71	3.72
Expense	3.03	3.04	2.91	3.08
Familiarity	3.11	3.15	3.24	3.17
Technical Quality	4.08	4.10	4.04	4.07
Comprehensiveness	4.02	4.03	4.04	4.04
Relevance	4.06	4.11	4.06	4.03
SME				
Accessibility	3.94	3.92	3.97	3.78
Ease of Use	4.06	4.09	4.15	3.93
Expense	3.58	3.58	3.20	3.48
Familiarity	3.42	3.39	3.54	3.30
Technical Quality	4.32	4.29	4.40	4.16
Comprehensiveness	4.32	4.29	4.38	4.14
Relevance	4.53	4.43	4.54	4.23

The AIAA and the SAE survey participants were also asked to rate the technical information products on six characteristics (Table 6). AIAA participants were asked to rate each product only if they used that product. SAE respondents were asked to rate each product even if they did not use it. Both groups rated the technical quality of journal articles and NASA technical reports as the highest. In-house technical reports were the most relevant to them. Both agreed that NASA technical reports were the most comprehensive. The SAE sample rated in-house technical reports as most accessible;.the AIAA rated journal articles as most accessible. Despite the relatively little use of NASA technical reports, both groups rated them highly for technical quality and comprehensiveness. These data indicate that aerospace engineers might use NASA technical reports to answer important questions when external STI is needed (i.e., when there is substantial uncertainty and complexity in the task), but they do not use them much in their day-to-day work.

Table 6: Ratings of Selected Technical Information Products (means).

	Conference/ Meeting Papers	Journal Articles	In-House Technical Reports	NASA Technical Reports
AIAA				
Accessibility	3.40	4.24	3.63	3.57
Ease of Use	3.64	3.81	3.74	3.81
Expense	3.23	3.65	4.34	3.98
Technical Quality	3.34	4.05	3.57	3.90
Comprehensiveness	3.08	3.58	3.37	3.68
Relevance	3.43	3.60	3.81	3.71
SAE				
Accessibility	2.84	3.39	3.88	3.23
Ease of Use	2.96	3.16	3.41	3.35
Expense	3.02	3.37	4.30	3.52
Technical Quality	3.17	3.48	3.40	3.58
Comprehensiveness	2.96	3.07	3.35	3.44
Relevance	2.99	2.97	3.61	3.15

Summary

US aerospace engineers and scientists come from diverse backgrounds and have varied duties, yet they share the need for substantial amounts of STI in their professional responsibilities. We started this Project with the goal of determining how effectively federally funded aerospace STI meets the STI needs of US engineers and scientists who work in industry and the academic world. We find there are considerable differences among the various types of aerospace engineers, and the diversity of aerospace engineers indicates the dissemination of federally funded STI cannot be assumed as simple, linear, or consistent across time and responsibilities.

In the past few years, the US aerospace industry has changed dramatically. With the decrease in NASA aeronautics and the DoD budgets, and a reduction in air travel, the major aerospace firms have substantially decreased employment. From 1989 through 1993, employment in the aerospace industry declined from 912,000 to 615,000 (US Department of Commerce, 1994). Many engineers were included in the employment decline. It is not likely that employment in the major firms (e.g., Boeing) will ever return to previous levels. US aerospace manufacturing should continue to be the largest and most productive in the world, but future employment growth in aerospace will be in second and third tier firms.

The loss of the substantial human capital invested in aerospace engineering can be recovered with the growth of smaller firms. Engineers should not expect lifetime employment by any one firm and should expect to move often in their careers. To maintain their employability, they will need to be skilled in accessing aerospace STI. Small, flexible firms that can respond quickly to market changes and bring innovations to market quickly will be successful. Aerospace engineers will need to access STI to research, design, and produce innovative systems and products. Since the new employment will come in smaller firms, the most-used form of STI (in-house technical reports) will no longer be available. Engineers are going to need substantial amounts of externally generated STI and, very likely, need more federally funded STI.

A quote from Christopher Hill of the National Academy of Engineering describes the importance of STI dissemination.

> "In the old era, only a few large wealthy firms had to be cognizant of the latest in fundamental science and engineering developments to be able to exploit breakthroughs as they occurred. In the new era, however, a greater number of smaller and a wider variety of firms -- many of them small and medium sized -- need access to a base of rapidly evolving new knowledge in science and technology..." (Hill, 1994; pg 283)

The ability of US engineers to access STI and the ability of the STI dissemination system to meet their needs will have tremendous impacts on the competitiveness of the US aerospace industry in this new era.

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