NASA/DoD Aerospace Knowledge Diffusion Research Project

Paper Twenty

Engineers as Information Processors: A Survey of U.S. Aerospace Engineering Faculty and Students

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Engineers as Information Processors: a Survey of US Aerospace Engineering Faculty and Students

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SUMMARY *US aerospace engineering faculty and students were surveyed as part of the NASA/DoD Aerospace Knowledge Research Project. Faculty and students were viewed as information processors within a conceptual framework of information-seeking behavior. Questionnaires were received from 275 faculty members and 640 students which were used to determine (1) use and importance of information sources, (2) use of specific print sources and electronic data bases, (3) use of information technology and (4) the influence of instruction on the use of information sources and products by faculty and students. As information processors, US aerospace faculty and students are 'information naive', seek out information alone or with the help of co-workers, tend not to make use of the information products and services oriented to them, make limited use of librarians, and make considerable use of computer and information technology. Little evidence was found to support the belief that instruction in library or engineering information use has significant impact either on broadening the frequency or range of information products and sources used by US aerospace engineering students.*

1. Introduction

The process of technological innovation in aerospace and in other engineering disciplines can be conceptualized as an information processing system that must deal with work-related uncertainty through patterns of technical communications. Throughout the process, data, information and knowledge are being produced, transferred and utilized. The fact that these data, the information and knowledge deal with hard technologies or may be, as Allen states, 'physically or hardware encoded,' [1], should not detract from the observation that, in aerospace research and development (R&D), the innovation process is fundamentally an information processing activity. The premise that the process of innovation can be viewed as an information processing activity has its roots in open systems theory [2] and the 'diffusion of innovation' work of Rogers [3] who states:

> The act and the process of innovating is clearly one that involves grappling with unknowns. These unknowns or uncertainties may be technological, economic, or merely the manifestation of personal and social values. Nevertheless, when faced with uncertainty, individuals typically seek information. Such information seeking to cope with uncertainty is why communication behavior cannot be ignored when studying innovation. Because innovation

> behavior always entails coping with a relatively high degree of uncertainty, such innovation is, *most centrally,* an information process.

The engineer can be viewed as the center of the information processing system. According to Sayer [4]:

> Engineering is a production system in which information is a raw material. Whatever the purpose of the engineering effort, the engineer is an information processor who is constantly faced with the problem of effectively acquiring and using data and information.

For purposes of the research being reported, US aerospace faculty and students are viewed as information processors within a conceptual framework of information-seeking behavior. Borrowing from Paisley [5], they are placed within the following four systems:

the political system—because the research is concerned with the diffusion of federally funded aerospace knowledge;

the formal organization—because the information-seeking behavior of US aerospace faculty and students is viewed in terms of their academic affiliation;

the reference group—because the research focuses on engineering faculty and students in the USA involved in aerospace education;

the formal information system—because the study is concerned with the information products and services designed to make information available to aerospace engineers and scientists.

The literature regarding the information-seeking behavior of engineers is fragmented and superficial, and the results of these studies have not accumulated to form a significant body of knowledge that can be used by engineering educators and information professionals. Little is known about the diffusion of aerospace knowledge, both in terms of the channels used to communicate data, information and knowledge, and the information-seeking behavior of US aerospace engineers and scientists. The limited number of studies concerning aerospace has been concerned primarily with the performance or effectiveness of a specific information service or system at a particular location or facility. As Menzel [6] points out:

> The way in which engineers and scientists make use of information at their disposal, the demands that they put on information services, the satisfaction achieved by their efforts, and the resulting impact on their future work are among the items of knowledge which are necessary for the wise planning of information systems and policy.

Difficulty in applying the findings reported in the literature has been attributed to the lack of a unifying theory, standardized methodology and common definitions [7]. Allen attributes the difficulty to the failure of researchers to take into account the essential differences between science and technology and engineers and scientists [1]. This fundamental difference is stressed by Vincenti [8] in his treatise *What Engineers Know and How They Know It: Analytical Studies From Aeronautical History.* Aerospace R&D is a process dominated by engineers as opposed to scientists. As Joenk points out [9], this fact, "leads to different philosophies, habits, and behavior not only about contributing to the technical literature but also to using the technical literature and other sources of information".

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2. Background

The aerospace industry presents important anomalies in structure and conduct that make it worthy of investigation from the standpoint of technological innovation and knowledge diffusion. These anomalies, and related factors, influence the rate and direction of innovation and the diffusion of knowledge within the aerospace community.

2.1. Unique Characteristics

The aerospace industry exhibits certain characteristics that make it unique among other industries. Firstly, the aerospace industry is becoming more interdisciplinary in nature and more international in scope. To compete internationally, US aerospace producers must maintain and improve the professional competence of aerospace engineers and scientists, enhance innovation and productivity, and maximize the inclusion of recent technological developments into the R&D process. 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 data, information and knowledge.

Secondly, the aerospace industry leads all other US industries in expenditure for R&D. The ability of aerospace engineers and scientists to identify, acquire and utilize data, information and knowledge is of paramount importance to the efficiency of the R&D process. Testimony to the central role of technical information in the R&D process is found in numerous studies [10]. These studies show, among other things, that aerospace engineers and scientists devote more time on average to the communication of technical information than to any other scientific or technical activity [11]. A number of studies have found strong relationships between the communication of technical information and technical performance at both the individual and group levels [12, 13]. This knowledge leads to the conclusion that the communication of data, information and knowledge is central to the success of the aerospace innovation process, in general, and the management of aerospace R&D activities, in particular.

Thirdly, the aerospace industry, in particular the commercial aviation sector, is characterized by the high degree of systemic complexity embodied in its products. Consequently, a substantial element of technological and marketplace uncertainty exists in the design and development of each product. The production, transfer and use of data, information and knowledge are important components of the strategies used by the aerospace industry to insulate itself from the adverse consequences of such uncertainty. A better understanding of the knowledge diffusion process in the aerospace industry would help to increase productivity, stimulate innovation and improve and maintain the professional competence of aerospace engineers and scientists.

Fourthly, the aerospace industry benefits as a technological 'borrower' from developments in other industries such as metallurgy, materials, chemicals and petroleum [14]. According to Bikson *et al.* [15], rapid advances that may occur in other industries can be fully exploited only if they are translated into further research and application. The traditional subject-focused mechanisms do not provide that kind of knowledge diffusion. A more multidisciplinary translation of aerospace data, information and knowledge is needed to complete the diffusion process.

Finally, the aerospace industry, principally the commercial aviation sector, has been the beneficiary of government-funded R&D. According to Mowery [16]:

> The commercial aircraft industry is virtually unique among US manufacturing industries in that a Federal research organization, the National Advisory

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> Committee for Aeronautics (NACA), and 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 benefited from considerable investment, in terms of research and procurement, by the US Department of Defense (DoD) [16]:

> 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.

2.2 Overview of the US Aerospace Knowledge Diffusion Process

A model (Fig. 1) that depicts the diffusion of aerospace knowledge in the USA is composed of two parts—the *informal* that relies on collegial contacts and the *formal* that relies on surrogates, information products and information intermediaries to complete the 'producer-to-user' transfer process. The main producers are NASA and the DoD, and their contracts and grantees. Producers depend upon surrogates and information intermediaries to complete the knowledge diffusion process. When NASA technical reports are published, the initial or primary distribution is made to libraries and technical information centers. Copies are sent to surrogates for secondary and subsequent distribution. A limited number are set aside to be used by the author for the 'peer-to-peer' exchange of information at the informal (collegial) level.

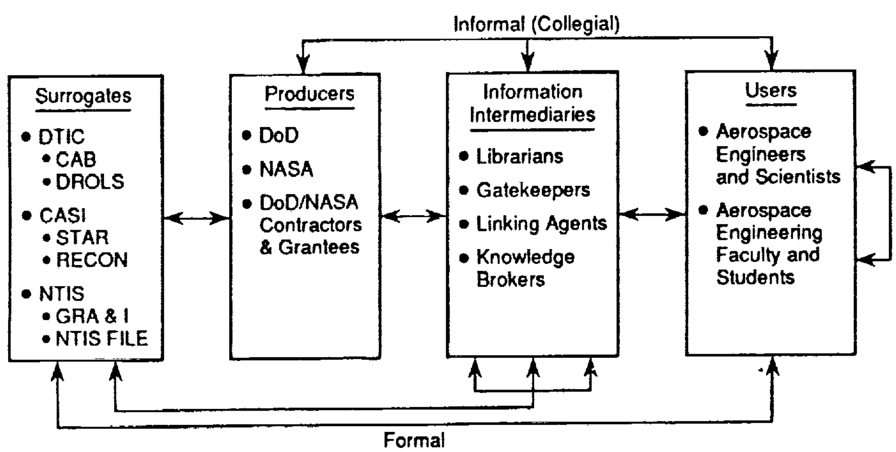

FIG. 1. Model depicting the US aerospace knowledge diffusion process.

Surrogates serve as technical report repositories or clearing-houses for the producers and include the Defense Technical Information Center (DTIC), the NASA Center for Aerospace Information (CASI) and the National Technical Information Service (NTIS). These surrogates have created a variety of announcement journals, such as CAB (*Current Awareness Bibliography*) and STAR (*Scientific and Technical Aerospace Reports*), and computerized systems, such as DROLS (Defense RDT&E On-line System) and *RECON* (REmote CONsole), that permit online access to US government technical reports. Commercial products such as *International Aerospace Abstracts* (IAA) and the *Aerospace Database* have been created by the American

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Institute for Aeronautics and Astronautics (AIAA) to promote access to aerospace conference and journal literature.

Information intermediaries are mainly librarians and technical information specialists in academe, government and industry. Those representing the producers serve as what McGowan & Loveless [17] describe as 'knowledge brokers' or 'linking agents'. Information intermediaries connected with users act, according to Allen [1], as 'technological entrepreneurs' or 'gatekeepers'. The more 'active' the intermediary is, the more effective the transfer process becomes [18]. Active intermediaries take information from one place and move it to another, often face to face. Passive information intermediaries, on the other hand, "simply array information for the taking, relying on the initiative of the user to request or search out the information that may be needed" [19].

The problem with the overall knowledge diffusion process is that the current system is 'passive, fragmented, and unfocused'. Effective knowledge transfer is hindered by the lack of "a coherent or systematically designed approach to transferring the results of R&D to the user" [20]. In their study of issues and options in scientific and technical information (STI) transfer, Bikson *et al.* [15] found that many of the interviewees believed "dissemination activities were afterthoughts, undertaken without serious commitment by those whose primary concerns were with [knowledge] production and not with knowledged transfer"; therefore, "much of what has been learned about how knowledge is diffused has not been incorporated into data, information, and knowledge diffusion activities".

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

Two problems exist with the *formal* part of the system. Firstly, it employs one-way source-to-user transmission. The problem with this kind of transmission is that such formal one-way 'supply-side' transfer procedures do not seem to be responsive to the user context [15]. Rather, these efforts appear to start with an information system into which the users' requirements are retrofit [21]. The consensus of the findings from the empirical research is that interactive, two-way communications are required for effective information transfer [15].

Secondly, the formal part relies heavily on information intermediaries to complete the knowledge transfer process. However, a strong methodological base for measuring or assessing the effectiveness of the information intermediary is lacking [22]. In addition, empirical findings on the effectiveness of information intermediaries and the role(s) they play in knowledge transfer are sparse and inconclusive. The impact of information intermediaries is likely to be strongly conditional and limited to a specific institutional context.

2.3 The NASA/DoD Aerospace Knowledge Diffusion Research Project

This research is sponsored by the NASA, Director of the Scientific and Technical Information Division (Code NTT) and the DoD, Office of the Assistant Secretary of the Air Force, Deputy for Scientific and Technical Information, and the Defense Technical Information Center (DTIC). The research project is a joint effort of the

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Indiana University Center for Survey Research and the NASA Langley Research Center. This four-phase project focuses on the information channels and the members of the social system associated with the aerospace knowledge diffusion process, and is providing a basis for understanding the aerospace knowledge diffusion process at the individual, organizational, national and international levels [23].

2.4 Phase 3—Aerospace Knowledge Diffusion in the Academic Community

The data reported in this article were collected as part of *Phase 3* which is concerned with aerospace knowledge diffusion within the academic community. Questionnaires were used to collect data from three groups in the academic aerospace community—faculty, students, and academic librarians. This article focuses on the faculty and student responses, although some librarians' responses are included. The following objectives were established for our investigation of aerospace knowledge diffusion in the academic community:

(1) to determine the use and importance of information sources and products in meeting the information needs of aerospace faculty and students;
(2) to determine the use of specific print sources and electronic data bases in meeting the information needs of aerospace faculty and students;
(3) to determine the use of information technology by aerospace faculty and students;
(4) to determine the influence of instruction on the use of information sources and products in meeting the information needs of aerospace faculty and students.

(Discussion of the *Phase 3* objectives concerned with NASA technical reports and the use of NASA information products is beyond the scope of this article.)

The faculty sample was obtained primarily from institutions with NASA/University Space Research Association (USRA)-funded capstone courses in aerospace departments. Also included were some institutions with aerospace programs accredited by the Accreditation Board for Engineering and Technology (ABET). Questionnaires were sent to 501 faculty members, 275 (55%) of whom responded to the survey.

The student sample included those students enrolled in a NASA/USRA-funded undergraduate capstone course in the spring 1990. Telephone calls and telefaxes to course instructors enlisted the participation of 39 instructors who agreed to distribute questionnaires to their students. (Some instructors could not participate because they had taught their capstone course during the fall semester.) Data were collected during April and May 1990. Some 640 students from 29 institutions responded.

In turn, 72 academic engineering or aerospace libraries were identified. Of the 72 eligible respondents, 68 or (95%) responded to the survey.

3. Survey Findings

Demographic data are presented for the faculty and student respondents. Faculty and student responses are presented according to the four objectives.

3.1 Demographic Findings

The faculty were asked to identify their rank, status, citizenship, gender and educational preparation. These demographic findings are shown in Table I. About 90% of the respondents hold traditional faculty appointments and slightly less than half hold

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the rank of full professor. About two-thirds of the faculty are tenured; 83% are US citizens and 97% are male. The majority of the faculty were trained as engineers with the remainder having been trained as either engineers, scientists or both.

TABLE 1. Demographic findings—US aerospace faculty

Rank held	
Professor	48%
Associate	21%
Assistant	21%
Adjunct	3%
Instructor	3%
Other	4%
Tenured	
Yes	64%
No	30%
Not applicable	6%
Citizenship	
US	83%
Other	17%
Gender	
Female	3%
Male	97%
Trained as	
Engineer	66%
Scientist	21%
Both	10%
Other	3%

Table II contains the demographic findings for the students. Students were asked to indicate their major, citizenship, class, if they are cooperative education students, if they hold professional society membership, and gender. A majority of students are aeronautical/astronautical engineering majors, seniors, and US citizens. Although engineering has an established record in cooperative education, 83% of the students are not cooperative education students. Approximately 80% of the students were members of a national professional society and 16% of the students were female.

3.2 Use and Importance of Information Sources and Products

Faculty and students were asked to indicate their use and the importance of selected information sources to them (Table III). A five-point scale was used to measure use and importance with '1' designating frequently/important and '5' designating never/unimportant. Both faculty (95%) and students (68%) make considerable use of the information that they keep close at hand, presumably information kept in their offices and residences. Faculty (95%) and students (74%) place considerable importance on their personal collections of information. Both groups make considerable use of interpersonal communications in meeting their engineering information needs. University and engineering libraries are used by both groups and are important to both groups. Librarians are consulted less and are far less important to faculty and students than are other information sources.

TABLE II. Demographic findings—US aerospace students

Major	
Aero/Astronautical engineering	83%
Civil engineering	1%
Electrical engineering	1%
Mechanical engineering	13%
Other engineering	1%
Other major	1%
Citizenship	
US	96%
Other	4%
Class	
Junior	1%
Senior	93%
Graduate student	6%
Cooperative education student	
Yes	17%
No	83%
Student member of a national professional society	
Yes	79%
No	21%
Gender	
Female	16%
Male	84%

TABLE III. Sources used to meet the engineering information needs of US aerospace faculty and students

	Use		Importance	
	Faculty (%)	Students (%)	Faculty (%)	Students (%)
Your personal collection of information	95	68	95	74
University library	45	44	65	55
Engineering or departmental library	37	46	43	57
Librarian	9	12	23	22
Your personal contacts within aerospace companies	25	13	34	27
Your personal contacts at NASA/DoD labs	26	10	41	22
Other students	19	65	22	67
Faculty members	—	55	—	72
Faculty members at your university	41	—	54	—
Faculty members at other universities	18	—	32	—

The percentages report combined '1' and '2' responses on a five-point scale.

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The same five-point scale was used to measure the use and importance that faculty and students place on specific information products in meeting their engineering information needs (Table IV). The information products they use most are generally the products both groups rate as important. Formal information products, such as journal articles, conference/meeting papers and textbooks, are used most often and are rated as most important. NASA technical reports, as for all other products, have a higher importance rating than use rate. Faculty and students make little use of foreign technical reports and technical translations, rating them as unimportant.

TABLE IV. Products used to meet the engineering information needs of US aerospace faculty and students

	Use		Importance	
	Faculty (%)	Students (%)	Faculty (%)	Students (%)
Conference/meeting papers	74	45	81	49
Journal articles	80	52	87	58
Handbooks	29	44	38	51
Textbook	66	77	71	—
Computer programs and documentation	35	44	37	46
Bibliographic, numeric, factual data bases	11	20	19	24
Thesis/dissertations	16	—	24	20
NACA reports	20	19	27	25
NASA reports	37	51	50	55
DoD reports	14	7	26	16
AGARD reports	11	6	19	11
Foreign technical reports	5	4	10	6
Technical translations	3	3	7	8
Patents	1	1	8	4
Aerospace company technical reports	11	26	19	33
University technical reports	12	21	21	31
Informal information products (e.g. vendor/supply catalogs, company literature, trade journals/magazines)	24	25	22	34

The percentages report combined '1' and '2' responses on a five-point scale.

3.3 Use of Specific Print Sources and Electronic Data Bases

Libraries house a variety of printed information products that are designed to indicate awareness of the existence and availability of information. Some of these, such as NASA STAR, indicate the availability of aerospace technical reports. As shown in Table V, the aerospace faculty and students in this study make little use of these printed sources of information.

A number of electronic data bases have been created to facilitate access to the literature. Some of these, such as NASA RECON, are specific to aerospace. Faculty and students were asked to indicate the number of times they used certain on-line data bases during the school year. Use of these data bases ranged from a high of 15%

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TABLE V. Using print sources to meet the engineering information needs of US aerospace faculty and students

Source	Per cent using one or more times this school year	
	Faculty	Students
Science—General		
Science Citation Index	37	8
Engineering—General		
Applied Science and Technology Index	32	34
Engineering Index	42	34
Aerospace		
Government Reports Announcement and Index	29	29
International Aerospace Abstracts (IAA)	36	37
NASA SCAN	19	1
NASA SP-7037 (Aeronautical Engineering: a Continuing Bibliography)	20	25
NASA STAR	34	21

(NTIS Online) to a low of 2% (BRS, Wilson Line and INSPEC) for faculty and a high of 8% (NTIS Online) to a low of 1% (DTIC DROLS and SCISEARCH) for students (Table VI).

TABLE VI. Using electronic data bases to meet the engineering information needs of the US aerospace faculty and students

Source	Per cent using one or more times this school year	
	Faculty	Students
General		
DIALOG including 'Knowledge Index'	7	2
BRS including 'After Dark'	2	1
Wilson Line Index	2	8
Science—General		
SCISEARCH	4	1
Engineering—General		
COMPENDEX	4	2
INSPEC	2	1
Aerospace		
Aerospace data base	9	7
DTIC DROLS	3	1
NASA RECON	13	7
NTIS Online	15	8

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Librarians and information intermediaries were asked how searches of these on-line electronic data bases are provided to engineering students on their campus (Table VII, number of respondents in parentheses). About 97% of the libraries offer on-line search services. Of those offering search services, about 37% of the students *pay all costs* associated with the search, about 34% of the students *pay a reduced cost*, with either the library or engineering department absorbing some of the cost, and about 12% of the students *pay no costs*, with either the library or the engineering department absorbing all the cost.

TABLE VII. Approaches used by US academic librarians in providing on-line searching for US aerospace engineering students

Not offered	2.9%	(2)
Students pay nothing—library or engineering department absorbs all cost	11.8%	(8)
Students pay a reduced cost—library or engineering department absorbs all cost	33.8%	(23)
Students pay all costs	36.8%	(25)
Other	14.7%	(10)

TABLE VIII. Approaches used by US academic librarians in performing on-line searching for US aerospace engineering students

Not offered	4.5%	(3)
Students do all searches	0.0%	(0)
Students do most searches	7.5%	(5)
Students do half of the searches themselves and half through an intermediary	4.5%	(3)
Students do most searches through an intermediary	22.4%	(15)
Students do all searches through an intermediary	53.7%	(36)
Other	7.5%	(5)

These same libraries were asked to indicate their library's approach to performing on-line search services for engineering students (Table VIII). About 54% indicated that students *do all searches* through an intermediary, that 22% of the students *do most of their searches* through an intermediary, that 5% of the students *do half of their searches themselves and half through an intermediary*, and that about 8% *do most of their searches themselves*.

Faculty and students were asked to indicate how they search on-line electronic data bases (Table IX). About 34% of the faculty and 41% of the students do not use electronic data bases. Of those using them, 82% of the faculty's searching is performed completely or in part by a librarian. However, 75% of the students do all or most of their own searching.

3.4 Use of Computer and Information Technology

Faculty and students make considerable use of computer and information technology although in different proportions (Table X), with faculty use outstripping that of

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TABLE IX. How US aerospace faculty and students search on-line (electronic) data bases

	Faculty		Students	
I do not use electronic data bases	34%	(88)	41%	(256)
I do use electronic data bases	66%	(170)	59%	(342)
I do all searches myself	14%	(24)	34%	(122
I do most searches myself	24%	(40)	41%	(149)
I do half by myself and half through a librarian	13%	(22)	12%	(43)
I do most searches through a librarian	16%	(27)	8%	(29)
I do all searches through a librarian	33%	(57)	5%	(20)

TABLE X. Use of computer and information technology by US aerospace faculty and students

Technology	Faculty (%)	Students (%)
Electronic data bases	18	26
Laser and video disks/CD-ROM products	9	16
Desktop publishing	43	41
Electronic bulletin boards	15	6
E-mail	46	14
Electronic networks	36	16
Fax/telex	57	9

The percentages report combined '1' and '2' responses on a five-point scale.

TABLE XI. Use of computer software by US aerospace faculty and students

	Faculty (%)	Students (%)
Word processing	98	96
Spelling checkers	63	84
Thesaurus	29	36
Grammar/style checkers	12	14
Outliners/prompters	8	10
Business graphics	15	27
Scientific graphics	65	71

The percentages report combined '1' and '2' responses on a five-point scale.

students in all categories except for electronic data bases and laser and video disks/CD-ROM products. Faculty and students reported substantial use of computer software (see Table XI). Student use exceeds overall faculty use, but most notably in the use of spelling checkers.

3.5 *Influence of Instruction on the Use of Information Products and Sources*

What influence might instruction in the use of engineering resources and materials have on the information products and sources students consult in meeting their information needs? Are their use patterns markedly different after students have received instruction? In pursuit of the answer, we began by measuring the value both US aerospace faculty and students place on 'the ability to communicate technical information effectively' and 'knowledge of engineering information resources' in terms of affecting the professional success of aerospace students (Table XII). Most faculty (98%) and students (97%) rate 'the ability to communicate effectively' as important. Both faculty (92%) and students (90%) view 'knowledge of engineering information resources' as being sightly less important to professional success.

The next step was to determine what instruction, if any, librarians offered to students (Table XIII). Approximately 71% of librarians offer general library tours, 69% make library presentations in engineering courses, 36% offer a library skills course and 51% offer engineering library tours. About 62% report offering formalized instruction in engineering information resources and materials.

TABLE XII. The importance of two factors affecting the professional success of US aerospace majors

	Faculty (%)	Students (%)
Ability to communicate technical information effectively	98	97
Knowledge of engineering information resources	92	90

The percentages report combined '1' and '2' responses on a five-point scale.

TABLE XIII. Services provided by US academic librarians to US aerospace engineering faculty and students

	Per cent providing one or more times in past six months	
Services	Faculty (%)	Students (%)
General library tour	52	71
Library presentation as part of an engineering course	43	69
Library skills course	6	36
Tour of engineering library	24	51
Introduction to engineering information resources and materials	19	62

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The next step was to determine if students had received instruction in 'engineering resources and materials' and 'departmental/engineering library use' (Table XIV). About 42% of the students had received instruction in 'engineering resources and materials' and about 52% had received instruction in 'departmental/engineering library use'. Of the students receiving either kind of instruction, most did so as credit rather than non-credit courses. The instruction was required, as opposed to elective, and was taken as part of an engineering course.

The next step was to determine whether this instruction has any measurable influence on the student's use of information products and sources. Figures 2 and 3 indicate that students with departmental/engineering library instruction exhibit few differences in the frequency of information product and source use as opposed to those students without this instruction. As Fig. 2 shows, the 'instructed' and 'uninstructed' students exhibit remarkable similarity in their use of formation products to meet their engineering information needs, although the degree of use varies somewhat. For example, students who had received instruction make less use of textbooks than those students who had not received instruction. Neither group makes substantial use of foreign technical reports and technical translations.

TABLE XIV. Instruction of US aerospace engineering students

	Engineering resources and materials	Departmental/ engineering library use
Instruction received	42% (265)	52% (321)
Instruction was		
a credit course	20%	18%
a non-credit course	3%	6%
a required course	15%	17%
an elective course	4%	3%
part of an engineering course	58%	44%
part of another course	15%	21%
a separate course	2%	2%

Percentages do not total 100 because students could take more than one course that included instruction in library use.

Information use was also measured in terms of the sources of information used to meet engineering information needs (Fig. 3). Once again, both 'instructed' and 'uninstructed' students display very similar responses. Both groups make substantial use of their personal collections of information followed by contacts with faculty members and other students. Both groups make considerable use of the university library; however, 'instructed' students do make greater use of engineering or departmental libraries than do 'uninstructed' students. Somewhat surprisingly, students make about the same use of personal contacts at aerospace companies and NASA/DoD laboratories as they do university librarians. This is surprising because the contacts at aerospace companies and NASA/DoD laboratories involve contacts with people outside the university community and who are probably unknown to the student on a collegial basis.

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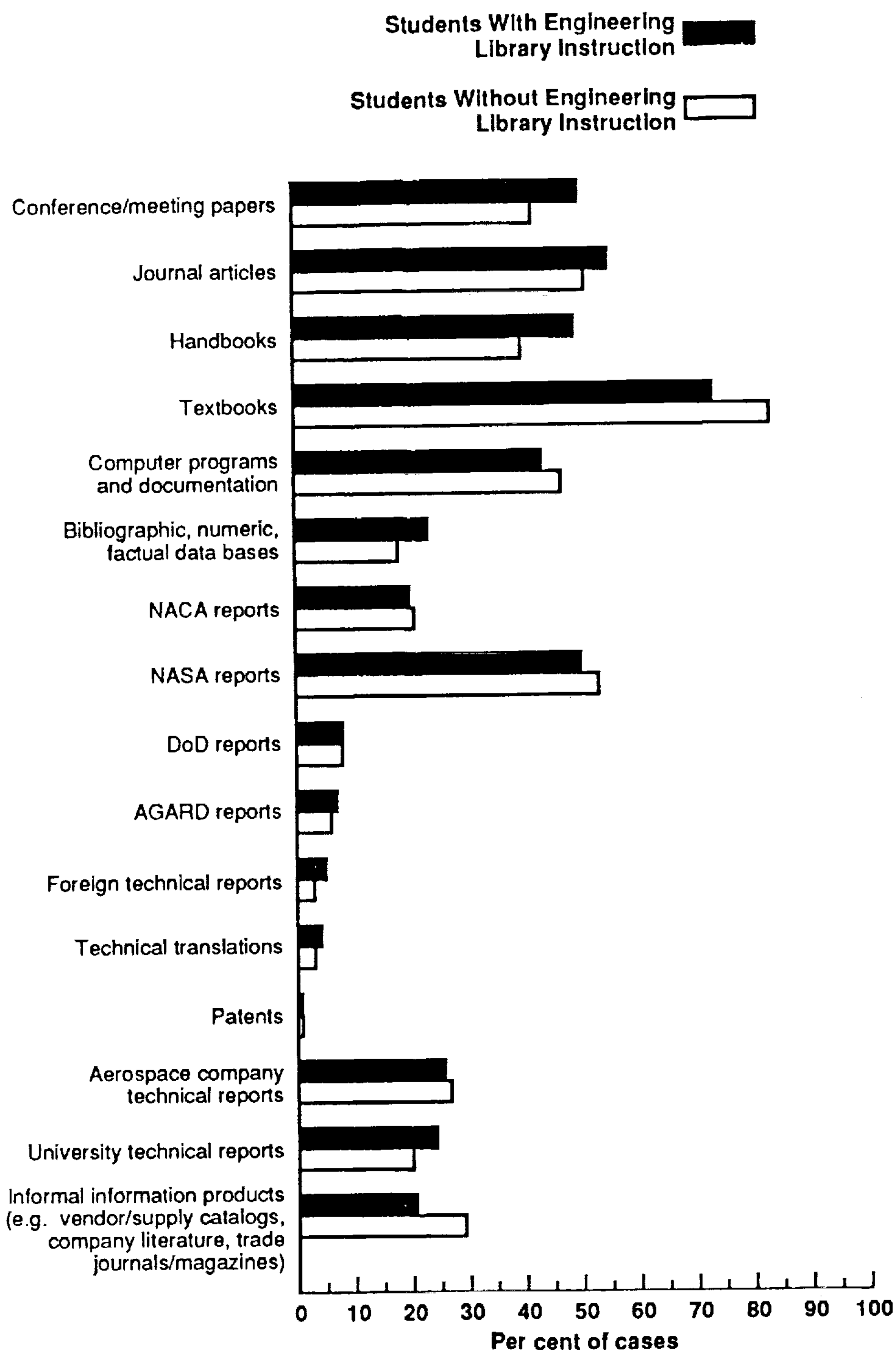

FIG. 2. Products used in meeting the engineering information needs of US aerospace engineering students.

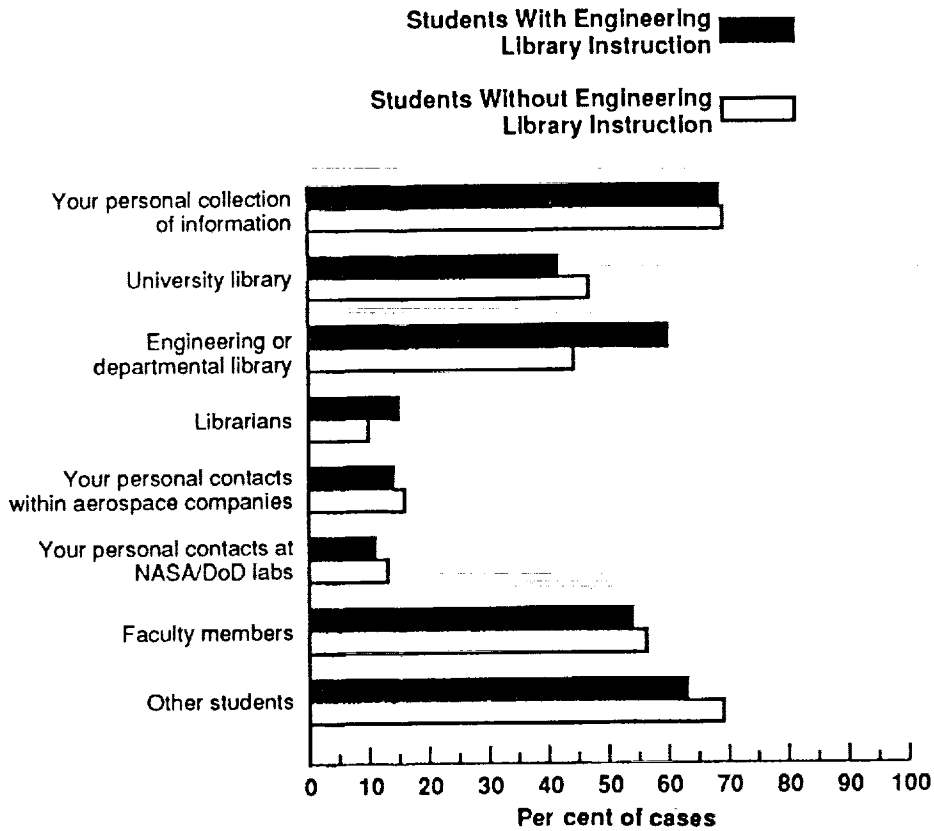

FIG. 3. Sources used for meeting the engineering information needs of US aerospace engineering students.

4. Discussion

Our study places the information-seeking behavior of US aerospace engineering faculty and students within the context of the model of aerospace knowledge diffusion shown in Fig. 1. This model views NASA and the DoD as the predominant producers of aerospace data, information and knowledge, and is concerned with its transfer to non-federal users. The model is actually a composite of three approaches to knowledge transfer—appropriability, dissemination and knowledge utilization—but it heavily emphasizes appropriability and dissemination [24, 25].

The *appropriability* approach emphasizes the production of knowledge and competitive market pressures to promote the use of knowledge. Deliberate transfer mechanisms and intervention by information intermediaries are viewed as unnecessary. Appropriability emphasizes the supply of knowledge in sufficient quantity to attract potential users.

The *dissemination* approach emphasizes the need to transfer information to potential users and embraces the belief that the production of quality knowledge is not sufficient to ensure its fullest use. Linkage mechanisms such as information intermediaries are needed to identify useful knowledge and to transfer it to potential users. This model assumes that if these linkage mechanisms are available to link potential users with knowledge producers, then better opportunities exist for users "to determine what knowledge is available, acquire it, and apply it to their needs" [26]. While the dissemination approach facilitates access, it is a passive structure that does not take users into consideration except when they enter the system and request assistance.

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

Our national study of aerospace engineering faculty and students raises some questions about the efficacy of the existing aerospace knowledge diffusion model and permits us to make certain general statements regarding the information-seeking behavior of US aerospace engineering faculty and students. These statements are specific to the population under investigation and may not be generalizable to non-US aerospace engineering faculty and students or to faculty and students in other engineering disciplines.

(1) As information processors, it appears to us that the information-seeking behavior of future engineers is well established while they are in school, and that they generally emulate the information-seeking behavior of the faculty.

(2) As information processors, it appears that US aerospace faculty and students display the following information-seeking characteristics: they are 'information naive' in that they prefer information that is close at hand, especially that which is kept within their office or work area; they prefer informal sources of information, especially that which can be obtained from familiar sources and people; they make little use of information produced outside the boundaries of the USA.

(3) As information processors, they may possess certain psychological traits that predispose them to seek out information alone or with the help of a co-worker or colleague. When they use the library they tend to use it more in a personal search mode.

(4) As information processors, they tend not to make use of the information products and services oriented to them or designed for their use.

(5) As information processors, US aerospace faculty and students make limited use of librarians, which certainly challenges the notion of the academic information intermediary as a significant link in the 'producer-to-user' interface.

(6) Furthermore, there seems to be little to substantiate the belief that instruction in library or engineering information use has significant impact either on broadening the frequency or range of information products and sources used by US aerospace engineering students.

(7) As information processors, they make considerable use of computer and information technology. Given the strong predilection to use near-at-hand information indicates to us that electronic access to information would be an effective 'linkage mechanism' for the US aerospace academic community.

5. Concluding Remarks

In our search for related literature, we found nothing with which to compare the findings of our national study. If our statement is valid, then the need for further

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studies seems obvious. We did find several studies specifically concerned with the information-seeking behavior of practising engineers and have summarized the findings of these studies [27].

The engineering portion of the US academic community has played a major role in creating the technological advances of the past century. The production, transfer and utilization of data, information and knowledge are essential components of technological innovation and economic development. Barabba & Zaltman state that knowledge is essential to the development of international economies, that the growth of these economies will increase the need for more frequent and more effective use of knowledge, while at the same time altering its use, and that more efficient 'linkages' will be needed to transfer knowledge between academic and industry [28]. Studies such as ours that investigate knowledge diffusion in the academic community by placing the engineering faculty and students in established systems represent a first step toward developing the designs and methodologies needed to understand the process.

However, what of the other industrialized countries, in particular those in Europe and Japan? Are different models for aerospace knowledge diffusion used in these countries? What role, if any, do information intermediaries play in the aerospace knowledge diffusion process? Does knowledge diffusion have a higher or lower importance or used for the production, transfer, and utilization of knowledge similar or different?

What is known about engineering information resources and the aerospace engineering curricula in these countries? Is 'the ability to communicate technical information effectively' and 'knowledge of engineering information resources' considered by aerospace faculty and students to be essential to professional success? Do aerospace engineering and science students in these countries receive technical communications and engineering library instruction? What can be learned from a comparative study of aerospace engineering curricula? What role, if any, should information training play in the aerospace engineering curricula? These are among the items of knowledge which are necessary for the wise planning of aerospace engineering curricula, the education of tomorrow's aerospace engineers, and the development of aerospace information systems and policy.

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