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Computer and Information Technology and
Aerospace Knowledge Diffusion

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Computer and Information Technology and Aerospace Knowledge Diffusion

by

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ABSTRACT

To remain a world leader in aerospace, the U.S. must improve and maintain the professional competency of its engineers and scientists, increase the research and development (R&D) knowledge base, improve productivity, and maximize the integration of recent technological developments into the R&D process. How well these objectives are met, and at what cost, depends on a variety of factors, but largely on the ability of U.S. aerospace engineers and scientists to acquire and process the results of federally funded R&D. The Federal government's commitment to high speed computing and networking systems presupposes that computer and information technology will play a major role in the aerospace knowledge diffusion process. However, we know little about information technology needs, uses, and problems within the aerospace knowledge diffusion process. This paper reports on the use of computer and information technology by U.S. aerospace engineers and scientists in academia, government, and industry.

INTRODUCTION

Since 1965, 7 out of 10 U.S. high technology industries have lost world market shares (Young, 1985). The President's Commission on Industrial Competitiveness (1985) concluded that "the nation's ability to compete has declined over the past 20 years; that we must be able to compete [internationally] if we are going to meet our national goals of a rising standard of living; and that we, as a nation, can no longer afford to ignore the competitive consequences of our actions or our inactions." In fact, American productivity, which is at the heart of competitiveness, has been surpassed by the world's major industrialized nations (Porter, 1990). The exception is the aerospace industry, which continues as the leading positive contributor to the U.S. balance of trade among all merchandise industries. Total factor productivity in the commercial aviation sector of the U.S. aerospace industry has grown more rapidly than in virtually any other U.S. industry during the postwar period (Mowery, 1985).

With its contribution to trade, its coupling with national security, and its symbolism of U.S. technological strength, the U.S. aerospace industry holds a unique position in the nation's industrial structure. However, this industry, in particular the commercial aviation sector, is in the midst of profound change and now faces a significantly more challenging competitive and global environment (National Academy of Engineering, 1985). Some features of change result from domestic policy actions such as airline deregulation while others result from external trends and events such as emerging foreign competition (Hannay, 1986). Worldwide the manufacture of aircraft is becoming an attractive industry, and many foreign companies enjoy a special supportive (financial) relationship with their governments.

Certain factors, events, and trends are changing the nature of the U.S. aerospace industry and the commercial aviation sector (Hannay, 1986). The continuation of the domestic airlines' traditional role in launching new aircraft is uncertain due to current economics and the deteriorating financial performance of U.S. carriers; consequently, domestic air travel is projected to grow less rapidly than in foreign markets. Countries are also demanding a participative role in manufacturing as the price of entry into their markets as U.S. producers simultaneously seek to spread risks and to develop additional capital. Thus, increasing U.S. collaboration with foreign producers results in a more international manufacturing environment. The changing composition of the industry will foster an increasing flow of U.S. aerospace trade. At the same time, international industrial alliances will result in a more rapid diffusion of technology, increasing pressure on the U.S. aerospace industry to push forward with new technological developments and to take steps that maximize the inclusion of those technological developments into the research and development (R&D) process. These circumstances emphasize the need to understand the aerospace knowledge diffusion process with respect to federally funded R&D; to recognize that scientific and technical information (STI) emanating from federally funded R&D is a valuable strategic resource for innovation, problem solving, and productivity; and to remove the major barriers that restrict or prohibit the ability of U.S. aerospace engineers and scientists to acquire and process the results of federally funded aerospace R&D.

Aerospace Knowledge Diffusion Research

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

This four-phase project is providing descriptive and analytical data regarding the diffusion of aerospace knowledge at the individual, organizational, national, and international levels. It is examining both the channels used to communicate and the social system of the aerospace knowledge diffusion process. Phase 1 investigates the information-seeking behavior of U.S. aerospace engineers and scientists and places particular emphasis on their use of federally funded aerospace R&D and U.S. government technical reports. Phase 2 examines the industry-government interface and places special emphasis on the role of information intermediaries in the aerospace knowledge diffusion process. Phase 3 concerns the academic-government interface and places specific emphasis on the information intermediary-faculty-student relationship. Phase 4 explores the information seeking behavior of non-U.S. aerospace engineers and scientists in selected countries.

As scholarly inquiry, our research has both immediate and long term purposes. In the first instance, it provides a practical and pragmatic basis for understanding how the results of NASA/DoD research diffuse into the aerospace R&D process.

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

Federal Aerospace Knowledge Diffusion

A model depicting the transfer of federally funded aerospace R&D through U.S. government technical reports appears in figure 1. The model is composed of two-parts - the **informal** that relies on collegial contacts and the **formal** that relies on surrogate information products and information intermediaries to complete the "producer to user" transfer process. The producers are NASA and the DoD and their contractors and grantees. Producers depend upon surrogates and information intermediaries to complete the knowledge transfer process.

When U.S. government (i.e., NASA) technical reports are published, the initial or primary distribution is made to libraries and technical information centers. Copies are sent to surrogates for secondary and subsequent distribution. A limited number are set aside to be used by the author for the "scientist-to-scientist" exchange of information at the individual level.

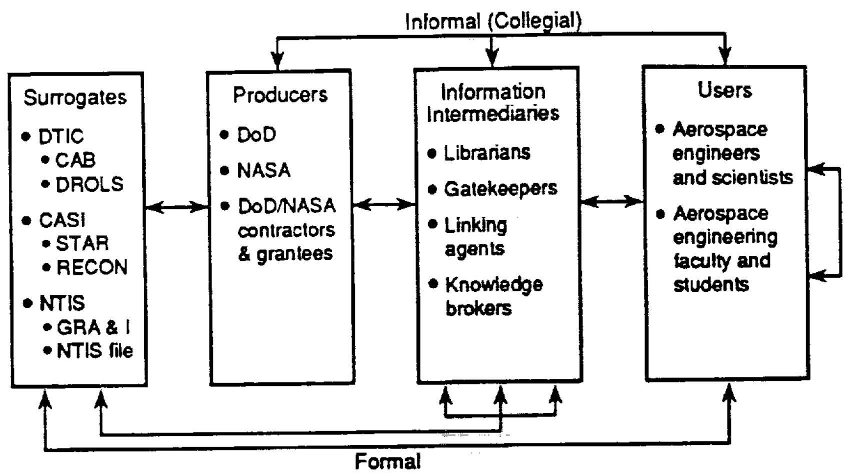

Figure 1. A Model Depicting the Dissemination of Federally Funded Aerospace R&D.

Surrogates serve as technical report repositories or clearinghouses for the producers and include the Defense Technical Information Center (DTIC), the NASA Center for Aero Space Information (CASI), and the National Technical Information Service (NTIS). These surrogates have created a variety of technical report announcement journals such as CAB (Current Awareness Bibliographies) and STAR (Scientific and Technical Aerospace Reports) and computerized retrieval systems such as DROLS (Defense RDT&E Online System) and RECON (REmote CONsole) that permit online access to technical report databases.

Information intermediaries are, in large part, librarians and technical information specialists in academic, government, and industry. Those representing the producers serve as what McGowan and Loveless (1981) describe as "knowledge brokers" or "linking agents." Information intermediaries connected with users act, according to Allen (1977), as "technological entrepreneurs" or "gatekeepers." The more "active" the intermediary, the more effective the transfer process becomes (Goldhor and Lund, 1983). Active intermediaries take information from one place and move it to another, often face-to-face. Passive information intermediaries, on the other hand, "simply array information for the taking, relying on the initiative of the user to request or search out the information that may be needed" (Eveland, 1987).

The overall problem with the total Federal STI system is that "the present system for transferring the results of federally funded STI is passive, fragmented, and unfocused." Effective knowledge transfer is hindered by the fact that the Federal government "has no coherent of systematically designed approach to transferring the results of federally funded R&D to the user" (Ballard, et al. 1986). In their study of issues and options in Federal STI, Bikson and her colleagues (1984) found that many of the interviewees believed "dissemination activities were afterthoughts, undertaken without serious commitment by Federal agencies whose primary concerns were with [knowledge] production and not with knowledge transfer;" therefore, "much of what has been learned about [STI] and knowledge transfer has not been incorporated into federally supported information transfer activities."

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

Two problems exist with the **formal** part of the system. First, the **formal** part of the system employs one-way, source-to-user transmission. The problem with this kind of transmission is that such formal one-way, "supply side" transfer procedures do not seem to be responsive to the user context (Bikson, et al. 1984). Rather, these efforts appear to start with an information system into which the users' requirements are retrofit (Adam, 1975). The consensus of the findings from the empirical research is that interactive, two-way communications are required for effective information transfer (Bikson, et al. 1984).

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

Furthermore, according to Roberts and Frohman (1978), most Federal approaches to knowledge utilization have been ineffective in stimulating the diffusion of technological innovation. They claim that the numerous Federal STI programs are "highest in frequency and expense yet lowest in impact" and that Federal "information dissemination activities have led to little documented knowledge utilization." Roberts and Frohman also note that "governmental programs start to encourage utilization of knowledge only after the R&D results have been generated" rather than during the idea development phase of the innovation process. David (1986), Mowery (1983), and Mowery and Rosenberg (1979) conclude that successful [Federal] technological innovation rests more with the transfer and utilization of knowledge than with its production. In a critique of Federal innovation policy, David (1986) states that "innovation has become our cherished child, doted upon by all concerned with competitiveness; whereas diffusion has fallen into the woeful role of Cinderella."

There is general agreement among policy makers that STI derived from Federally funded R&D enhances technological innovation and economic competitiveness in aerospace. These same policy makers acknowledge the potential of high speed computing and national networking to solve "grand challenges" in engineering and to improve U.S. industrial productivity. What is not understood, however, are the linkages between the various sectors of the technology infrastructure and how computer and information technology contributes to the knowledge diffusion process. The Federal government's commitment to high speed computing and networking systems presupposes that computer and information technology will play a major role in the aerospace knowledge diffusion process. However, we know little about the information technology needs, uses, and problems within the aerospace knowledge diffusion process.

ENGINEERS' USE OF COMPUTER AND INFORMATION TECHNOLOGY: A REVIEW OF THE LITERATURE

Engineers work in teams to research, develop, design, test, and manufacture a wide range of systems, products, and processes. Engineering is a complex activity that involves creativity in addition to scientific, technical and managerial problem-solving and the coordination of many independent efforts. Communication technologies would appear to offer many opportunities for improving the efficiency and effectiveness of information-intensive engineering work.

Introduction

The popular and professional literature describes engineers' use of computing and communications applications such as computer-aided design (CAD), computer-integrated manufacturing (CIM), engineering information systems (EIS), and electronic mail and conferencing systems. Most of this literature concentrates on the technical, financial, or management aspects of these new systems, while little attention is focused on problems, issues, and impacts from the users' point of view.

A number of authors discuss the strategic importance of new information and communication technologies to organizational performance, and present examples from a variety of settings. Walton (1989) presents numerous case studies, including one in an aerospace company, to draw out important concepts, strategies, and techniques for improving the implementation process associated with new information technologies. He stresses the importance of considering both the technical and social aspects of system implementation. Keen (1986) presents a variety of case studies to support his argument that telecommunications is an important feature of any organization's strategy to improve its competitive advantage. Morton (1991) presents a number of perspectives on the introduction and impact of information and communication technologies in today's global economy. All of these authors argue that new technologies are revolutionizing the way people in organizations work and communicate and that the changes that are occurring must be better understood.

Today, engineers use computers to perform calculations; to produce and evaluate drawings, designs, and prototypes (CAD/CAM); to maintain and archive the "corporate memory," i.e., all the contracts, designs, schedules, assumptions, constraints, procedures, data associated with each particular project; to write and edit documents and prepare presentations; to run project management software; and to control equipment. Gunn (1982) provides an early report on the use of computers and electronic networks to "mechanize" design and manufacturing. A collection of papers on the application of computers to engineering design, manufacturing, and management is offered by Lastra, Encarnacao, and Requicha (1989). Ettlie and Stoll (1989) present a collection of essays and case studies on managing the design to manufacturing process. This work is especially intriguing because it draws attention to the philosophical and cultural changes that must accompany the implementation of new computing and communications if this new technology is to bring about the desired effects. Rockart and Short (1989) describe the need of organizations to manage interdependence. They give a number of examples of engineering firms using electronic networks and computerized tools and databases to integrate the stages of product development, distribution, and service; support team work; and facilitate coordination and control.

The policies, principles, and techniques of "concurrent engineering," derived from the perceived need to improve industrial productivity and competitiveness, aim to improve engineering quality, reduce costs, increase the speed of product development, and improve customer satisfaction. Concurrent engineering calls for integrating engineering functions so that they may be performed in parallel rather than in series. It strives to improve communication in order to coordinate the work and integrate the information contributed by all of the many people involved in the development, production, and marketing of a particular technology.

Many engineering organizations are exploring the ability of computers and electronic networks to facilitate concurrent engineering and improve the performance of engineers and the technical quality of their work. A report by Lewis et al. (1990) provides an in-depth treatment of the methodology and tools for developing networked systems for concurrent engineering at General Electric's R&D headquarters. Kaplan (1991, p. 32) notes that "[t]oday, teamwork and concurrent engineering are the important organizational issues, so workstations must be tied together into networks that optimize the use of shared resources."

Computer Use in Engineering

Computer networks are playing an increasingly important role in engineering work because they link design and analysis tools with other important resources to create integrated engineering information systems (EIS) that can be used by engineers from their own desktops. Dirr and Stockdale (1989) describe 3M's transition from the use of CASD systems to a distributed computing strategy in which "[a]ll authorized users would have access to information anywhere in the network, and CAD and project management would be joined in a single integrated system" (p. 50). Heiler and Rosenthal (1989, p. 431) define an EIS as the combination of "software tools, data base managers, data bases and hardware to provide integrated environments for engineering design and management." They also describe the rationale for such systems (p. 431):

> Engineering environments can be extremely complex. They must support long, complex, and interdependent tasks that produce and manipulate highly specialized data. Often multiple representations of the same information are required to support different tasks. Moreover, more than one engineer may work concurrently on different aspects of the same design, which may introduce inconsistencies into the data.

The use of computers and networks to automate the manufacturing process is becoming more widespread. Boll (1988) describes the role of the manufacturing automation protocol (MAP) in accomplishing the integration of the manufacturing process: "machining, assembly, warehousing, quality assurance, packaging and dispatch." Schatz (1988) describes the increase in computer-integrated manufacturing (CIM) investments worldwide, noting that they are expected to double between 1988 and 1992, reaching about $91 billion.

Electronic data interchange (EDI) is used to exchange orders and invoices with vendors and suppliers, and contracts with clients and customers (Beckert, 1989; Purton, 1988). Thus, networks are also used in engineering environments to facilitate formal business communication outside the firm. Networks are used in some firms for information retrieval (IR) in connection with both in-house and commercial databases. Information retrieval systems have received mixed reviews from engineers. Christiansen (1991, p. 21) discusses results of an informal IEEE survey on how engineers obtain the information they need to do their jobs. He reports that engineers have difficulty performing online searches and often obtain inadequate results. He also interprets the tendency of engineers to "scan and save" large amounts of material as a response to their dislike of retrieval systems. Breton (1981; 1991) presents a more compelling argument for the underutilization of information retrieval systems. He concludes that the informal and visual material that is important to engineers is not included in most IR systems and, further, that current indexing techniques fail to retrieve information according to those dimensions, such as "desired function," that are useful to engineers. Gould and Pearce (1991) describe the results of an assessment, based largely on interviews, intended to relate information needs in engineering to current systems for storing, organizing, and disseminating that information. Mailloux (1989) reviews current literature on EDI. She provides an overview of a variety of engineering systems and devotes considerable attention to a discussion of how EIS support engineering work and communication behavior.

Finally, the literature suggests that engineers also use electronic networks for a variety of interpersonal communication purposes. Borchardt (1990) includes electronic mail among his suggestions for improving in-house technical communication in order to facilitate the sharing of ideas, provide a more stimulating work environment, and prevent the duplication of efforts (p. 135). Beckert (1990, p. 68) notes that engineers can use electronic mail to send text, data, and graphics to their colleagues and to automate the notification status change process between engineering, manufacturing, and external entities. She notes that electronic communication eliminates telephone tag and problems associated with time-zone differences, and also saves time in scheduling meetings and responding to technical questions. Mishkoff (1986) describes computer conferencing as the answer to the problems corporations face when they employ geographically-dispersed work groups. He reports that Hewlett-Packard employs thousands of engineers in over 70 divisions, one-third of which are located outside the United States. Mishkoff describes how computer conferencing is used in place of more expensive mechanisms to allow groups of engineers to share their knowledge efficiently and coordinate their work (p. 29).

The power of computer conferencing systems to form the base of "electronic expert networks" in organizations is described by Stevens (1987), although he does not focus exclusively on engineers. His discussion applies the assertions about the importance of informal communication in organizations, discussed above, to the electronic environment. He argues that electronic networks are an important source of expertise for employees because "[t]he best answers frequently come from surprising sources. An unknown peer with relevant experience can sometimes provide better help than a more famous expert, who may be less accessible or less articulate" (p. 360). Stevens also notes that "[w]hile expert networks can be used by traditional organizations to strengthen their effort to produce and provide products and services, expert networks also seem to represent almost a new form of organization" (p. 369).

Many organizations hope that by facilitating communication and improving coordination, electronic networks will decrease both the costs and the time needed by bring products to market. Due to proprietary and security concerns, a number of engineering organizations have implemented their own private, high-speed networks that are used only by their own employees. The need for high-bandwidth, completely reliable electronic transfer of critical data also makes the use of most public commercial networks unfeasible for some industries and applications. Werner and Bremer (1991, p. 46) note that even companies involved in industry-academia-government R&D cooperatives prohibit electronic links to external consortium members for fear of security leaks.

The National Research Council's Panel on Engineering Employment Characteristics (National Research Council, 1985) conducted an informal survey of engineering employers in which they obtained employers' views on the impact of new tools on engineering productivity. Survey results (p. 68) indicated that about one-third of employers had widely available computer-aided drafting or design systems in place, few had computer-aided manufacturing systems, and about 50 percent had engineering information systems. Fewer than one half of the respondents had formally evaluated their systems, although they estimated productivity gains of about 100 percent for drafting systems, 50 percent for design systems, and 35 percent for information systems. The Panel concluded that "these new computer-aided tools permit increasingly sophisticated products to be designed in less time with substantially greater accuracy and with greater cost-effectiveness" (p. 27) although they also noted that "their net effect on engineering and on industry as a whole cannot be forecast with confidence (p. 26).

Computer Use in Aerospace

The aerospace industry possesses a number of characteristics that make it a natural environment for the use of information technology. It is a high technology industry, already highly computerized. It involves significant R&D, which is a communication-intensive activity. Further, its end products are highly complex, calling for a great deal of work task coordination and the integration of information created by diverse people. In describing the business and technology strategy in place at British Aerospace, Hall (1990) emphasized the need for increased computing and communications capabilities in aerospace firms aiming to design, develop, make and market complex systems while maintaining a technical competitive edge and reducing costs (p. 16-2). He noted that a number of typical information technology opportunities were particularly relevant to the aerospace industry, such as "improved productivity, better competitive edge, reduced time scales, closer collaboration, more streamlined management, better commonality of standards across sites, more operational flexibility, [and] constructive change of work force skill levels" (p. 16-2).

Rachowitz et al. (1991) describe efforts at Grumman Aerospace to realize a fully distributed computing environment. Grumman's goal is to implement a system of networked workstations in order to "cost-effectively optimize the computing tools available to the engineers, while promoting the systematic implementation of concurrent engineering among project teams" (p. 38). The network includes PCs and software to be used for communication. Grumman assumes that their computer/information integrated environment (CIE) will result in "product optimization quality products manufactured with fewer errors in shorter time and at a lower cost" (p. 66).

Black (1990) presents a brief overview of the uses and advantages of computer conferencing systems, noting that computer conferencing is a "very powerful tool for the transfer of information in all areas of research and development and "a natural for the AGARD [Advisory Group for Aerospace Research and Development] community" (p. 13-4). Moholm (1990) describes the application of the Department of Defense Computer-aided Acquisition and Logistics Support (CALS) initiative to the aerospace community. CALS mandates the use of specific standards for the electronic creation and transmission of technical information associated with weapons systems development. Eventually all Department of Defense contractors and subcontractors will be required to create and distribute in digital form all the drawings, specifications, technical data, documents, and support information required over the entire life cycle of a military project. The CALS system may be a significant impetus to networking for aerospace firms.

The literature reveals that a number of engineering organizations are using electronic networks for a variety of communication activities, distributed computing, and shared access to information resources. Networks are being implemented to serve organizational goals and business strategies, i.e., to achieve impacts in terms of better and faster product development and cost savings. Such motivations for network investments suggest factors that may encourage network use in particular engineering organizations and obviate the need for them in others. The literature also hints at a number of factors that may hinder network use, such as security and proprietary concerns, the failure of indexing techniques to retrieve stored information in a way useful to engineers, and the substantial financial outlays required to implement networked systems.

Descriptions of computer and information technology needs, uses, problems, and impacts in engineering environments are scarce. Furthermore, the literature is fragmentary and anecdotal. Few empirical studies have been reported in the literature. Shuchman (1981) conducted a broad-based investigation of information transfer in engineering. The respondents represented 14 industries in the following major engineering disciplines: aeronautical, chemical and environmental, civil, electrical, industrial, and mechanical. As part of this study, she examined the use of computer and information technology by engineers to "identify the attitudes [of engineers] toward and use patterns of computer and information technology in an effort to forecast the potential value of new information technologies" (p. 36). Overall the survey results indicated that computer and information technology has high potential usefulness but relatively low use among engineers. In analyzing this finding, it is important to keep in mind that the state of the art in computer and information technology has changed dramatically since Shuchman's study was released.

In Shuchman's study, respondents were asked to indicate the use, non-use, and potential use of 21 computer and information technologies categorized into four groups. Overall, aeronautical engineers made greater use of computer and information technologies than did the other respondents. Aeronautical engineers also reported the highest use of "information transmission technologies" (fax, telex, teleconferencing, and video conferencing). They also had the highest use rate for what Shuchman identified as "recorded/pre-recorded information technologies." Of the emerging technologies (e.g., digital imaging), aeronautical engineers reported the highest rate of current use and predicted use.

A pilot study conducted as part of Phase 1 of the **NASA/DoD Aerospace Knowledge Diffusion Research Project** investigated the technical communications habits and practices of U.S. aerospace engineers and scientists (Pinelli, et al. 1989). One of the objectives of this study was to determine the use and importance of computer and information technology to them. Approximately 91 percent of the respondents reported using computer and information technology to communicate STI. Approximately 95 percent of those respondents who reported using this technology indicated that it had increased their ability to communicate. The lowest rates of use for any technology were those reported for the mature technologies (e.g., micrographics). The rate of use for maturing technologies (e.g., electronic data bases) was relatively high, approximately 60 percent. Overall, 50-60 percent of the respondents predicted that they would use the nascent or emerging technologies (e.g., electronic networks).

PRESENTATION OF THE DATA

In this presentation, we report data from three surveys conducted as part of the Project. Two mail surveys were based on samples of the members of the American Institute for Aeronautics and Astronautics (AIAA). The third survey was based on a list of readers of *Aerospace Engineering* provided to us by the Society of Automotive Engineers (SAE). From the AIAA list, two random samples were drawn to select 3,298 (sample one) and 1795 (sample two) persons from their 1989 membership list. Overall, 2,016 aerospace engineers and scientists responded to the first survey and 975 responded to the second survey. The adjusted response rate (correcting for sample problems) for both of the surveys was about 70 percent. The surveys were conducted during summer and fall of 1989. The SAE survey was conducted by telephone during August 1991. A sample of 670 persons yielded interviews with 430 persons. Again, after correcting for sample problems, the response rate was approximately 70 percent.

Demographics

We present the data from both AIAA surveys and the SAE survey because they indicate some differences among the use of computer and information technology. First, the AIAA surveys asked different questions about the use of information technology. Second, the surveys were conducted approximately two years apart, so we can measure some recent changes in technology use among aerospace engineers and scientists.

There are some differences between the two organizations. (See Table 1.) The AIAA is a professional research society and the characteristics of its members reflect a research orientation. Over 31 percent of the respondents hold a doctorate and an additional 39 percent have earned master's degrees. Most of the sample are managers, designers, developers, or researchers. Of the 28 percent who reported their principal job activity as "design/development," we expect them to be especially involved in information production, transfer, and use.

The distribution of the characteristics of the readers of *Aerospace Engineering* shows a number of differences between the groups, particularly in education, organizational affiliation, and professional duties. Seventy-seven percent of the SAE indicated their duties involved design/development compared to 28 percent for the AIAA. Relatively few of the SAE sample have earned doctorates (4 percent vs 31 percent) and a much higher percentage have earned bachelor's degrees (51 percent vs 27 percent). About 86 percent of the SAE were employed in industry compared to 53 percent of the AIAA sample.

Table 1. Characteristics of the AIAA and the SAE Samples

	AIAA %	SAE %
Education		
No Degree	1	9
Bachelor's Degree	27	51
Master's Degree	39	35
Doctorate	31	4
Other	2	1
Organization type		
Academic	13	1
Government	23	12
Industry	53	86
Other	11	1
Occupation		
Engineer	68	66
Scientist	8	1
Manager/Other	24	33
Duties		
Research	17	14
Management	39	*
Design/Development	28	77
Teaching	10	*
Other	6	9
Years Employed in Aerospace		
Less than 10	27	24
10 - 19	22	21
20 - 29	26	20
30 - 39	22	27
Over 40	3	8

*Not asked.

Use of Computer and Information Technology

The data in Table 2 are from the first AIAA survey. Fifteen computer and information technologies were placed in three groups: **mature, developed**, and **emerging. Mature** technologies include videotape, fax, telex, micrographics and microfilms. **Developed** technologies include teleconferencing, video conferencing, and electronic databases. **Emerging** technologies include electronic networks, bulletin boards, and mail, laser disks, video disks, and CD-ROM products. Their use was analyzed for differences among AIAA members. Those who used at least one of the technologies in their work are considered to be users.

Table 2. Use of Computer and Information Technologies by Selected Characteristics

[AIAA survey; N = 1839]

Characteristics	Percent using—		
	Mature technology	Developed technology	Emerging technology
Education			
Bachelors Degree or Less	94	79	65
Graduate Degree	94	73	64
Education/Career Preparation			
Engineer	94	74	66
Scientist	92	74	67
Years in Aerospace			
Under 15	94	72	69
15 or more	94	75	64
Organization			
Academic	91	68	65
Government	95	80	75
Industry	96	76	63
Duties			
Managers	95	80	69
Others	93	70	65

Aerospace engineers and scientists in the AIAA sample tend to use many forms of computer and information technology. Almost all used the mature technologies. Smaller percentages use the developed and the emerging technologies. While the emerging technologies were least often used, they were used by at least two-thirds of the sample. Overall there were very few characteristics which distinguished users from non-users.

Respondents to the second AIAA survey were asked a series of questions regarding their use of NASA STI in specified electronic formats. (See Table 3.) In particular, they were asked how likely they would be to use data tables/mathematical presentations and computer program listings in electronic form. They were also asked how likely they would be to use online systems and CD-ROM products as replacements for NASA technical reports that currently are produced in paper and fiche. Those who said they were unlikely to use these products in electronic forms were then asked why they would not use them.

Table 3. Attitudes Toward the Use of NASA STI in Specified Electronic Formats

[AIAA survey; N = 975]

Format	Likely To Use %	Not Likely To Use %	Reason(s) Not Likely To Use %
Data Tables/Mathematical Presentations	57	43	—
Computer Availability/Access			13
Hardware/Software Incompatibility			14
Prefer Printed Form			42
Other			31
Computer Program Listings	55	45	—
Computer Availability/Access			16
Hardware/Software Incompatibility			19
Prefer Printed Form			28
Other			37
Online NASA Technical Reports	56	44	—
Computer Availability/Access			17
Hardware/Software Incompatibility			12
Prefer Printed Form			51
Other			20
NASA Technical Reports on CD-ROM	39	61	—
Computer Availability/Access			23
Hardware/Software Incompatibility			27
Prefer Printed Form			32
Other			18

A majority of aerospace engineers and scientists are likely to use data tables/mathematical presentations and computer program listings in electronic form. Among those who selected "not likely to use," there is no clear reason. About one-third said they would have some computer access or compatibility problems that make it unlikely they would use these forms. More than 50 percent of the sample would consider using online versions of NASA technical reports, but preference for printed formats explains why many would not chose the online versions. It appears that the cost (embedded in "other") and computer availability/access would prevent many aerospace engineers and scientists from using NASA technical reports if they were available on CD-ROM.

These data show similar findings to Table 2. Most of the sample are using computer and information technologies and would be likely to use them even more if the information they were seeking were available electronically. There is some indication that the access to CD-ROM products in 1989 made some of the respondents feel they were not likely to receive NASA technical papers if they were made available on CD-ROM. If this question were asked again in 1992, the percentages favoring this format would likely be higher.

Use of Electronic Networks

Changes in the accessibility of computer and electronic technology have occurred rapidly over the past few years. These changes would be especially quick in the technologically sophisticated aerospace industry. One portion of the SAE survey conducted last August focused specifically on the use of electronic networks. (See Table 4.)

Table 4. Use of Electronic Networks
[SAE survey; N = 430]

Type of Use	% Using
Connect to Distant Sites	71
Electronic Mail	78
Electronic Bulletin Boards or Conferences	50
Electronic File Transfers	78
Work using Remote Computers	55
Control Remote Equipment	16
Information Searching/Data Retrieval	76
Exchange Files/Messages Within Work Group	76
Exchange Files/Messages Within Organization Outside Work Group	76
Exchange Files/Messages Outside the Organization	50

The percentages in Table 4 are based on respondents to the SAE survey who use electronic networks. Eighty percent of the respondents have access to and use electronic networks. Among the users, nearly half said they used their networks less than 10 percent of the past work week. About one-third said that 10-25 percent of their past work week was spent working on a network and about one-fifth spent more than 25 percent of their past work week on an electronic network. Slightly more than two-thirds of the respondents could connect to geographically distant sites with their networks. Over three-fourths of the respondents use networks for a variety of communication purposes and to exchange data and other files. About one-half use networks to access bulletin boards and conferences, exchange files outside their organizations, and to work on remote computers. Overall, these data indicate a fairly intensive use of electronic networks.

Concluding Remarks

The U.S. aerospace industry accounts for more than 25 percent of all the nation's R&D expenditures, with a total investment of $24.3 billion in 1990 (AIA, 1990). Aerospace employment in 1989 accounted for 6.7 percent of the total employment in all U.S. total payroll outlays by all U.S. manufacturing firms. In 1990, aerospace ranked sixth in value of shipments and tenth in employment among all U.S. industries. More important, aerospace is the nation's leading exporter, sending abroad products worth $38 billion in 1990 to 135 countries around the world. 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, 1991). In short, the U.S. aerospace industry is a national and global leader and a critical element of the U.S. economy.

International Competitiveness

The U.S. aerospace industry faces increasing challenges overseas. While the U.S. retains both market and technology leadership within the global aerospace industry, its position has eroded. In 1990, U.S. aerospace shipments still led the world but shrank to less than 60 percent of the worldwide market. This decline reflects the success of other countries in their efforts to foster the growth of their national aerospace industries. Many foreign governments have strong ambitions for competitive aerospace industries and have supported their growth with subsidies for product development and production. They have also required offsets and technology transfers in which purchases of U.S. aerospace products are contingent upon their own firms supplying some of the components. In addition, some governments have encouraged consolidation and cooperation among local companies to reduce domestic competition and thus enable them to compete more effectively with established U.S. companies (U.S. Department of Commerce, 1991).

Europe continues to provide the most formidable competition to the U.S. aerospace industry, and the European aerospace industry is largely responsible for the erosion of U.S. market share. According to European Community (EC) statistics, the EC's aerospace industry grew almost twice as fast as the U.S. industry during the period 1978-89. Aerospace industries of individual countries, such as Germany, grew three times faster. Japan will be a serious future competitor in certain segments of the industry. Other countries also seek bigger shares of the global industry: Canada, Brazil, South Korea, China, Taiwan, Singapore, Sweden, Israel, and Australia (U.S. Department of Commerce, 1991).

International Competition and Aerospace Knowledge Diffusion

Computer and information technology is being advanced as a powerful tool that will increase productivity, research, communication, and information management in aerospace and other U.S. industries. It is also being advanced as a tool that will facilitate the diffusion of federally funded aerospace R&D. Much information is needed before the "truth" of these claims can be substantiated. The data presented here represent the first systematic collection of a comprehensive set of data bases on computer and information technology use in aerospace and a first step toward "validation." The results of these surveys and others conducted as part of the **NASA/DoD Aerospace Knowledge Diffusion Research Project** indicate a widespread acceptance and use of "electronic" technology. Much experimentation and analysis remain to be done before we will know better how to use this technology to increase economic competitiveness, work place productivity, and the professional competency of U.S. aerospace engineers and scientists.

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