The Role of Computer Networks in Aerospace Engineering

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ABSTRACT

THIS ARTICLE PRESENTS selected results from an empirical investigation into the use of computer networks in aerospace engineering. Such networks allow aerospace engineers to communicate with people and access remote resources through electronic mail, file transfer, and remote log-in. The study drew its subjects from private sector, government, and academic organizations in the U.S. aerospace industry. Data presented here were gathered in a national mail survey, conducted in Spring 1993, that was distributed to aerospace engineers performing a wide variety of jobs. Results from the mail survey provide an overview of the current use of computer networks in the aerospace industry, suggest factors associated with the use of networks, and identify perceived impacts of networks on aerospace engineering work and communication. Such data are important in planning for the development of policies and features of the National Research and Education Network (NREN) if it is to meet the needs of its intended users.

INTRODUCTION: THE NEED FOR USER-BASED STUDIES OF ELECTRONIC NETWORKING

Both individual engineering organizations and the federal government in the United States are making large investments in computer networks (i.e., telecommunications links that connect computers to each other or to other devices) in order to, among other things, increase research and development (R&D) productivity, facilitate technology transfer, and improve industrial competitiveness. Federal policy-makers, network system designers and service

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providers, and workplace managers are struggling to implement effective systems and to develop appropriate policies to govern network implementation and use. The success of institutional networking endeavors—and national efforts, such as those associated with the National Research and Education Network or, more broadly, the National Information Infrastructure (NII)—will depend on the development of network features, policies, and support programs that are based on a solid knowledge of users' needs and habits and substantiated links between network use and engineering outcomes. But little empirical information has been gathered that can be used to help in understanding the impact of networking investments, designs, and policies on engineering work. And little is known about the extent of computer network use across different types of engineering organizations. Thus, many major investment, design, and policy decisions are being made solely on the basis of educated guesses about the current use of networks and the assumed contribution of networking to scientific and technical enterprises.

In order to help remedy this situation, the author undertook an empirical investigation of computer networking in engineering that collected data from the network user's point of view. The study's aim was to describe and explore the use of electronic networks by one particular group—aerospace engineers. It focused on the way that networks are currently used by aerospace engineers to facilitate communication and otherwise assist in the performance of work tasks. The study was guided by the following research questions:

1. What types of computer networks and network applications are currently used by aerospace engineers?
2. What work tasks and communication activities do aerospace engineers use computer networks to support?
3. What work-related factors are associated with the use of computer networks by aerospace engineers?
4. What are the impacts of network use on aerospace engineering work and communication?

In order to include subjects representing a wide range of work and communication activities and to look at as many aspects of the aerospace industry as possible, "aerospace engineer" was interpreted very broadly. It included people engaged in all phases of the development and production of military and commercial aeronautical or aerospace equipment and processes.

Background: Computer Networking in Engineering Settings

Engineers are employed to research, develop, design, test, and manufacture technology, which may exist in the form of either materials, products, systems, or processes. Engineering is a complex, information- and communication-intensive activity that involves invention, problem-solving, and coordination of many independent efforts (for interesting discussions of the nature of engineering work and communication, see Adams, 1991; Allen, 1977; Constant, 1984; Ferguson, 1992; Layton, 1974; Pinelli et al., 1993; and Vincenti, 1990). "Concurrent engineering," a notion that is currently popular in engineering management circles, focuses on the perceived need for better and faster communication, coordination, and integration of the work and information contributed by all of the 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 (see, for example, Dirr & Stockdale, 1989; Heiler & Rosenthal, 1989; Keen, 1986; Mishkoff, 1986; Rachowitz et al., 1991; Schatz, 1988). Industrial organizations hope that, by facilitating communication and improving coordination, electronic networks will decrease both the costs and time needed to bring products to market. Due to proprietary and security concerns, many engineering organizations have implemented their own private high-speed networks that are used only by their employees and affiliates. The need for the completely reliable electronic transfer of very large amounts of data also makes the use of most commercial networks inadequate for some industries and applications.

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, and so on, associated with each particular project; to write and edit documents and prepare presentations; to run project management software; and to control equipment. Computer networks are also playing an increasingly important role in engineering work. For example, engineers use networks to receive data collected by remote instruments. Networks facilitate the transfer of documents and designs and are used to automate the manufacturing process. Electronic data interchange (EDI) is used to exchange orders and invoices with vendors and suppliers, and contracts with clients and customers. Networks are also used for information retrieval in connection with both in-house and commercial databases (Gould & Pearce, 1991; Mailloux, 1989).

Finally, engineers also use computer networks for a variety of communication purposes (Beckert, 1990; Borchardt, 1990; DeMeyer, 1991; Stevens, 1987; Perry, 1992). For instance, they can exploit computer-based message systems to call on the expertise, ideas, and advice of other members of their community and to locate resources. Electronic mail and various computer conferencing applications are also used to schedule and coordinate work or even conduct meetings, since they can be used to contact project team members, managers, people in other departments or divisions, and consultants in outside organizations. Electronic mail and bulletin boards are sometimes used to facilitate communication with customers and funders as well.

There is a growing body of empirical research that examines the characteristics, use, and effects of computer-mediated communication (Bikson & Eveland, 1990; Hiltz, 1988; Rice, 1980; Steinfield, 1986a, 1986b; Sproull & Kiesler, 1991). Few studies attempt to describe these variables in terms of particular kinds of work, except by comparing broad job categories—for example, managers, professionals, and clerical workers (Rice & Shook, 1990). With the recent proliferation of electronic networks, a number of empirical efforts dedicated to exploring the use of electronic networks for communication by scientists and engineers have been undertaken (Bizot et al., 1991; Eveland & Bikson, 1987; Feldman, 1987; Gerola & Gomory, 1984; Hesse et al., 1993; Hiltz, 1984; McClure et al., 1991; Schatz, 1992; Sproull & Kiesler, 1986; Foulger, 1990). There seems to be agreement that electronic communication is used for administrative, technical, and social purposes. Much of this work seems compatible with findings about the nature of engineering communication and its relationship to engineering work and productivity, although virtually no studies have dealt exclusively or extensively with engineers. The capabilities and characteristics of electronic communication, in other words, seem to "match," to some extent, the nature and requirements of engineering work, knowledge, and communication. But new questions and issues have been raised and a number of conflicting findings have been presented. All in all, very little is known about the characteristics, use, and impact of electronic communication from the engineer's point of view.

The aerospace industry possesses a number of characteristics that make it a natural environment for the implementation of electronic networks. It is a high technology industry, already highly computerized. It involves significant R&D, which is an especially 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 unit costs. 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 timescales, closer collaboration, more streamlined management, better commonality of standards across sites, more operational flexibility, [and] constructive change of workforce skill levels..." (pp. 16-30).

Rachowitz et al. (1991) describe efforts at Grumman Aerospace Corporation 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 personal computers 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 "can be a very powerful tool for the transfer of information in all areas of research and development" and "a 'natural' for use by the AGARD [Advisory Group for Aerospace Research and Development] community..." (pp. 13-14). Molholm (1990) describes the application of the Department of Defense's 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.

Few empirical studies of computer networking in the aerospace industry have been conducted, although a number of the surveys conducted as part of the NASA/DoD Aerospace Knowledge Diffusion Project have included small components assessing the use of computing and communications technologies by aerospace students, faculty, researchers, and engineers. Beuschel and Kling (1993) conducted a case study of computer-integrated manufacturing (CIM) in an aerospace firm and found that effective technological integration was limited by complex social requirements for group coordination processes, such as negotiation and interpretation.

These reports reveal that a number of engineering organizations, including those in aerospace, 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. The motivations for network investments noted in these reports suggest factors that may encourage network use in particular engineering organizations and obviate the need for them in others. These reports also point to a number of factors that may hinder network use, such as security and proprietary concerns, the inability of networks to accommodate the negotiation and interpretation aspects of communication, and the substantial financial outlays required to implement networked systems.

A User-Based Study of Computer Networking in the Aerospace Industry: Method

This section describes briefly the method of the study whose results are reported here. As noted earlier, data to answer the study's research questions were gathered from a wide variety of aerospace engineers, and the study sought specifically to collect data that reported network use: (1) from the user's point of view, and (2) from within the context of aerospace engineering work and communication. The study drew upon methodological approaches and techniques that have evolved in the fields of library and information science, communications, management, computer science, and sociology (e.g., Bizot et al., 1991; Feldman, 1987; Hiltz, 1984; McClure et al., 1991; Dervin & Nilan, 1986; Wilson et al., 1989; Wixon et al., 1990; Gould et al., 1991; Murotake, 1990). Because it is user-based, the study aimed to collect data directly from individual aerospace engineers on networking topics and issues that were specifically related to their personal experiences and concerns. Understanding relationships among network use, work, and communication will be useful to those people and organizations trying to estimate the potential impact of electronic networks on aerospace engineers, on their organizations, and on national productivity and competitiveness in the aerospace industry. Further, the results should be suggestive of the potential impact of global networks on other kinds of work, based on the degree to which they resemble aerospace engineering work. It was the aim of this research to identify work characteristics and needs that underlie the use of networks. This type of user-based research on information and communication technology is important because it not only evaluates the status quo, it points to networking system features, implementation strategies, and use policies that could improve the effectiveness of the next generation of networked systems.

The primary mechanism for gathering data was a national mail survey conducted in Spring 1993. The mail survey was preceded by site visits and in-depth interviews and a national telephone survey. These preliminary activities were used to refine the mail survey instrument, to supply anecdotal and interpretive data not easily gathered in a mail survey, and to triangulate study results. This article will present results from the mail survey only.

The mail survey's respondents came from a stratified random sample of 2,000 U.S. subscribers to *Aerospace Engineering,* a weekly trade magazine published by the Society of Automotive Engineers (SAE), whose membership includes both automotive and aerospace engineers. The database containing records for the 54,600 journal subscribers is maintained by SAE, but subscribers are not required to be SAE members. The database includes practicing aerospace engineers working on a broad range of aerospace products, in a wide variety of organizations and subfields, and with a variety of professional duties. The SAE sample possesses characteristics in proportions that are similar to those reported in NSF employment data on the aerospace industry as a whole. The final unadjusted response rate for the mail survey was about 48 percent with 950 usable surveys returned.

The mail survey consisted of a ten-page booklet containing items on network availability and use, work and communication characteristics and activities, perceived network impacts, and demographic and employment characteristics of respondents (the questionnaire is reproduced in the Appendix). Most questions required respondents to circle the number of their selected answer or to fill in a matrix by placing check marks in cells corresponding to their answers. Several questions called for respondents to supply numerical answers or open-ended textual replies.

Study Results

The mail survey's results are presented here with simple descriptive summaries. Most survey respondents were engaged primarily in design or product engineering (23 percent), advanced or applied development (14 percent), or research (13 percent); the majority were employed in industry (54 percent) or government (30 percent) settings. Other characteristics of survey respondents appear below (figures represent percentage of respondents):

Gender	
Male	97
Female	3
Age	
20-29 yrs.	3
30-39	24
40-49	24
50-59	32
60+	17
Size of Parent Organization (if private sector business)	
1-4 employees	10
50-99	3
100-499	13
500-999	6
1000-4999	21
5000-9995	10
9996+	37
Job Type (self-identified)	
Engineer	46
Manager	39
Scientist	5
Other	10
Branch of Aerospace (self-identified)	
Aerodynamics	6
Structures	12
Propulsion	9
Flight Dynamics & Control	5
Avionics	12
Materials & Processes	14
Other	42
Primary Job Function (self-identified)	
Administration	10
Research	13
Advanced or Applied Development	14
Design or Product Engineering	23
Industrial Engineering	6
Quality Control	6
Production	1
Sales or Service	7
Information Processing	3
Teaching	5
Other	12

In general, survey results paint a picture of widespread use of electronic networks. The majority of respondents (74 percent) reported that they personally used networks, while 11 percent used networks through some kind of intermediary, such as a secretary or a librarian. Only 15 percent declared that they never used any kind of computer network (from linked workstations within an organization, to a personal computer connected to a printer down the hall or a supercomputer across the country, to a dial-up link to the Internet) in their work. In interpreting these figures, however, it should probably be assumed that results are biased in favor of network use (i.e., because of the length and topic of the survey, it is likely that potential respondents who did not use computer networks at all would be less inclined to complete and return the questionnaire even though the cover letter emphasized the importance of the responses of nonusers). One survey question attempted to put this potential bias in perspective by asking respondents to describe not their personal use, but the general use of computer networks in their workplace. These results suggest, in fact, a similar high level of use. In describing the extent of computer networking at their workplace, 40 percent of respondents reported that: "Networks are used by most people; many tools are available on networks; most computer systems are linked together by a network; and network use is required or strongly encouraged." A slightly higher proportion (48 percent) characterized the extent of networking at their workplace as use by "some" people, and only 7 percent reported use by "few" people with "little" organizational encouragement or even discouragementof network use.

Respondents also reported on availability and use of different types of networks (see Table 1). It appears as if those networks providing access to the broadest range of other people are least likely to be available at the aerospace engineering workplace. Computers connected to commercial networks that link users to people, tools, or information outside of their own organization—such as CompuServe—were available to the smallest percentage of respondents (about 30 percent); 50 percent had access to an external research network such as the Internet; 74 percent reported that they were connected to an organizational network that linked them to resources beyond one workplace building; and 85 percent reported access to a local area network. On the other hand, respondents were about equally likely to use any type of network available to them. Between 85 percent and 91 percent of respondents reportedly used each type of available network. As Table 2 indicates, the overwhelming majority of respondents used computer networks at work as opposed to at home or at some other location; of the various types of networks,

TABLE 1.
NETWORK AVAILABILITY AND USE
(PERCENTAGE OF RESPONDENTS SELECTING EACH RESPONSE)

Type of Network	*A computer or terminal connected to such a network is AVAILABLE for my use*	*Available network is USED*
Local	85	91
Organizational	74	89
External/Research	50	88
External/Commercial	30	85

TABLE 2.
LOCATION OF NETWORK USE
(PERCENTAGE OF RESPONDENTS SELECTING EACH LOCATION)

Type of Network	*Work*	*Home*	*Other*
Local	84	10	4
Organizational	76	11	3
External/Research	52	8	2
External/Commercial	28	19	2

external/commercial networks were, not surprisingly, most likely to be used at home.

The mail questionnaire also asked respondents to describe the availability, use, and perceived value of various types of computer network applications (see Table 3). File transfer was the computer network application reportedly available to the greatest percentage of respondents (85 percent), followed by electronic mail (82 percent), accessing remote data files (82 percent), remote log-in to run a computer program (80 percent), and electronic bulletin boards or conferencing systems (77 percent). These applications were also the network features most likely to be used. Less available were applications that supported access to published literature, such as electronic journals or newsletters (61 percent) or online library catalog searching (62 percent). It should be noted that these responses indicate a lack of perceived availability; some aerospace engineers may simply not be aware that certain applications are available to them. As a point of general comparison, 94 percent of respondents indicated that fax was available in their workplace, and 77 percent reported the availability of telephone voice mail. The percentage of respondents considering the value of each computer network application

TABLE 3.
NETWORK APPLICATIONS

APPLICATIONS	*% Who say that application is AVAILABLE*	*% USING application (if available)*	*% Who consider VALUE of application as "great" or "some"*
E-mail	82	84	83
BBs, mail lists, conferencing	77	70	67
Real-time interactive messaging	70	51	54
Videoconferencing	66	44	58
Voice mail	77	78	76
Fax	94	96	94
Electronic journals	61	41	50
EDI	61	23	42
Run program on remote computer	80	71	73
Access data on remote computer	82	72	75
Search government, commercial database	66	49	59
Card catalog search	62	57	62
Operate remote devices	62	27	43
CIM	63	24	41
Transfer data between computers	85	81	81
Access images	74	56	69
Other	69	50	52

application to be "great" or "some" varied from a high of 83 percent for electronic mail to a low of 41 percent for computer-integrated manufacturing.

Throughout the survey, value judgments were made by all respondents, whether or not they currently had access to or used the network feature in question. Overall value judgments, in this particular instance, may be colored by whether or not a specific application is used by a large number of respondents, even though respondents were also given the answer option of "Application is NOT APPLICABLE to My Work." For example, CIM may be assessed by a smaller percentage of respondents as valuable to their work because it is directly applicable to the work of a relatively smaller number of the aerospace engineers who completed this survey.

Tables 4-5 report the availability, use, and value of network access to various work resources in aerospace engineering. In describing network access to human resources (Table 4), more respondents (about 85 percent) were able to communicate electronically with people within their own organization more so than with people in other

TABLE 4.
WORK RESOURCES AND NETWORK USE: PEOPLE

WORK RESOURCES USED	*% With Net ACCESS to Resource*	*% USING Net Access*	*% Who consider VALUE of access as "great" or "some"*
People in your workgroup or department	85	88	78
Other people in your organization	86	89	81
Colleagues in academia, government	70	72	66
Colleagues in private industry	66	62	62
External clients, customers, sponsors	62	58	66
External vendors, suppliers	61	52	63
Other	46	22	42

organizations, which coincides with the greater availability of local and organizational networks reported earlier. Private sector colleagues or associates were least likely to be accessible over the network, with between 61 percent and 66 percent of respondents reporting such access. Network access to people in other departments of one's own organization was judged valuable by the greatest number of respondents (81 percent), while access to external colleagues, customers, vendors, and so on was apparently considered slightly less important. This may reflect the feeling—accepted as common knowledge by observers of the engineering enterprise—that internal communication of any kind is generally more critical in engineering work than is external communication. On the other hand, the number of aerospace engineers who do use networks to communicate with various kinds of people outside their own organizations (between 52 percent and 72 percent) may surprise those who thought that such links, at least in the private sector, were still largely prohibited due to proprietary and security concerns.

Network access to information resources (Table 5) ranged from a low of 50 percent for lab notebooks to a high of 77 percent for computer code and programs. Other information resources to which at least 70 percent of respondents reportedly had electronic access were company newsletters or bulletins, directories of people, internal financial data, production control data, and drawings or designs. Those resources actually accessed via networks by at least 70 percent of the respondents with network access were document citations and abstracts, internal technical reports, company newsletters and

TABLE 5.
WORK RESOURCES AND NETWORK USE: INFORMATION

WORK RESOURCES USED	*% With Net ACCESS to Resource*	*% USING Net Access*	*% Who consider VALUE of access as "great" or "some"*
Document citations, abstracts	69	76	74
Journal, trade magazine articles	55	50	63
Equipment/procedures manuals	59	57	62
Internal technical reports	66	71	72
Company newsletters, bulletins	70	75	61
Suppliers' catalogs	52	34	61
Codes of standards & practices	58	57	63
Directories of people	73	79	72
Training material, tools, programs	67	67	69
Internal financial data	71	73	70
Production control data	70	69	64
Experimental data	66	73	76
Product, material characteristics	60	61	71
Technical specifications	62	69	79
Design change forms	61	58	61
Lab notebooks	50	33	47
Drawings and designs	71	74	79
Computer code/programs	77	82	79
Other	61	56	78

bulletins, directories of people, internal financial data, experimental data, drawings and designs, and computer code and programs. The range of resources here suggests that network access to information supports a broad array of specific engineering tasks. Network access to those resources most crucial to the actual design and production of technologies—such as technical specifications and designs—was considered of "great" or "some" value by the greatest number of respondents.

Respondents were also asked to report the two most significant communication channels they used to perform an important work task. They could either choose one of the twenty-one work tasks presented in the questionnaire list or supply a task not listed. The tasks selected by the greatest number of respondents were:

- identify requirements;
- conduct experiment or run test;

- interpret results of experiments, tests;
- produce drawings, designs;
- assure conformance with requirements;
- plan tasks, projects, programs, and so on;
- coordinate work;
- negotiate with coworkers, clients, vendors, students, and so on;
- solve technical problem;
- write proposal, report, paper, and so on.

Figure 1 portrays the extent to which different communication channels were used in task performance regardless of which task was performed. Face to face communication was used by a clear majority of respondents (69 percent), followed by the examination of printed material (37 percent), and use of the telephone (36 percent). Use of a computer network link to people, information, or a computer was greater than the reported use of either voice mail or U.S. or internal mail service. In examining other survey data to explore the use of network channels for specific tasks, "Learning how to do something" was found to be the one task that accounted for substantial use of all three kinds of network channels. Network links to information were also used most heavily for producing drawings or designs and identifying problems. Network links to people were also used most extensively to support work coordination and for writing proposals and reports. Finally, network links to computers were also used most often to develop theories and concepts or produce drawings or designs.

Survey results discussed so far address extent of network use in the aerospace industry and the use of networks to support aerospace engineering work and communication tasks. Another aim of the study was to explore factors that might be associated with network use. One questionnaire matrix asked respondents to report the extent to which they agreed or disagreed with a number of statements describing their work and networking environments. Comparing the responses of network users to nonusers reveals possible relationships among network use and various factors (see Table 6). For example, a greater percentage of network users, compared to nonusers, agreed that their work is integrated with the work of others, that the people they need to communicate with are all in their building, that they require a diverse range of information from a wide variety of sources, and that time pressures in their work are tremendous. A greater percentage of network nonusers, as opposed to users, agreed that they spent their day working independently. The accessibility of a networked computer is strongly associated with network use, as is work output that is stored in computerized form; these are frequently cited in the literature as factors that encourage network use, but they may

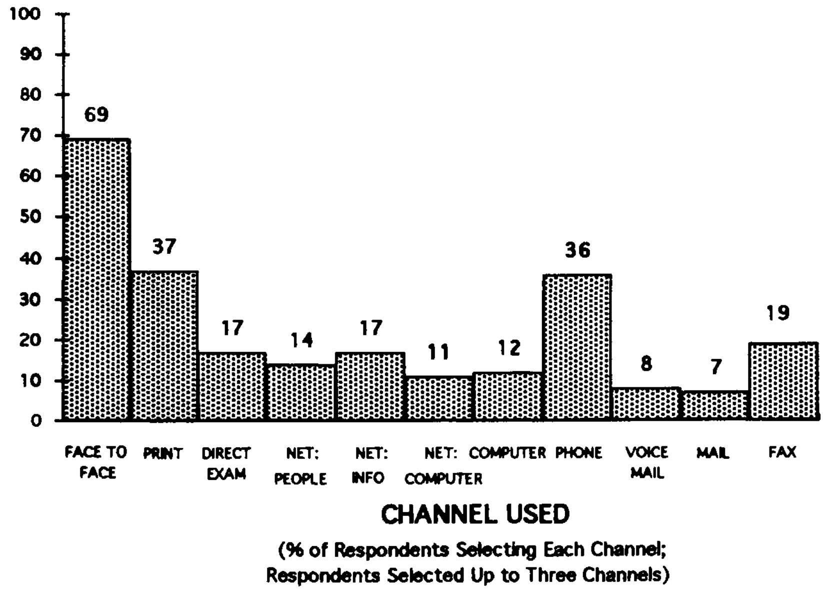

Figure 1. Use of networks, compared to other channels, for performing work tasks

also, of course, be effects of extensive network use as opposed to causes. Organizational reward and external demand seem to be significant factors in encouraging network use among this survey's respondents. Interestingly, more network users agreed that networking is not seamless, and that many incompatible systems exist; nonusers, perhaps, are simply more optimistic about network capabilities.

Cross tabulating various respondent characteristics with network use (see Table 7) revealed, for the most part, only small differences in use due to respondent characteristics. Network use did not vary greatly by age except for those over sixty who were much less likely to be network users. Network use appears to increase with educational level. Network use is more extensive in academia, as opposed to other sectors and is more widespread in very large organizations. Table 8 reports variations in network use according to different work characteristics. Scientists appear to use networks more than engineers. In terms of primary job function, network use is most extensive among those engaged in teaching, research, advanced or applied development, and industrial engineering. Aerospace engineers working in aerodynamics or flight dynamics and control are slightly more likely to use networks than are those in other branches of aerospace.

TABLE 6.
FACTORS AFFECTING NETWORK USE

FACTORS	*% of USERS agreeing with statement*	*% of NON-USERS agreeing with statement*
The results of my work are integrated with the work of others	89	77
I spend my day working independently	42	63
All the people I need to communicate with are in my building	~~75~~ 14	26
I require a diverse range of information from a variety of sources	84	65
Time pressures are tremendous in my work	76	59
My work is routine, predictable	7	13
Work discussions require having documents, devices and drawings in hand	67	66
I examine physical devices, instruments, materials, processes, etc.	59	62
The products I design, develop, or produce are highly complex	69	59
I work in a field that is extremely competitive	69	59
My organization is hierarchically structured (not project-based)	48	41
My organizational culture is rigid and authoritative	34	24
My work is classified	22	21
Results of my work are proprietary	49	55
Results of my work are stored in computerized form	67	40
I started my professional career without networks	88	84
I like to learn new computer things just for the fun of it	65	56
Networking requires too much effort to learn and keep up with	23	16
I know all about networked information services relevant to my work	19	7
Networking help comes from formal training or support programs	25	16
Network transmission is unreliable	15	5
Existing network applications are well-suited to my work	44	16
All the people, tools, resources I need are on the network	16	4
Networking is not seamless—many unconnected incompatible systems	61	21
Networking costs outweigh its benefits	11	12
Network use is actively encouraged, rewarded by my organization	35	11
Lack of networking experience makes it hard to predict costs/benefits	45	36
A networked computer is easily accessible to me	77	15
Customers, clients, sponsors are demanding that I use networks	20	9

TABLE 7.
RESPONDENT CHARACTERISTICS AND NETWORK USE (NETWORK USE IN %)

RESPONDENT CHARACTERISTICS	*USE Networks*	*NEVER USE Networks*
Gender:		
Male	85	15
Female	81	19
Age:		
20-29	89	11
30-39	93	7
40-49	92	8
50-59	86	14
60+	61	39
Education Level:		
High School	80	20
Technical Degree	69	31
Bachelor's Degree	83	17
Master's Degree	88	12
Ph.D.	93	7
Post Doctorate	100	0
Type of Organization:		
Industry/Manufacturing	85	15
Government	92	8
Academic	98	2
Nonprofit	83	17
Retired	12	88
Other	60	40
Organization Size:		
<50	58	42
50-99	53	47
100-499	81	19
500-999	87	13
1000-4999	87	13
5000-9995	95	5
9996+	94	6

The final aspect of networking considered in this study was its impact on aerospace engineering work and communication. The percentage of respondents selecting various replies to the question "Overall, how would you describe your current reaction to computer networks" is presented below:

They have revolutionized aerospace work	(21%)
They are very useful in many respects	(55%)
They have certain worthwhile uses	(19%)
I am neutral or indifferent to them	(4%)
I have reservations about their value	(1%)
They have limited value and can cause serious problems	(.4%)
They are worthless and should not be implemented	(0%)

TABLE 8.
WORK CHARACTERISTICS AND NETWORK USE (NETWORK USE IN %)

RESPONDENT CHARACTERISTICS	*USE Networks*	*NEVER USE Networks*
Job Title:		
Engineer	84	16
Manager	87	13
Scientist	91	9
Other	84	16
Job Function:		
Administration	80	20
Research	94	6
Advanced/Applied Development	91	9
Design/Product Engineering	81	19
Industrial Engineering	91	9
Quality Control	85	15
Production	80	20
Sales or Marketing	73	27
Service or Maintenance	75	25
Information Processing	88	12
Teaching	98	2
Aerospace Branch:		
Aerodynamics	94	6
Structures	85	15
Propulsion	85	15
Flight Dynamics and Control	90	10
Avionics	85	15
Materials	83	17

Thus the overwhelming majority of aerospace engineers surveyed perceived the impact of computer networks on aerospace to be positive.

The survey also solicited aerospace engineers' assessments of specific networking impacts. In one questionnaire matrix, respondents first indicated whether they thought networks decreased greatly, decreased somewhat, had no effect on, increased somewhat, or increased greatly each of the aspects of work and communication listed. They then indicated whether they considered the perceived networking effect to be a major problem, a major benefit, or neither/both. Table 9 presents selected results from this section of the survey. Responses citing some degree of increase or decrease were grouped ("don't know" and "no effect" responses are not reported in the table so percentages do not total 100 percent). Results appear in descending order, with the effects perceived by the greatest percentage of respondents listed first. The table also shows the percentage of respondents who felt that each network effect represented a major problem or benefit in aerospace work ("don't know" and "neither/both"

TABLE 9.
NETWORK IMPACTS

	% Reporting Effect is to:		% Reporting Effect is:	
Aspects of Work and Communication	*Decrease*	*Increase*	*Major Problem*	*Major Benefit*
Amount of information available	2	87	3	76
Exchange of information, ideas across organizational boundaries	3	74	1	72
Efficiency of contacting people	4	70	3	64
Ability to complete projects on schedule	6	65	3	64
Responsiveness to customers, clients, etc.	2	65	3	65
Ability to stay on the cutting edge of new knowledge	2	64	1	61
Documentation, evaluation of work processes	4	64	2	60
Ability to communicate with otherwise inaccessible people	2	63	2	62
Use of expensive computers & devices	11	62	24	28
Ability to express ideas at point of need	5	60	3	57
Need for face-to-face interaction	55	35	11	34
Performance of work at home, on the road, off-site	2	53	3	51
Management control	8	53	6	49
Feasibility, size of collaborative efforts	3	53	2	51
Flexibility in work structures, patterns	3	53	3	48
Coherence with one's work community	8	52	4	45
Duplication of effort	52	14	11	48
Ability to complete projects within budget	6	47	5	46
Turnaround time on solving problems	29	47	3	70
Major system security problems	4	43	45	5
Amount of time spent fooling around	9	43	29	9
Leaks of proprietary or sensitive information	4	38	41	5
Number of changes required in final products	32	16	7	42
Degree of status among one's peers	1	30	2	21
Sense of ownership, committment to work product	7	29	5	27
Rate of career advancement	2	24	3	22
Communication with people NOT on the network	22	14	22	14
Number of staff employed	22	11	7	19

responses are not reported). Over half of the respondents felt that major benefits of networks were that they increased:

- the amount of information available;

- the exchange of information and ideas across organizational boundaries;
- the efficiency of contacting people;
- the ability to complete projects on schedule;
- responsiveness to customers, clients, etc.;
- the ability to stay on the cutting edge of new knowledge;
- the documentation, evaluation of work processes;
- the ability to communicate with otherwise inaccessible people;
- the ability to express ideas at point of need;
- the performance of work at home, on the road, off-site;
- the feasibility and size of collaborative efforts;
- the turn-around time on solving problems.

Citing the increased turn-around time in solving problems as a major benefit seems counterintuitive, if one assumes that it is always advantageous to solve problems as quickly as possible. It may be that some respondents had difficulty with the "decrease/increase" scale used in that question, applying it rather as the degree of "bad" to "good" influence of networks. Another possible explanation is that some respondents felt that networks allowed for more input into the problem-solving process, which increased the time required to arrive at a solution but also improved the quality of the solution.

Of the major problems cited, the risk of system security and leaks of proprietary information were perceived by over 40 percent of respondents. Almost one-third of aerospace engineers surveyed felt it was a major problem that networks increased the time that people spent "fooling around," while about one-fifth cited the problem that communication with nonusers of networks was reduced. A number of these impacts, such as "increases the amount of information available," are generic in the sense that they may be felt as well by other types of users beyond those in the engineering community. Some of the reported impacts relate directly to efficiency or effectiveness gains. Others, such as the increased "coherence with one's work community," describe second order effects, which are also important within the general work context.

CONCLUSIONS

Few studies have appeared that examine networking in engineering, as opposed to scientific or scholarly work, or that relate electronic communication determinants and effects to the situations and environments of particular communities of users. The current study hoped to extend existing knowledge by employing a user-based approach to explore the role of electronic networks in engineering work and communication.

This article has reported selected data from the author's survey on the use of electronic networks in aerospace engineering environments. Networks appear to be used widely for both communication and computation purposes by engineers in the aerospace industry, with interorganizational links available to half of those surveyed. Nonetheless, respondents perceived internal electronic links as being more valuable than external communication capabilities. A significant number of respondents reported that they had network access to a variety of tools and resources and judged network access highly valuable for accessing a variety of resource types, from analytical tools like computer programs, to experimental data, to literature citations and abstracts. While computer networks are apparently not as important as face-to-face, telephone, and print channels in the conduct of aerospace engineering work, they were used more often than voice mail or regular mail services, and almost as often as fax. Electronic mail and file transfer are the applications that are most available, most used, and judged most valuable.

While organizational sector and size—as well as primary job function—appear to influence network use, other demographic characteristics of respondents do not, generally, seem to differentiate network users from nonusers as well as specific job and organizational environment characteristics (e.g., accessibility of networked computers, whether network use is rewarded by one's organization or whether one requires a wide range of information to perform one's job). Lack of network training and awareness were noted by both network users and nonusers; this may be one area that organizations could target if they wish to increase network use by their employees. The impact of computer networks on the aerospace industry has apparently been overwhelmingly positive, with respondents generally reporting gains in areas of work efficiency, effectiveness, and satisfaction. A number of significant problems were also perceived, including lack of ubiquitous connections and inadequate security controls.

In addition to the questionnaire findings, comments made by study respondents in in-depth interviews suggest some of the limitations and advantages of electronic communication in engineering work. Although electronic communication is perceived to contribute to engineering efficiency and effectiveness, its use is limited (at least in terms of today's technology) by engineers' need for immediate highly interactive discussion of complex problems of both a technical and nontechnical nature. Networks do not provide adequate means to convey the multifaceted multimedia information that is typically exchanged in those situations where, for example, engineers discuss issues and negotiate while simultaneously consulting drawings, contracts, financial data, test results, and physical devices. Use may also be limited by an organization's lack of experience with electronic communication: while dangers are easy to imagine and costs easy to tally, benefits are harder to predict and quantify.

Research conducted from a user perspective can be utilized by network policy-makers, system designers, and service providers (at both the national and organizational levels) in a number of ways. It can help them:

- anticipate and avoid conflicts by discovering where attitudes and expectations vary among different groups;
- understand and estimate networking impacts and benefits by revealing both direct and second order effects;
- develop products and services well-suited to customer/client needs;
- choose appropriate network designs and features to meet users' real needs;
- devise strategies to promote network use;
- develop appropriate management and use policies;
- implement effective mechanisms for user training and support by finding out who is having what kind of problem;
- prepare appropriate evaluations of network systems and services by identifying a variety of goals and objectives and assessing the degree to which they have been met.

Thus user-based research is important in planning for the NREN and the NII. It offers an important complement to networking investigations that concentrate on technical and financial analyses and can help assure that national networking goals will be optimally met.

ACKNOWLEDMENT

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APPENDIX

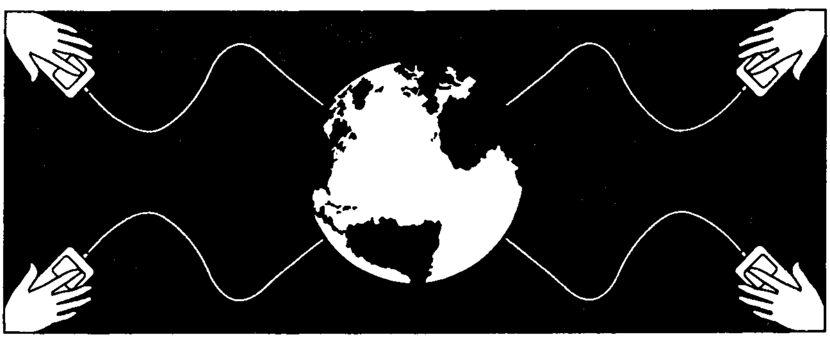
QUESTIONNAIRE USED IN THE SURVEY

PHASE 1 OF THE

NASA/DOD AEROSPACE KNOWLEDGE

DIFFUSION RESEARCH PROJECT

The Role of Computer Networks in Aerospace Work and Communication: SAE Study



SPONSORED BY THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AND THE DEPARTMENT OF DEFENSE WITH THE COOPERATION OF INDIANA UNIVERSITY, THE UNIVERSITY OF ILLINOIS, AND THE SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

APPENDIX *(Cont.)*

QUESTIONNAIRE USED IN THE SURVEY

SURVEY ON THE ROLE OF COMPUTER NETWORKS IN AEROSPACE WORK AND COMMUNICATION

The purpose of this survey is to learn more about the current and potential impact of computer networks on work and communication in the aerospace industry from the point of view of a wide range of individuals. Your opinions and experiences are important, even (perhaps especially) if you do not use computer networks. So please answer each question as completely as possible.

PLEASE READ THIS DEFINITION BEFORE BEGINNING THE SURVEY:

COMPUTER NETWORKS are defined as telecommunications links between computers. They take many forms, for example: linked workstations within an organization; a desktop computer or terminal connected to a nearby printer or linked to a central mainframe; a dial-up link between your computer and a supercomputer or database located in some other part of the country; or a link through your computer to services on the Internet or CompuServe. With a computer network, you can communicate with other computer users, utilize remote computers or computerized devices, and access information located on systems beyond your own desktop. IN THE CONTEXT OF THIS SURVEY, COMPUTER NETWORKING DOES NOT INCLUDE VOICE MAIL or TELEPHONE TELEFACSIMILE TRANSMISSION (FAX).

1. Overall, how would you describe **your current reaction to computer networks**? (Circle number of best response)

    1 They have revolutionized aerospace work.
    2 They are very useful in many respects.
    3 They have certain worthwhile uses.
    4 I am neutral or indifferent to them.
    5 I have reservations about their value.
    6 They have limited value and can cause serious problems.
    7 They are worthless and should not be implemented.

2. Which description below BEST characterizes the **extent of computer networking at your workplace?** (Circle number of best response)

    1 Networks are used by *most* people; *many* tools and resources are available on networks; *most* computer systems are linked together by a network; network use is *required or strongly encouraged.*

    2 Networks are used by *some* people; *certain* tools and resources are available on networks; *some* computer systems are linked together by a network; network use is *encouraged in some cases.*

    3 Networks are used by *few, if any* people; *few, if any* tools and resources are available on networks; *few, if any* computer systems are linked together by a network; *organization does little to encourage, or even discourages network use.*

    4 Don't know/Not applicable

3. Do you ever use any kind of **computer** in your work, such as a PC, terminal, mainframe, laptop, handheld computer, etc.? (Circle number of your response)

    1 No, I never use computers
    2a Yes
    → 2b **If yes,** approximately what percent of your typical work week is spent using computers? ___ %

4. Do you ever use any kind of **computer network** in your work? (Circle number of best response)

    1 No, I never use computer networks
    2a Yes, I personally use computer networks
    2b Yes, I use computer networks, but <u>only</u> through an intermediary; e.g., secretary, librarian, computer support staff
    → 2c **If yes,** approximately what percent of your typical work week is spent using computer networks? ___ %

APPENDIX *(Cont.)*
QUESTIONNAIRE USED IN THE SURVEY

COMPUTER NETWORK AVAILABILITY, VALUE, AND USE

This section of the survey aims at obtaining a clearer picture of the current availability, perceived value, and use of specific types of computer networks in aerospace.

5. Please complete the chart below by placing check marks in the appropriate cells to describe **YOUR** access to, assessment, and use of specific types of computer networks.

<u>If you NEVER use networks</u>, please complete COLUMNS I-II. Record in column II your personal assessment of the POTENTIAL VALUE of each type of network listed.

<u>If you DO use some type of network</u>, please complete COLUMNS I-III. Record in column II your personal assessment of the ACTUAL VALUE of each type of network that you use and the POTENTIAL VALUE of each type that you do not use. Record the LOCATION OF YOUR NETWORK USE in column III.

Very often, people cannot say for sure what kinds of computer networks are available to them. That's fine; please place a check mark in the "Not Sure" cell, if this is the most appropriate response.

AVAILABILITY, VALUE, AND LOCATION OF USE / TYPE OF NETWORK	I Is a computer or terminal connected to such a NETWORK AVAILABLE for your use? *(Check only one)*			II VALUE of this type of network TO YOUR WORK? (ACTUAL value if used; POTENTIAL value if not currently used) *(Check only one)*					III IF YOU USE this type of network, WHERE do you use it? *(Check ALL that apply)*		
	Yes	No	Not Sure	Great	Some	Slight	None	Don't Know	Work	Home	Other
LOCAL: Connects you to people, tools, or information within ONE BUILDING AT YOUR WORKPLACE (i.e., Local Area Network or LAN)											
ORGANIZATIONAL: Connects you BEYOND ONE WORKPLACE BUILDING to people, tools, or information WITHIN YOUR OWN ORGANIZATION (e.g., corporate Wide Area Network or WAN; campus network)											
EXTERNAL/RESEARCH: Provides a variety of services. Connects you to people, tools, or information OUTSIDE YOUR OWN ORGANIZATION and is INTENDED FOR RESEARCH AND EDUCATIONAL USE (e.g., Internet, BITNET, NSFNet, Usenet)											
EXTERNAL/COMMERCIAL: Provides a variety of services. Connects you to people, tools, or information OUTSIDE YOUR OWN ORGANIZATION and is OPEN FOR USE BY THE GENERAL PUBLIC (e.g., Prodigy, BIX, CompuServe, GEnie, MCIMail)											
OTHER (please describe):											

APPENDIX *(Cont.)*

QUESTIONNAIRE USED IN THE SURVEY

WORK RESOURCES IN AEROSPACE

This section of the survey asks about the wide variety of resources you use in your work and the extent to which these resources are accessible over any kind of computer network. **Please complete the entire chart below FOR ANY WORK RESOURCE YOU USE, even if you don't use networks.**

6. First, CHECK OFF ANY RESOURCE THAT YOU USE in your work. Then, place check marks in each of THOSE ROWS ONLY to describe **YOUR use and assessment of computer network access to that work resource.** If any resources you use do not appear in the chart, add them in the "Other" rows.

For any resource CURRENTLY ACCESSIBLE TO YOU VIA COMPUTER NETWORK, describe your assessment of the ACTUAL VALUE OF NETWORK ACCESS to that resource, based on your experience.

For any resource NOT CURRENTLY ACCESSIBLE TO YOU VIA COMPUTER NETWORK, describe your assessment of the POTENTIAL VALUE OF NETWORK ACCESS to that resource, based on your opinion.

WAIT! *Information resources (e.g., journal articles, internal financial data)* ***should NOT be considered network accessible unless the full text or content*** *of the information--as opposed to just the bibliographic citation or database listing--can be viewed over the network.*

	USE AND VALUE OF NETWORK ACCESS / WORK RESOURCES	IS RESOURCE USED in your work? (Check if yes)	When using this resource, HOW OFTEN DO YOU ACCESS IT VIA A NETWORK? vs. by telephone, in print, etc. (Check only one)					VALUE of NETWORK ACCESS to YOUR work? vs. telephone, etc., access (ACTUAL value if network access exists now; otherwise POTENTIAL value) (Check only one)				
			Not Applicable--No Network Access	Usually	Sometimes	Rarely	Never	Great	Some	Slight	None	Don't Know
HUMAN RESOURCES	People in your workgroup or dept.											
	Other people in your organization											
	Colleagues in academia, government											
	Colleagues in private industry											
	External clients, customers, sponsors											
	External vendors, suppliers											
	Other:											
INFORMATION RESOURCES	Document citations, abstracts											
	Journal, trade magazine articles											
	Equipment or procedures manuals											
	Internal technical reports											
	Company newsletters, bulletins											
	Manufacturers' or suppliers' catalogs											
	Codes of standards and practices											
	Directories of people											
	Training materials, tools, programs											
	Internal financial data											
	Production control data											
	Experimental or test data											
	Product or materials characteristics											
	Technical specifications											
	Design change forms											
	Lab notebooks											
	Drawings or designs											
	Computer code or programs											
	Other:											

APPENDIX *(Cont.)*
QUESTIONNAIRE USED IN THE SURVEY

NETWORK APPLICATIONS IN AEROSPACE

It's important to gain a fuller picture of the extent to which different network applications (computer AND non-computer) are used in aerospace and which ones are considered the most valuable. **Please complete the entire chart below, even if you don't use networks.**

7. Place check marks in EACH ROW to describe **YOUR use and assessment of each of the specific types of network applications listed.**

For any network application that YOU CURRENTLY USE, describe your assessment of its ACTUAL VALUE, based on your experience.

For any network application that YOU DO NOT CURRENTLY USE, describe your assessment of its POTENTIAL VALUE, based on your opinion.

AVAILABILITY, USE, AND VALUE / NETWORK APPLICATIONS	How FREQUENTLY do YOU use this application AT YOUR WORKPLACE? *(Check only one)*					VALUE of application TO YOUR WORK? (ACTUAL value of application IF USED; otherwise POTENTIAL value) *(Check only one)*					
	Application NOT AVAILABLE at Workplace	Daily	Weekly	Monthly or Less	Never	Application NOT APPLICABLE to My Work	Great	Some	Slight	None	Don't Know
Electronic mail (sending messages to individuals)											
Electronic bulletin boards, mailing lists, discussion groups or computer conferencing systems (for group messages)											
Real-time, interactive messaging											
Videoconferencing											
Voice mail											
Telefacsimile (Fax)											
Electronic journals or newsletters											
Electronic data interchange (EDI) for exchanging orders, bills, etc.											
Logging into a computer NOT on your desktop to run a program (e.g., CAD/CAM, spreadsheet, modeling)											
Logging into a computer NOT on your desktop to access data or text files (e.g., personnel or project data, reports)											
Online bibliographic searching of commercial or government databases											
Online library card catalog searching											
Operation of computerized experimental, test, or production devices without being physically present											
Computer-integrated manufacturing											
Transferring data or text files between computers											
Accessing or transferring images											
Other:											

Appendix *(Cont.)*
QUESTIONNAIRE USED IN THE SURVEY

AEROSPACE TASKS AND ACTIVITIES

In interviews conducted earlier, people working in aerospace discussed the wide variety of important tasks and activities they perform. This section of the survey asks how YOU performed some particular task that was important to your work.

8. **The one most important work task I performed during my last work week was to** (Circle number of SINGLE BEST response):

1 Come up with new ideas, approaches
2 Keep up with new developments
3 Develop theories, concepts
4 Identify requirements
5 Learn how to do something
6 Select or design methods and procedures
7 Conduct experiment or run test
8 Perform mathematical analysis
9 Interpret results of experiments, tests
10 Produce specifications
11 Produce drawings, designs
12 Identify resources
13 Produce prototypes or products
14 Assure conformance with requirements
15 Troubleshooting, maintenance
16 Plan tasks, projects, programs, etc.
17 Coordinate work
18 Identify problem
19 Negotiate with co-workers, clients, vendors, students, etc.
20 Solve technical problem
21 Write proposal, report, paper, etc.
22 Other: ______________________

9. Please describe the task briefly: ____
____

10. Approximately how many **OTHER** people were directly involved in performing this task with you?
____ other people (Please supply number from 0 up)

11. What was the **geographic span** involved in performing the task, in relation to your primary work location at the time? (Circle number of best response)

1 Same office/lab
2 Same building
3 Same worksite
4 Same town
5 Same country
6 Across countries
7 Don't know

12. What was the **organizational span** involved in performing the task, in relation to your primary work location at the time? (Circle number of best response)

1 Same workgroup
2 Same department
3 Same division
4 Same organization
5 Across organizations
6 Don't know

13. In performing this task, did you come into contact with any useful people, information sources, or tools **not previously known** to you? (Circle number of response)

1 Yes
2 No

APPENDIX *(Cont.)*

QUESTIONNAIRE USED IN THE SURVEY

14. What were the two most important communication channels you used in performing this task? On the lines provided below, please WRITE a "P" in front of the PRIMARY communication channel used. WRITE an "S" in front of the SECONDARY channel used.

		Mechanism Code
___	Face-to-face interaction with other person(s)	FTF
___	Examining printed material in own office or other location	P
___	Own direct examination, testing of physical objects, devices, processes	D
___	Use of computer network to communicate with people	NP
___	Use of computer network to access information or data	NI
___	Use of computer network to operate a computer or other device	NC
___	Use of a non-networked computer	C
___	Telephone	T
___	Voice Mail	VM
___	Internal (e.g., company or campus) or U.S. Mail	M
___	Fax	F
___	Other (please describe): ____________	O

15. What was your MAIN REASON for choosing the PRIMARY channel used? (circle SINGLE BEST response)

1 Preferred mechanism not available: ____ (Supply *Mechanism Code* from previous question to specify preferred mechanism)
2 Tradition demanded it
3 It was quickest way to accomplish the task
4 It required the least effort on my part
5 It was cheapest
6 It was the most reliable
7 It allowed the greatest accuracy of information flow
8 It allowed for the most complete expression, interpretation, or interaction in information flow
9 It allowed for the most presentable expression of information
10 It's what everyone involved was set up for
11 Other (please describe): ____________

NATURE OF YOUR WORK ENVIRONMENT

This section seeks information about your work environment in order to explore work-related factors that may be associated with network use.

16. In your present job, do you consider yourself primarily a(n)? (Circle number of SINGLE BEST response):

1 Engineer
2 Manager
3 Scientist
4 Other (please describe): ____________

17. In which branch of aerospace do you work? (Circle number of SINGLE BEST response)

1 Aerodynamics
2 Structures
3 Propulsion
4 Flight dynamics and control
5 Avionics
6 Materials and processes
7 Other (please describe): ____________

18. What do you think are the biggest barriers to network use that you experience? ____________

19. What are the most important factors that encourage your network use or potential use? ____________

Appendix *(Cont.)*

QUESTIONNAIRE USED IN THE SURVEY

20. Please complete this chart on YOUR WORK AND NETWORKING ENVIRONMENT by placing a check mark in each row to indicate the **extent to which YOU agree or disagree with each of the statements listed. Please complete the entire chart, even if you don't use networks.**

Section	STATEMENTS CONCERNING WORK AND NETWORKING ENVIRONMENT	EXTENT TO WHICH YOU AGREE? *(Check only one)* Not applicable/ Don't know	Disagree strongly	Disagree somewhat	Neither agree nor disagree	Agree somewhat	Agree strongly
WORK ENVIRONMENT	The results of my work are integrated with the work of others						
	I spend my day working independently						
	All the people I need to communicate with are in my building						
	I require a diverse range of information from a wide variety of sources						
	Time pressures are tremendous in my work						
	My work is routine, predictable						
	Work discussions require having documents, devices, drawings all in hand						
	I often examine physical devices, instruments, materials, processes, etc.						
	The products I design, develop, or produce are highly complex						
	I work in a field that is extremely competitive						
	My organization is hierarchically structured (as opposed to project-based)						
	My organizational culture is rigid and authoritative						
	My work is classified						
	Results of my work are proprietary						
	Results of my work are stored in computerized form						
NETWORKING ENVIRONMENT	I started my professional career without networks						
	I like to learn new computer things just for the fun of it						
	Networking requires too much effort to learn and keep up with						
	I know about all the networked information, services relevant to my work						
	Networking help comes mostly from formal training or support programs						
	Network transmission is unreliable						
	Existing network applications are well-suited to my work						
	All the people, tools, resources I need are on the network						
	Networking is not seamless; still many unconnected, incompatible systems						
	Networking costs outweigh its benefits						
	Network use is actively encouraged, rewarded by my organization						
	Lack of experience with networking makes it hard to predict costs, benefits						
	A networked computer is easily accessible to me						
	Customers, clients, sponsors are demanding that I use networks						

APPENDIX *(Cont.)*

QUESTIONNAIRE USED IN THE SURVEY

IMPACT OF COMPUTER NETWORKS

In interviews conducted earlier, people involved in the aerospace industry suggested a wide variety of impacts, representing both problems and benefits, that may result from network use. **Please complete the entire chart below to share YOUR OWN OPINIONS AND EXPERIENCES, regardless of whether or not you currently use networks.**

21. Indicate in COLUMN I the extent to which **YOU believe that** NETWORKS INCREASE OR DECREASE each work aspect listed. Place a check in COLUMN II **IF YOU HAVE PERSONALLY EXPERIENCED** that effect. Indicate in COLUMN III whether you believe the effect represents a **MAJOR PROBLEM OR BENEFIT** in aerospace work.

EFFECT OF NETWORKS / ASPECTS OF WORK	I Is the effect of networks to INCREASE? or DECREASE? each aspect of work *(Check only one)*						II	III If effect occurs, is it a MAJOR PROBLEM or BENEFIT? *(Check only one)*			
	Don't know/ Not applic	DECREASE Greatly	DECREASE Somewhat	NO EFFECT	INCREASE Somewhat	INCREASE Greatly	Have you PERSONALLY experienced this effect? *(Check if yes)*	Don't know/ Not applic.	MAJOR PROBLEM	MAJOR BENEFIT	Neither/Both
Ability to express ideas, problems at point of need											
Amount of information available											
Need for face-to-face interaction											
Coherence with one's work community											
Communication with people NOT on the network											
Exchange of information, ideas across organizational boundaries											
Efficiency of contacting people											
Number of changes required in final products											
Use of expensive computers and computerized devices											
Ability to complete projects within budget											
Turnaround time on solving problems											
Ability to complete projects, develop products on schedule											
Duplication of effort											
Ability to stay on the cutting edge of new knowledge											
Sense of ownership, commitment to work product											
Performance of work at home, on the road, off-site											
Rate of career advancement											
Degree of status among one's peers											
Ability to communicate with otherwise inaccessible people											
Documentation, evaluation of work processes											
Management control											
Feasibility, size of collaborative efforts											
Flexibility in work structures, patterns											
Number of staff employed											
Leaks of proprietary or sensitive information											
Major system security problems											
Amount of time spent fooling around											
Responsiveness to customers, clients, etc.											
Other (please specify):											
Other (please specify):											

APPENDIX *(Cont.)*

QUESTIONNAIRE USED IN THE SURVEY

IMPORTANT BACKGROUND INFORMATION

The information that you provide in this section will be used to help determine whether people with different backgrounds and jobs differ in regard to their network use.

22. Gender (Circle number of your response):
    1 Male
    2 Female

23. Age: ___

24. Highest degree obtained (Circle number of the <u>SINGLE BEST</u> response):
    1 High School Diploma
    2 Technical/Vocational Degree
    3 Bachelor's Degree
    4 Master's Degree
    5 Doctorate
    6 Post Doctorate
    7 Other (please describe): ____________________

25. Years of professional aerospace work experience: ____ years

26. Type of organization where you work (Circle number of <u>SINGLE BEST</u> response):
    1 Industry/Manufacturing
    2 Government
    3 Academic
    4 Not-for-Profit
    5 Retired or Not Employed
    6 Other (please describe): ____________________

27. If you work in an organization other than an educational institution, what is the approximate <u>number of employees</u> in your organization? (Please supply number of people for each category below that is applicable):

    27a _____ people in parent organization

    27b _____ people in my division

    27c. _____ people in my location

    27d _____ people in department (or the equivalent)

28. Which category BEST describes your primary job function? (circle number of <u>SINGLE BEST</u> response)
    1 Administration
    2 Research
    3 Advanced or Applied Development
    4 Design/Product Engineering
    5 Industrial/Manufacturing Engineering
    6 Quality Control/Assurance (testing, inspection, etc.)
    7 Production
    8 Sales/Marketing
    9 Service/Maintenance
    10 Information Processing/Computer Programming/Systems Management
    11 Teaching/Training (may include research)
    12 Other: ______________________________

29. What is your current job title? ______________________________

30. Does your own work involve, as a primary feature, the development or analysis of computer systems, components, softw[illegible], or data? (Circle number of your response)
    1 Yes
    2 No

APPENDIX *(Cont.)*
QUESTIONNAIRE USED IN THE SURVEY

CONCLUDING THE SURVEY

31. What do you most want to convey to network policymakers, service providers, or organizational managers about the impact of computer networks on work and communication in aerospace?

32. Is there anything else you would care to say about the use of computer networks in the aerospace industry? About this study?

33. Would you be interested in participating in follow-up research related to this study, such as a brief telephone interview or a short questionnaire on some specific aspect of network use? (Circle number of your response)

1 Yes
2 No

THANK YOU!

Mail to:

NASA/DoD Aerospace Knowledge Diffusion Research Project
NASA Langley Research Center
Mail Stop 180A
Hampton, VA 23681-0001

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Errata

In volume 42, number 4, the table on page 709 of Ann Peterson Bishop's article, "The Role of Computer Networks in Aerospace Engineering," contained an error. On the following page is the corrected table:

TABLE 6.
FACTORS AFFECTING NETWORK USE

FACTORS	*% of USERS agreeing with statement*	*% of NON-USERS agreeing with statement*
The results of my work are integrated with the work of others	89	77
I spend my day working independently	42	63
All the people I need to communicate with are in my building	14	26
I require a diverse range of information from a variety of sources	84	65
Time pressures are tremendous in my work	76	59
My work is routine, predictable	7	13
Work discussions require having documents, devices and drawings in hand	67	66
I examine physical devices, instruments, materials, processes, etc.	59	62
The products I design, develop, or produce are highly complex	69	59
I work in a field that is extremely competitive	69	59
My organization is hierarchically structured (not project-based)	48	41
My organizational culture is rigid and authoritative	34	24
My work is classified	22	21
Results of my work are proprietary	49	55
Results of my work are stored in computerized form	67	40
I started my professional career without networks	88	84
I like to learn new computer things just for the fun of it	65	56
Networking requires too much effort to learn and keep up with	23	16
I know all about networked information services relevant to my work	19	7
Networking help comes from formal training or support programs	25	16
Network transmission is unreliable	15	5
Existing network applications are well-suited to my work	44	16
All the people, tools, resources I need are on the network	16	4
Networking is not seamless—many unconnected incompatible systems	61	21
Networking costs outweigh its benefits	11	12
Network use is actively encouraged, rewarded by my organization	35	11
Lack of networking experience makes it hard to predict costs/benefits	45	36
A networked computer is easily accessible to me	77	15
Customers, clients, sponsors are demanding that I use networks	20	9