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*The Value of Computer Networks in Aerospace*

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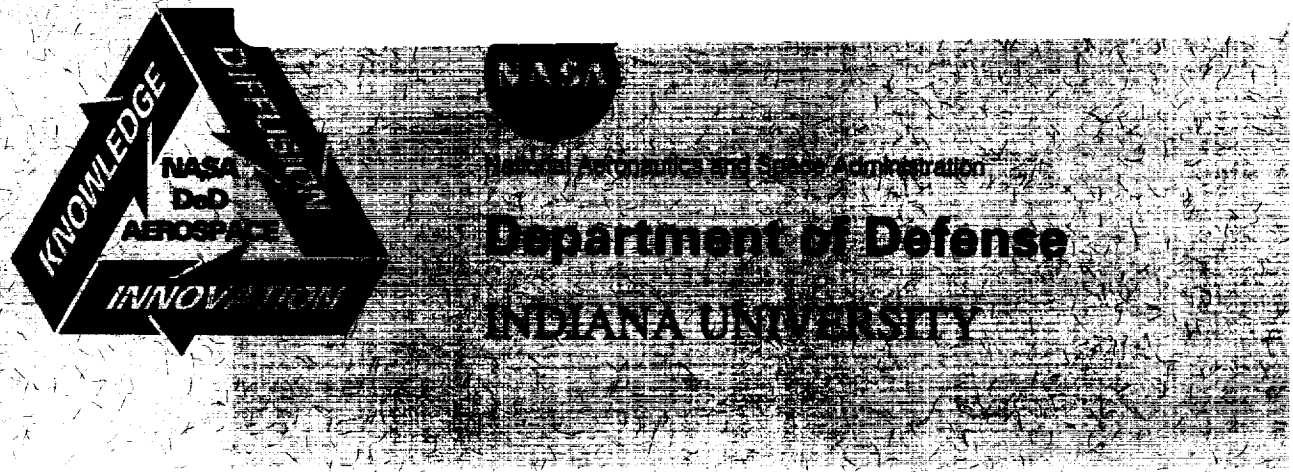

# THE VALUE OF COMPUTER NETWORKS IN AEROSPACE ENGINEERING

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## Abstract

This paper presents data on the value of computer networks that were obtained from a national survey of 2000 aerospace engineers that was conducted in 1993. Survey respondents reported the extent to which they used computer networks in their work and communication and offered their assessments of the value of various network types and applications. They also provided information about the positive impacts of networks on their work, which presents another perspective on value. Finally, aerospace engineers' recommendations on network implementation present suggestions for increasing the value of computer networks within aersospace organizations.

## Background

The Federal government and individual aerospace engineering organizations are implementing computer networks in order to enhance productivity and competitiveness. Projected benefits may not be achieved, however, unless network systems are well-suited to the work and communication activities and environments of intended users. In order to gather information to address this problem, the author conducted a study aimed at describing and exploring the use of computer networks by aerospace engineers. The study investigates networking from the user's perspective and presents data on the types of networks and network applications used by aerospace engineers, the work tasks and communication activities supported by networks, factors associated with network use, and network impacts. The study collected data through site visits and interviews, a telephone survey, and a mail survey. (An overview of the study's methodology and preliminary results appears in an earlier publication by the author.) [1]

Data presented in this paper focus on the value of computer networks in the aerospace industry and were culled from the study's mail survey of 2000 aerospace engineers performing a variety of jobs (including R&D, design engineering, management, and production) in a diverse range of organizations. The survey sample was drawn from the list of subscribers to *Aerospace Engineering*, a trade magazine published by the SAE. The majority of the survey's 950 respondents were employed in private sector industry (54%) or in government (30%) organizations . Most characterized themselves as either engineers (46%) or managers (39%), with only a small percent identifying themselves as scientists (5%) or members of some other basic job type (10%).

In this paper, the concept of "value" is employed in several ways. The value of computer networking in aerospace is explored by examing selected survey responses on:

- Extent of computer network use;
- Perceived value of various network types and applications;
- Reported impact of computer network use; and
- Recommended improvements in the implementation of networks.

Together, these various perspectives describe the current and potential value of computer networks in the aerospace industry, as seen by a wide variety of individual engineers.

## Extent of Computer Network Use

In general, mail survey results paint a picture of widespread use of electronic networks in

aerospace engineering. The majority of respondents to the question "Do you ever use any kind of computer network in your work?" reported that they personally used networks (74%), while 11% used networks through some kind of intermediary, such as a secretary or a librarian. Only 15% declared that they never used any kind of computer network in their work (whether linked workstations within an organization, a personal computer connected to a printer down the hall or a supercomputer across the country, or a dial-up link or direct connection to the Internet). In describing the extent of computer networking at their workplace, 40% 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%) characterized the extent of networking at their workplace as use by "some" people, and only 7% reported use by "few" people with "little" organizational encouragement or even discouragement of network use.

Respondents also reported on their use of different types of networks. Computers connected to commercial networks that link users to people, tools, or information outside of their own organization--such as CompuServe--were used by the smallest percentage of respondents (about 26%); 44% used an external research network such as the Internet; 66% reported that they utilized an organizational network that linked them to resources beyond one workplace building; and 77% reported use of a local area network that connected them to people and resources within one workplace building.

The mail questionnaire also asked respondents to describe their use of various types of computer network applications. More than two thirds of respondents used networks for electronic mail or to transfer data or text files between computers. Somewhat more than half used electronic bulletin boards or remote login. Networks were used to access or transfer images by about 40% of respondents. About one third used online library catalogs, bibliographic databases, or videoconferencing, and about one quarter used electronic journals or newsletters. Networks were used by only about 15% of survey respondents for computer-integrated manufacturing (CIM), electronic data interchange (EDI), or the operation of remote experimental or test equipment.

Survey results indicate that networks are currently playing a valuable role in aerospace engineering, if one measures value according to extent of use. Networks appear to be of greatest value in supporting internal organizational connectivity, interpersonal communication, sending and receiving data and textual information, and access to remote computer programs and data stores.

But are all aerospace engineers equally likely to use, and hence derive value from, computer networks? Cross-tabulating various mail survey respondent characteristics with network use provides data that suggest some variation in network use among aerospace engineers. Men and women used networks about equally. Network use did not vary greatly by age, except that those over sixty were much less likely to be network users. Network use appears to increase with educational level. Engineers who had been in the aerospace industry for a year or less were least likely to use networks, while those people who had been in the field for five to 19 years were the most likely to use networks.

Some broad job characteristics also seem related to network use. Network use among survey respondents was more extensive in academia, as opposed to industry, government, or not-for-profit sectors. A greater percentage of respondents characterizing themselves as "scientists" used networks, as compared to those calling themselves "engineers" or "managers." In terms of primary job function, network use was most extensive among those engaged in teaching, research, advanced or applied development, and industrial engineering; those engaged in sales or marketing, service or maintenance, administration, and production appear to be the lightest network users. Mail survey results further reveal that aerospace engineers working in aerodynamics or flight dynamics were slightly more likely to use networks

than were those in other branches of aerospace. Finally, network use increased steadily with the size of one's parent organization.

Survey respondents reported the extent to which various communication channels were used to perform particular work tasks. These results indicate the value of computer networks, compared to other communication channels. Face-to-face communication was selected as the primary channel used in performing a recent, important work task in about 41% of the cases of task performance. Use of computer networks to access information, people, or computer resources occurred about equally (in about 13% of cases) with the use of printed material or the telepone. Fax, voice mail, and internal or U.S. mail were used much less often.

Results also suggest that networks are currently more valuable for performing some work tasks than others. Computer networks were used by 67% of those performing mathematical analyses. Networks were used by between 40% and 45% of those learning how to do something, producing drawings or designs, developing theories or concepts, or selecting design methods or procedures. Networks were used by between 30% and 40% of those identifying problems, conducting experiments or tests, producing prototypes or products, planning tasks or projects, solving technical problems, identifyng requirements, or writing proposals or reports. Networks were used by fewer than 20% of those identifying resources, producing specifications, or assuring conformance with requirements.

## Perceived Value of Networks

Aerospace engineers ascribed various degrees of value to different types of networks and network applications. Among users of each type of network, 62% judged local networks to be of great value in their work, while great value was assigned by 54% of users of organizational networks, 37% of users of external/research networks, and 27% of external/commercial networks. Networks were judged to be of greater value in contacting people within one's organization than in contacting external people in academia or government. And they were perceived as being of even less value in contacting colleagues in industry, clients or customers, and vendors or suppliers.

The following figures report the percent of aerospace engineers who considered networks to be of great value in accessing various types of information resources (only the responses of those people who actually had network access to each resource are reported):

- Computer code, programs 62%
- Drawings, designs 59%
- Experimental or test data 52%
- Internal financial data 52%
- Production control data 51%
- Technical specifications 46%
- Design change forms 44%
- Product, materials characteristics 44%
- Directories of people 41%
- Document citations, abstracts 40%
- Internal technical reports 39%
- Training materials 35%
- Company newsletters, bulletins 30%
- Codes of standards and practices 29%
- Manuals 28%
- Lab notebooks 27%
- Journal, magazine articles 26%
- Manufacturers', suppliers' catalogs 26%.

Similarly, the figures below show the percent of users of each network application who considered that application to be of great value:

- Transferring data or text files 68%
- Accessing or transferring images 64%
- Remote login 63%
- Electronic mail 63%
- CIM 60%
- Remote access to data, text files 60%
- Operation of remote devices 56%
- Online library catalog searching 49%
- Real-time messaging 45%
- Online bibliographic searching 42%
- Electronic bulletin boards 35%
- Videoconferencing 35%
- Electronic data interchange (EDI) 35%
- Electronic journals, newsletters 24%.

## Network Impacts

Another perspective on the value of computer networks in the aerospace industry is gained through aerospace engineers' own reports of the positive impacts of networking on their work and communication.

It is clear that the overwhelming majority of aerospace engineers surveyed perceived the impact of computer networks on aerospace to be positive. In answer to a question with pre-coded response categories, about one fifth of the respondents declared the impact to be "revolutionary," while slightly more than half indicated that networks were "very useful in many respects." About one fifth were somewhat lukewarm, declaring that networks had "certain worthwhile uses." Only about 5% of respondents indicated that they were "neutral or indifferent" about networks, had "reservations about their value," or considered them to be of "limited value and capable of causing serious problems."

Table 1 summarizes the responses of aerospace engineers when asked to describe, in their own words, the major impacts associated with computer networks (only the positive impacts are reported here). Content analysis procedures were employed to categorize the responses obtained. The numbers in parentheses indicate the number of responses in each category. Examples of the actual respondent comments that were assigned to each category appear in italics. These responses suggest that networks are of greatest value in enhancing work productivity and improving information access and handling.

Table 2 presents aerospace engineers' perceptions of the specific effects of computer networks, as elicited in a matrix related to network impacts. In completing the matrix, respondents indicated their assessment of the direction and degree of the impact of networks on various aspects of work and communication. Matrix results suggest that positive impacts related to the engineer's status and career arise less often than postive impacts associated with improved work performance and information access and exchange.

**Table 1. Open Responses on Computer Network Impacts**

1. Enhances productivity, quality of work processes and products (60)

   *There is a tremendous improvement in the quality of design work and accuracy of translating designs into manufactured products*

2. Improves information access, processing (38)

   a. Improves information access (21)

      *Vastly enhanced capability to access the"greatest" volume of "current" data and doing so in the "least" amount of time*

   b. Improves information storage, updating, transfer, and control (17)

      *They are certainly necessary for prompt information flow*

3. General (35)

   *A very significant positive impact!*

4. Improves efficiency (25)

   *Increases efficiency*

5. Improves communication (24)

   *"PROFS", no longer available at my work location, provided a major improvement in communication...*

6. Facilitates teamwork, integration of efforts, information and resource sharing (20)

   *Networks provide an invaluable link between individuals, work groups, divisions, and subsidiaries within a company*

7. Enhances competitiveness (12)

   *Greatly needed to stay competitive in the global market*

8. Saves money (9)

   *Will be highly cost effective*

9. Improves quality of worklife, job satisfaction (3)

   *People ... can have more flexibility in their work environment.*

## Table2. Perceived Impacts of Computer Networks

| *Aspects of Work and Communication* | *Respondents Reporting Effect Is To:* Decrease N | (%) | Increase N | (%) | *Respondents Reporting Effect Is a Major:* Problem N | (%) | Benefit N | (%) |
|---|---|---|---|---|---|---|---|---|
| Amount of information available | 18 | ( 2) | 771 | (87) | 20 | ( 3) | 562 | (76) |
| Exchange of information, ideas across organizational boundaries | 22 | ( 3) | 645 | (74) | 9 | ( 1) | 471 | (72) |
| Efficiency of contacting people | 36 | ( 4) | 609 | (70) | 23 | ( 3) | 434 | (64) |
| Ability to complete projects, develop products on schedule | 53 | ( 6) | 563 | (65) | 17 | ( 3) | 411 | (64) |
| Responsiveness to customers, clients | 17 | ( 2) | 563 | (65) | 20 | ( 3) | 417 | (65) |
| Ability to stay on cutting edge of new knowledge | 20 | ( 2) | 555 | (64) | 7 | ( 1) | 390 | (61) |
| Documentation, evaluation of work processes | 31 | ( 4) | 557 | (64) | 14 | ( 2) | 388 | (60) |
| Ability to express ideas, problems at point of need | 46 | ( 5) | 523 | (60) | 22 | ( 3) | 372 | (57) |
| Need for face-to-face interaction | 486 | (55) | 85 | (10) | 75 | (11) | 226 | (34) |
| Performance of work at home, on the road, off-site | 18 | ( 2) | 463 | (53) | 18 | ( 3) | 315 | (51) |
| Management control | 65 | ( 8) | 458 | (53) | 36 | ( 6) | 305 | (49) |
| Feasibility, size of collaborative efforts | 24 | ( 3) | 460 | (53) | 12 | ( 2) | 301 | (51) |
| Flexibility in work structures, patterns | 30 | ( 3) | 456 | (53) | 16 | ( 3) | 289 | (48) |
| Coherence with one's work community | 70 | ( 8) | 454 | (52) | 26 | ( 4) | 283 | (45) |
| Duplication of effort | 451 | (52) | 120 | (14) | 67 | (11) | 309 | (48) |
| Ability to complete projects within budget | 48 | ( 6) | 410 | (47) | 32 | ( 5) | 284 | (46) |
| Turnaround time on solving problems | 223 | (29) | 408 | (47) | 22 | ( 3) | 472 | (70) |
| Number of changes required in final products | 281 | (32) | 136 | (16) | 41 | ( 7) | 253 | (42) |
| Degree of status among one's peers | 7 | ( 1) | 259 | (30) | 11 | ( 2) | 122 | (21) |
| Sense of ownership of, commitment to work product | 62 | ( 7) | 251 | (29) | 28 | ( 5) | 159 | (27) |
| Rate of career advancement | 13 | ( 2) | 209 | (24) | 19 | ( 3) | 124 | (22) |
| Number of staff employed | 192 | (22) | 92 | (11) | 39 | ( 7) | 107 | (19) |

## Recommendations on Networking Offered by Aerospace Engineers

About two thirds of the mail survey respondents took advantage of an open question inviting them to communicate their thoughts on network impact to policymakers and managers. Their recommendations provide a view, from within the aerospace industry itself, of what is needed to achieve the maximum value from computer networks.

Respondents' recommendations paint a clear picture of what was uppermost in their minds as they considered the manner in which computer networks are currently incorporated into the workplace. The clustering of the majority of the responses around several suggestions and the vehemence and eloquence of many of individual comments are both noteworthy. The greatest cry among respondents was to improve the usability of networks by, first and foremost, making systems simple and easy to use and, second, by improving the means by which aeropace engineers are trained in network use. A smaller, but still substantial, number of respondents focused quite specifically on the need to incorporate direct knowledge of users' needs into the design and implementation of networked systems.

Improved access appears to be a major user need; recommendations in this area included increasing the number of networked stations in the workplace, allowing greater access to workplace systems from remote locations, increasing the number of resources (especially external resources) available on the network, and striving to ensure that network use was incorporated into the jobs of all aerospace workers and not just those in certain fields or occupations.

Achieving standardization and compatibility among systems clearly arises as the major technical improvement demanded by respondents; the multi-faceted and collaborative nature of engineering work seem to demand the ability to transform and transmit information easily to a diverse range of people. Greater bandwith and reliability were the other technical improvements sought by a significant number of respondents.

Security and resource issues appear to be major areas of concern, but, in contrast to the other recommendation categories, suggestions in both of these areas conflict somewhat with each other. While the majority of responses strongly advocated increased security controls, about a third warned against a myopic disregard for the importance of open information access and communication. Recommendations for the best means of dealing with the expense of networking were fairly evenly split between pleas for reduced costs and virtual taunts that organizational managers should stop nitpicking over costs and start focusing on the obvious benefits. A significant proportion of responses were criticisms directed toward workplace managers generally, faulting them for their lack of understanding (both technical and functional) of networks and the basic lack of proper planning and implementation in the realm of networking.

A final topic addressed by a fair number of respondents was the need to improve the content and retrieval of networked information. The less than overwhelming number of suggestions in this area may be due to the general feeling--apparent from other survey data--that existing increases in access to information overshadow the remaining problems. Or perhaps respondents subsumed specific calls for improving network navigation and retrieval under more general comments about making systems more user-friendly.

One important impact-oriented theme emerging from the recommendations made by aerospace engineers is the integration of workplace efforts made possible by networks. Without more ubiquitous access, greater expertise in the workforce, and the ability to easily link and transfer information across disparate systems, organizational productivity that depends on coordination and collaboration of individuals and departments cannot be maximized.

## Conclusions

Computer networks are clearly of great value to a wide range of engineers in the aerospace industry. Value is evident in the extent to which

computer networks are used, the explicit value assessments offered by engineers, and the reported benefits resulting from network use. Networks are not only used by a majority of aerospace engineers, users report important improvements in work quality, efficiency, and integration due to networks. Nonetheless, the value currently derived from computer networks varies according to several individual, task, and organizational characteristics. Some network types, applications, and features are deemed more valuable than others. Finally, aerospace engineers enumerated a range of social, technical, and administrative problems that must be overcome if computer networks are to achieve maximum benefits in the aerospace industry.

Network usability, training and support, access, compatibility across systems, capacity, and security all appear to need significant improvement. In addition, many managers in aerospace organizations appear to lack a fundamental understanding of the manner in which computer networks transform work processes; this lack of knowledge leads to problems in implementing networks and predicting costs and benefits.

## References

1. Bishop, Ann Peterson. The Role of Computer Networks in Aerospace Engineering. Library Trends, vol. 42, no. 4 (1994), 694-729.