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# SCIENTIFIC AND TECHNICAL INFORMATION EXPLOSION

*BARRY R. EMRICH*

TECHNICAL REPORT AFML-TR-70-182

NOVEMBER 1970

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## FOREWORD

This special report was prepared by the Aerospace Materials Information Center (AMIC) which is sponsored and operated by the Air Force Materials Laboratory, Air Force Systems Command at W-PAFB, Ohio 45433. The AMIC Program is accomplished under Project 7381 "Materials Application" and Task 738103 "Materials Information Development Collection and Processing". Mr. Harold B. Thompson is Program Director.

This technical report has been reviewed and is approved.

EDWARD DUGGER
Chief, Material Information Branch
Materials Support Division
Air Force Materials Laboratory

# ABSTRACT

A concise review of statistics concerning the expanding volume and user needs of scientific and technical information is presented. It is intended to acquaint one with the magnitude of the so-called "Information Explosion" problem and illustrate how the various forms of communication play a role in meeting the needs of the technical community. Statistics are provided on the increases in communication transfer through books, journals, semiformal media and informal means.

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# AEROSPACE MATERIALS INFORMATION CENTER

## SCOPE

The Aerospace Materials Information Center collects, interprets, organizes into retrievable form and disseminates technical information on all materials of concern to the Air Force Materials Laboratory in conjunction and coordination with other Air Force Materials Information Centers.

## SUBJECT FIELDS

Materials covered by this Center are adhesives, coatings, lubricants, fibrous materials, composites, oils, polymers, metals, ceramics, various types of manufacturing procedures, methods of materials evaluation and all non-biological materials of interest to the USAF.

## COLLECTION

A collection of more than 45,000 scientific and technical reports on the above listed materials is now in retrievable form. The monthly accession rate is 500 reports. Although the primary source of documents is internal and contractor generated reports, reports from other government agencies, their contractors and general industry are also included.

## INFORMATION SERVICES

The center provides coordinated use of all pertinent information sources to AFML personnel. Makes technical replies to inquiries from other sources especially on subject matter not covered by other information centers. Prepares review reports and handbooks such as the Aerospace Structural Metals Handbook and the Space Materials Handbook.

QUALIFIED USERS: Defense Scientific and Technical Community

ADDRESS: Aerospace Materials Information Center
Air Force Materials Laboratory
(LAM), W-PAFB, Ohio 45433
Telephone (513) 255-2160 or 255-5177
TWX 810-459-1682

# INTRODUCTION

The steadily expanding volume of scientific and technical information, the emergence of new disciplines and of new links between existing ones, and the increasing number and diversity of user groups and user needs are three urgent aspects of the information problem. Scientific and technical information constitutes the principal result of an annual research and development expenditure in the United States alone that is mounting above $27 billion. The Federal Government now supports three-fourths of all science and technology of the U.S. and the remaining 25 percent of U.S. R&D is financed through the private sector. Thus the effectiveness of future work in universities, government laboratories, and industry depends on the efficiency of information transfer.

The greatest single villain in the scientific publication picture is simply the enormous increase in scientific and technical literature, the so-called "information explosion." Statistics on the increases in different forms of communication, such as books, journals, scientific papers, semiformal media, and informal communication are not always consistent but generally substantiate the accelerating growth. A brief review of some of these statistics gives an indication of the magnitude of the problem.

## JOURNALS

In the area of science and technology between 35,000 and 50,000 technical periodicals are published annually throughout the world. These journals contain nearly two million technical articles. Three new journals are being founded every day while one dies. The quantity of scientific papers is increasing by about 6 percent each year. Figure 1 illustrates this proliferation of information.

The estimates range from 5% to 8% annual increase and from 10 to 15 years doubling span. This means that if the scientific output was 2000 pages a minute in 1962, it will be 4000 pages a minute sometime before 1975 or a scientist who found it necessary to read 20 pages a day in 1962 will have to read 40 pages a day in 1973 which will indeed double his time spent on reading.

A survey of 18 engineering societies showed the increase in number of pages published in three types of primary publications: (a) proceedings, 1000 pages in 1946 to 26,700 pages in 1966, a 2500 percent increase; (b) transactions, 11,800 pages in 1946 to 62,000 pages in 1966, a 420 percent increase; and (c) periodicals, 4,400 pages in 1946 to 10,000 pages in 1966, a 125 percent increase. The American Institute of Physics, for example, reports that the number of pages it published each year increased from nearly 8,000 in 1940 to 54,000 in 1966, a 575 percent increase over a 27-year period. The Institute of Electrical and Electronics Engineers (IEEE) reports an increase from 3,000 pages in three journals in 1946 to over 30,000 pages in 42 journals in 1966, a tenfold increase in 21 years. Kargin, a noted authority on polymer chemistry, pointed out that nearly 100 works are published every day throughout the world on polymers alone.

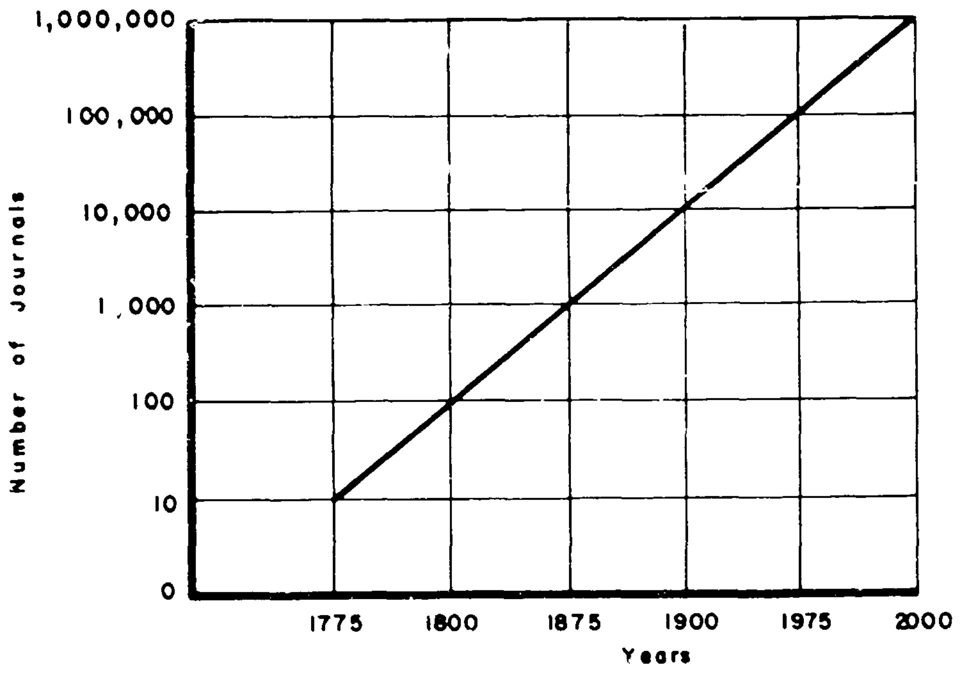


Figure 1. The Information Explosion in Science and Technology (Reference 2)

The Office of Aerospace Research (OAR) responsible for the total Air Force basic research program and a small portion of the exploratory development area efforts results essentially in a single product: Scientific and technical information. This information is documented in approximately 4,000 reports a year, more than 3,000 of these reports appear in some 500 scientific or professional journals. OAR supports about 50 to 60 conferences and symposia each year to allow for rapid and more effective exchange of information. (Reference 17).

The fundamental mission of engineering societies has been accomplished largely through publications. In 1966, for example, eighteen leading engineering societies spent nearly one-half of their total combined budgets, or about $14 million, on literature programs totaling more than 177,000 published pages of communications.

The frequency with which an article from a journal is used is inversely related in a linear fashion to the age of the article. Approximately 95 percent of all journals read are less than 20 years old, and nearly 50 percent are less than 5 years old. (Reference 3)

BOOKS

The number of books published per year for science and technology as a whole has also been increasing. The 1963 Census of Manufacturers shows that the annual number of these books sold from 1958 to 1963 almost doubled (from 15.6 million to 29.6 million copies). Though the number of books published is quantitatively different from the number of titles published, data of both types give evidence of growth. The Library of Congress estimates that their Library holdings in the category of scientific and technical monographs and books number well over 2 million titles. The prospect of university collections doubling from three million to six million volumes in the next 15 years, with a concurrent trebling of cost suggests either gradual concentration on a narrower specialty or improved methods of information transfer. It has been pointed out that if a scientist could read technical material at a rate of 200 to 300 words per minute and if a man were to try to catch up with a single year's output, reading 24 hours a day, 7 days a week, it would take him 50 years. (Reference 1)

INFORMAL COMMUNICATION

The informal and semiformal communications, such as personal contacts, letters, memoranda and reports with limited distribution plays an important role in the dissemination of scientific and technical information.

Accurate, quantitative comparison of the effectiveness of the very informal interpersonal techniques of communication — conversations in the laboratory or at lunch, telephone calls, casual get-togethers at meetings — with that of other communication methods would be difficult to measure and achieve since it attempts to collect the necessary data which would interfere to some extent with the informality of the procedure, thus affecting the phenomenon being measured. The qualitative evidence makes it very definite that a substantial portion of communication about developments and discoveries in science and technology occurs in this manner.

Several attributes of informal information dissemination have had to place heavy reliance on it as a major means of transfering knowledge. Some of these attributes are the following: (a) timeliness; (b) the interactive nature — It is the principal source of feedback so highly valued by professionals; he invariably obtains immediate reactions to which he in turn reacts; (c) informal communication is user-directed; the decision on what, when and to whom to communicate rests mainly with the scientist. This greatly enhances the intelligibility of that which is communicated. Another consequence of user-directedness is the frequent fulfillment of an unrecognized, unvoiced information need; (d) increased possibility of including speculation, accounts of failures, and procedural details; (e) Generally involves a relatively small expenditure of effort and time. (Reference 1)

A principal function of informal communication relates to the knowledge-application interface. The importance of personal communication in the transfer and application of science and technology has probably played a large part in reducing the median time between discovery and application from some 30 years in the 1920's to about ten years in the 1960's.

Scientific meetings are important occasions for truly personal and more formal modes of information transfer. The scientific meetings (conferences, symposia, conventions) provide those attending with opportunities to talk informally, and is a particularly economical and effective method for bringing together small groups having similar interests. They also provide for formal sessions and somewhat less tangible benefits of the scientific fellowship and enthusiasm.

The Johns Hopkins University Center for Research in Scientific Communication obtained comparative data on a variety of aspects of the dissemination of information at the annual meetings of a number of scientific and engineering societies. (Reference 4) The analysis of the October 1966 Annual Meeting of the Optical Society of America (OSA) illustrates the types of data obtained in these meetings. Some of the principal findings were the following:

"1. The meeting attracted persons with a higher level of academic training than was typical of the field of optics as a whole.

2. Research and development were the paramount areas of effort of most participants, with authors of papers especially emphasizing basic research and the preparation of manuscripts on their work.

3. While most of the material presented dealt with single research projects, a fourth of the presentations were reviews of a series of experiments in which the speakers were involved.

4. Generally, work covered in a presentation began about a year before the meeting and became reportable a few months before it.

5. Though most of the work has been presented in oral and/or written form prior to the meeting, such dissemination tended to be of limited scope; therefore, more than three fourths of the authors planned further reports, typically as journal articles, very soon after the meeting.

6. Substantial percentages of all groups reported significant informal interaction at the meeting, with postmeeting follow-up planned in most cases.

7. Respondents who had modified, or who planned to modify, their own work as a result of information received from specific formal papers about which they were questioned, or from interaction about these papers, varied from a seventh (for session attendants) to a fourth (for authors).

8. Additionally, more than half of the attendants reported some modification of their work as a result of aspects of the meeting other than the specific papers about which they were questioned." (Reference 1)

A survey on user needs of 85 private organizations including 1500 persons interviewed and covering a population of 119,470 personnel was made by North American Aviation, Inc. (Reference 5). The main questions and summary of findings resulting from this survey are described below.

## What Information is Involved?

The class of information was over 60 percent design and performance (Figure 2)

Figure 3 shows that almost half of the information was in the engineering field, and almost 40 percent was in the scientific field.

As might be expected, the class and field of information sought are mostly related to the kind, class and field of the research. (Figures 2 & 3)

## By What Media Does the User Desire to Receive the Information?

The significant characteristics of the desired media for conveying information are defined in terms of their formality (composition and layout), volume (extent) of documentation and depth of detail (Figure 4).

More than one out of three users desired to receive information orally, and more than one out of three users desired to receive it semiformally written.

Nearly three out of five users desired a textual layout.

More than three out of five wanted more than one document.

Nearly all users wanted more detail than once over lightly (almost three out of five wanted a specific answer).

The volume and depth of information obtained was less than that desired in about one-seventh of the cases.

A. Those responses with over 3 percent are: "Oral Contacts-All Other" (18%) and "Oral Contacts with Manufacturer" (3.5%)

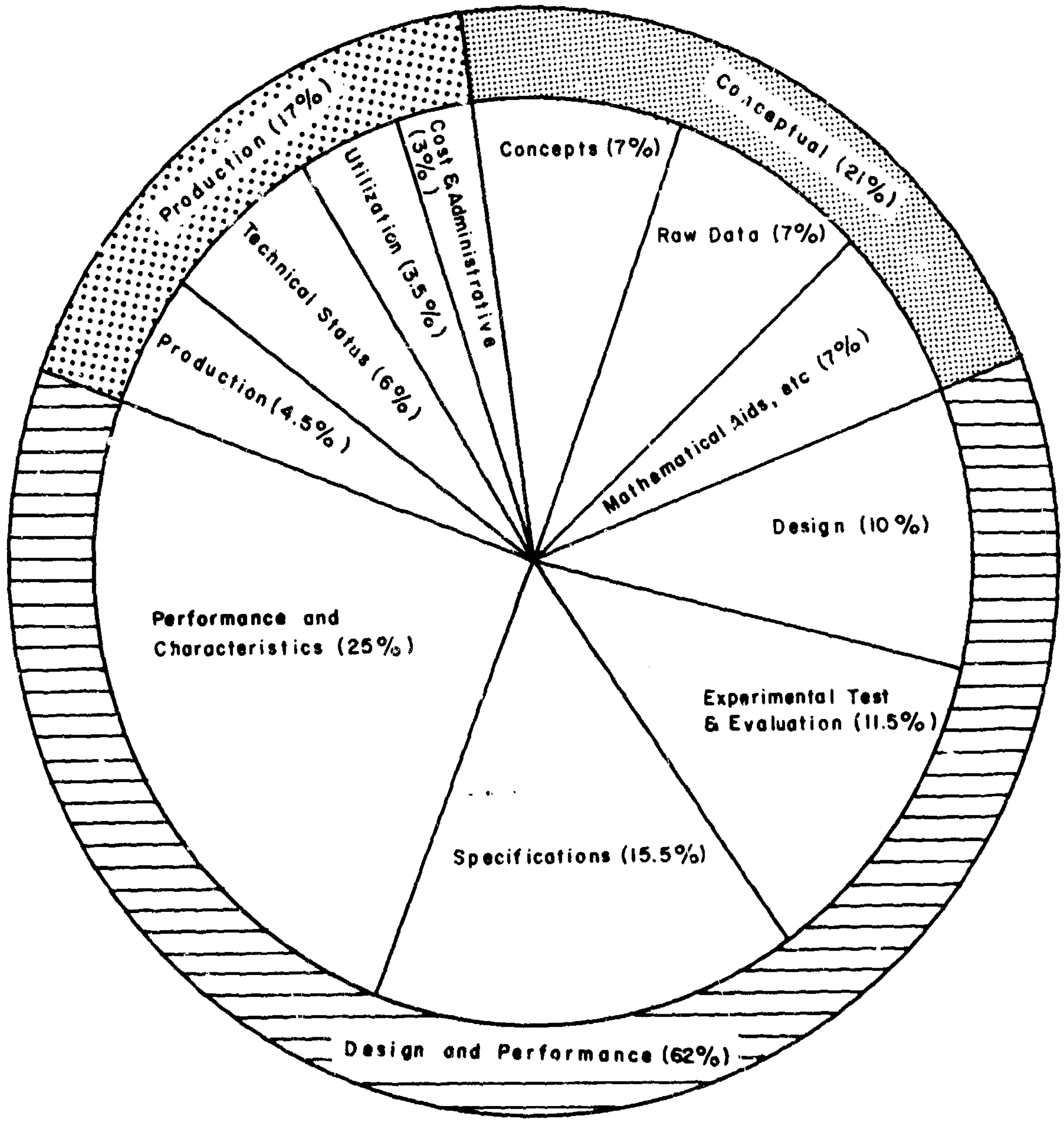


Figure 2. Class of Information

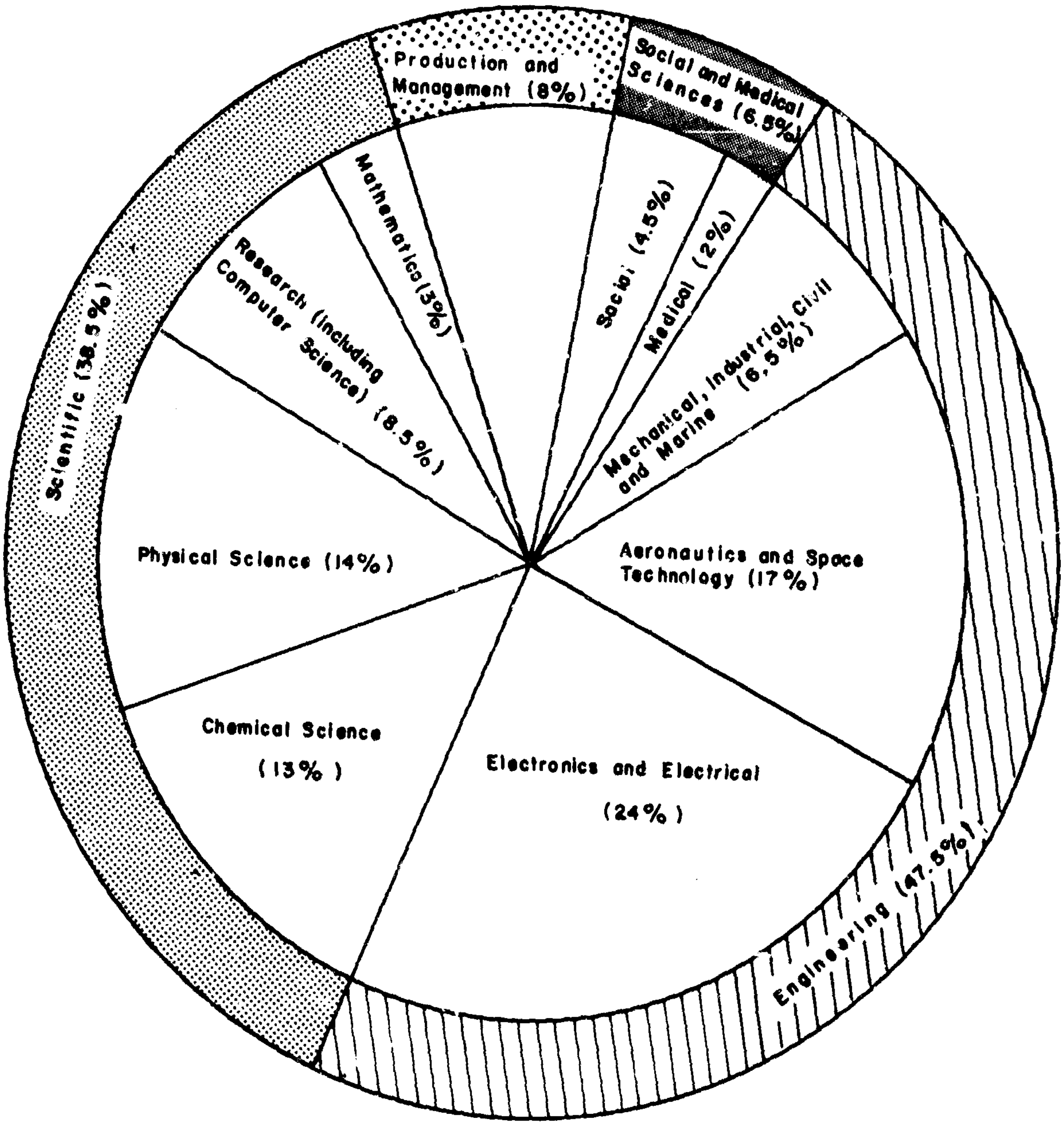


Figure 3. Field of Information (Reference 5)

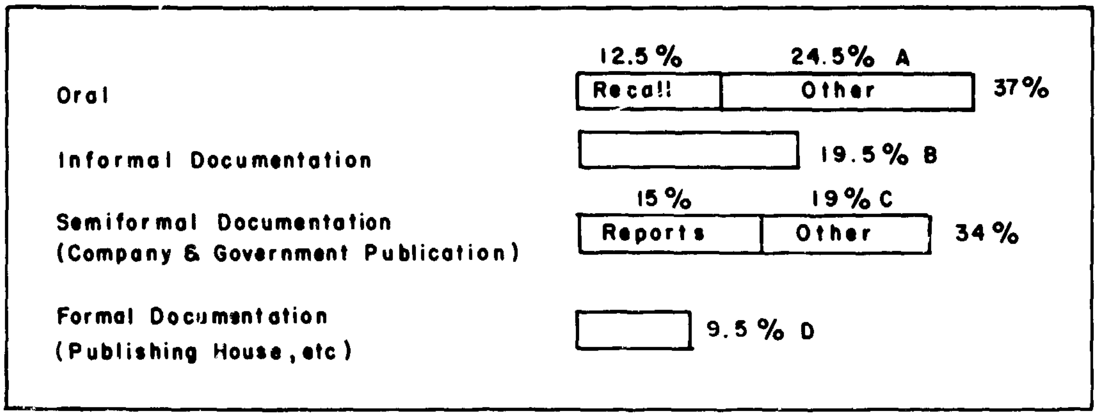


Figure 4. Desired Formality For Information Media (Reference 5)

B. These responses with over 3 percent are: "Personal Notes, Personal Logs and Personal Files" (3%); "Correspondence, Memos and TWX" (6%); and "Drawings and Schematics" (5%).

C. Those responses with over 3 percent are: "System Specification Document (QMR, TDP, Etc)" (4.5%) and "Manuals" (3.5%).

D. Those responses with over 3 percent are: "Journals" (4.5%) and Textbooks" (3.5%).

The analysis revealed an important relationship which indicates that the desired composition and layout of the media is mainly related to the desired extent of the media which, in turn, largely depends on the duration of the task.

To Which Source Does the User Go First?

About 30 percent of the users' information needs were satisfied without search, and 50 percent of his needs were sought within his local work environment (Figure 5). These sources almost always yielded part or all of the information needed.

The following significant relationships were found regarding the first source that was used:

The first source used is mainly related to the reason for its use and the composition and layout of the media. The sources more remote from the individual were used more often when they were known to have the desired information and for the more formally documented information.

As allowable search time increases, there is a tendency to use first sources that are at a greater distance from the user.

What was obtained from the first source depends on the desired composition and layout (formality) of the medium from which the information was to be obtained, and the amount of time available. As the desired formality and time available increased, the quantity of information gained from the first source decreased.

When Is the Information Needed and Acquired?

Almost 75 percent of the information is needed within 30 days, while over 80 percent is acquired within 30 days.

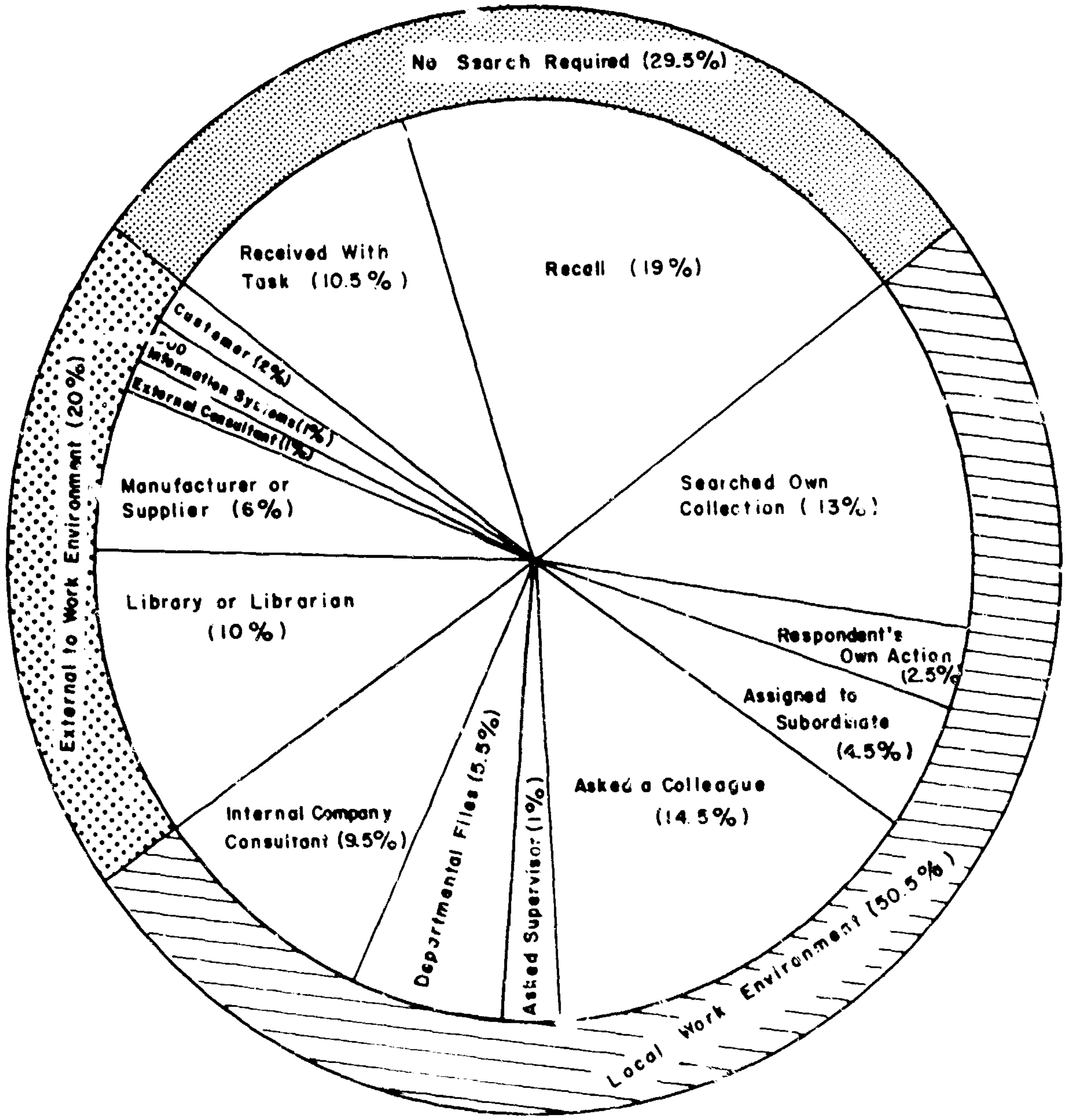


Figure 5. First Source Contacted For Information (Reference 5)

The following relationships were found involving the time by which information was needed and the time in which it was acquired:

The allowable amount of time for the search of information is related to the duration of the task.

The time to obtain the information is (1) related to the duration of the task, and (2) the desired composition and layout of the media.

Some very significant findings concerning the utilization of information centers and services were also provided in the North American Aviation study. A brief review of these results are shown in Figure 6.

A survey similar to the North American Aviation study covering DOD user needs was performed by the Averbach Corporation (Reference 8). Approximately 1500 of the 35,000 research, development, test and evaluation personnel in the DOD community were interviewed. One very significant result of this survey, shown in Figure 7, illustrates the quantity of the different forms of communication by which the information was transmitted to the user.

The important role that oral communication plays in the dissemination of scientific and technical information is substantially documented (References 6-16).

SEMIFORMAL COMMUNICATION

The semiformal media such as preprints, technical reports with Limited Distribution and memoranda offer greater speed, greater flexibility

| Service | IACs[1] | DDC[2] | TAB[3] | STAR[4] |
|---|---|---|---|---|
| Use It | 44 | 45 | 55 | ~20. |
| Know Of, But Do Not Use | 19.5 | 23.5 | 21.5 | ~14. |
| Do Not Know Of It | 36.5 | 31.5 | 43.5 | ~66. |

1 Information Analysis Centers (DOD).
2 Defense Documentation Center
3 Technical Abstract Bulletin
4 Scientific and Technical Aerospace Reports (NASA)

NOTE: All Values are in Percent

Figure 6. The Utilization of Specialized Information Centers and Services (Reference 5)

| | Frequency | Percent |
|---|---|---|
| A. Brochures, catalogs, standards and codes, drawings, schematics, parts lists, and system specification documents (QMR, TDP, etc.) | 872 | 11 |
| B. Oral contacts with manufacturer, oral contacts - all other; meetings and symposia | 2276 | 29 |
| C. Live demonstration, physical measurement or experiment | 260 | 3 |
| D. Directives, handbooks, and manuals | 579 | 8 |
| K. Correspondence, memos, TWX, personal notes, personal logs, and personal files | 634 | 8 |
| N. Newsletters and other mass media | 37 | 0 |
| R. Reports and proposals | 1289 | 17 |
| S. Texts | 446 | 6 |
| T. Photographs, maps and films | 60 | 1 |
| P. Pre-prints, reprints, and journals | 379 | 5 |
| V. Previous knowledge | 830 | 11 |
| W. Computer printout | 82 | < 1 |
| Z. Other | 46 | < 1 |
| TOTAL | 7790 | |

Figure 7. Media By Which Information Was Transmitted (Reference 8)

in adapting communications to context, and more details. They are of particular value in serving the needs of emerging scientific disciplines during their awkward "interdisciplinary" years. The number of items carried by the major government services for access to technical reports provide a rough estimate of the volume of this semiformal literature. In 1967, the Technical Abstracts Bulletin (TAB) of the Defense Documentation Center reported 47,000 items; U.S. Government Research and Development Reports, 45,000 items; and Scientific and Technical Aerospace Reports (STAR), 31,000 items. Since overlaps exist among these organizations, these figures are not additive. TAB reported 32,000 items in 1963 as compared with 47,000 in 1967, an increase of 44 percent in five years. Growth rate for the various services are still in the process of being completed.

Two projects, in particular, are relevant to preprint distribution; the first is a six-year operational study conducted by the National Institutes of Health (NIH), and the other, a feasibility study carried out by the American Institute of Physics (AIP), with partial support from the Atomic Energy Commission (AEC). "The former, which NIH called its Information Exchange Group (IEG) program, was initiated in 1961 to examine experimentally various aspects of the informal, rapid exchange of information common within small groups of scientists with similar research interests. Basic to the design of the experiment was the belief that each special-interest or profile group contains a core of 'elite', representing roughly five percent of the total group. Members of this core group are 'in the know' at all times, since they function as referees and editors and as competent critics in relation to their students, staff members, or colleagues. Further, they exchange information with one another for reaction and stimulation. A principal objective of the experiment was to make information as rapidly available to the entire profile group as it was to the core of elite so that all would be able to base their day-to-day research decisions on the latest information. A second basic belief was that a rapid flow of information would accelerate scientific advance throughout a profile group. The experiment was intended to gather data relevant to this thesis--i.e., to document those instances of a saving of research time or money that resulted from having had access to a preprint that was distributed well in advance of a journal article." (Reference 1)

"The mechanics of operation, as planned by the NIH, were relatively simple. The Institutes established a communication center to which the research papers originating within a group of scientists with common research interests could be sent, there to be duplicated (by photo-offset), with copies mailed promptly to all members of the group. The Institutes exercised no control whatever within any group, referring any problems with regard to input to each group's chairman for decisions. Also, the NIH made no changes in any scientific communication, but served, in effect, only as a mail drop. The program was carried on for three years with a single group of research scientists before others were added. Eventually, there were seven. Figure 8 presents the subject areas of these groups, the initial and final membership of each, and the total number of communications circulated." (Reference 1)

| Groups | Final Age (Years) | Total Membership | | Total Communications Sent |
|---|---|---|---|---|
| | | Initial | Final | |
| I Oxidative Phosphorylation and Terminal Electron Transport | 6.00 | 32 | 735 | 774 |
| II Hemostasis | 2.92 | 19 | 127 | 176 |
| III Computer Simulation of Biological Systems | 2.75 | 40 | 171 | 69 |
| IV Molecular Basis of Muscle Contraction | 2.29 | 95 | 296 | 141 |
| V Immunopathology | 2.42 | 72 | 611 | 320 |
| VI Interferon | 2.21 | 98 | 250 | 275 |
| VII Nucleic Acids and the Genetic Code | 2.00 | 222 | 1,472 | 806 |

Figure 8. Age, Growth, and Communications of Information Exchange Groups in the NIH Experiment

Among the main findings of the experiment are the following:

"1. Each of the subject groups became the nucleus of a growing body of scientists which, probably, would have increased to the point of approximate saturation in the research fields involved had the experiment continued.

2. Approximately half the communications were full research reports, already submitted and sometimes accepted for publication.

3. Participants generally appeared uninterested in back-and-forth comments and frequently unwilling to call attention to points of error or disagreement; however, there were indications of much private 'back-flow' from readers to authors.

4. Of two groups questioned after the program had operated nearly four years, nearly all (98-99 percent) indicated that participation in IEG helped them to keep up with current literature, and more than four fifths (83-84 percent) believed that the rate of progress in their fields increased as a result of IEG.

5. In response to a final questionnaire, 466 participants reported 1,111 instances in which advanced information received through IEG influenced their research decisions, cited 346 instances in which such information prevented unnecessary duplication, and described 15 instances in which they were misled by, detected an error in, or disagreed with the advance data.

6. The 466 scientists also provided quantitative estimates of time and money saved or lost as a result of IEG information; the 421 reported instances amounted to an estimated total saving of 1,959 months and over $500,000 (or a net saving of about 75 cents per document copy mailed)." (Reference 1)

"The NIH concluded that the IEG experiment had fulfilled its initial objectives, and as it had been set up as a feasibility test, with no contemplation of or provision for a continuing NIH-based preprint distribution service, the experiment was terminated some six years after its inception. The NIH also suggested that this kind of quick-communication program is well worth considering for subject areas that are highly focused and readily definable, and that such a program will function most efficiently and with least friction when managed by an appropriate society or other group also involved in journal publication in a given field." (Reference 1)

The second project grew out of an AIP-AEC discussion of the AEC's tentative plans to establish within its own organization a centralized preprint distribution system in the field of theoretical high-energy physics. Following this discussion and an Information Symposium sponsored by the American Physical Society, it was decided that AIP would conduct a study to determine the desirability of a centralized service for distributing informal communications in this field. If the results were affirmative, the AIP would then draft the rough design of an experimental service. This AIP study began in April 1966 with interviews of 45 high-energy physicists and the mailing of questionnaires to more than 550 more; a separate questionnaire was sent to 36 U.S. and 47 foreign institutions likely to have 'preprint libraries' of one kind or another. The main questions raised in the interviews and the personal questionnaires were the following: (a) Would the innovation under consideration affect the journal publication system adversely; and (b) if so, all things considered, would any such effect be outweighed by the benefits of the innovation? The crucial question then asked was: 'Considering the advantages and disadvantages you have listed, should a centralized preprint service in theoretical high-energy physics be tried on an experimental basis?' A breakdown of the 543 replies showed that 42 percent were wholly in favor; 36 percent indicated, 'yes, with reservations'; 13 percent were against the idea; and 9 percent were undecided. These results, together with the interview findings, which were compatible, suggested that at least an experiment in centralized preprint distribution was warranted, with a final decision regarding establishment of a full-fledged continuing service to await the results of such a test. Consequently, the AIP designed a trail system that would combine the following services: announcement of preprints; maintenance and circulation of a directory of high-energy theorists; and provision, at the discretion of the author, of copies of preprints on request and/or automatically in preselected categories." (Reference 1)

"The Division of Particles and Fields of the American Physical Society, which was regarded as the most appropriate group to have cognizance of such an experimental service, is considering the proposal but has not reached a decision on its implementation. In the meantime, the AEC and its laboratories probably will begin to provide this kind of service within the nuclear-energy community." (Reference 1)

RELEVANCY

Some 30 years ago the conscientious scientist could maintain awareness of most of the information in his own and other relevant specialities. In the 1960's the amount of relevant information is not only greater, but at the same time more rapidly produced. Figure 9 depicts a qualitative difference for the typical scientist.

To alleviate this problem the authors of the Weinberg Report strongly urged the vital functions of consolidation and review as a major step toward its solution.

TRANSLATIONS

The non-English-language portion of the world's scientific and technical literature required by U.S. scientist and technologists has been estimated to be as much as 50 percent. An indication of the

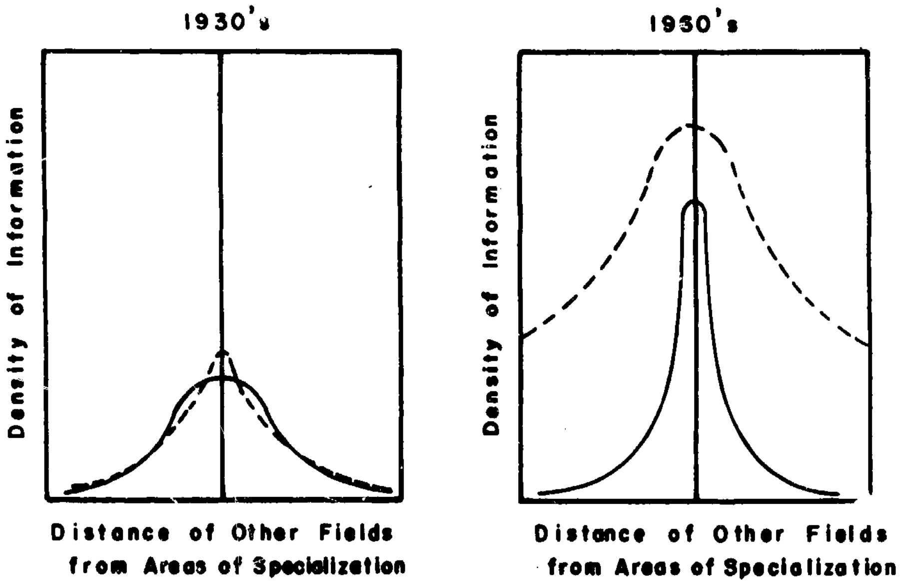


Figure 9. Amount of information of which a scientist is aware (solid lines) as compared with the amount of information relevant to his specialty (dashed lines). (Reference 1)

growth of Journal Translation Activity in the United States is depicted below in:

TABLE I

GROWTH OF JOURNAL TRANSLATION ACTIVITY IN THE UNITED STATES (REFERENCE 1)

| Year | Number of Titles Published |
|---|---|
| 1955 | 55 |
| 1958 | 108 |
| 1961 | 154 |
| 1964 | 224 |
| 1967 | 283 |

## CONCLUDING REMARKS

The growth of literature is well documented and is creating some concern to scientists as to whether knowledge is growing too fast for men to adjust. The industry of education, communication media, information services, research and development and information machines, sometimes referred to as the knowledge industry, accounted for 26% of the GNP or $136 billion in 1958 and 33% of the GNP or $195 in 1963 may be related to both the rate of innovation and the emerging need. It is critical that knowledge relating to real life grows with the literature growth. (Reference 18)

Scientific and technical communication activities must be as responsive as possible to the needs, desires, and innovative ideas of the groups that they serve. These activities should be sufficiently flexible to adapt rapidly to changes in user needs and information transfer techniques. Future philosophy for scientific and technical communication should recognize the need for continuing change in the ways of doing the work of science and technology. One of the necessary steps to maintain an effective information system is to call upon scientists and engineers to take a greater personal role in its development.

"Expression is a Better Means of Communication Than Impression"

B. R. Emrich

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13. ABSTRACT

A concise review of statistics concerning the expanding volume and user needs of scientific and technical information is presented. It is intended to acquaint one with the magnitude of the so called "Information Explosion" problem and illustrate how the various forms of communication play a role in meeting the needs of the technical community. Statistics are provided on the increases in communication transfer through books, journals, semiformal media and informal means.

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| Formal Communication Techniques | | | | | | |
| Information Needs | | | | | | |
| Scientific Information Problems | | | | | | |
| Scientific Information Growth | | | | | | |