DESIGN AND TEST OF A SPONSOR'S MEASURE OF EFFECTIVENESS
FOR SCIENTIFIC AND TECHNICAL INFORMATION CENTERS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

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* * * * * *

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PREFACE

The motivation for this study stems from two sources: first, the need for an appraisal; and second, the challenge posed by a complex problem. The need for appraisal appears to be felt widely among designers and managers of information storage and retrieval systems. Do the systems accomplish something more—or do something in a better way—than would have been done without them? Does the difference justify the effort? These questions are fundamental to the improvement and continued existence of centers of the type studied. Complexity of the job arises in part from the same people who perceive a need for evaluation. Like practitioners from many new disciplines (e.g., digital computer programming, or hybrid computer applications), they sense the presence of some undefinable but important element in their work. Can some simple, economical, practical measure do justice to their efforts? If criteria are based on "What do users do with the information they get?" some meaningful insights may be obtained. This study opens the question at the level of "use," "retain," or "discard" the information. Better answers will depend on greater depth of analysis of user behavior within these general patterns.
ACKNOWLEDGMENTS

Tracing out the sources of ideas, productive effort, and criticism for this work is a far-reaching task. It indicates that most of any possible value in the study is contributed in some way rather than added by the investigator. Categorically, the following groups provided direct help without which the job would not have been done.

1. The graduate faculty of The Ohio State University (names shown in the accompanying vita) provided essential training and guidance.

2. The technical community using center outputs supported use of the interview guide and questionnaire in a serious and meaningful way. They pointed out many factors to improve the measure and experiment.

3. Sponsors of scientific and technical information centers have provided the environment and climate in which this work could be done.

4. Center managers cooperated with outstanding objectivity and candor. Particular acknowledgment must be made to the staff of Metcut Research Associates, Inc., as pioneers in both technology and information science who gave unlimited access, direct support, and complete freedom as to method.

Additionally, the forebearance and assistance of one's family must be noted. The role of editor and production manager is no easy one for a busy wife and mother. Finally, I must look back to the one who taught me always to seek learning as the one possible source of real value—my mother, Margaret Lee Holt, to whom I dedicate this work.
VITA

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Studies in Finance: Professors Leo D. Stone, Elvin F. Donaldson, and John K. Pfahl

Studies in Economics: Professors Robert D. Patton, Alvin E. Coons, and Paul C. Craig
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CHAPTER I

INTRODUCTION

The prevailing level of technology acts with other factors in an economy to determine the productivity of labor and in turn the production function. As a result, the total supply curve is affected; and since national income is derived from output, the total demand curve is also a function of the level of technology. Although short-run economic models tend to employ a static state of the art as given, an economy with a rapid growth rate is likely to involve dynamic and changing productive techniques. Historically, the two most important growth factors in the United States economy appear to have been population and technology. Within such an economy, business firms and other organizations need better scientific and technical information. The solution to this problem involves—among other developments—new measures of effectiveness to evaluate institutions which provide such information.

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Nature and Importance of the Problem

Managers whose organizational income and costs are dependent on the level of technology need technological intelligence. Frequently the required information exists somewhere, but the publication of information on technology exceeds the capabilities of using the record effectively. Better media and institutions for transferring information are needed—and their effectiveness should be measured as a basis for improvements. This problem confronts industrial, educational, and governmental organizations alike. The attitude of the industrial manager can be summarized by the following statement:

Information is a valuable commodity. We are all concerned because the retrievability of this information does not match today's needs. Because of the intense technological competition in industry and the exponential growth of information, new methods are needed to assure management that engineers are getting the information that they need quickly, completely, and economically. In the world of engineering the price of ignorance is technological surprise. The greatest wisdom and effort will be required to utilize our growing capabilities. How effectively any organization uses the information available to it will significantly contribute to the status of that organization in the future. An educational manager points out that academic personnel encounter difficulties in knowing what information is available and in assimilating that which has been found. The involvement of governmental managers

---


with information concerning technology—apart from the matter of economic planning measures—has been stated as follows:

The breadth of the Government's interest in this area has expanded tremendously since just before World War II, primarily because of the rapid growth of RDT & E contracts and R & D grants. These RDT & E projects now penetrate into almost all facets of our scientific and technical community.

And, of course, one of the central aspects of any program should be the retention of useful information and the culling and discarding of obsolete information. The tree of knowledge bears both fruit and leaves. The fruit should be gathered and preserved; the leaves on the other hand should be allowed to fall and disintegrate—and not be preserved along with the fruit.7

The Technological Frontier

With the present accelerated rate of technological change, a new frontier of great economic promise has opened. This technological frontier has been described by the United States Assistant Secretary of Commerce for Science and Technology as follows:

If there is a single, definable characteristic of nations in the mid-twentieth century, it is that science and technology are the determining factors in national growth and national strength. The most obvious manifestation of this truism is seen in the shift of source of military strength from manpower to brainpower. In fact, the modern establishment of any major nation would be almost unrecognizable, by virtue of the high technological content, from the historic concept of what is needed for national defense. But the most important benefit from applications of our technological resources is to economic growth. Our ability to maintain enormous present-day military and space programs, and future programs as yet unforeseen—is absolutely dependent upon our civilian economy's ability to support these programs.

Technological resources consist primarily of knowledge, and people who are able to understand this knowledge and apply it to the needs of man. Within this context, the dissemination of scientific and technological information, where it is

needed and when it is needed, becomes a matter of crucial concern to us all.

The exponential growth of science, scientists, and hence scientific information has reached the point where the published output is no longer manageable by traditional methods. The last decennial cumulative index of Chemical Abstracts ran about 20 volumes, or 30,000 pages. In five years, or half the time, 40 volumes will be required. No wonder it is often cheaper today to start from scratch to do re-research than to search the published literature.

Development of electronic information handling systems will take care of only part of the problem—the storage and retrieval of basic data primarily, which also must be refined and critically evaluated.

Other mechanisms and institutions are needed. The volume of published information is not only overwhelming; its half-life is getting shorter through accelerated obsolescence. We must encourage and facilitate . . . the interchange of ideas.\(^8\)

The rate at which new discoveries are made is largely a function of the number of people working at the interface between the present state of the art and the unknown. In reviewing the increasing number of scientists since the mid-seventeenth century, a leading educator points out that as a population doubles, its number of scientists increases by a factor of ten. One result of this growth rate is that about 90 per cent of all the scientists that have ever lived are still alive. At any point during the last three centuries this same 90 per cent survival would have applied equally well.\(^9\) In the United States there were an estimated 2,370,000 scientists, engineers, and technicians in 1960.

The projection to 1970 is that there will be 4,000,000 or approximately


4.7 per cent of the total labor force. The recent historical perspective of scientific manpower in the United States is shown in Table 1 on page 6. The long-run view of the technological frontier foresees that this sector of the economy may stabilize at a high level of activity.

My guess is that we began to meet the special problems of Big Science—the new basic problems of manpower and literature—around the beginning of World War II, but that the crisis was then masked by the extraordinary conditions of wartime. It would follow from this that within the next decade or two we must approach the end of a 300 year long scientific and industrial revolution. After a prolonged adolescence we must begin to plan for a new phase of scientific maturity.11

The economic promise of the technological frontier will be realized only if the nation’s institutions for accomplishment of economic goals can accept and exploit information relating to technological advances. To a large extent, business firms do so today. The extent to which scientific and technical information enters into operations of today’s industrial organizations has been shown by Mr. W. J. Mayo-Wells, a consultant for the organization of a national scientific and technical center. In a typical organization various types of technical information are used within the functions of finance, research and development, design, engineering, sales and advertising, office facilities, and personnel. The same author also relates scientific and technical information to management responsibilities of profit control.


11 Price, loc. cit.
### TABLE 1
HISTORICAL PERSPECTIVE OF SCIENTIFIC MANPOWER

<table>
<thead>
<tr>
<th>Group</th>
<th>1940</th>
<th>1950</th>
<th>1960</th>
<th>1963 (Est.)</th>
<th>1970 (Est.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Population</td>
<td>132.0</td>
<td>152.3</td>
<td>180.7</td>
<td>190</td>
<td>209</td>
</tr>
<tr>
<td>Labor Force</td>
<td>56.2</td>
<td>64.7</td>
<td>73.1</td>
<td>76</td>
<td>86</td>
</tr>
<tr>
<td>Science &amp; Technology Manpower</td>
<td>0.86</td>
<td>1.47</td>
<td>2.37</td>
<td>2.7</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Percentage of Labor Force

| Science & Technology Manpower      | 1.5  | 2.2  | 3.2  | 3.6         | 4.7         |

Thousands

| Scientists                         | 145  | 245  | 435  | 500         | 740         |
| Engineers                          | 300  | 545  | 840  | 935         | 1,400       |
| Technicians                        | 300  | 550  | 875  | 1,000       | 1,600       |
| Teachers of Science & Mathematics in Secondary Schools | 110  | 130  | 220  | 250         | 300         |
| Physical Scientists, Mathematicians| 65   | 120  | 225  | 225         | 390         |
| Life Scientists including          |      |      |      |             |             |
| Psychologists                      | 50   | 80   | 140  | 160         | 235         |
| Social Scientists                  | 30   | 45   | 70   | 85          | 115         |
| Civil Engineers                    | 80   | 135  | 160  | 170         | 240         |
| Electrical Engineers               | 50   | 110  | 180  | 220         | 325         |
| Mechanical, Aeronautical & Astronautical Engineers | 75   | 130  | 210  | 240         | 370         |
| Industrial, Chemical & Other Engineers | 95   | 170  | 290  | 305         | 465         |
| All Scientists & Engineers         | 445  | 790  | 1,275| 1,435       | 2,140       |
| Doctoral Scientists & Engineers    | 28   | 45   | 89.2 | 106         | 170         |
| Doctoral Scientists                | 27.5 | 43.5 | 81.7 | 96          | 153         |
| Doctoral Engineers                 | 0.5  | 1.5  | 7.5  | 10          | 17          |

*U.S., Committee on Scientific & Technical Information, op. cit., II, p. 7-3.*
maintenance of product standards, achievement of personnel and customer satisfaction, and meeting competition. Mr. Mayo-Wells' categories for management responsibilities are easily related to the more generally accepted management functions of planning, organizing, staffing, directing, and control.

Emergence of the technological frontier has stimulated developments in information and communication theory, hardware design, national planning, and the formation of numerous first-generation efforts to cope with various segments of the over-all information problem. This study is concerned with these early efforts. Questions of particular interest include (1) the volume and diversity of output of information in science and technology, (2) resulting problems in collection and use of information, and (3) emergence of scientific and technical information centers as institutions to fill these growing needs. Once these aspects of the technological frontier have been discussed, consideration will turn to the unfilled need for professional management in the field of scientific and technical information.

Output of information in science and technology

More information is potentially available to the individual scientist or engineer today than ever before in history. Statistical studies with respect to scientific papers have shown that the numbers

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of papers written are related to the numbers of scientists by a function which enables either to be computed from the other. The number of authors who each write a given number of papers is inversely proportional to the square of that number of papers. The approximate number of journals resulting from this output is shown in Table 2.

TABLE 2

APPROXIMATE NUMBER OF SCIENTIFIC JOURNALS IN PRINT OR PROJECTED FOR THE PERIOD 1800-2000

<table>
<thead>
<tr>
<th>Year</th>
<th>Abstract Journals</th>
<th>Scientific Journals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1800</td>
<td>0</td>
<td>70</td>
</tr>
<tr>
<td>1850</td>
<td>3</td>
<td>800</td>
</tr>
<tr>
<td>1900</td>
<td>12</td>
<td>8,500</td>
</tr>
<tr>
<td>1950</td>
<td>125</td>
<td>14,000</td>
</tr>
<tr>
<td>2000</td>
<td>1,300</td>
<td>990,000</td>
</tr>
</tbody>
</table>

Data approximated from graph by Price, op. cit., p. 38.

Speaking at the Symposium of the American Documents Institute at the University of Wisconsin, November 21 and 22, 1963, Congressman Roman Pucinski cited figures which are illustrative of the current volume of scientific and technical information:

The average person, reading 12 hours a day for 50 years, could complete about 15-18 thousand technical books. There are about 30 million books in the world today.
There are more than 120,000 technical journals in the world. . . seven million patents on file with our Patent Office. . . 500 specialized science information services. . . 130,000 government originated R&D projects a year (each with its reports) . . . and the World Bibliography of Bibliographies contains more than 100,000 entries.15

Another estimate of technical publication volume is a study reported by the United States Committee on Scientific and Technical Information (COSATI). This committee, which is organizationally under the Federal Council for Science and Technology, National Bureau of Standards, U.S. Department of Commerce, reports:

Most of us know that the sheer number of journals, reports, books, and pamphlets is increasing. Individually, we are inundated by too much material. But how many of us stop to think that the number of publications doubles about every 15 years. One estimate places the number of technical documents published in 1961 at 658,000 and the number to be published in 1970 at 1,143,000. In 1964 the Library of Congress had over 43,000,000 items in its collection. This collection grew over 180 per cent in the last 26 years.16

Since the federal government is the nation's principal sponsor of research, development, test, and engineering activities, many surveys of the volume of scientific and technical documentation are related to government-sponsored activities.17 For example, in 1965 Senator Hubert H. Humphrey observed that the Department of Defense had approximately 45,000 research projects in being or completed, about 33,000 of which were represented by documents indexed by the Defense Documentation Center, and that the center was acquiring new documents at the rate of

16 COSATI, op. cit., II, p. 3-2.
400 a week. Passing note should be made that the volume of scientific and technical literature is growing internationally. One author points out that the emergence of substantial amounts of publications from nations which have only recently become serious contenders in science and technology.

Today there are more scientific and technical journals in Russian than in German, more in Japanese than in French, more estimates vary with definitions, but it can be said that there are now somewhere between 50,000 and 100,000 technical journals being published in more than sixty languages. New journals keep appearing at the rate of at least two a day. This year's journals will carry between one million and two million scientific and technical articles, a two or three fold increase over 1940. To this must be added an increase in complexity of content so vast it cannot be measured.

Detailed statistics concerning publication volume in many countries are becoming available, as are reports of efforts to cope with resulting problems by industrial firms, technical institutes, universities, and governments. For the interested reader a graphic presentation of the current coverage of various national and linguistic origins by abstracting and indexing services is available.

Problems in collection and use of information

At least three viewpoints should be considered with regard to

problems in collection and use of information: (1) the user's, (2) the information specialist's, and (3) the manager's. Problems of the user stem from considerations of volume and complexity. Those of the information specialist are problems of adaptation--satisfaction of user needs from the diversity of raw materials available within the cost and time limitations imposed upon him. The manager's problems involve achievement of organizational objectives which may involve technical specialties largely beyond his training and experience. Illustrations of each of these problem areas will help to provide substantive background for appraisal of new institutions for transfer of scientific and technical information.

The user's problem involves both production and use of scientific and technical information. Whether the technical activity staff consists of a single person, perhaps working part-time, or of a large, well organized group of people, the basic functions of production and use of scientific and technical information are present. This study is oriented primarily to the use of information in measuring institutional effectiveness in the supply of needed information. The effects of both volume and complexity are brought out in this statement.

The research scientist--the ultimate consumer of scientific information--finds himself running faster and faster in his attempt to stay in the same place. To the extent that primary and secondary publications expand their services, he has more primary journal papers to read, more abstracts and index entries to check, more bibliographies to look through, and so forth. This would have posed a serious problem for him even if the scope of his research interests, in terms of conventional disciplines, had remained about the same. But it has not. More and more he is finding that discoveries and developments of

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21 Swanson, loc. cit.
great potential pertinence to his work may turn up in research areas far removed from his specialty.\textsuperscript{22}

The researcher in one field must locate highly selective elements of information from a series of large collections, and may seek information in other fields relating to his project.\textsuperscript{23} The Vice-president, Engineering, of the General Electric Company stresses the need for relevant information from outside fields:

Engineers are responsible for design; for the expression of creative, inventive ideas. Raw material for ideas is information. But what information does an engineer need to be able to design?

Two information inputs are pretty well known and recognized: "scientific knowledge of nature" and "engineering technology." Scientific input is from the fund of our knowledge and understanding of the forces and materials in the natural universe. Engineering technology input is from our fund of mathematical, analytical, and measurement techniques . . . plus the design ideas and data engineers have accumulated in applying knowledge to fill the needs and wants of man.

To get the best design for use in the general economy, there must be a third input of information—which might be called "other relevant information."

This other relevant information fund includes, for example, marketing, manufacturing, finance, law, transportation, psychology, and even fad and fashion. "Relevant" items may be market saturation data, interchangeability standards, safety codes, machine tool capabilities, personal expenditures from disposable income, or a host of other elements.\textsuperscript{24}

The user's problem comes down to a fundamental lack of time to devote to the literature. This problem may be complicated by unwillingness to delegate the search for existing information to the information spe-

\textsuperscript{22}\textsuperscript{22}U.S. Congress, Senate, Committee on Government Operations, Document-\textsuperscript{23}\textsuperscript{23}ation, Indexing and Retrieval of Scientific Information, Document No. 113 (Washington: U.S. Government Printing Office, June, 1960), p. 120.

\textsuperscript{24}\textsuperscript{24}Mayo-Wells, \textit{op. cit.}, p. 9.

cialist. Reasons for refusal to delegate may be that valuable information might be missed or that literature search and selection of method for solution of the problem should interact. The user will usually feel that an efficient and useful literature survey can be accomplished only when a clear understanding is established between the researcher and the information specialist. The problem of communicating the user's need to information specialists is crucial. An effective response must be evoked, but presently available techniques of indexing and selecting information are inexact.

In all library systems developed to date, from the Rapid Selector to Walnut, the selection of relevant information takes place essentially as follows: A human indexer reads a document and assigns it to one or several information categories. The names of these categories are the tags which are used to index the document in question. Similarly, a user who wants information from the system must formulate his request in terms of one of several information categories and, again, his request formulation takes the form of a logical function of index tags. Once the library index data and the request are converted to digital form, the search strategy followed by the automatic system consists in matching each item in its file to determine whether or not its set of index tags is logically compatible with the set of tags which constitutes the request in question. If so, the item is selected for retrieval.

However, it is clearly a gross and damaging over-simplification to identify a document or a request simply in terms of a set of index tags; such methods of representation do not do justice to the complexity of the document in question. That is to say, the use of a set of index terms to identify the subject content expressed by the complex language of a document is bound to result in a loss of accuracy since the relationship between an index tag and the subject or field of knowledge which it purports to describe must necessarily lack any kind of a precise correspondence. A given tag may denote several different subjects and conversely different tags may denote the same subject to a greater or lesser degree. We may characterize this situa-

tion by saying that index tags are "semantically noisy." And, of course, not only are the tags used to index documents noisy, but similarly the tags used to represent a user's request also contain semantic noise. In view of this fact it should not be surprising that the conventional library searching strategy which performs an exact logical matching of two sets of noisy tags (those of the document and those of the request) must necessarily result in the retrieval of many documents which are irrelevant to the real needs of the user, and even worse, in the omission of relevant items.  

Because of dissatisfaction with information sources and unfamiliarity with techniques for using these systems, the user may turn to other sources such as desk files and telephone calls to personal contacts.  

Cursory investigation may result in duplicative research. Since duplication of effort is part of the problem at both the technical and management levels, the following account of industrial experience shows the need for both to take advantage of what is already known:

Let us illustrate by example how a technical information service can help laboratory research. Our people had under consideration an exploratory program in the field of productive research; the need for it seemed beyond question. It would take a month, perhaps longer, to find the required answers, and we were about to give the go ahead when one of our information researchers came up with a document that made the whole project unnecessary. In another case, an analysis of more than 100 chemical compounds was stopped, just before starting laboratory work, when a literature search turned up the fact that someone else had already done the work.

Duplication of scientific work can truly be a sinful waste of time, money, and brainpower, and no research organization that I know of has an oversupply of any of these commodities. Of the three, time is perhaps the most important.


27 COSATI, op. cit., I, p. 3-3.

The information specialist's problem involves retrieval effectiveness, which depends to a large extent on the quality and depth of indexing accomplished. This problem may be inherent in the work to a degree that it will always exist. Two experts in the same field might arrive at different indexing determinations for the same document, and any one person might make different decisions at different points in time. Factors which contribute to these ambiguities include (1) individual differences resulting from background or training, (2) relative precision of the indexing system used, (3) importance attached to the material being indexed, and (4) extent of terminology specialization. There is a similar lack of common viewpoint between information specialists and users which makes the problem difficult to resolve.

The indexing and abstracting of scientific literature are major problem areas. For the well-being of research and development, these areas must be looked at objectively, despite the fact that there tend to be two viewpoints which often do not see eye to eye: that of the creators of the services and that of the consumers. The former are apt to be on the defensive, the latter to be outspoken, especially when it comes to national defense. It is not easy to bring defensive and outspoken people to a common point of view; and this is the somewhat uneasy stage of evolution which has been reached in the United States, which is probably the most important indexing--and abstracting--country today. The major question to be determined is whether this phase can be regarded as a transitional one, perhaps one of short duration. Our sense of historical perspective must guide us to a large extent in seeking clarification of the issue.

This first problem of the information specialist is conceptual rather than operational in character. Sophisticated processing procedures and


high-speed automated equipment can only magnify the problem if they perpetuate an ineffective system of indexing. The essence of this problem has been captured in the following statement:

Information-retrieval techniques to make the vast store of knowledge conveniently accessible are still far short of what's needed. The difficult problem is not devices and technology, it's the intellectual job of matching what's known and what's wanted.\textsuperscript{31}

The information specialist is beset by many difficulties other than improving the quality of indexing and selection of information. A partial listing of these other problems follows:

1. Critical budgetary limitations, particularly where funding is private or on a local level.

2. Shortage of professional personnel and decreasing percentage of entrants into the field.

3. Curtailment of services because of inadequate resources.

4. Inadequacy of traditional means of communications, resulting in the use of new information-exchange mechanisms which may be complex and costly.

5. Existence of large backlogs of documents and books which cannot be processed into collections.

6. Increasing production lag and decreasing scope of coverage in the availability of Library of Congress catalog cards.

7. High cost of modern technology systems.

8. Traditionalism on the part of users (discipline oriented) and

conventional information specialists (library oriented). 32

The manager's problem with respect to scientific and technical information is characterized by difficulties in determining facts to be used as a basis for decision. Part of this difficulty stems from relatively obscure technicalities which may surround the work of scientific personnel and information specialists. Another part of the difficulty arises from the fact that accounting techniques hardly exist to show the value of information or the cost of not having information. Situations used to justify support or non-support of technical-information projects may turn out to be false or inapplicable when the audit trail is followed. 33 Yet the general case that economic loss results from poor use of available information is widely accepted. In addition, it is recognized that these costs can involve the use of inferior experimental methods, poorly planned investigations, or useless duplication of work already reported. 34 An estimate of the magnitude of the duplication problem is contained in an address made to the San Diego Chapter of the Armed Forces Communications and Electronics Association:

Outright duplication of technical research and development in doing over again what has already been done, costs the United States $1 billion a year. Up to $6 billion a year additional might be saved if scientists and engineers were fully aware of all previous work in the field. Presently, much of the data from earlier programs is unavailable or lost. Giving our engineers and scientists easy access to knowledge gained from previous

32 COSATI, loc. cit.


34 Northrup and Crooks, loc. cit.
projects, would add fifty thousand experienced man-hours to the United States' technological effort.35

This estimate compares fairly well in order of magnitude with others published in leading periodicals.36, 37 Whatever the real cost, the inexactitude of these estimates attests the nature of the problem, and it is likely that careful audit would disclose many inaccuracies and irrelevancies. Nevertheless, there is a real problem associated with inability to use information, and management has difficulties in getting accurate information about the problem.

Managers also need better ways to measure performance of those who acquire, analyze, store, and disseminate scientific and technical information. According to a recent comprehensive survey of the needs for such information on a national scale, "tools and techniques for assessing the adequacy of information systems and their continuing ability to serve their users are among the areas of most pressing needs for research."38 This problem embodies the principal area of research for this study--development and test of a sponsor's measure of effectiveness for the scientific and technical information center. Another problem area for managers relates to the extent to which they can participate in technical and informational activities. An example of recognized need for


36 Bello, loc. cit.


38 COSATI, op. cit., pp. 4-16 and 4-17.
management participation in the functional area of information acquisition is provided by the following statement:

The acquisition of information for an IR system is not an EDP problem but a management problem. Management must establish some system to insure that any information which has value beyond the use for which it is initially generated reaches the IR system for coding and storage. This is not always a simple matter, since different types of scientific and industrial operations have different traditions with regard to the reutilization of information generated in the course of regular operations.39

Despite the unfamiliar technical details which may confront the manager, sufficient contact with scientists, engineers, and information specialists should be maintained so that management responsibilities can be discharged.

Emergence of the scientific and technical information center

The scientific and technical information center as a unique type of institution is of fairly recent origin, as evidenced by the following chronology:

1. During the 1930s the volume of published literature attained "critical mass," starting today's information explosion. 40

2. During the 1940s the problem became more aggravated as a result of wartime pressures, resulting in recognition of need for new institutions and new procedures. 41


41 Bush, loc. cit.
3. During the 1950s the term "information retrieval" was coined, generally credited to C. N. Mooers; computer techniques were applied to information searching problems on an increasing scale (although with slow progress initially); and early information-retrieval centers were brought into being, some of which are operating yet. During this decade proposals began to arise for the establishment of a national technical information service which might be superimposed upon the emerging specialized small centers.

4. During the 1960s, large numbers of centers came into being and additional proposals were made for the establishment of a national organization, presumably one which would coordinate the activities of a network of individual specialized centers. Early surveys of these centers were conducted along diverse guidelines, so that coverage and enumeration were fragmentary and overlapping in these surveys.

The question of how many centers existed at any one time or exist today can be answered with differing counts depending on definitions used and surveys referenced. In 1958, the National Science Foundation

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46 COSATI, op. cit., II, pp. 6-1 through 6-93.
reported the existence of 25 operating nonconventional technical information systems, increasing the number to 34 in 1959, to 62 in 1960, and to 87 in 1962. Based on a different but partially overlapping classification system, the same organization in 1961 reported the existence of 427 different organizations or projects providing specialized science information services in the United States. At about the same period in time, the Office of Aerospace Research listed 919 research and development information systems. Another directory reflected over 10,000 specialized libraries and information centers, obviously achieving such a large enumeration by inclusion of specialized libraries. Before any further review is made of the activities of these centers, a few working definitions and distinctions are necessary for proper identification of the research area attempted by this study.


Perhaps the first distinction which should be made is that between
specialized libraries on the one hand and technical information-retrieval
centers on the other. The first type of institution has a long his-
tory and a large population, while the second is relatively new and its
members number less than a tenth of those of the first. These two types
of institutions represent a development called for by the head of the
Office of Science Information Service, National Science Foundation, in
this statement:

The problem which the nation faces in this area has two
principal aspects—first, improvement of present information
services that use known and tested techniques and, second,
development of new and more effective techniques for coping
with the rapidly expanding body of scientific and technical
literature. 54

The following definitions are offered to classify the information center
and to distinguish it from the technical library.

A scientific information center exists for the primary pur-
pose of preparing authoritative, timely and specialized reports
of the evaluative, analytical, monographic or state-of-the-art
type. It is an organization staffed with scientists and en-
gineers and, to provide a basis for its primary function, it
conducts a selective data and information acquisition and pro-
cessing program. 55

The information center is defined by its function of
offering selected, specific, and synthesized information de-
derived from a carefully preselected store of documents. 56

The specialized information center is a technical institute
not a technical library. It differs from a library in that


those who operate it are expected to know, in the usual sense that a scientist knows, the contents of the materials contained in the center. It uses the tools of the librarian and it cannot function without the support of librarians, but its point of view is that of the scientist.

The best of the specialized information centers have contributed centrally and directly to the advancement of the science they serve.\textsuperscript{57}

One author has tabulated the characteristics of information centers and technical libraries as shown in Table 3 on page 24. These comparative characteristics can be interpreted in a broader sense than that conveyed by the literal statements. First of all technical libraries are not restricted in their location and sponsorship to companies. Obviously, they may serve other types of organizations including communities. Second, a given organization may have characteristics of both the technical library and the information center. Depending upon its range of characteristics, one organization might represent both entities. Conversely, if one set of characteristics is clearly dominant, it would classify the organization in its group even though a partial set of other characteristics is present.

Once the technical information center is recognized as something distinct from the technical library, a further distinction is needed. This further distinction relates to whether the system retrieves references or documents on the one hand (commonly called information retrieval)\textsuperscript{58} or whether it retrieves data content from the documents handled on the other (often known as data retrieval)\textsuperscript{59} A similar differentiation

\textsuperscript{58}Coblans, \textit{op. cit.}, p. 33.
\textsuperscript{59}\textit{Ibid.}, p. 58.
### TABLE 3
COMPARATIVE CHARACTERISTICS OF SPECIALIZED INFORMATION CENTERS AND TECHNICAL LIBRARIES

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Information Center</th>
<th>Technical Library</th>
</tr>
</thead>
<tbody>
<tr>
<td>Users</td>
<td>Widespread clientele</td>
<td>Restricted to company</td>
</tr>
<tr>
<td>Products</td>
<td>State-of-the-art reviews; data sheets; bibliographies; data and information in response to inquiries.</td>
<td>Answering technical questions; bibliographies; loan of books, periodicals, and documents bibliographies and references.</td>
</tr>
<tr>
<td>Evaluation of input</td>
<td>Mission or discipline determined.</td>
<td>Related to company's interests.</td>
</tr>
<tr>
<td>Evaluation of output</td>
<td>Critical evaluation of data.</td>
<td>Oriented to user's request.</td>
</tr>
<tr>
<td>Information needs of users</td>
<td>For special data and information within limits of the mission.</td>
<td>Specific and general information in wide areas of interest.</td>
</tr>
<tr>
<td>Storage and retrieval methods</td>
<td>Use of standard library techniques plus some automated techniques.</td>
<td>Standard library techniques plus some automated techniques.</td>
</tr>
<tr>
<td>Operating personnel</td>
<td>Scientists; engineers; librarians.</td>
<td>Librarians, mainly.</td>
</tr>
<tr>
<td>Indexing techniques</td>
<td>Quite specific.</td>
<td>Specific, but more general than information centers.</td>
</tr>
</tbody>
</table>

is found in use of the terminology "document retrieval systems versus fact retrieval systems." If scientific and technical information centers are defined in the sense of preparing specialized or evaluative reports, the number of such centers in existence is probably between 200 and 400. Other classifications should be recognized for the many institutions serving this field, such as one used by the director of the Office of Research, Office of Emergency Planning, Executive Office of the President, who lists three types: (1) the abstracting and indexing services, (2) the government information projects, and (3) the specialized centers such as the Thermophysical Properties Research Center at Purdue University. For purposes of this study, the centers of primary interest are those termed specialized centers, information analysis centers, data retrieval centers, fact retrieval systems, or names involving similar connotation. Adjunct functions—such as compilation of bibliographies; preparation of abstracts; or composition, reproduction, and dissemination of documents—may also be present.

The Unfilled Need for Professional Management

A lack of emphasis on management of scientific and technical information activities is obvious from a review of current literature. Least

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62 Weinberg, loc. cit.
management function in the references used for this study is that of staffing. Little or no attention has been given to the recruitment, training, and development of a management class for scientific and technical information centers. A recent article dealing with the emerging design for a national system of handling scientific and technical information is typical of this lack of emphasis. It recognizes politicians, users, and information specialists— but ignores managers—as important groups:

Where are the pressures coming from for new and dynamic communications mechanisms? They come from a number of sources: (i) from the politicians, whose approach may be that of viewing with alarm and urging bold new ventures; (ii) from people now in the information business, whose approach is ambivalent: The situation exists, it is serious and challenging, but give us the resources and we'll lick it; and (iii) from the "customer"— the scientist and the engineer. While the "customer" is less vocal than the politician or the information specialist, he is dissatisfied, and this fact merits attention.64

Since the literature review encountered occasional attention to the management area, early statements concerning two industrial centers should be acknowledged. The first of these involves an interview with the man who is now chairman of the Committee on Scientific and Technical Information (COSATI) of the Federal Council for Science and Technology.

"Our prime job is to stimulate the men on the bench," says William T. Knox, who heads Esso's information division. "We don't relieve the technical man of his responsibility; we try to help him use his time most efficiently, by acting as an intermediary between his problem and the available information."

What prodded Jersey Standard into full-time information research? According to Mr. Knox, an internal survey in 1956 revealed a surprising feeling of inadequacy on the part of the company's scientific personnel. Most of the research men believed they weren't sufficiently up-to-date in their own fields, had insufficient opportunity to benefit from possible "cross-

64 Ibid.
fertilization" from other fields, and weren't even adequately informed of past or current work within the company itself. When management heard this, it acted quickly.65

The contemporary industrial effort--within E. I. duPont de Nemours and Company--also reflects management commitment and participation from the outset:

In 1956 a special study group in our Engineering Department was assigned the responsibility of investigating possible applications of some newly emerging engineering management concepts. Among these concepts was the idea of increasing the effectiveness of the engineering force by making better use of recorded engineering knowledge. From the efforts of the study group there emerged a better understanding of the need for and means of using our recorded knowledge properly. DuPont is now implementing these new concepts in many departments of the company.66

Management contributions and unfilled needs with respect to scientific and technical information centers involve both operating managers and sponsoring managers. Problems involved in effectiveness measurement are of mutual interest to the two groups.

Specialization of first-generation management in technology fields and information sciences

The literature screened for this study was characterized by reports on functions and activities of information specialists. To a significant but smaller extent emphasis was given subject-matter disciplines from many fields. The inference is reasonably clear that first-generation managers stem from these two areas. As a professional management class


emerges, sponsoring managers are likely to become the first group to be clearly identified. Additional inferences which might be drawn—simply by analogy to other fields of organized human activity during the early stages of development—include the following:

1. Regardless of specialized background, the operating manager of a scientific and technical information center today is more of an innovator than a professional administrator. The innovator's approach to management is likely to involve adaptations of method from other fields such as engineering, science, systems design, or special librarianship. Part of the work of innovation will consist of synthesizing for this new field some specialized adaptation of the management process. During the formative stages, differences between individual centers tend to be exaggerated because of the personal influence exercised by key individuals. Eventually, basic management functions will be structured as versatile building blocks for constructing the managerial framework of a center. This natural evolution away from the stage of innovation should result in greater standardization, compatibility among centers, and completeness of functional definition for these new and widely differing institutions.

2. First-generation managers may emphasize project rather than process management. During their careers many practitioners in science, engineering, and information systems design are accustomed to sequential assignments which bear little relation to one another. When managing information centers, these men are likely to emphasize projects leading to step-by-step development of the organization through a series of intermediate goals. Such an approach may not emphasize sustained effort directed at continuous, standardized productive output. As the centers
mature, transition toward continuous production and process management is to be expected.

3. Early efforts at self-evaluation will tend to be introspective. Since introspection can lead to a paradox (closed-loop self-contradiction) a need exists for external objective evaluation. In some cases first-generation managers have backgrounds representative of more than one contributing discipline. Such a situation exists with respect to the center selected for evaluation for this study. However, most first-generation managers of scientific and technical information centers can be divided into two groups: (1) individuals who are primarily scientists, engineers, or technologists from a field representing sources and users of information; and (2) individuals who represent any other primary specialization, such as systems design or librarianship.

Participation by scientists and engineers as managers of information centers is a response to the need for selectivity and quality in output. This need is increasingly recognized, and it is probably a key factor in effectiveness measurement.

If we tried to make such a mass attack on the information problem we would inundate the users of the system with paper, each item of which qualified as relevant to his inquiry. As those who code computer programs say, "garbage in, garbage out." Here we would be producing garbage in very large piles indeed.

What is needed, and what has been missing in most of the information schemes, is the judgment and selection of people skilled in the field in question.67

This emphasis on using disciplines represents specialization and division of effort within the technical staff. One writer views the direct technical effort as a line activity (involving self-management by individual

67 Green, loc. cit.
workers) such that its staff support can be either inter-organizational or in the form of outside service such as the scientific and technical information center:

A clue as to how one might deal with the transfer of information to the individual is to be found in the "staff" system of management.

Science has also responded to difficulties of communication by inventing a sort of staff. However, since each individual scientist is a "boss" in the sense that he allocates his own resources, it is impractical to give a separate staff to each scientist (although some highly placed scientist-administrators do have their personal staffs who keep them informed). Instead, science has delegated to some of its practitioners the task of compacting, interpreting, and otherwise reviewing the literature for the rest of the scientific community. The reviewer and the abstractor have played, for science generally, the role that the staff in a business organization plays for management.

The "staff" system in science sees its full development in the so-called specialized information centers, of which there are about 400 in the United States. Ideally, such a center is a technical institute manned by working scientists who make it their business to know as much as possible about a certain specialized area of science, and who critically compact, review, and synthesize information for the technical community. The input of the specialized information centers is documents and uncorrelated data; its output is reviews, correlated data, and compilations.68

If this trend toward specialization and staff separation is followed, a class of personnel will emerge with the characteristics of both the technical investigator and the information specialist.

The information engineer is a specialist who has an actual working knowledge and comprehension of the process involved in solving a particular research problem. He understands the process that is to be followed from the time of the early definition of the research problem to its final solution. His training equips him to evaluate the information as he assembles it; thus, he is able to be more selective. Also, his technical background permits him to be critical as well as selective during the information development.

Because of his specialized training, the information engineer is not diverted into areas that are not relevant to the purpose

68 Weinberg, loc. cit.
of the project, and so he is able to assemble all associated material in the light of the final objectives. An information engineer works with his mind tuned to the technical requirements of the particular project.\textsuperscript{69}

The foregoing descriptions highlight important elements within the technological frontier: (1) need for competence in subject-matter disciplines, (2) efficiencies to be gained through specialization, and (3) the need for hybrid skills in a newly specialized class of people. They do not identify managers for scientific and technical information centers in the context of management functions within a management process. Presumably the information engineer supporting the direct technical effort is largely self-managed. A different viewpoint sees the engineer delegating the information problem to technicians and machines while emphasizing the innovational, managerial, and multi-disciplinary aspects of his work.\textsuperscript{70}

The second group of center managers within the first generation are characterized by a unifying principle: each uses his own background as the basis around which the new institution is developed. Related skills and disciplines are acquired through a process of extension. Thus, the developer and user of methodologies for designing systems sees the use of systems analysis as design and the significant characteristic of the documentation movement--overriding in importance the characteristic that documentation centers operate as integrated systems.\textsuperscript{71} In the opinion of

\begin{footnotes}


\end{footnotes}
one of the pioneers of information storage and retrieval technology, "the information officer, who is deputizing for the researcher in his reading, must necessarily be an information scientist." Yet this term is used in the sense of information-science and technical librarianship orientation as opposed to emphasis on using disciplines. Similar leanings exist at professional symposia held for such relevant fields of interest as information storage and retrieval, special libraries, computers, and systems design. As an example, sessions of the Second Technical Information Center Administration Conference sponsored by the Graduate School of Library Science, Drexel Institute of Technology (Philadelphia, June 14-16, 1965), covered the following subject areas: (1) translation services and their problems, (2) document storage and handling systems, (3) chemical information and technical information centers, (4) user education, (5) report writing, and (6) evaluation of system performance. The evaluation topic emphasized operational technique rather than accomplishment of objectives.

Considering the wealth of ability attracted to this relatively new field, it is only natural that some professional managers have appeared. A majority of these have backgrounds related to systems design and informational specialties. These prototype managers have expressed clearly recognizable and reasonably complete management functions in meetings of

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national interest. As a leading center for such activities, the American University (Washington, D. C.) has sponsored a number of institutes on information storage and retrieval. The fourth such institute, held in February, 1962, resulted in publication of a collection entitled Information Retrieval Management. At that session a member of the National Science Foundation staff presented a paper dealing with the management process and science information systems. In this paper he pointed out that management can be considered in two ways: (1) as part of the over-all process involved in scientific research and development activities, and (2) in terms of the science information center itself. This classification seems to be compatible with that of sponsors versus internal managers. The total collection of papers from this institute, however, deals more with mechanization, economic justification, and system-design questions rather than management, simply because these were key problem areas during the development of these institutions. A more complete recognition of functions within the management process is provided by another author. He advocates adoption of a formal charter for design and planning. He discusses principles based on experience within each topical area of the charter as described in the following list:

There are 13 more or less specific categories of subjects to be considered and a broad area of "General Principles." The 13 specific areas of consideration are the User Group, Coverage,


Sponsors' qualifications and attitudes

Sponsors of scientific and technical information centers are the management group making decisions to establish, further develop, or discontinue these centers. They are also involved in assignment of responsibilities, allocation of resources, and establishment of objectives and priorities. These managers are characterized by several attributes:

(1) a need to accomplish objectives which create a demand for centers of this class, (2) remoteness from the practical details of technical and informational disciplines involved, (3) need to rationalize or account for commitments with respect to centers, and (4) responsibility to evaluate center performance as a basis for future action. They are in a position of approving expenditures of considerable magnitude largely on faith in the hope that benefits will accrue in areas of technological productivity, time saving, and cost saving. They must decide what fraction or amount of total research and development funds support informational activities and the mechanism through which funds will channel.

It's management's responsibility, for example, to decide when work should begin on a research project, and when it should terminate. In most industrial laboratories, there are always far more ideas being generated than there are people to carry them out.

In all of our experience, we can't recall anyone's ever scratching his head and saying: "I wonder what we ought to do next." Technical literature is one of management's most useful

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guides in making the decision as to which project should get going and which should wait or be scrapped entirely.\textsuperscript{78}

Sponsors' objectives

Sponsors of scientific and technical information centers base their support on objectives which are easily understood although difficult to express quantitatively. Those engaged in competitive enterprise wish to survive and make progress within the technological frontier. Those in government and organizations not subject to direct competition are concerned with carrying out assigned missions in an environment characterized by scarcity of resources and lack of time. The industrial view is summarized by a report based on successful experience of one of the earliest pioneer industrial information centers. It points out that technology must be exploited to support basic corporate objectives, although it stops short of stating the derivative objectives of the scientific and technical information center.

Now, to go further into why we have technical information services, let us first consider the four principal objectives of technical management in industry. The first is to maintain the company's capital and operating costs at the lowest possible effective level. Second, to help the company obtain new high-quality products, efficient processes, and other technical assistance at a level that will improve or at least maintain its competitive position. Third, to provide the company with new opportunities for attractive capital investments and new markets for new and existing products. And fourth, to achieve the first three with a minimum of research expenditures, including those for technical information.

These objectives can be difficult to achieve. You can't schedule creativity or inventiveness as you can manufacturing output. There has to be a reasonable degree of investigative freedom. On the other hand, it's hardly feasible to create technology at an outlay of time and money that makes it economically useless. So management must take the attitude that

\textsuperscript{78} Dwight E. Gray, "Information and Research--Blood Relatives or In-laws?" \textit{Science}, CXXXVII, No. 3526 (July 27, 1962), pp. 263-266.
industrial research is a business to be managed as a business. 
And, be assured, a vigorous, well working technical information 
agency is essential to the businesslike conduct of industrial 
research and engineering.79

As shown by Table 4 below, the majority of support for these centers 
comes from government sources. Accordingly, the statement of the 

TABLE 4

SAMPLING OF INFORMATION CENTERS BY TYPE OF SPONSOR8

<table>
<thead>
<tr>
<th>Type of Sponsor</th>
<th>Number of Centers</th>
<th>Per Cent of Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government Exclusively</td>
<td>8</td>
<td>20.0</td>
</tr>
<tr>
<td>Government and Industry</td>
<td>11</td>
<td>27.5</td>
</tr>
<tr>
<td>Industry Exclusively</td>
<td>9</td>
<td>22.5</td>
</tr>
<tr>
<td>Industry and Public Agencies</td>
<td>4</td>
<td>10.0</td>
</tr>
<tr>
<td>Public Agencies Exclusively</td>
<td>2</td>
<td>5.0</td>
</tr>
<tr>
<td>Government and Industry and</td>
<td>2</td>
<td>5.0</td>
</tr>
<tr>
<td>Academic Institutions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government and Public Agencies and</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government and Academic Institution</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Academic Institutions Exclusively</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Government and Public Agencies</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>40</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

8Adapted from Mayo-Wells, op. cit., p. 56.

Commanding General of the Air Force Research and Technology Division is 
an even more representative indication of sponsors' objectives.

79
To cite just one example: The Systems Command presently is administering more than 70,000 contracts, with more than 5,000 different contractors and valued at $59 billion. Moreover, no research activity can hire all the scientific or technical talent in the free world in one technical area, let alone, in the following seven diversified technical areas of:

1. Electromagnetics
2. Weapons
3. Rocket Propulsion
4. Aero-Propulsion
5. Avionics
6. Flight Dynamics, and
7. Materials

which are the responsibilities of the Air Force laboratories of the Research and Technology Division.

Furthermore, it becomes increasingly apparent that the problem grows in order of magnitude when one realizes that we must also maintain complete cognizance over the voluminous amount of technical work being accomplished by the Office of Aerospace Research, the other military services, the National Aeronautics and Space Administration, and the scientific and industrial community.

In an earlier era, back here at Wright-Patterson AFB, some 20 years ago, the gap between scientific discovery and application was not only longer, but was more often primarily of academic interest. In recent years, the time lapse between discovery and application has shrunk rapidly--a symptom of technological age. But, even more lately, the necessity to make prompt continued application has become a matter of greater economic and political significance, even to the extent of national survival.

Suffice it to note that today's world rivalries and "megabuck and gigabuck defense spending levels," as General Donnelly pointed out in his fine talk, demand that we squeeze every dollar's worth out of every dollar spent if the taxpayer's considerable investment in research and development is to yield optimum results. One way to do this is to pay close attention to the management and dissemination of information on current, as well as completed, research and development projects. 80

Since sponsoring managers have supported scientific and technical information centers as a means of accomplishing more basic objectives, the centers represent technical staff functions. Evolution and separation of staff functions represent specialization and division of work.

In summary, sponsors are reallocating functions and modifying organizations in an attempt to support primary objectives more efficiently and effectively.81, 82

Role of sponsors in establishment and operation of scientific and technical information centers

The call for establishment of scientific and technical information centers has come from scientists and information specialists rather than from sponsors. As a result, the attitude of many sponsors is permissive rather than aggressive, and individual sponsoring managers may be largely unfamiliar with the intricacies of center operations. Managers in a situation of this type are hardly in a position to study day-to-day operations and improve operating efficiencies. They should determine whether the right job is being done before they examine into costs and efficiencies. However, the sponsor's position is difficult because of technical complexities, lack of criteria and operational data, and the widening span of management. In principle information is an economic good (characterized by scarcity and capacity to satisfy human


wants) with supply and demand curves and marginal utility. As yet, however, placing a value on the output of scientific and technical information centers is inexact and difficult at best.

If information is to be treated as a commodity, some value must be placed upon it. But this is difficult to do. The reasons include:

1. The lack of an established market for information in the usual sense of the words. Direct users of information either obtain it for nothing or pay for it in such an indirect way that the specific value of a specific piece of information is not obvious. Thus there is no "going price" for information as with other commodities.

2. The lack of a standard unit of information on which to put a price tag. A piece of information may be anything from a single fact to a complex theory. No group of simple parameters permit reducing all pieces of information to a commensurate set.

3. Information is essentially intangible and this compounds the difficulties of assigning value.

Tracing effects on technical productivity requires evaluation across a wide span of organization, extended time periods, and reporting systems designed for other purposes. In addition, the lack of attention to staffing has resulted in a wide span of management so that sponsoring managers are unable to spend enough time on problems in the informational area.

The sponsor's rationale

Sponsors can rationalize their support of scientific and technical information centers as financial commitments intended to improve over-

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87 Hillier, op. cit., pp. 54-60. 88 McCormick, loc. cit.,
all effectiveness of their organizations or spheres of influence. It is
doubtful whether they can consider financial support as their only obli-
gation. Other obligations of managers with respect to scientific and
technical information activities are identified by one writer as follow:

Turning now to management's obligations, let us discuss
three of them: (1) management's obligation to understand the
varied individuality of the scientist and engineer; (2) manage-
ment's obligation to understand the dynamic and changeable
nature of information systems; and (3) management's obligations
to other users as well as to those within his own organization.89

Discharge of the financial obligation in the absence of a close rapport
with personnel and functions can, of course, result in poor control.
New tools such as advanced systems and improved processing techniques
offer high levels of capability. However, there is no guarantee that
application of new tools within the organizational environment will have
the effects sought. Yet the prospect that these new institutions may
help is sufficiently attractive that financial risks have been taken.
Once the initial sponsoring commitments have been made, however, faith
and logic are not enough. Experience must be measured and evaluated so
that this heuristic process can lead to a successful outcome.

Some of the major stumbling blocks have been the inability
to gain insight into the reactions of systems users: (1) to
various levels of sophistication and precision of service;
(2) to various forms of response to their needs; and the diffi-
culty of establishing formal feedback mechanisms to permit rapid
reaction of the systems to requirements for change.90

89 Joel M. Kibbee, "Management's Needs and Obligations for STINFO,"
Proceedings of the 1st USAF Scientific and Technical Information Confere-
90 Allen Kent, "The Hueristic Information Retrieval Game," American
The sponsor's rationale justifies his initial commitment with respect
to scientific and technical information centers only if he extends his
work into the areas of effectiveness evaluation and improvement of ef-

ciency.

The sponsor's decision to evaluate
effectiveness

There is a growing readiness by sponsors to attempt evaluations
of the effectiveness of scientific and technical information centers.
As will be shown more fully in Chapter II of this study, the published
literature attests to this trend by reflecting the numbers and kinds of
evaluations attempted. First, the number of evaluations of all types
is growing at an increasing rate. Second, the emphasis given to effec-
tiveness as opposed to efficiency and other factors is beginning to be
felt.

Progress in the IR field has been inhibited by the lack of:
(1) precise criteria for evaluating new and existing systems
and services; (2) methods for measuring performance of systems
quantitatively; and (3) means for modeling IR systems and pre-
dicting their operational performance.91

To date there have been bench-mark studies, but there are no common
guidelines or generally accepted standards for such measurements. The
status of the effectiveness-measurement problem is simply that a deci-
sion is being taken on an increasing scale to attack the problem.

The problem of effectiveness measurement

As in the case of many new fields of human endeavor, scientific
and technical information centers present a variety of difficulties

91 Ibid.
with respect to their evaluation. This problem exists with respect to
system components as well as total systems.

Moreover, the effectiveness and efficiency of the components
of retrieval systems such as indexing languages and devices have
not been established, since adequate test methodology is still
under investigation. . . . The truth is that we know very little
about the intellectual processes which we are trying to automate
in retrieval systems.92

One of the first questions to be considered is whether the objectives
can be defined with sufficient precision to permit measurement of accom­
plishment versus specific goals. The nature of these centers implies
that they will provide information which cannot be identified or speci­
fied in much detail until demand occurs. Information important today
may be overshadowed in the future by material not yet recognized as
having potential value. The need for greater precision in evaluating
such intangibles has been recognized.

A series of studies should be conducted to sort out methods
to aid and support value judgments. Requirements for informa­
tion activities are founded on value judgments. The decision is
made on the basis of strong beliefs and advocacy. "I think we
need it and I believe it's worth the cost"—these are the words
backing up the decision maker putting resources on information.
He should have more than this to support his case. For instance,
can techniques from Operations Research and Market Analysis be
applied to the information situation?93

The current lack of precision in evaluation may encourage a given center
to regard itself as an "ivory tower" answerable only to its own value
judgments. A second difficulty arises from the relative newness and

92 Alan M. Rees, The Information Network—Libraries, Systems, Cen­
ters and Services (Cleveland: Western Reserve University, 1964), p. 8.

of the Air Force Second Scientific and Technical Information Conference
complexity of the functions being accomplished. Specialists in this field are hampered by lack of common terminology and frame of reference in describing functions to sponsors. Occasionally, centers may find it difficult to establish rapport with users as well as with sponsors. This aspect of the problem obviously calls for further education leading to the development of mutual understanding. Even if the first two difficulties were resolved, the real work would still lie ahead. The third difficulty in effectiveness measurement involves setting up and applying measures. Two of the basic questions in this area relate to (1) whether a given measure could be applied within the situational context confronting the sponsor, and (2) how meaningful it would be if it could be applied. This over-all problem of effectiveness measurement has been summarized by one sponsor as follows:

In discussing the value of an information center the question inevitably arises. How is its effectiveness to be determined? Such an evaluation is extremely difficult and this should be realized. Is the center actually saving work for the investigators and money for the organization supporting it, be it DOD or a private company? If it doesn't do these two things its value is limited. But, how is this determined? To date, there are no accepted criteria, a problem recognized in the Auerbach report. The best proof, of course, would be able to show concrete, specific examples of how information or data saved hundreds or thousands of dollars of experimental work, or prevented duplication of effort. Unfortunately, these are hard to come by. Most often the user is not sure of the savings it has provided to him. Sometimes he may be reluctant to admit that he has been unaware of a program, similar to his which the information center has unearthed. Feedback is always slow and the most tangible area on which a center can rely is the number of people that do use it and as important, if not more so is the number that use it periodically.94

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Objectives of This Study

The objectives of this study are (1) to construct a sponsor’s measure of effectiveness for scientific and technical information centers, (2) to conduct an experiment using the measure, (3) to evaluate the measure and the center under study, and (4) to initiate planning for continuing research in this field of study. These objectives are intended to interact in such a way that research results prompt changes in design of the measure and experimental techniques for future research.

The Measure of Effectiveness

At the present stage of evolution of scientific and technical information centers, effectiveness is the most important aspect for review and evaluation by sponsors. Improvements in efficiency can be made once there is some assurance that the right job is being done. Since these centers represent complex combinations of functions, personnel, informational resources, and facilities, over-all effectiveness should be a more feasible area for initial study than sub-function effectiveness. Once over-all effectiveness has been measured, systematic methods can be developed to determine essentiality and contribution of sub-functions. If comparative evaluation of centers is to be attempted, the over-all effectiveness measure should represent some common factor or index by which one organization can be shown to achieve similar or contrasting results versus those of other centers. Finally, over-all effectiveness measurement is a more immediate need at the present stage of development in order to justify continued support by sponsors. For these reasons, sub-function effectiveness measurement is withheld for future study.
Experimentation

The sponsor's measure of effectiveness is intended to show cause-and-effect relationships. An operational analysis is needed which will treat the actual work of an existing center as the experimental variable within a controlled experiment, as opposed to experimentation based on modeling techniques. However, reference to a model is needed for two purposes: (1) to conform the measure itself to centers of the class selected for study, and (2) to assure that the individual center studied is representative of the class. The experiment must take into account conditions which may affect the outcome: (1) loosely defined center objectives, (2) effects which are remote in time and organizational span, and (3) a lack of readily compiled and available information. Because users are involved in the proposed measure, the experiment will be a behavioral study which makes use of an opinion survey. Additionally, the rate of development and change of scientific and technical information centers is rapid enough that the initial survey will be taken at a single point in time, although a succession of tests will be considered in the plan for continuing research.

A variation of ex post facto experimental design has been selected from among several candidates for test of the proposed measure of effectiveness. The principal modification of basic ex post facto experimental design is the addition of a comparison group composed of center personnel. The control group is composed of potential users. Actual users form the experimental group. Hypotheses are that there are no significant differences with respect to groups compared for factors listed in Table 5 below.
### TABLE 5

**STRUCTURE OF EXPERIMENTAL HYPOTHESES**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Groups Compared</th>
<th>Inferential Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of reading</td>
<td>Experimental group</td>
<td>Matching experimental group and control group</td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td></td>
</tr>
<tr>
<td>Time spent reading</td>
<td>Experimental group</td>
<td>Matching experimental group and control group</td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td></td>
</tr>
<tr>
<td>Corporate orientation</td>
<td>Experimental group</td>
<td>Matching experimental group and control group</td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td></td>
</tr>
<tr>
<td>Amount retained from the open</td>
<td>Experimental group</td>
<td>Matching experimental group and control group; relevan-cy</td>
</tr>
<tr>
<td>literature</td>
<td>Control group</td>
<td>rating, open literature</td>
</tr>
<tr>
<td>Percentage applied in use,</td>
<td>Experimental group</td>
<td>Matching experimental group and control group; pertinency</td>
</tr>
<tr>
<td>open literature</td>
<td>Control group</td>
<td>rating, open literature</td>
</tr>
<tr>
<td>Amount retained from Center</td>
<td>Experimental group</td>
<td>Relevancy rating, Center output</td>
</tr>
<tr>
<td>outputs</td>
<td>Comparison group</td>
<td></td>
</tr>
<tr>
<td>Percentage applied in use,</td>
<td>Experimental group</td>
<td>Pertinency rating, Center output</td>
</tr>
<tr>
<td>Center output</td>
<td>Control group</td>
<td></td>
</tr>
</tbody>
</table>

**Evaluation of Experimental Results**

Experimental results will be evaluated as to significance of the measure and suitability of the experimental technique. In order to accomplish this objective, (1) results of measurement should be compared with independently acquired evidence, and (2) alternative techniques of measurement should be considered versus that used. Since an effectiveness rating will be established for overall performance of the center
selected for study, its choice depends in part on availability of some means of independent appraisal. Within the alternatives offered by the situation studied, some ranking of suitability of approaches is needed both before and after the experiment. The actual rating obtained for the center studied is of interest more as a reflection of measure performance than of information-center performance. In the planned future research, however, the outcomes will be sought increasingly as measures of center performance.

Planning for Future Research

Within the management process, effectiveness evaluation undergoes continuing application and refinement. This study represents a single measurement. As such, it is a small step toward application of the management process to scientific and technical information centers. More research is needed. Based on the experience and conclusions resulting from this step, a plan for extended and continuing research can be developed. Presumably, such a plan will undergo revision cycles as more effectiveness measurements are made. Items which will be included in the plan include

(1) refinement of the measure and application technique,
(2) conduct of multiple-center tests (comparative measurement),
(3) extension of measurement into time series,
(4) use of additional measures to determine over-all effectiveness, and
(5) development of measures for sub-function effectiveness. During the continuation of research, the plan will undergo revision and further development. If a sponsor of these centers elects to attempt measurements of this type as a standing procedure, a regular planning cycle can be established.
Methods Employed

This study involves both secondary and primary research. The secondary research consists of a review of the literature in the field of information storage and retrieval with emphasis on the subject headings of management, measurement, experimentation, effectiveness, efficiency, and system design. Unpublished data were used in the form of operating records of centers and their users. Primary research consisted of interviews, observations, and a questionnaire survey. Personnel of scientific and technical information centers, using organizations, the technical community, and sponsoring organizations were included in the primary research effort. Appendix A describes these methods.

Secondary Research

Secondary research in this subject is greatly facilitated by the availability of abstracting and indexing services, as well as by the existence of a number of excellent bibliographies which have been compiled within the past five years. Factors such as widespread interest in scientific and technical information centers and scholarly qualifications of pioneers in the field have resulted in a rich and growing body of descriptive literature. Unpublished data, particularly with respect to details of operating experience, have been more difficult to secure. There appears to be a gap between the objectives and design concepts discussed in the literature and the facts of accomplishment as shown by operating results. Yet few reports of deficient performance exist, and little emphasis has been placed on measures needed to help fulfill the conceptual promise. An important conclusion reached as a result of
cases analyzed during secondary research is that more direct evidence is needed than has been compiled for effectiveness evaluation to contribute to further development and improvement. Additional detailed findings of secondary research are presented throughout this study.

Primary Research

The primary research effort reported in this study actually began in 1962, approximately four years before the test of a proposed sponsor's measure of effectiveness. At that time, the investigator engaged in survey and design studies as a consulting systems analyst with contractors of the Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio. This work involved direct personal contact with operating centers, users, the technical communities, and sponsors for analytical purposes. Since that time continuing study has been made with the Air Force Machinability Data Center. Practice in this field has been an invaluable source of information. At the time the present phase of study was conceived, opportunities existed to conduct the work at locations other than the one selected. The review leading to extension of the existing study activity is summarized in Chapter V of this report.


In order to establish an approach for this study, users were interviewed at length. For this purpose an interview guide was developed from prior work by the investigator and from that of other available sources.\textsuperscript{98, 99, 100} After use of the interview guide (Appendix B of this report) a measure and experimental design for its test were developed. A questionnaire to gather information relating to the experiment was then designed and tested with a number of users. On the basis of results obtained, the questionnaire was revised and expected response was defined. Finally, sampling details were worked out, and information was gathered from a mailing of the questionnaire. During this phase of study, other information from sponsors and users was secured as a basis for evaluation of the experimental results. In addition, a general functional model of scientific and technical information centers was prepared to aid in definition of the measure and selection of a suitable study vehicle.

\textbf{Scope and Limitations}

The subject area of this study can be described partly in terms of topical coverage and partly by the amount of information reviewed in the course of the work.


\textsuperscript{99}CEIR, Inc., Proposal, Lecture Notes, and Questionnaires for The Army Research Office Scientific \& Technical Information Survey (working papers in the files of the investigator).

\textsuperscript{100}Science Information Exchange, Smithsonian Institution, Questionnaire on The Notice of Research Project (NRP) (unpublished papers in the files of the investigator).
Subject Matter Included in Study

Based on the topics covered in secondary research and the results of systematic analysis and primary research, this study deals with the following questions:

(1) What research has been reported to date with respect to information centers of this class in the areas of management, effectiveness measurement, and experimental designs for measurement?

(2) How can an over-all measure of effectiveness suitable for use by sponsors be constructed and tested?

(3) Of the various centers which might be studied, which offers the best expectation of productive research results in comparison to the effort required?

(4) What are the characteristics of a general case as compared to the measure and study vehicle selected?

(5) What are the characteristics of the technical community served by the center selected for study?

(6) What are the logical detailed steps to be taken in measuring effectiveness?

(7) Is the center selected covering essentially the proper (relevant) subject matter for its users?

(8) What differences in quality (relevancy, pertinency, and completeness) do users find in center outputs as compared with literature available for the same technical field?

(9) How closely does user evaluation of the center's output quality match the center's self-evaluation?

(10) Can the measurements obtained be verified independently?
Amount of Material in Study Inputs

Table 6 shows the number of items of various classes reviewed for this study. Because of numerous duplications of individual listings by various sources, the total number of titles and abstracts has been adjusted downward to eliminate duplication in counting.

**TABLE 6**

**APPROXIMATE NUMBER OF RELEVANT ITEMS REVIEWED FOR STUDY BY TYPE OF ITEM**

<table>
<thead>
<tr>
<th>Type of Item</th>
<th>Number of Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete bibliographies</td>
<td>9</td>
</tr>
<tr>
<td>Indexing, abstracting, and cataloging sources</td>
<td>7</td>
</tr>
<tr>
<td>Estimated total number of titles screened</td>
<td>3,250</td>
</tr>
<tr>
<td>Estimated total number of abstracts reviewed as an intermediate basis for selection</td>
<td>1,700</td>
</tr>
<tr>
<td>Estimated total number of documents actually examined (both secondary and primary)</td>
<td>1,200</td>
</tr>
</tbody>
</table>

Number of input items pertinent to this study found in the material reviewed is shown in Table 7. These counts are not mutually exclusive; for example, a research project may be an efficiency study.

**TABLE 7**

**APPROXIMATE NUMBER OF PERTINENT ITEMS DERIVED FROM SCREENING**

<table>
<thead>
<tr>
<th>Subject Area</th>
<th>Number of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Projects</td>
<td>100</td>
</tr>
<tr>
<td>Information Retrieval System Models</td>
<td>50</td>
</tr>
<tr>
<td>Effectiveness Studies</td>
<td>17</td>
</tr>
<tr>
<td>Efficiency Studies</td>
<td>58</td>
</tr>
<tr>
<td>Items with Management as Major Subject</td>
<td>21</td>
</tr>
<tr>
<td>Items with Management as Minor Subject</td>
<td>113</td>
</tr>
<tr>
<td>Experimental Designs</td>
<td>11</td>
</tr>
<tr>
<td>Background and Specific Interest</td>
<td>674</td>
</tr>
</tbody>
</table>
Additional material used for this report includes interviews, returned questionnaires, and schematics as discussed in the following chapters.

**Areas Excluded from Study**

This study represents an attempt to measure performance of a variable. As such, it deals with the environment and substrate disciplines only to the extent necessary to qualify and condition the study. The following specific limitations have been imposed:

1. This study is not expected to develop further or modify the subject of information theory.

2. The number of centers and subject-matter disciplines considered in developing a general case will be sufficient that the study is representative, but much of the field will receive only cursory note.

3. Even though this field is receiving attention abroad, particularly in the USSR, Germany, France, and England, this study will be limited to developments in the United States.

4. Questions of detailed operating procedure will receive limited attention as needed for treatment of the main questions rather than study in depth.

5. The study will cover a single characteristic for one center.

6. Although designed for later extension into time series, the single-point measure will cover 1965 performance only.

7. Emphasis will be placed on effectiveness, with no special effort being made to inquire into efficiency.
CHAPTER II

A GENERALIZED MODEL OF THE ORIGIN AND FLOW OF SCIENTIFIC
AND TECHNICAL INFORMATION

The literature reviewed in Chapter I proclaims the advent of a new
class of institutions for better economic and social exploitation of
technology. Although distinctions have been made between various kinds
based on functions performed and media handled, a general case can be
formulated such that all of the centers reported are variants of a basic
type. Because these institutions are relatively new, apparent differ-
ences or similarities may change significance after further experience
and study. Many of the new organizations are subsidized "captives" of
large enterprises, structured as cost centers rather than profit centers.
In such situations, some of their essential functions may be carried on--
perhaps contributed--by personnel outside the formal organization of the
scientific and technical information center. A reasonably complete set
of functions can be identified through examination of representative cen-
ters and existing statements of the general case. The restatement of
these descriptions constitutes a generalized model inclusive of all kinds
of centers, in that it describes the entire process of origin and flow of
scientific and technical information. This model is useful as a guide
for reviewing other studies of centers, for designing a measure of effec-
tiveness, and as a guide for selection of a specific study vehicle.
Review of Existing Description Patterns

Scientific and technical information centers have been described in a variety of ways. As shown in Table 8 below, the flow chart is the most commonly used descriptive technique for centers on which information is available. Most of the descriptions enumerated in this table represent specific individual centers; however, a substantial minority are attempts at statement of the general case.

TABLE 8

DESCRIPTIVE TECHNIQUES FOR SCIENTIFIC AND TECHNICAL INFORMATION ACTIVITIES

<table>
<thead>
<tr>
<th>Primary Descriptive Technique</th>
<th>Dominant Modeling Emphasis</th>
<th>Relative Frequency of Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Charts</td>
<td>Functions</td>
<td>72</td>
</tr>
<tr>
<td>Formulae</td>
<td>Symbolic (mathematical)</td>
<td>9</td>
</tr>
<tr>
<td>Graphs</td>
<td>Analogue</td>
<td>5</td>
</tr>
<tr>
<td>Program Statements</td>
<td>Combined Symbolic and Analogue</td>
<td>7</td>
</tr>
<tr>
<td>Slide Rules</td>
<td>Quantitative (time-volume-cost calculation)</td>
<td>2</td>
</tr>
<tr>
<td>Classification Listings</td>
<td>Qualitative</td>
<td>3</td>
</tr>
<tr>
<td>Pictures (annotated)</td>
<td>Iconic</td>
<td>2</td>
</tr>
</tbody>
</table>

a Based on 103 reported descriptions.

Specific Centers

Existing scientific and technical information centers were studied to determine whether their descriptions could support development of a generalized model. The following listed centers were studied through both visitation and review of their existing documentation.

Aerospace Industries Association
Aerospace Metals and Plastics Handbooks Projects
Air Force Machinability Data Center
Air Force Materials Information Center (University of Dayton)
Air Force Mechanical Properties Information Center
American Society for Metals Documentation Service
Chemical Abstracts
Defense Documentation Center
Defense Metals Information Center
Electronic Properties Information Center
Engineers Joint Council
General Electric Company Technical Information Center
Library of Congress National Referral Center
National Bureau of Standards
Office of Science Information Service, National Science Foundation
Thermophysical Properties Research Center

Although available descriptions of these systems were in diverse forms and terminology, they can be fitted into a tabular descriptive format. Eight of these systems are described as to functions in Table 9, page 57, and to scope in Table 10, page 58.
TABLE 9

FUNCTIONAL COMPARISON OF SELECTED TECHNICAL INFORMATION CENTERS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Available if needed</td>
<td>Available if needed</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Surveillance</td>
<td>No</td>
<td>Yes</td>
<td>Partial</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
</tr>
<tr>
<td>Acquisition</td>
<td>Passive</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
<td>Active</td>
</tr>
<tr>
<td>Technical Evaluation</td>
<td>Limited compared to scope of collection</td>
<td>No discrimination on input; output is reviewed</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Indexing and Coding</td>
<td>Terms: classical to semi-professional</td>
<td>Terms, roles, links: professional</td>
<td>Classification scheme</td>
<td>Classification scheme plus terms</td>
<td>Primary terms</td>
<td>Primary terms</td>
<td>Classification scheme plus terms</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>File Maintenance</td>
<td>Data processor</td>
<td>General purpose computer</td>
<td>Punch card files</td>
<td>Manual</td>
<td>Punch cards plus data processor</td>
<td>Data processor plus computer</td>
<td>Manual, punch cards</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Search Formulation</td>
<td>Terms: Boolean and plus &quot;levels&quot;</td>
<td>Terms, roles, links</td>
<td>Category selections or terms plus &quot;browsing&quot;</td>
<td>Terms plus &quot;browsing&quot; or terms</td>
<td>Terms plus &quot;browsing&quot;</td>
<td>Terms plus &quot;browsing&quot;</td>
<td>Full range of index features plus &quot;browsing&quot;</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Retrieval Processing</td>
<td>System specialist</td>
<td>System specialist</td>
<td>System specialist</td>
<td>System specialist</td>
<td>System specialist</td>
<td>System specialist</td>
<td>System specialist or user</td>
<td>System specialist</td>
<td>System specialist</td>
</tr>
<tr>
<td>Output Analysis</td>
<td>Limited</td>
<td>Verify relevancy and pertinency</td>
<td>Technical</td>
<td>Technical</td>
<td>Limited plus user</td>
<td>Limited plus user</td>
<td>Technical</td>
<td>Limited plus user</td>
<td>Limited plus user</td>
</tr>
<tr>
<td>Arrangement and Presentation</td>
<td>Limited</td>
<td>Preferred form including plots</td>
<td>Standard volumes of tables plus indexes</td>
<td>State-of-the-art articles plus extracts</td>
<td>Standard tables and indexes</td>
<td>Limited</td>
<td>Complete output composition</td>
<td>Limited plus user</td>
<td>Limited plus user</td>
</tr>
<tr>
<td>Applications Assistance</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Reversions or Additions</td>
<td>No</td>
<td>Limited</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Disposals</td>
<td>No formal program</td>
<td>Store segmented by time periods</td>
<td>Limited</td>
<td>No formal program</td>
<td>No formal program</td>
<td>No formal program</td>
<td>Systematic policing of file</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

TABLE 10
SERVICES, SCOPE, AND CONTENT COMPARISON OF SELECTED TECHNICAL INFORMATION CENTERS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Coverage</td>
<td>Broad</td>
<td>Broad</td>
<td>Primarily metals, some plastics</td>
<td>Any matter</td>
<td>Selected defense metals</td>
<td>Semiconductors insulators</td>
<td>Broad</td>
<td>All aerospace materials</td>
</tr>
<tr>
<td>Property Coverage</td>
<td>Broad</td>
<td>Broad</td>
<td>Mechanical</td>
<td>Thermophysical</td>
<td>Significant to current state of the art</td>
<td>Electrical and electronic</td>
<td>Broad</td>
<td>Significant to machining</td>
</tr>
<tr>
<td>Machining Information</td>
<td>Only as occurring in basic documents</td>
<td>Only as occurring in basic documents</td>
<td>No</td>
<td>No</td>
<td>Limited</td>
<td>No</td>
<td>Limited</td>
<td>All</td>
</tr>
<tr>
<td>Abstracts</td>
<td>Yes</td>
<td>Yes</td>
<td>Limited</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Documents</td>
<td>Yes</td>
<td>Yes</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable except DMIC articles</td>
<td>Not applicable</td>
<td>In-plant distribution or loan</td>
<td>Limited</td>
</tr>
<tr>
<td>Bibliographies</td>
<td>Yes</td>
<td>Yes</td>
<td>Available for data selected</td>
<td>Yes</td>
<td>Yes (selective)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Original Data</td>
<td>Only as occurring in basic documents</td>
<td>Only as occurring in basic documents</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Usually in file for center use only</td>
<td>Yes</td>
</tr>
<tr>
<td>Reduced Data</td>
<td>No</td>
<td>No</td>
<td>Limited</td>
<td>Yes</td>
<td>Yes</td>
<td>Limited</td>
<td>Limited</td>
<td>Extensive-recommended values</td>
</tr>
<tr>
<td>Compiled Data</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Index to System</td>
<td>Thesaurus plus instructions and guides</td>
<td>Category or subject list</td>
<td>Recently published formats and code books</td>
<td>Yes</td>
<td>Permuted by card file - not published</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>User Group</td>
<td>Primarily DOD plus military contractors</td>
<td>Industry in general</td>
<td>Aerospace industry plus DOD</td>
<td>Industry and research organizations</td>
<td>Aerospace industry plus DOD</td>
<td>Aerospace industry plus DOD</td>
<td>General Electric</td>
<td>Aerospace industry plus DOD</td>
</tr>
<tr>
<td>Relevant Sources</td>
<td>DOD Reports</td>
<td>World literature</td>
<td>DOD Reports primarily</td>
<td>World literature</td>
<td>World literature</td>
<td>World literature</td>
<td>World literature</td>
<td>World literature</td>
</tr>
<tr>
<td>Relation to MIC</td>
<td>Source of accession lists and documents</td>
<td>Source of accession lists and documents</td>
<td>Limited but complementary for use</td>
<td>Limited but complementary for use</td>
<td>Limited but complementary for use</td>
<td>Limited but complementary for use</td>
<td>Possible area of active cooperation</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

Additional descriptions of existing scientific and technical information centers were reviewed relative to the tabulation scheme derived for the first eight. Use of a limited number of differentiated statements for each function and classification category provides a good summary description of all centers studied. Usually two to six variations of the category description will cover all cases. These findings tend to support the idea that a general case can be stated for the origin and flow of scientific and technical information.

Generalized Models

An information system has been defined as "a complex of people, equipment, and procedures--working together to provide needed information to a group of users."¹ Within the area of documentation systems, a compatible definition has been offered which points out some of the broader implications of the work involved.

The mission of documentation is to get together the appropriate documents and the technical user who needs them, and when he needs them. The basic problem is the necessity of predicting the future needs of one group of human beings for the products, already produced, of another group of human beings. This is sociology.²

In attempts to identify the basic characteristics of centers of this class, a number of studies were made during the past decade as operating centers emerged in strength. As early as 1958, a report was given on


²Leah Bohnert, CEIR, Inc., Lecture Notes for The Army Research Office Scientific and Technical Information Survey (working papers in the files of the investigator).
the structure of information retrieval systems. The question of a preferred systems approach was covered by a review of several models in 1959. Under National Science Foundation Grant G2470, a continuing study of theories and models of information storage and retrieval has analyzed models based on Boolean algebra and developed propositional calculus and logical algebras for the generalized description of these systems. Another system model study supported by the National Aeronautic and Space Administration involves the use of a linear programming application by the information center manager. Studies of models have gone so far as to cover proposed national systems wherein all existing centers could be linked to cover all of the science and technology fields. These examples of studies concerning models of the general case have been cited to indicate the importance attached to such work by pioneers in this field. For the purposes of sponsoring managers,

5 D. J. Hillman, Study of Theories and Models of Information Storage and Retrieval (9 reports; Bethlehem, Pa.: Lehigh University, 1962-1964).
8 COSATI, op. cit.
however, the models reported are generally unsuitable either as to categories of analysis used or scope of the content presented. In the ensuing paragraph selected models will be discussed to illustrate these problems.

By 1960, the Committee on Government Operations, United States Senate, published a study of federal and nonfederal science information processing and retrieval programs with both general models and specific systems diagrams. A reproduction of the Committee's schematic of the scientific process appears as Figure 1 on page 62. This presentation includes three basic elements: (1) the organizational categories involved in the process, (2) the documentary products involved, and (3) the information flow channels along which products travel in going from one organization to another. Since the functions performed are not explicit, they must be inferred as those necessary and feasible in the light of the elements stated. Discussion provided with the schematic offers some insight to the kind of work done, and brings out the idea of the life cycle of information as a basic element in the process description.

Research produces a statement in words, numbers, graphs, or a combination of these, of the observed results of investigation, whether theoretical or experimental. A variety of motivations urges the scientist to add his results to the sum of human knowledge. In order for his additions to be valid and to satisfy his motivations, he feels bound to survey and utilize the record before making his contribution. This is the life cycle of information.

No single description of the scientific communications network is completely satisfactory. Both the existing and the ideal information system may be described in administrative terms as consisting of generators, processors and users of information, or the system may be described in terms of the information itself according to the functions information performs, for
example, to provide current awareness or a retrospective view of a topic or field.\(^9\)

FIGURE 1

SENATE COMMITTEE SCHEMATIC, HOW THE SCIENTIFIC INFORMATION PROCESS FUNCTIONS

Extension of this model in depth, based on additional information included in the Committee Report could very well provide a generalized model suitable for use in this study. An attempt at more detailed expression of information center functions is provided on page 224 of the Committee Study, by the schematic reproduced as Figure 2, below. Better elucidation of functions (as in Table 9, page 57) and more detailed expression of external factors are needed in lieu of those shown in

FIGURE 2

ITEK CORPORATION SCHEMATIC, OUTLINE OF MAJOR FUNCTIONS
FOR A DOCUMENTARY INFORMATION SYSTEM

Notes:
1. "User feedback" data generated by users of the output of the system is often of value and can be input, processed and treated as new input.
2. It is desired that if it is possible to output portions or all of document derivative data of all or portions of stored data or new input, arrangement and ordering of data to be fully flexible.
3. Tools for several system operations
Figure 2 on page 63. This schematic emphasizes the following elements: (1) various levels of information products internal and external to centers, (2) internal sub-functions in terms of data-processing procedures, and (3) the lines or channels which link the elements described. Notes provided on the schematic imply additional functional areas such as refinement and regeneration of information by users and selective composition of outputs by the information system. This description is heavily influenced by the specialization of the preparing organization in the area of media to be used in processing.

A model developed for use with U. S. Naval intelligence data and stated in general form emphasizes roles of users on the one hand and information retrieval system personnel on the other, as shown by Figure 3 on page 65. This model is a typical flow chart made in preparation for computer programming. Its emphasis on the iterative nature of the process probably stems from the fact that the model is intended for simulative operation using a large-scale computer. This example shows how limitations may be imposed on models to emphasize some particular process for study and exclude related factors. The authors of this model have recognized and stated these limitations.

The present information retrieval model is intended to reflect fundamental aspects of a mechanized system's response to a user's request for data. In the present stage of development, several assumptions have been made that restrict the scope of the model; hence, may limit the real world domain of systems reflected. This limitation is intentional and has been made in order to expedite the development and validation of the basic model. Once the basic model has been successfully tested, model expansion can be considered with respect to the utility and limitation in applying simulation results.

\footnote{Ibid., pp. 223-225.}
FIGURE 3
HRB-SINGER SCHEMATIC, BASIC MODEL LOGIC

START
FORM QUESTION

ASK QUESTION

RE-FORM QUESTION

ACCEPT ANSWER?

YES

INTERPRET ANSWER

NO

ASK QUESTION AGAIN?

YES

USER

INTERPRET QUESTION

INFORM USER

DELIVER ANSWER

NO

END

IR SYSTEM

ACCEPT QUESTION?

NO

POSE SET OF QUERIES

PROCESS QUERIES

PREPARE ANSWER

END

END OF ITERATION
The following assumptions are explicit in the present model development effort:

a. Information retrieval is accomplished with computer processing.
b. The user interacts with the system at only two points; i.e., he poses a question and receives an answer—he does not monitor intermediate processing.
c. The system is responsive to one user at a time; i.e., it is not a time sharing system.

These assumptions essentially focus attention upon the simulation of computer based information service systems and do not consider on-line time sharing systems.11

Other versions of models offer various combinations of the elements previously discussed and add related factors. The block diagram shown in Figure 4, page 67, shares the orientation of the Itek model (Figure 3, page 65) and emphasizes the items of equipment to be used.12 Its flow lines are differentiated as to control information, information transfer, and the retrieval process. However, disadvantages of this type of presentation are (1) prejudice as to equipment and media selection, (2) omission of major system elements, and (3) resulting loss of generality in the description. A presentation by Battelle Memorial Institute,13 as shown in Figure 5, on page 68, emphasizes the total process, diversity of sources of input information and need for discrimination as to what should be accepted into the system. Basically, the chart covers the movement of documents from the outside world

13 G. S. Simpson, Jr., "The Management of Scientific Intelligence," Recurring Presentation to visitors at Defense Metals Information Center, Battelle Memorial Institute, from working papers in files of the investigator.
FIGURE 4

SYSTEM DEVELOPMENT CORPORATION BLOCK DIAGRAM OF GENERALIZED INFORMATION RETRIEVAL SYSTEM

INFORMATION SOURCE
- Document
- Descriptor Terms

REQUESTOR
- Descriptors
- Instructions

INPUT CONVERTER
- Camera
- Film Processor
- Digital Encoder/Translator
- Optical Reader
- Keyboard
- Card or Tape Reader,
  Punch, or Writer

STORAGE
- Alterable Sequence
  - Cards, Chips, Slides, in Slots
  - or Stacks in Magazines
- Matrices, Film Strips-Short
- Fixed Sequence
  - Film, Reeled
- Tape

TRANSFER MECHANISM
- Retrieval, Return, Sort,
  Merge, Purge

OUTPUT CONVERTER
- Permanent
- Printers
- Photo Copiers
- Xerographers
- Temporary
- Projectors-Group Local
- Viewers Individual Local
- Crt, Kinescope - Remote

LOGIC UNIT
- Process Control
- Logical Searching, Indexing
- Decision Making:
  - Recognition
  - Priority
  - Queueing
  - Computation

LEGEND: CONTROL INFORMATION ——— INFORMATION TRANSFER ——— RETRIEVAL PROCESS
FIGURE 5

BATTELLE MEMORIAL INSTITUTE SCHEMATIC, THE PRIMARY FUNCTIONS OF SCIENTIFIC INFORMATION CENTERS
through very broad functional areas of selective acquisition, storage, retrieval, and production of outputs to return to the outside world.

For the purposes of this study, further detail is needed as to the nature of basic functions and their interaction with real world activities. A final example which closely approximates the type of presentation needed for this study has been prepared under contract for the National Science Foundation, shown as Figure 6, on page 70. This model traces the step-by-step procedures of documents and inquiries passing through a generalized document retrieval system. It is supported by a detailed system of taxonomy for describing system variables of each function in the following categories:

Process

Inputs and input variables

System variables

Personnel

Procedures

Equipment

Outputs and output variables

The model schematic combined with detailed process charts constitutes a powerful tool for description of document centers. Although well-suited to the purpose for which it was developed, this model suffers the following shortcomings from the viewpoint of this study: (1) it is conditioned to the class of centers known as document systems; (2) the functional

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*More traditional terminology is presented in parentheses. It should be noted that in some cases there are no traditional terms available to represent those used here. The terms in the boxes are those used in this report.*
breakdown provided is too detailed in some respects and too general in others; (3) admissible functions such as origin or new information and disposal of system content are omitted. A reorganization of the functional structure is needed as a basis for a revised model.

**Functional Synthesis**

The functional synthesis in this section relates descriptions of scientific and technical information centers to the description of overall information origin and flow in science and technology. This approach assumes that the scientific and technical information center has emerged as an institution for the specialized performance of organic functions already present in some form in society. If the functions to be reflected by the generalized model are present regardless of whether specialized institutions exist, they may represent suitable elements from which various types of systems can be composed. In the event a given institution performs only a portion of those functions which might accrue to the specialized institution, the presence of the remaining functions somewhere within the organization's environment will still be recognized. Individual systems descriptions and general models reviewed in the preceding sections do not reflect possibilities of functional trade-offs between centers and their communities. This thinking has been extended through lack of a descriptive level which integrates the two areas and provides a framework for the development of organization-independent functional statements for the specialized centers.

Most of the functions involved in the origin and flow of scientific and technical information, including specialized institutions involved in the process, can be compiled from the descriptions previously
reviewed. Some of these descriptions assume given types of media and equipment, with the result that the activities indicated have been conditioned along these lines and represent topics for procedures manuals instead of organic functional statements. Some of these procedural versions may be immaterial with respect to the over-all origin and flow of scientific and technical information. Even when information center functions are generalized, similar difficulties arise as shown by the following example:

This section discusses important functions common to many information systems. The discussion is not intended to constitute an "operating manual" or a listing of all factors, or even a detailed description of all important operations. Rather, it concentrates on facets of each operation which are critical, or on those facets which are often overlooked in information system design and operation. All information products and services described in the preceding sections are produced by some combination of the following system functions.

These are eight basic functions of IS & R systems from which all such systems can be assembled:

1. **Origination** (including initial publication) of an information item.
2. **Acquisition and/or selection and evaluation of informational items for use or for input into current-awareness, announcement, and/or retrieval systems into correlation processes.**
3. **Surrogation including indexing and/or abstracting.**
4. **Announcement of informational items.**
5. **Index Operation including recording of index information into a physical medium and the searching of that medium to provide an output of references and/or other item surrogates.**
6. **Document Management including storage, retrieval (based upon item addresses only), reproduction, dissemination, inventory control, etc., of documents.**
7. **Correlation of many informational items.**
8. **End-Use information.**

The basic functions can be combined into 10 basic types of systems.\(^1\)

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This description of basic functions has been selected because of its direct convertibility into a generalized model of the institutions represented. As shown in Figure 7, on page 74, the resulting generalized model is annotated to identify function combinations which result in different classes of centers. The basic idea of functions from which various centers can be assembled is also used in this study.

Based on a review of individual center descriptions, general models of centers, and descriptions of the total origin and flow of scientific and technical information, 13 fundamental informational activities are organic functions. The basis used to achieve functional separation was that an organic function must meet at least two of the following criteria: (1) specialization of equipment, personnel or procedures required for the activities; (2) occurrence of activities in time or location unsuited for combination with otherwise similar processes; and (3) a major difference in primary objective served by the activities included. If rigidly applied, these criteria might lead to an even further breakdown of the functional tendencies. Accordingly, some basis was needed to optimize the extent of separation and to permit combining of slightly dissimilar sub-functions into a single major function. The following criteria were applied to combine activities, subject to any over-riding basis for separation: (1) close procedural similarity involving shared personnel, equipment, skills, and processes; and (2) intimate proximity in sequence of operation such that the functions are impacted to an almost inseparable condition. All of these functions may be present within a scientific and technical information center. They may be performed in more than one way for different classes of users or
FIGURE 7
GENERALIZED MODEL OF THE ORIGIN AND FLOW OF SCIENTIFIC AND TECHNICAL INFORMATION

Scientific and Technical Activities
give rise to

Primary Work Functions

APPLICATION OF SCIENTIFIC AND TECHNICAL GUIDELINES

Application of principles, methodologies, approaches

DATA COLLECTING AND ANALYSIS

Collecting, analyzing, verifying, testing

APPLICATION OF SCIENTIFIC AND TECHNICAL COMMUNICATION

Presentation, review, feedback, criticism

ASSESSMENT AND CRITICISM

Evaluation, comparison, modification, integration

DECREASE AND AMENDMENT

Formulation, search, discovery

Consolidation, integration, extrapolation, innovation

STATE-OF-THE-ART

Inquiry

Information Life Cycle

Information Use Cycle

(regeneration)

(application)

(selection)

(display or presentation)

(retrieval)

Derivative Information Flow Functions

Involving

Sociological and Cultural Influences

Operational Limitations

Field Constraints

Analytic, methodologic, social, institutional

Contextual Factors

Models, correlations

Contextual Influences

Professional, institutional, sponsoring

Information Values

Publications, indices, individuals

Value judgments, goals
for the processing of different types of information media. They need
not be performed only by the center to the exclusion of external institu-
tions or personnel. Any one of the functions may be the basis for forma-
tion of a separate, specialized institution, although several are usually
required for the institution to qualify as a scientific and technical
information center. For example, the disposal activities could be ac-
complished by an audit team coming in from the outside, which would not
represent a center of the class under study. Sub-functions included with-
in each of the 13 major functions will be illustrated during discussion
of the generalized model based on this functional synthesis. The 13
major functions derived from this analysis are as follow:

Origin
Recognition
Capture
Evaluation
Conditioning
Storage or Access
Inquiry
Retrieval
Display
Selection
Application
Regeneration
Disposal
Over-all Structure of the Generalized Model

The functional synthesis of the models and individual system schematics reviewed for this study indicates that a completely generalized model can be developed to represent the origin and flow of scientific and technical information. The same basic functions should also be those of scientific and technical information centers. Differences in existing representations involve primarily (1) the level of detail shown in procedural steps, (2) the kind of equipment upon which the model is based, (3) completeness of the model with respect to functions and environment, and (4) the extent to which the model remains oriented to some fixed subject matter. Generalized, comprehensive categories for expression of the model include two basic areas—functions performed and the conditions under which they are performed. Since functions have already been identified, the question remains as to what system-environmental factors should be used. In the view of one author, environments for personnel of information centers involve categories analogous to markets, tools, and social aspects:

The personnel of information-processing centers exist in three inter-related environments: the task, equipment, and cultural environments.

A. The task environment is the set of changing external conditions to which the organization must adjust if it is to achieve the purpose for which it was formed.

B. The equipment environment is the set of equipment and facilities which the organization has available to deal with the task environment.

C. The cultural environment is the set of attitudes, values, and aspirations of the members of the organization relative to the purpose and activities of the organization.

In information-processing centers these three environments are in continual interaction, access to the task environment being mediated by the equipment and the cultural environment.
affecting the ways in which the task and equipment environment are perceived. 15

Equipment and interpersonal behavior, however, are internal factors of specific centers. If a center is to be evaluated on over-all performance, external factors are needed to express the input-output differences representing center performance. Study of the equipment environment can be waived until effects of internal factors are evaluated. In the area of social aspects, intergroup (involving external organizations) rather than interpersonal relations are important. Accordingly, the generalized schematic attempted for this study as shown in Figure 7, page 74, includes three broad determinants of the structure of any system or center of this kind, namely: (1) the real world activities of research, development, tests and engineering for the given field of science or technology; (2) the derivative information flow functions arising from and returning to the primary activities; and (3) the socio-cultural environment which conditions fields of specialization and their informational counterparts. Each of these three basic areas can be divided into functional or class groupings which generally follow the life cycle of information elements. When these three arrays are aligned as in Figure 7 to form a grid or mesh, the general model is formed. This treatment reflects a foldback of the information flow cycle, with new information flowing downstream and utilization of information representing a reverse flow. They are not intended to rule out the many other interactions and cross-coordinations which involve additional combinations of model elements. For a specific scientific and technical information center, some

of the functional areas may be performed or contributed by outside sources.

The attempt to establish a symmetrical pattern for system determinants is intentional, although somewhat arbitrary, at this stage of synthesis. Symmetrical arrays can be used to imply the existence of fundamental factors or to demonstrate irrelevancy and redundancy of elements. Since each of the models found through literature search can be subsumed by this general model, it appears to be adequate for purposes of this study. Its usefulness as an analytical tool is not necessarily seriously impaired if it departs from nature in some areas while serving to illustrate others.

It is often useful to distinguish between the problems at issue and the models to be employed. For instance, merely because a problem is 'nonlinear' it does not necessarily follow that the model must also be nonlinear. On the other hand, an undue emphasis on distinctions between 'qualitative' and 'quantitative' aspects of a problem can be misleading and possibly even frustrate creative possibilities for dealing with important aspects of a total problem.16

This model can serve as a pattern for review of reported performance measurements, selection of a study vehicle, and test for a measure of effectiveness. Additionally, it provides a framework for subsequent analysis of factors affecting the principal variable--output quality of the information center as compared to quality of the open literature. Beyond the scope of this study, it is offered as a single iteration within the formative process which will eventually produce a widely accepted model. Finally, its classified structure suggests the refinement

of taxonomic patterns to deal with any case of the flow of scientific and technical information. The need for such modeling tools is recognized.

Often there is a plethora of data which might be used in different ways. The results of one study may, for instance, point to the need for a further study. When the latter is executed—or at least when a whole sequence of studies has been executed—there is no machinery conveniently available for assembling and exploiting all of the accumulated study results. Another way of making the same point is to say—with only slight exaggeration—that the limitations of currently employed methodologies make it necessary to ignore the results of previous studies in order to focus on assimilation of the last one that has been executed.

Note, then, that it should be one task of a well designed model to assimilate and exploit all pertinent features of such previously executed studies.17

**Explanation of the Generalized Model**

The general model assumes that the production, handling, and use of scientific and technical information interact with the social and cultural environment in which they occur. As shown in the model schematic, closed loop and feedback characteristics support an evolutionary cycle. In addition, the passage of any given element of scientific and technical information through the model involves a life cycle from origin through disposal, even though intervening regenerative loops may be involved. Both deterministic and stochastic coupling of factors are implicit, depending on combinations selected for analysis.

**Scientific and Technical Activities**

The primary activity segment or external task environment of the model creates, limits, and conditions the counterpart information flow system. Beginning with physical experimentation or discovery and continuing through secondary research, these activities force the upward

movement of the technological spiral. At the end of each cycle of the spiral, another upward step has been made in state-of-the-art advancement. For a given center or class of centers, the needs and contributions of the using community predicate information-handling system parameters.

Primary work functions

Widespread continuing activities in the technical disciplines give rise to essentially new information. Viewed in the light of information theory, it is likely that much of the information implicit in the structure of events involved in an experiment never comes to light.\(^{18}\) The nascent information potentially available from an event may be lost through a lack of recognition or failure to capture and retain information. Even if this information is recorded, it may remain near its place of origin without achieving status and location from which it can be used. Knowledge of its existence may be restricted to one or a very few individuals. Ensuing changes in personnel, organizations, records, and projects can impede access to information costly in terms of time and money. Yet output of new information depends on the basic activities of research development tests and engineering practice.

Application of scientific and technical guidelines

The ability to gain information or learn from an experiment depends upon precepts and other scientific and technical guidance in existence. Uniform conventions and standards in a given technical area

formalize its methodology and assure that some of the significant information will be recognized as it arises from basic tests. These organized stereotypes underlie field constructs which aid in recognition and regeneration of significant information.

**Observation and analysis of Phenomena**

Once there is agreement or understanding of what information should be retained, observation and analysis become orderly processes. These procedures both facilitate and limit the future use which may be made of the information gained. Normative constraints such as models are often applied during this work. As large numbers of verified observations become available, the new information enters the next stage for reporting and publication where it becomes potentially retrievable. The operational phase during which observations are made also represents the period of application of retrieval data during the use cycle.

**Scientific and technical communication**

General awareness of the existence of new information in any field of science or technology usually depends on reports of investigations. Some writers equate publication with origination.

Origination involves the publication of information in some recorded form. A publication may be intended for general or private distribution and the information contained therein may be of ephemeral or lasting value.  

Since the introduction of error could result in serious problems, widespread review, criticism, and rejoinder occurring during scientific

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19 Berul, loc. cit., p. 5-5.
communication are used to refine or purify the new knowledge. Groups involved in the communication process include both formal and informal organizations of many types and sizes. This process makes necessary a selection function in the use cycle because of specific aggregations in the reported and published units.

**Assimilation and synthesis**

As contributors bring in additional evidence bearing upon some central question, relationships are perceived, quantitative values are standardized and made relatable to one another. Explanations arise as to the meaning of reported events. Throughout this sequence of events the new information has stood somewhat apart from previously existing knowledge. Reconciliations, modifications, and statements of new problems (unexplained variance) must be made to integrate the body of knowledge and show the direction for further work. During the use cycle, manner of display or presentation is a specialized version of the conditioning of data performed during assimilation and synthesis.

**Secondary research**

The information utilization cycle begins with secondary research. Stores of information are searched and retrieval products collected. Detailed correlations and questions are sought, often requiring data considered to be unrelated or non-pertinent in the original reports. Browsing activities may uncover unexpected but important collected material. The needs of these investigators and practitioners are the basis for establishment of specialized tools and institutions for handling scientific and technical information. As secondary research proceeds, the
field is further advanced, and the basic activities of research, development, tests, and engineering proceed from a higher level.

State-of-the-art advancement

The cumulative effect of gaining new knowledge and building on old foundations is a recognizable change in the state of the art in a given field. Outmoded answers are discarded. A new era of capability may be entered, or major revisions and consolidations may occur. In some cases completely new discipline may be born to occupy its own place in the total scheme of human knowledge, with or without the continuance of the older field of activity. Contributions of scientific and technical information centers to advancement are of two kinds: (1) addition to the accessible body of knowledge, and (2) strengthening of the learning process itself. The fundamental importance of these factors to society has been pointed out by the Dean of the Graduate Division of the University of California at Irvine.

Evolution is the long-range molding of a system by its environment and, clearly, the more malleable the system, the more readily it will change. This is a sort of learning by experience and applies equally to the evolution of the species, the development of the individual, the history of the society, and, in the more specific sense, to the education of or learning by the individual. But the crowning achievement of evolution is not learning but learning to learn; not being malleable, but increasing malleability.

Man as a whole, and not only in the underdeveloped areas, is continuously experiencing revolutions in expectations and in performance.

As science and technology have shrunk our world and expanded our universe, so they are creating the intellectual and material tools for dealing with the more complex systems they have generated. . . . Whether boon or burden (and I remain deeply convinced that it is the former) the taking over of lesser tasks by automata clearly does demand that humans be able to handle the greater ones. And this implies the upgrading of human capacity on a large scale. Indeed, as Gunnar Myrdal urges, a business
upsurge in this country would today bounce back from the low ceiling of managerial talent.  

Derivative Information Flow Functions

The life cycle of an element of scientific or technical information proceeds from its origin in real world basic activities through a number of processing steps, including utilization and regenerative loops, presumably reaching an end point at some future time. Some information elements such as physical constants are useful for long periods of time. It has been possible at the Thermophysical Properties Research Center, Purdue University, to correlate and integrate data elements occurring all over the world during a half century or more. As basic physical knowledge is applied through engineering and design functions, the learning process accelerates and the time during which information is valuable enough to keep becomes shorter. Changes in technology give rise to obsolescence of data. It appears probable that as information elements are assembled into successively more complex arrays, the complex message configurations have more specific (narrower) application and shorter retention life than the more simpler elements from which these complex structures can be assembled.

Origin of information

Information results from occurrence of physical events or from the association of existing elements of information. The plan of an experi-

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ment may be significant information. When the experiment is actually conducted, information is present as to the facilities used and the events which occur. Unless steps are taken to capture such information, however, it exists only in the mind of the investigator for a limited time. Whether it will be reduced to usable form depends largely on what the investigator has been trained to regard as important and worth capturing. This function is the information flow cycle is analogous to exposure to stimulus in behavioral models generally.

Recognition

Potentially usable information is recognized when some criterion (such as a rule of procedure or an anticipated use-value) is related to the observations being made. As the recognition function becomes more directly oriented to goals of field-of-interest advancement, these determinations tend to become more comprehensive and standardized. Conventions and other guidelines result which exert a common-denominator influence throughout the field of activity. These guidelines essentially determine the scope and limitations of the body of knowledge affected. Since the body of technical knowledge itself is in a state of continuous evolution and growth, the recognition function is involved with both new observations and regeneration of information arising from its use. The recognition function is closely related to the process of perception in behavioral models.

Capture

Capture of information occurs when it is reduced to a retainable and communicable form. It may be accomplished in a variety of automatic
and manual procedures. The capture or initial acquisition of technical information affects the completeness, accuracy, validity, timeliness, and usefulness of the total store of information for the field of science or technology involved. In the concept of this model, capture is more nearly the act of recording prior to reporting than that of reporting or publication.

**Evaluation**

Admissability of information into the accepted body of knowledge is determined by evaluation. Reporting and publication are the principal information-transfer processes used to communicate information and the responses which it evokes. During use and regeneration, retention priorities are set by the same process. Through process of accepting, ignoring, or modifying proffered information, practitioners in a field exercise broad evaluation. Some of the scientific and technical information centers rely on community evaluation rather than exercise discrimination. Regardless of whether the function is properly within an information center or left to the professional field at large, it is part of the total information flow process. After acceptance of information, the process of synthesis undertakes to condition, modify, or normalize material to be held and used further.

**Conditioning**

The function of conditioning normalizes information with respect to the field. Conversion in scales and units of measure may be required, as well as derivation of information products in more usable form through the application of established algorithms. At this point, the information is assimilated into the body of knowledge for its fields of interest.
This function is transitional in nature between the role of the investigator or practitioner on the one hand and the librarian or information-retrieval specialist on the other. Subfunctions performed by scientific and technical information centers include translation, screening, comparison to other sources, and input editing.

Storage or access

Physical preparation and retention of information in a variety of media are involved in the storage function. Descriptive information is compiled relating to content of the subject matter, annotations as to sources, and the procedures needed to recover and use the material stored. Many levels of the storage function exist, ranging from the individual's bookshelf to the library network and complex of scientific and technical information centers. The subfunctions of indexing and coding are part of this work.

Inquiry

The function of interrogation is defined as any demand for information made to a holder. It is considered to include the following cases:

1. Browsing of available materials for exploratory purposes.
2. Use of automatic dissemination of information, including definition of information products and their users by class or enumeration. This activity may be based either on an established cycle or some predetermined criteria resulting in a "technological alert."
3. Question as to availability of specified content within a store.
(4) Request for materials under any set of specifications as to kind of information desired.

(5) Request for analytical data on the operation of the system.

(6) Submission of test case interrogations for comparison of results with independently compiled objective data.

Search

The search function includes subfunctions such as indexing and encoding of inquiries, as well as actual file entry. It may involve the use of external sources such as auxiliary centers. These activities represent a substantial portion of the workload in accomplishment of secondary research. To a large extent they can be delegated by the practitioner from the scientific and technical information center or specialized library. This work highlights the increasing specialization and division of labor being attempted, as well as the application of the staff concept in support of engineers and scientists. The search function is the upstream analog of the storage function and shares its media and facilities.

Retrieval

The retrieval function represents recovery of an initial subset of items from the set stored. Further work is usually needed to arrive at an ideal subset. Retrieval is characterized more by the output than by work activities, as it is essentially the outcome of the search function. For purposes of distinguishing activities, search results in decisions to select or reject items. Retrieval is the physical implementation of the decision reached. It may involve verification of the accuracy or
suitability of search decisions. When the final system output is merely a list of references compiled by a data processor, search and retrieval have been combined into continuous sequential functions. Differences between retrieval subsets and the total store, as well as between retrieval subsets and available total knowledge, offer opportunities for performance evaluation.

Display or presentation

A newly emerging function is represented by display and presentation techniques. This process originated when excerpts from retrieval information were provided in lieu of the output product itself. Prints might be made from microfilm, or a viewer might be used. As the man-system interface becomes more complex because of the complexities of equipment, procedures, and files, display and presentation become more significant. Summary of many data points into a set of curves is an example of the growing kinds of service included in this functional area. Advanced systems permit on-line presentation of some portion of retrieval output during the inquiry session as search continues. This capability permits adaptive search and further combines functions into a continuous, sequential, recirculating process. It terminates when the most nearly ideal retrieval subset is selected.

Selection

The transition from information-handling to information-using functions begins with the act of selection. User decisions are the basis of selection, even when information specialists provide assistance and recommendations. Differences between the selected and retrieved
subsets, as well as between selected subsets and actual needs, offer opportunities for performance evaluation. The reasons for selection or non-selection of specific elements of information may have an important bearing on whether the material reviewed should be retained within the over-all system for future use.

Application

The use of retrieved information again joins the information-flow cycle with basic activities of research, development, test, and engineering. Through such use some measure of value is presumably added to whatever work is in process. On many occasions, attempts to use existing information points up a need for verification or origination of additional information. It may create new informational products because of the relationships investigated.

Regeneration

Refinements or additions to existing information are generated by users in accomplishing their work. This function is a form of information origin. It results in essentially new inputs to the flow of scientific and technical information leading back through recognition, capture, evaluation, conditioning, and storage as previously discussed. This sequence of functions for regenerated information may be simplified as compared with earlier cycles as the process results in improved working and reporting practices on the part of investigators.
Disposal

As the technological frontier advances, outmoded or superceded information becomes noise in the channel and should be removed. This function usually occurs slowly with the processes of education and retrospective appraisal. It is almost never timely and systematic. With the introduction of scientific and technical information centers, purposeful efforts on their parts to maintain a significant body of knowledge up to date may make the disposal function an active part of the information flow cycle.

Sociological and Cultural Influences

Technical activity and its related information flow functions are influenced directly and indirectly by social, cultural, and physical influences. Organizational techniques, media characteristics, language efficiency, and value judgments within society are examples of factors which interact with the primary and derivative functions. Technologists and information specialists must live and work in their respective environments. Whatever new levels of human capability are to be achieved through their efforts will arrive through an evolutionary process which is shaped by and in turn helps to shape the social and cultural influences.

Operational limitations

The design and conduct of experiments providing new knowledge is no better than the logic, apparatus, and operative models which have been achieved. New instruments open up new fields of measurement but most of man's unanswered questions must await the development of still
better capabilities. At best they are derived through a series of slow, painstaking steps interrupted by an occasional breakthrough. With each advance in the state of the art, new social attitudes and goals arise leading to activities which originate more new information.

Field constructs

Since total human knowledge is too vast and complex to be handled as such, divisions are necessary to permit groupings, classifications, measurements, interpretations, and orderly arrangement. The "field" is simply a category of analysis, man-made to conform to needs for empirically valid data. The field can be modified when changes are found necessary, and new fields can be introduced when useful. Such an analytical construct affects the organization of both physical and social sciences, and tends to produce reasonably distinct bodies of knowledge integrated around some unifying theme or principle. During the review for this study of fields represented by scientific and technical information centers, a post-hoc hypothesis was formulated that the subject-matter specialization pattern in these centers is a direct manifestation of the organization processes of human intellect. Should large-scale so-called artificial intelligence evolve based in part on information retrieval techniques, it may be that field constructs will be greatly altered. As of today, however, these analytical constructs are the patterns for organization of scientific and technical activities as well as their derivative information flow counterparts.

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Normative constraints

Not only does human intellect act as a filter through which the cosmos is known imperfectly, but other human factors also affect science and information. Language, sensory capabilities, motivational constraints, and motor abilities underlie normative constraints which influence the activities under study. Perceived experience and correlation abilities help shape the models used for basic activities and information processing. Whatever values may be imputed to the work of scientific and technical information centers, they originate in and must be measured against normative criteria arising from human factors.

Cooperating facilities

Since the biological capabilities of individuals are quite limited with respect to purposeful operations which they might undertake in a physical environment, organizations arise among people to permit cooperative activity. Whether formal, as in the case of states and firms, or informal, as in the case of professional colloquia, these organizations influence the terms of technical fields and their counterpart information systems. In Simon's treatment of organizations, groundwork is through models presented for viewing a given technical field (analytical construct) as a large informal organization composed of many formal and informal organizational components. Such a viewpoint gives rise to the notion of emergence of leadership and demand for


control within the field organization. The goal-seeking influences exerted by control and leadership are considered as an additional environmental influence in this general model.

Authority structures

A field of specialization produces outstanding individuals who become generally accepted as leaders in the field. These individuals affect the definition of the field, establish both its drive and inertia, and determine the degree of synthesis accomplished. The extent to which vogues, mainstreams of thought, and concepts of professionalism are tied to key individuals is usually obvious. The influences are bred back into the field through educational processes and through dicta echoed by sponsors. Broad value judgments as to what information is worth retaining and using come from these authority structures.

Information media

The memory of society is vested in the retention and recall capabilities of a specialized functional group—practitioners of library and informational sciences. These keepers of knowledge maintain the body of knowledge in a variety of media, receive interrogations, search the repositories and bring forth whatever is available. The degree of effectiveness and efficiency of these supporting functions affects the qualitative performance level of the basic technical activities in the field.

25 Ibid., pp. 41, 43.
Social appraisal

The demand for change arises from man's growing aspirations and his perception of new fields to be conquered. Social appraisal of accomplishments in a given field gives rise to new objectives involving requirements for new information. The outcome of basic technical activities is an advancement in the state of the art accompanied by discarding of outmoded ideas and information. The very act of advancement forms the groundwork for the next step which will bear fruit in some later step of advancement. As more becomes known, additional gaps and discrepancies in knowledge are isolated and work begins on discoveries to bring new information into the system. Performance evaluation of the institutions selected to carry out society's goals in this area must take into account that "man is the measure of all things; and there is no other measure."26

Effects of the Model on This Study

The generalized model of origin and transfer of scientific and technical information serves as a frame of reference upon which this study is developed. First, the review of previous attempts of performance measurement of centers uses the perspective of the model for classifying both supporting studies and actual attempts at performance measurement. Secondly, the design of a sponsor's measure of effectiveness depends on the generalized model for determination of points of measurement, identification of functions included within the span of

measurements, and indication of interacting factors inside and outside the span of measurement. Third, the model serves as a guide for selection and qualification of an individual center as a typical case to serve as a study vehicle. Finally, the generalized model itself will be questioned in the light of findings of the study. The plan for future study will involve extension of the model in depth for analysis of effects of detailed factors and for subfunction evaluation. This plan will also predicate revision of the generalized model based on continuing research and experience.

Effects on Review of Performance Measurement Studies

The generalized model assumes interaction between scientific activities, information transfer functions, and the socio-cultural environment within which these functions are performed. The study of performance measurement of scientific and technical information centers extends into all three areas. Measurements of effectiveness with which information transfer functions are performed constitute specific, primary performance measurements. These performance measurements often rest on studies of more general viewpoint. For example, a given field of technology may be studied so that its users can be identified and described. The description of users provides an analysis of their needs on which primary objectives of information centers are based. These objectives in turn provide the concepts on which performance measurements are based. Other examples of studies supporting the performance measurement process include formulation of definitions, establishment of criteria and figures of merit, improvements in system design capabilities, and the development of methods for performance measurement.
During the review of specific performance measurements, the functional scope of individual studies is identified in relationship to the general model. Specialized activities such as indexing, search, and file ordering are recognized as procedural classifications within the mere general functions of the model itself. Such a treatment is useful for indicating areas of possible needs not yet covered by performance measurement studies, for showing the heavy concentration of existing studies within a few relatively narrow areas, and for indicating the scarcity of studies which measure over-all center performance without restriction as to demand which can be placed on the center.

Since existing studies relating to performance measurement are reviewed with respect to the same model used for development of the measure and center selection, direct contributions from previous work are easily taken. These contributions include both elements to use and features to avoid. The model serves as a means for avoiding duplications and as a basis for concentrating this study within a problem area of major importance.

Effects of a design of a measure of effectiveness

Since the proposed sponsor's measure of effectiveness conforms to the general model, it should be applicable to almost any scientific and technical information center. Centers which perform partial sets of the information-transfer functions called out by the model can be evaluated by the measure, as can centers performing all of those functions. Only in the case where all users are personnel of the center itself is the measure inapplicable--because of loss of independence. In view of
future use planned for the measure of effectiveness in multiple-center measurements, time-series extension, and subfunction evaluation, the model offers a unifying basis for more detailed studies. Thus, the model establishes the kind and extent of versatility and adaptability of the measure. These effects relate primarily to functional span and level of the measure.

The range of alternatives allowed for design of the measure is an important feature of the model. Since the model is independent with respect to detailed system components, the measures based on it can be either general or specific. Choices are open as to what aspects of the following factors are considered:

Users
Information sources
Goals or purposes
Resources or available means
Personnel
Facilities and equipment
Information concerning operations
Information stored and retrieved
Adaptive techniques\(^27\)

Effects on Selection of Study Vehicle

Use of the general model as a guide for selection of a study vehicle narrows the field of prospective candidates. In order to cover

the model's functional scope, the study vehicle should accomplish both document retrieval and information-analysis functions. Its performance should be influenced by the quality and extent of its recognition of surrounding technical, social, and cultural factors. Demand on the center should be virtually unrestricted in order for actual user needs and bonafide performance efforts to make their effects felt. Since the model is characterized by open choices concerning factors at the operating level, a center is needed for study which exercises both short-run and flexibility in many areas. Otherwise, the evaluation may rate a choice of equipment or any other factor regarded as fixed. The center management should be goal-oriented to an extent that independent judgment is exercised in selections among alternatives. Thus, the quality of management and viability of the socio-economic relationships will be tested. Finally, the study vehicle should offer records or ways of obtaining information relating to factors described by the model.
CHAPTER III

PERFORMANCE MEASUREMENT OF SCIENTIFIC AND TECHNICAL INFORMATION CENTERS

Performance measurements of scientific and technical information centers represent a number of tests, measurements, and experiments involving specific centers. They also involve studies and investigations which contribute to performance measurement capabilities even though not involving specific measurements. Analysis of these background and supporting studies is a key to understanding the measurements themselves. Of the many ways in which these studies can be classified or grouped, a basis for arrangement has been selected which will facilitate design and test of the sponsor's measure of effectiveness. Preliminary discussion of the problem of effectiveness measurement in Chapter I has shown that the following factors set the stage for performance evaluation: (1) specialization, division of effort, and organizational adaptation in response to development of a technological frontier, (2) lack of a suitable mechanism such as the open market for appraisal of cost and value relationship, (3) the importance of overall center performance as compared to performance of subfunctions, (4) the need for measurement of operational rather than simulative performance, (5) the importance of user reaction to center performance, and (6) suitability and feasibility of measurement method. These
fundamental considerations in the problem of effectiveness measurement provide a useful basis for classification of prior efforts. This organization of the material identifies usable elements, points out difficult areas, and indicates gaps for which additions to technique will be needed.

**Studies Supporting the Performance Measurement Process**

To some extent over 50 per cent of studies and investigations relating to scientific and technical information centers indirectly support the process of effectiveness measurement. This general relevancy has been summarized in the background review provided in Chapter I. Fewer studies are directly pertinent to the problem of effectiveness measurement without being actual attempts at measurement. These include (1) definitions of fields of interest, (2) appraisals of users' needs, (3) studies which identify objectives, (4) evaluations of system design methods, and (5) studies for the development of evaluation methods.

**Definitions of Fields of Interest**

The field construct identifies an area of responsibility of a scientific and technical information center with respect to technical content required and--by association--the principal group of users. Because these studies set the stage within which centers operate, they provide much of the context within which performance measurements are attempted. Questions of usefulness, accuracy, and completeness of products should be evaluated in terms of field-of-interest definitions.
These may be general or specific, simple or complex. The level of subject-matter classification varies widely from one field to another. Some definitions include quantitative parameters such as: (1) estimates of the total volume of information present, (2) rate at which new information becomes available, (3) time lags between origin and availability of information, (4) numbers and types of individuals and organizations in the using community, (5) number and identity of major contributing sources, and (6) norms relating to accuracy and sufficiency.

The Air Force Materials Laboratory at Wright-Patterson Air Force Base, Ohio, offers a range of examples of field definition. The laboratory itself is concerned with all aerospace materials and related processes. Many branches of science and engineering are subsumed under the charter of this organization. To maintain adequate resources of scientific and technical information, the Air Force Materials Laboratory has defined a number of sub-fields in terms of: (1) its internal organizational components, and (2) several external organizations which it sponsors. Internally, the organization's sub-fields are as follow:

Advanced Filaments and Composites
Metals and Ceramics
Nonmetallic Materials
Manufacturing Technology
Materials Physics

1 Edward Dugger, op. cit., p. 28.
Externally, separate sub-fields are represented by scientific and technical information centers supported or used by the Air Force Materials Laboratory, as follow:

- Binary Constitution Information Service
- Defense Metals Information Center
- Radiation Effects Information Center
- Thermophysical Properties Research Center
- Electronics Properties Information Center
- Ceramics and Graphite Information Center
- Mechanical Properties Information Center
- Machinability Data Center

In addition, another materials information center operated by the University of Dayton is maintained as a document information center. An example of generalized field-of-interest definition, it stores and retrieves documents specified by the sponsoring laboratory. Within this limitation the center is responsible for analyzing documents received and indexing all materials and processes for which information is given. With respect to this case, the question remains as to what basic or underlying study contributed to the field-of-interest definition. It is typical in two respects: (1) the areas of responsibility of all centers studied involve field-of-interest definitions, and (2) few if any formal studies can be found providing the definitions.

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Edward Dugger, loc. cit.

These definitions arise over extended periods of time as a result of exercise of the planning function, evaluation of experience, and continuing efforts in the design and improvement of organizations and systems.

Although most field-of-interest definitions result from informal or unpublished work, other cases exist. Some of these appear to document the work of definition after the fact. They may have arisen for performance-measurement purposes to establish the background. Others arise as a result of feasibility and design studies prior to the operational establishment of centers. These latter studies are of particular interest in the performance-measurement process because they provide an opportunity to measure in terms of design intent and to criticize the quality of planning from a position of hindsight. An early example of field-of-interest definitions involves the Thesaurus of the Defense Documentation Center (DDC), formerly the Armed Services. This list of some 6,000 terms provides a kind of definition. Initially, it grew through a somewhat piecemeal selection and adaptation of categories and through a natural acquisition of expanding terminology from documents indexed. At a point of major appraisal, experience was analyzed and the Thesaurus rewritten. Benefits expected from this redefinition of the field of interest have been expressed as follow:

Also, tremendous gains are possible by building a vocabulary as compatible as possible with other information activities, such as those of NASA, AEC, OTS, and SOS activities and contractors. The eventual pay-off here is computer-to-computer interchange of information and the interchange of magnetic

tapes. If, for example, a DOD contractor has a problem requiring information on a certain subject, the holdings of not only ASTIA, but those of NASA, AEC, OTS, and any other specific cooperating activity could be searched with the reports of ASTIA and references to documents and other services supplied to the contractor in one package; all in a matter of minutes. A reciprocal arrangement would be possible for all participating activities.\(^6\)

Another example of field definition in advance of an operational phase is provided by the Air Force Machinability Data Center. Based on field investigation, sponsor's objectives, and professional evaluation, the study group arrived at a definition in terms of sources, users, media, and information content.\(^7\) Perhaps the most elaborate field-of-interest definition attempted is that of Task I of the U. S. Army Engineering Data and Information System Study Series. The structure of these studies has been defined as follows:

1. **Task I: Determine Data and Information to be Handled**
   a. A classification of the data needed.
   b. A classification of the data existing and/or available.
   c. Identification of sources, types and volume of the demand and supply of data.
   d. A study of existent data handling systems applicable to engineering data.

2. **Task II: Develop Programming and Procedures**
   Development of formats, procedures and an effective common language for identification and transfer of data and information within the system and for input/output outside the system.

3. **Task III: Develop Network Design**
   a. Evolutionary development of an EDIS network, using interim reports generated by Tasks I and II as guidelines.

\(^6\)Ibid.

b. Cataloging of available automatic equipment applicable to information handling.
c. Development of administrative and managerial controls and personnel requirements for EDIS.
d. Recommendation of a complete network design and of a pilot system, including specification of pilot tests.

A summary description of the field-of-interest definition reached has been provided in part of the Task I reports.

The primary purpose of this report is to identify and define disciplines and fields in the RDT and E cycle, which are practiced and/or utilized by Army RDT and E personnel. Disciplines are broad areas of knowledge, which are composed of fields and descriptors. Examples of disciplines are Aeronautical Technology, Chemistry, and Electronics and Electrical Technology. A field is a division of a discipline, which is composed of descriptors. Examples of fields are Aeronautics, Inorganic Chemistry, and Computers. Since descriptors have been used to define disciplines and fields, it is necessary to define the term "descriptor." A descriptor is a division of a field, which represents the narrowest level of classifying an area of knowledge. Descriptors range from broad terms to very specific terms. Examples of descriptors for Aeronautics are Aircraft Landings, Airspeed, Aviation Accidents, Aviation Safety, Buffeting, Carrier Landings, Descent, Ditching, Flight, Formation Flight, etc.

The investigation of disciplines and fields is an important preliminary step in the design of the interface between EDIS Switching centers and the EDIS data banks. By designing a categorization scheme based on Army RDT and E disciplines and fields, communication of a query can be accomplished with a common language.

The examples given of disciplines and fields are subject oriented. The scope of this study extends to other orientations such as missions, projects, items, and expertise.

Evaluation of Users' Needs

Once the importance of users was clearly understood from field-of-interest definitions, the user emerged as the focal point for

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studies in support of systems design and performance measurement. Fields of interest became reflections of users' needs. The need for an approach to user analysis has been recognized by the authorities listed in Table 11, page 109. Criticism of user studies has been offered along the following lines: (1) users' equivocation and uncertainty make them difficult to stereotype,\(^1\) (2) use studies are needlessly duplicative but fail to replicate each other,\(^1\) and (3) these studies have suffered from "lack of funds, a lack of coordinate planning, lack of quality, and lack of sufficient recognition of their value."\(^1\) Since the research task structure interacts with information sources,\(^1\) user studies must probe deeper than they have in the past to support adequately the areas of system design, performance, and effectiveness evaluation.

Individuals exhibit wide ranges of creative talent, knowledge, needs. Each person in each situation has his present compromises--unstated assumptions about what it is futile to ask for--and these are certainly far from the ideal satisfaction of all useful needs for access to recorded knowledge. His statements about his needs will almost always reflect his bondage to present habits of obtaining and using technical information.


\(^{12}\) COSATI, op. cit., p. 8-10.

In practice, his statement of need prior to search will frequently be inconsistent with his success rating after the search— for the later classifications suggested above— because he learned something during the search. There is even some evidence that the modifications of statements about need are different for manual and mechanized search.

Increased efficiency of use might follow more studies of real need, as distinct from conventionalized and compromised statements of need.\(^1\)

Contribution of user studies made to date are summarized in Table 12, on page 110. Three caveats entered against reliance on user perception to establish system controls involve: (1) limitations on system resources, (2) idiosyncratic search behavior, and (3) adaptability of users rather than systems.\(^2\) Policies should be defined in each of these areas in order for performance evaluations to be meaningful.

**Studies Relating to Goal Identification**

As goal-oriented organizations, scientific and technical information centers can define their objectives in terms suitable for the performance-measurement process. Reported studies on definition of goals involve four subject areas: (1) objectives involving quality and quantity of performance, (2) estimates of economic value of output, (3) measurement and control of cost, and (4) establishment of criteria and figures of merit relating to these areas. Such studies represent a third level of complexity in the background studies supporting the measurement process. Just as field-of-interest definition leads to

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## TABLE 11

**AUTHORITATIVE VIEWPOINTS ON THE NEED FOR USAGE ANALYSIS IN INFORMATION RETRIEVAL SYSTEM DESIGN AND EVALUATION**

<table>
<thead>
<tr>
<th>Investigator and Topic</th>
<th>Significant Concepts Relative to Performance Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charles P. Bourne</td>
<td>User requirements are part of problem definitions, and ten methods are given for their determination which shape system performance.</td>
</tr>
<tr>
<td>&quot;A Review of the Methodology of Information System Design&quot;*a</td>
<td></td>
</tr>
<tr>
<td>Harold Borko</td>
<td>Categories of information usage should be found through field studies, case studies, surveys, and experimentation as an interacting component in the system.</td>
</tr>
<tr>
<td>&quot;Determining User Requirements for an Information Storage and Retrieval System: A Systems Approach&quot;*a</td>
<td></td>
</tr>
<tr>
<td>Saul Herner</td>
<td>Compromise is sought to satisfy the greatest segment or discommode the smallest segment of the user-group</td>
</tr>
<tr>
<td>&quot;The Determination of User Needs for the Design of Information Systems&quot;*a</td>
<td></td>
</tr>
<tr>
<td>Joseph Becker</td>
<td>Successful information storage and retrieval systems must satisfy unbounded user needs which vary over time.</td>
</tr>
<tr>
<td>&quot;Getting to Know the User of an IR System&quot;*a</td>
<td></td>
</tr>
<tr>
<td>C. Allen Merritt</td>
<td>Maintaining user satisfaction requires constant monitoring of what a user gets from a system and how valuable it is to him.</td>
</tr>
<tr>
<td>&quot;The User and the Technical Information Center&quot;*b</td>
<td></td>
</tr>
<tr>
<td>D. C. Englebart</td>
<td>Automatic systems are needed which will match specific needs of users in terms of individualized concepts, facts, considerations, etc.</td>
</tr>
<tr>
<td>&quot;Special Considerations of the Individual as a User, Generator, and Retriever of Information&quot;*c</td>
<td></td>
</tr>
</tbody>
</table>

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*c* American Documentation, XII, No. 2 (April, 1961), pp. 121-125.
### TABLE 12
EXAMPLES OF USER AND USE STUDIES FOR SCIENTIFIC AND TECHNICAL INFORMATION CENTERS

<table>
<thead>
<tr>
<th>Investigator and Project</th>
<th>Significance to Performance Evaluation Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auerbach Corporation User Needs Survey&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>(1) Quantitative parameters of needs</td>
</tr>
<tr>
<td>Howard Research Co.&lt;sup&gt;c&lt;/sup&gt;</td>
<td>(2) User judgment is not a sufficient criterion of information problem existence.</td>
</tr>
<tr>
<td>EDIS Task I—Identification of User Needs</td>
<td></td>
</tr>
<tr>
<td>Saul Herner</td>
<td>(1) Correlated three major user studies</td>
</tr>
<tr>
<td>Survey of Scientists at Johns Hopkins University</td>
<td>(2) Verified homogeneity of user needs across multiple fields and organizations.</td>
</tr>
<tr>
<td>Ralph R. Shaw&lt;sup&gt;e&lt;/sup&gt;</td>
<td>Only factors related to information-gathering habits were fields of work, type of scientific organization, and</td>
</tr>
<tr>
<td>Diary Study of Information Use by Scientists at U.S. Forest</td>
<td>pure versus applied science.</td>
</tr>
<tr>
<td>Products Laboratory</td>
<td>(1) Established crucial importance of</td>
</tr>
<tr>
<td>Shilling et al.</td>
<td>(2) Linked ranks of scientists to their information behaviors.</td>
</tr>
<tr>
<td>Study of Informal Communication among Bioscientists</td>
<td>Correlated information inputs (communications) with technical productivity (outputs).</td>
</tr>
<tr>
<td>Herbert Menzel</td>
<td>Significance of informal, unplanned episodes in scientific information flow.</td>
</tr>
<tr>
<td>Information Exchange among Biochemists, Chemists, and Zoologists&lt;sup&gt;g&lt;/sup&gt;</td>
<td>Planned series of 12 studies since 1963 established comparative data.</td>
</tr>
<tr>
<td>American Psychological Association Information Exchange among Psychologists&lt;sup&gt;h&lt;/sup&gt;</td>
<td>Established value of information through comparison with alternative means of getting equivalent material.</td>
</tr>
<tr>
<td>T. J. Allen</td>
<td>Scientists perceive value in promptness, pertinency, participation, and use of journals and centers.</td>
</tr>
<tr>
<td>Utilization of Information Sources during R&amp;D Proposal</td>
<td>Technical information needs are similar regardless of vertical engineering classification or location.</td>
</tr>
<tr>
<td>Preparation</td>
<td></td>
</tr>
<tr>
<td>C. P. Bourne et al., Survey prior to Establishing Atomic and Molecular Processes Information Center</td>
<td></td>
</tr>
<tr>
<td>N. P. Levy, Western Electric Co. Stratified Random Sample of Engineers by Vertical Classification</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 12--Continued


analysis in terms of user needs, identified needs become the basis for definition of goals. The resulting defined values are the points of comparison for the performance-measurement process.

Objectives pertaining to quality and quantity of performance are based on the relative thoroughness of field-of-interest coverage, production of outputs, performance of specialized services (such as answering inquiries or assisting with use of information), technical and orthographic accuracy, and timeliness of performance. The objectives of a typical scientific and technical information center illustrating each of these areas appears in Table 13 on page 113. To the extent that users' needs recognize the factors described as important, each will be included in the total framework of objectives for the center.

The necessity for allocation of scarce resources gives rise to questions of value of products and services performed. Although referred to in the literature, the concept of marginal utility of information is inadequately developed at this time to permit evaluations based on economic models. As an exploratory study points out, indicators of values in output would be useful indeed, but few have been found.\(^{16}\) Output of a given center may have initial or immediate value in terms of alternative costs of securing equivalent information, elimination of organizational slack (which is often susceptible to cost appraisal), or the estimated fee that the user would be willing to pay to obtain the services involved. Beyond this proximate concept of value, ultimate effects of information used are almost impossible to trace.

\(^{16}\) Case Institute of Technology, Measurement of Value of Recorded Scientific Information (Cleveland, Ohio: Case Institute of Technology, 1961).
### TABLE 13

**CLASSIFICATION OF STATEMENT OF OBJECTIVES OF THE AIR FORCE MACHINABILITY DATA CENTER**

<table>
<thead>
<tr>
<th>Stated Objectives⁸</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>To provide a base for improved technical communications among aerospace users, contributors, and sponsors.</td>
<td>performance of specialized services</td>
</tr>
<tr>
<td>To provide timely, comprehensive, reasonably complete, qualified information to aerospace users and their sponsors.</td>
<td>production of outputs; technical accuracy; timeliness</td>
</tr>
<tr>
<td>To document adequately the state of the art in machining technology.</td>
<td>thoroughness of field-of-interest coverage; orthographic accuracy</td>
</tr>
<tr>
<td>To define a program base and areas of need for developmental work in machining research and engineering.</td>
<td>performance of special services</td>
</tr>
<tr>
<td>To devise continuous improvement in the support of engineering effort by the use of artificial intelligence (machine), including the application of advanced information storage and retrieval techniques aided by computers.</td>
<td>performance of special services</td>
</tr>
<tr>
<td>To participate in a well-coordinated manner in the growing community of defense technical information centers and the general defense documentation program.</td>
<td>thoroughness of field-of-interest coverage</td>
</tr>
<tr>
<td>To perform technical evaluations and delineate the extent of validity and acceptability of information reviewed.</td>
<td>technical accuracy</td>
</tr>
<tr>
<td>To assist in controlling costs of the overall machining information program, and in turn the areas of use affected.</td>
<td>performance of special services</td>
</tr>
</tbody>
</table>

Nevertheless, there is speculation that the application of information values in economic activities involves some multiplier effect analogous to that of capital investment.

Today there is a need for more complete systems to provide detailed reference to specific information. How do we justify the cost to satisfy this need? One way is to treat information as a commodity. Buying and selling this commodity through a mechanized Information Retrieval system can result in a significant saving for any company.

When trying to equate this commodity with dollars, we find two contributing factors which must be included:

1. The dollar value of the time saved in locating the needed information. Also consider that under many manual systems the information may never have been found.
2. The dollar value of resulting production after the information has been located.

An information system provides only the first of these, but the savings resulting from the second must be considered. 17

These studies of value in informational products are not likely to provide quantitative measures. 18 However, they support the performance-measurement process by providing an abstraction or an absolute concept which aids development of alternative techniques having better operability. Regardless of whether value measurements are perfected for this field, the search for values leads to rational appraisal. Productivity changes for an industry or using community may be attributable to information use patterns during the conduct of these studies. 19


In the absence of quantitative values for information outputs, other criteria are needed for use in the performance-measurement process. A variety of figures of merit have been established by operating centers but no common-denominator criteria have been accepted. The simplest criteria represent identification of some figure of merit in connection with the performance objective. When the performance objective is compliance with the letter of the inquiry, relevance is a measure. However, relevance may be tied to user needs instead of query structure, making a more general value-judgment necessary. As management seeks to discover and control positive factors of desired performance, these criteria become more complex. Often they are set up with respect to subfunctions and processing procedures in the attempt to influence over-all performance. Some of the more important criteria developed to date are shown in Table 14, on page 116. These criteria imply some level of acceptability for the performance factor involved. This concept is quite useful in the process of management by objectives, and further development of figures of merit appears to be desirable. This study of a proposed sponsored measure of effectiveness for scientific and technical information centers will provide benchmark data for each factor tested.

Studies relating primarily to costs of operation are probably the most common and best-defined of all the topics involved in goal formula-


## Table 14

**Performance Measurement Criteria for Scientific and Technical Information Center**

<table>
<thead>
<tr>
<th>Study Orientation</th>
<th>Criterion Suggested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptation of Shannon's &quot;entropy&quot; to Retrieval Cost-Effectiveness&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Efficiency = ( \frac{CT}{R} ), ( C = \text{Cost} ), ( T = \text{Time} ), ( R = (e_1 N)(e_2 \frac{F}{N}) ), ( e_1 = % ) of each active record of interest, ( e_2 = % ) of actual records, ( F = \text{File Size} ), ( N = \text{File Item Length} ).</td>
</tr>
<tr>
<td>System improvement costs, versus users' manhours&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Efficiency = ( \frac{\text{Service Units}}{\text{Cost}} ), Service Units = item-use days, item = catalog entry, use is defined by user processes.</td>
</tr>
<tr>
<td>Pertinency is need-oriented, relevancy is question oriented.&lt;sup&gt;c,d&lt;/sup&gt;</td>
<td>Performance = ( f(u,v) ), ( v = C(T) = \text{efficiency} ), ( u = \text{effectiveness} = f(\text{sensitivity, specificity}) = p(A=I) + p(A=I^<em>) - 1 ), where ( C = \text{Cost} ), ( T = \text{Time} ), ( A = \text{system output} ), ( I = \text{ideal set} ), ( I^</em> = \text{non-selected items and undesired set} ).</td>
</tr>
<tr>
<td>Basis for developing independent measures&lt;sup&gt;e,f&lt;/sup&gt;</td>
<td>(1) user satisfaction, (2) comparison of systems, (3) comparison to ideal. Uses query-oriented ratings: crucial, relevant, non-relevant.</td>
</tr>
<tr>
<td>Review on Costs and Evaluation of Centers&lt;sup&gt;g&lt;/sup&gt;</td>
<td>Quantitative factors have led to poor measures; user satisfaction statements have been qualitative. Better quantitative measures are needed.</td>
</tr>
<tr>
<td>Plan for National Information Center&lt;sup&gt;h&lt;/sup&gt;</td>
<td>Currency, range of interest (pertinency), reliability, assimilability, credibility, regularity (relevancy), randomness (entropy), and completeness.</td>
</tr>
<tr>
<td>Criticism of proposed measure&lt;sup&gt;i&lt;/sup&gt;</td>
<td>Relevance to search request leads to suboptimization; exploratory IR System can fulfill higher goals.</td>
</tr>
<tr>
<td>Model and Simulator for IR System Performance&lt;sup&gt;j&lt;/sup&gt;</td>
<td>Performance = ( f(\text{Cost, Time, Volume}) ). Comparative evaluations of systems are facilitated; simulations are feasible.</td>
</tr>
<tr>
<td>Analysis of Natural Language Texts&lt;sup&gt;k&lt;/sup&gt;</td>
<td>Relevance may be either complete matching to question or something less. Implies degrees of relevance.</td>
</tr>
</tbody>
</table>
TABLE 14--Continued


h Mayo-Wells, op. cit., pp. 61-73.


tion. Requirements for the use of budgets and imposition of accountability on the centers have forced the establishment of cost objective by functions, departments, products, facilities and equipment and other categories. Direct costing is simple to apply in these centers. Little work has been done, however, on the question of how to amortize investment-type costs such as file-building over its foreseeable use period. Typically, stores of information have been gathered on a crash basis to achieve operational status so that large non-typical costs are incurred during the early years of a center's operation. Cost information generally supports efficiency studies but enters into the question of effectiveness only in special cases such as when a cost-effectiveness ratio is used as a measure of performance. Some authors, however, attempt to introduce the cost aspect as a part of effectiveness. A summary of selected contributions on cost as a factor in performance measurement appears in Table 15, page 119. Costs are significant to sponsors in the consideration of alternative approaches, in arriving at value added where estimates of value are available, and in locating areas of potential interest in the improvement of factor efficiency. For the purposes of the present investigation, however, they are outside the meaning of the term "effectiveness" which is considered to relate only to goal accomplishment.

Evaluation of Method for System Design

After defining the field of interest, needs of users, and their various goals, centers begin to ask whether the methods used in their design were conducive to obtaining a system with the desired performance characteristics. This inquiry leads to the question of what
### TABLE 15

**SELECTED VIEWPOINTS ON COST AS A FACTOR IN PERFORMANCE MEASUREMENT**

<table>
<thead>
<tr>
<th>Project Orientation</th>
<th>Significant Cost Aspects Developed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need for time standards in IR Systems⁸</td>
<td>Unit costs in manhours can be established for processing steps</td>
</tr>
<tr>
<td>Commodity concept for information³</td>
<td>Production costs and &quot;selling prices&quot; to be compared to costs of alternative method</td>
</tr>
<tr>
<td>Standardized method for costing computer jobs⁶,⁶⁻,⁶⁻</td>
<td>Detailed structures for comparative cost allocation and accounting</td>
</tr>
<tr>
<td>Conversion from manual to automated library system⁵</td>
<td>Man-machine cost tradeoff; cost of service during conversion</td>
</tr>
<tr>
<td>Cost savings with &quot;peek-a-boo&quot; equipment⁹</td>
<td>Equipment, supplies, indexing, input preparation: file building as an investment</td>
</tr>
</tbody>
</table>

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design methods and techniques can be expected to produce good systems for scientific and technical information centers, and research on this question is in progress. This investigation shows a need for defining field of interest, user needs, and performance criteria as part of the design phase. It also shows that performance measurement should be anticipated at this point, and that provisions for this process should be included in the design of the organization and its functions.

One of the more important recent studies concerning methods for systems design including design of information storage and retrieval systems offers a model of the system-design process itself. Developed principally by Dr. Robert M. Hayes, for the U. S. Air Force Rome Air Development Center, this study synthesizes the design process, derives a model, and tests the model in the approach to actual design problems. A reasonable inference from the result obtained in this work is that the kind of design method used affects the outcome in terms of system, composition and, in turn, system performance. Salient features of other design studies, most of which are currently in progress are summarized in Table 16, on page 121.

Studies Concerning Evaluation Methodology

As design method recognizes the need to provide for evaluation of performance in the system, investigations are undertaken concerning methods of evaluation. Some studies deal with the nature of the evalua
tion process in general; others, like this one, concentrate on a

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## TABLE 16

EXAMPLES OF STUDIES ON DESIGN METHOD WHICH SUPPORT THE PERFORMANCE-MEASUREMENT PROCESS

<table>
<thead>
<tr>
<th>Investigator and Organization</th>
<th>Subject of Investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Edward C. Bryant</td>
<td>Theoretical foundations for associative retrieval</td>
</tr>
<tr>
<td>Westat Research Associates, Inc.</td>
<td></td>
</tr>
<tr>
<td>Dr. G. Kaskey, Mr. E. Fossum</td>
<td>Optimization and standardization, IR</td>
</tr>
<tr>
<td>Sperry Rand Corporation</td>
<td>language and systems</td>
</tr>
<tr>
<td>Dr. Donald J. Hillman</td>
<td>Formal theory of conceptual affiliation for document reconstruction</td>
</tr>
<tr>
<td>Lehigh University</td>
<td></td>
</tr>
<tr>
<td>Mr. Saul Herner</td>
<td>Study of indexing procedures and mechanics</td>
</tr>
<tr>
<td>Hermer and Company</td>
<td></td>
</tr>
<tr>
<td>Dr. Ralph R. Shaw</td>
<td>Scientific bases for information processing</td>
</tr>
<tr>
<td>Rutgers University</td>
<td></td>
</tr>
<tr>
<td>Dr. Morris Rubinoff</td>
<td>Information system design for the information-processing field</td>
</tr>
<tr>
<td>University of Pennsylvania</td>
<td></td>
</tr>
<tr>
<td>Mrs. Lea M. Bohnert</td>
<td>Standardized language for describing documentation systems</td>
</tr>
<tr>
<td>C.E.I.R., Inc.</td>
<td></td>
</tr>
<tr>
<td>Mr. Robert S. Taylor</td>
<td>Study of the man-system interface in libraries</td>
</tr>
<tr>
<td>Lehigh University</td>
<td></td>
</tr>
<tr>
<td>Dr. Gerald Jahoda</td>
<td>Analysis of personal index structures and uses</td>
</tr>
<tr>
<td>Florida State University</td>
<td></td>
</tr>
<tr>
<td>Drs. Selye and Gabbiani</td>
<td>Analysis of information storage, search, and retrieval processes</td>
</tr>
<tr>
<td>University of Montreal</td>
<td></td>
</tr>
<tr>
<td>Mr. Robert A. Fairthorne</td>
<td>Unification of theory and empiricism in information retrieval</td>
</tr>
<tr>
<td>Hermer and Company</td>
<td></td>
</tr>
<tr>
<td>Dr. Edward W. Bastin</td>
<td>A sequential logic for information structuring</td>
</tr>
<tr>
<td>Cambridge Language Research</td>
<td></td>
</tr>
</tbody>
</table>

particular case or method. Many of the studies which purport to take up the general question of how to develop an evaluation method turn out to be advocates of some selected set of ratios, criteria or other factors. Areas of major emphasis for representative studies and their relationship to the generalized model, of origin and flow of scientific and technical information, are listed in Table 17, on page 123. The contribution of these studies to the performance measurement process is two-fold: (1) they provide criteria such as those applied in Chapter IV of this study for the construction of actual measures, and (2) they provide examples of both proposed methods and experience showing results from attempted measurements. As additional work is done in this important area, it is likely that a systematic approach will emerge for the development of evaluation processes.

**Application of Performance Measures**

Taking advantage of the work on what to measure and how to measure, many attempts at actual performance measurement have been made. Subjects studied range from unit processes to total centers. Case histories, descriptive studies, controlled experiments—all are present in the work which has been attempted to date. Most of these efforts were undertaken by the centers themselves in efforts to gain continuing support. Some were undertaken by sponsors or by independent groups at the invitation of either centers or sponsors. Accomplishments to date are diverse types of ratings obtained occasionally or intermittently.
**TABLE 17**

EXAMPLES OF STUDIES ON EVALUATION METHOD WHICH SUPPORT THE PERFORMANCE-MEASUREMENT PROCESS

<table>
<thead>
<tr>
<th>Evaluation Method</th>
<th>Significance in Performance Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis prior to system conversion&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Offers criteria for evaluating impact of proposed changes</td>
</tr>
<tr>
<td>Efficiency as a ratio of subcollection accessibility to relative demand frequency&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Offers weighting-factor approach for subcollections and descriptors; can show cost of poor performance</td>
</tr>
<tr>
<td>Measurement of consistency of document classification&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Shows fundamental problem regarding file-content identification</td>
</tr>
<tr>
<td>Effect of system design components on performance&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Permits comparison of effectiveness and cost for alternative factors</td>
</tr>
<tr>
<td>Experimental design based on defined system components&lt;sup&gt;e&lt;/sup&gt;</td>
<td>Conducts experiments in laboratory setting with improved controls</td>
</tr>
<tr>
<td>Experiment based on diary and interview techniques&lt;sup&gt;f&lt;/sup&gt;</td>
<td>Successfully applies after-the-fact hypotheses to user response data</td>
</tr>
</tbody>
</table>

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<sup>c</sup>Harold Borko, "Measuring the Reliability of a Subject Classification by Men and Machines," American Documentation, XV, No. 4, pp. 268-73.


<sup>e</sup>A. J. Goldwyn, Purpose and Objectives of the Comparative Systems Laboratory (Cleveland: Western Reserve University, 1964).

Continuing performance measurements of a standardized nature have not appeared, nor have they been attempted with respect to multiple centers.

Functional Levels Studied

Review of attempted performance measurements in terms of their functional scope contributes to the development of an approach for this study. First, performance measures of subfunctions or groups of functions below the level of the total center will be of interest only during the planned future work. Because the plan for future work involves analysis of subfunction and factor effectiveness, a brief review of studies at this time contributes to the development of the plan. In addition, studies based on models rather than actual operations will be analyzed for criteria helpful in designing the measure. But information on actual experiences will be sought before design choices are made. Even when an operating center is studied, if the interaction with users is highly restricted, the performance measurement attempted may not be suitable for use in a situation of unrestricted demand. Adaptation to changing environmental conditions is likely to be a significant factor in performance. Those studies of greatest interest to this investigation are ones which measure the over-all performance of operating centers under conditions of relatively great management autonomy and unrestricted demand.

Studies of subfunctions

The most common studies of subfunctions involve indexing and subsequent retrieval of information. Since the principal test of indexing effectiveness is the ability to retrieve information at a later date,
these subjects are closely related. An additional relationship between the two factors results from the fact that preparation of an inquiry for file search involves some form of indexing of the inquiry itself. In terms of the generalized model, these subfunctions are part of the major function of conditioning, storage, inquiry, search, and retrieval. They are located at the heart of any information-retrieval system at the first junction of the life and use cycles of information. A tabulation of subfunction studies reviewed to support the planning aspect of this investigation appears in Table 18, on page 126. Because of the interaction of functions within the generalized model, subfunctions other than indexing and retrieval could contribute to an entirely different performance rating than that of the central processing functions.

Modeling techniques

Performance measurement through modeling techniques contributes mainly to the establishment of expected values or outcomes. It may be used to establish the range of effects for factors. The advantages of this approach are numerous. Costs can be controlled and elapsed time to obtain results can be compressed, sometimes by orders of magnitude. Extraneous and random variables can be included through some simulation technique or excluded. The effects of specific changes can be identified and developed into statements of cause-and-effect relationship. These same factors contribute to the difficulties in relying on modeling techniques. Economies in cost and time exclude many factors which may be significant. If a design feature of the system is omitted from the model, it simply does not make itself felt. Finally, the cause-and-effect relationships identified are true only within the limitations of
<table>
<thead>
<tr>
<th>Subfunction Studied</th>
<th>Major Aspects Emphasized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production of abstracts(^a)</td>
<td>Performance accuracy and time</td>
</tr>
<tr>
<td>Production of report summaries(^b)</td>
<td>Effect of formats on efficiency</td>
</tr>
<tr>
<td>Indexing(^c)</td>
<td>Machine versus manual preparation</td>
</tr>
<tr>
<td>Indexing and search(^d)</td>
<td>Effect of links and roles</td>
</tr>
<tr>
<td>Indexing(^e)</td>
<td>Coordinate versus algorithmic associative</td>
</tr>
<tr>
<td>Searching(^f)</td>
<td>Coordinate search strategy</td>
</tr>
<tr>
<td>Indexing(^g)</td>
<td>Effect of aids on indexer reliability</td>
</tr>
<tr>
<td>Indexing(^h)</td>
<td>Test methods for mechanized index</td>
</tr>
<tr>
<td>Indexing(^i)</td>
<td>Experience versus consistency</td>
</tr>
<tr>
<td>Indexing(^j)</td>
<td>Effect of probabilistic approach</td>
</tr>
<tr>
<td>Document evaluation(^k)</td>
<td>Relevance based on titles</td>
</tr>
<tr>
<td>Dissemination(^l)</td>
<td>Effect of classification system</td>
</tr>
<tr>
<td>Document classification(^m)</td>
<td>Effect of automatic techniques</td>
</tr>
</tbody>
</table>


\(^b\) John D. Ford, Jr., *Evaluation of Report Summaries: Quantitative Results and Discussion* (Santa Monica, California: System Development Corporation, 1962).


TABLE 18—Continued


8V. Slamecka and J. Jacoby, Effect of Indexing Aids on the Reliability of Indexers (Bethesda, Maryland: Documentation Incorporated, 1963).


10J. Jacoby and V. Slamecka, Indexer Consistency under Minimal Conditions (Bethesda, Maryland: Documentation Incorporated, 1962).


14John H. Williams, Jr., Discriminant Analysis for Content Classification (Bethesda, Maryland: IBM Corporation Federal Systems Division, 1966).
the artificial context established. For these reasons, comparisons are needed between outcomes arrived at in modeling situations and those obtained through real-world studies. Differences encountered may point the way to either better modeling techniques or design improvements for operating centers. Some of the more important studies of scientific and technical information centers based on performance-measurement modeling techniques are described in Table 19 on page 129.

Centers under restricted demand

Actual centers operating in controlled environments are somewhat different from models. Even though demand may be restricted or conditioned, performance is in response to real problems. It occurs in normal time and unplanned events may affect performance. Since demand is controlled, an opportunity exists for changing the pattern of demand confronting the center and noting changes in center performance. Conversely, demand can be held fixed and changes in functional composition or other internal factors can be introduced to study their effects on over-all performance. The shortcoming of these studies for purposes of this investigation is that the experimenter controls both the subject and the environment. Complete awareness of factors present on both sides of the transaction is likely to affect selection of function sets and condition sets. As pointed out previously, scientific and technical information centers represent one group of people attempting to provide for the future needs, concurrently unknown, of another group of people. The attribute of incomplete knowledge of the nature of demand may be quite significant in affecting management decisions and the resulting
TABLE 19
EXAMPLES OF MODELING STUDIES WHICH SUPPORT THE PERFORMANCE-MEASUREMENT PROCESS

<table>
<thead>
<tr>
<th>Type of Model</th>
<th>Major Features and Significance to Performance Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic indexing based on quantitative approach</td>
<td>Uses word-frequency counts and word-document association measures to build index. Effectiveness is limited by term availability and lack of recognition of sentence structures and semantic relations between words.</td>
</tr>
<tr>
<td>Automatic indexing: hierarchial model with synonym lists</td>
<td>Each node of the hierarchy is a class to which text terms are related. Retrieval effectiveness becomes a function of the skill with which semantic associations are recognized and applied in index construction.</td>
</tr>
<tr>
<td>Automatic indexing: hierarchial model with tree structures</td>
<td>Sentence- and phrase-structure relationships are added to index terms. Retrieval effectiveness additionally becomes a function of the depth to which structural analysis is accomplished.</td>
</tr>
<tr>
<td>Pilot study on medical literature based on Western Reserve University semantic code indexing</td>
<td>Covers experimental application of major system (ASM Metallurgical Searching Service) to new field, using &quot;manufactured&quot; questions. Shows difficulties encountered in attempting to apply techniques to new situations and &quot;loose coupling&quot; between techniques and effectiveness.</td>
</tr>
<tr>
<td>Coordinate indexing for retrieval of documents (unformatted text)</td>
<td>Approached evaluation through analysis of retrieval errors which result from different methods of processing queries. Shows a key function as a factor contributing to effectiveness.</td>
</tr>
<tr>
<td>General model of the data retrieval system</td>
<td>Characterizes model as a four-part communication system involving analysis, storage, search, and answer routines. Provides a general framework for description and evaluation of a wide range of systems.</td>
</tr>
<tr>
<td>Experimental model of information retrieval systems</td>
<td>Includes provision for calculating theoretical effect of indexing depth and for obtaining data. Permits measurement of factor contribution to effectiveness.</td>
</tr>
<tr>
<td>TABLE 19—Continued</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td></td>
</tr>
<tr>
<td>^b^ Defense Documentation Center, Guidelines for Using ASTIA Descriptors (Cameron Station, Virginia, 1965).</td>
<td></td>
</tr>
</tbody>
</table>
performance of centers. Significant studies of real centers operating in controlled environments analyzed for this study are shown in Table 20 on page 132.

Centers under unrestricted demand

Relatively few studies have been attempted covering operating centers in situations of unrestricted demand. An evaluation of one of the nation's oldest and largest centers was published in 1964. Among other findings, user satisfaction ranged from poor to excellent. Many deficiencies were noted, including problems relating to search. The center in question was also evaluated with respect to the single function of indexing by a group of outside evaluators. Apparently, one of the significant results of this work to date is that the outcomes are somewhat controversial. Since this series of studies over several years has involved different organizations and functional groups, only a part of the work can be referred to in this report. The results have prompted a searching criticism of all aspects of the method attempted. Taking the authors' viewpoint, this study tested efficiency. However,


TABLE 20
EXAMPLES OF STUDIES OF CENTERS OPERATING IN CONTROLLED ENVIRONMENTS
WHICH SUPPORT THE PERFORMANCE-MEASUREMENT PROCESS

<table>
<thead>
<tr>
<th>Center Studied</th>
<th>Areas of Interest for Performance Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental center at Lincoln Laboratories\textsuperscript{a, b}</td>
<td>Elaborate systems of information retrieval alone do not significantly aid the flow of scientific information. Interactions of additional factors must be considered and tested.</td>
</tr>
<tr>
<td>Computation laboratory at Harvard University\textsuperscript{c, d, e}</td>
<td>Retrieval results are compared based on several different procedures for indexing, search, and retrieval. Function contribution is shown.</td>
</tr>
<tr>
<td>IBM Research Center internal system\textsuperscript{f}</td>
<td>Investigates patterns of users within which information-exchange channels are efficient. Shows importance of finding &quot;rare&quot; items as opposed to mere volume</td>
</tr>
</tbody>
</table>

\textsuperscript{a} M. M. Kessler, \textit{An Experimental Communication Center for Scientific and Technical Information} (Lexington, Mass.: Massachusetts Institute of Technology, 1960).


\textsuperscript{f} M. Kochen and E. Wong, \textit{An Experimental System for the Exchange of Scientific Information} (Yorktown Heights, N. Y.: IBM Research Center, 1962).
since relevance ratios were used, the data could be applied to a suitably devised test of effectiveness. Table 21, on page 134 provides a summary of the principal features of the ASLIB-Cranfield study at Western Reserve University, together with notes as to questions raised in critique of the study.

Methods and Viewpoints Adopted for Performance Measurement Purposes

Early attempts at performance evaluation of scientific and technical information centers began with descriptions of specific cases or examples showing how favorable results had been obtained in given situations. These evaluations were enlarged to cover over-all activities for extended time periods. Almost all of this descriptive study was accomplished by the centers themselves, although an occasional consulting firm or external study group might be used. Introduction of experimental methods in performance measurement has been much slower. The trend, however, appears to be toward evaluations based on experimental design conducted at the behest of sponsoring agencies and carried out by independent evaluators.

Research design

Many of the early studies of center performance were flexible with little or no formal design. Situational examples of good and bad performance results were developed. To the extent available, secondary data were reviewed and ideas were sought from people conversant with the situation. These exploratory studies were to lead to development of hypotheses and planning for more advanced work in performance meas-
TABLE 21
SELECTED FEATURES OF THE ASLIB-CRANFIELD TEST OF THE WESTERN RESERVE UNIVERSITY INDEXING SYSTEM

<table>
<thead>
<tr>
<th>Factors</th>
<th>Significant Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choice of indexing system&lt;sup&gt;a&lt;/sup&gt;</td>
<td>The type of system selected is of less importance in determining operating efficiency than has been assumed generally.</td>
</tr>
<tr>
<td>Testing techniques&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Sophisticated tests can be based on recall and relevance. Relevance measures are poor at best and need further development.</td>
</tr>
<tr>
<td>Mechanization&lt;sup&gt;c&lt;/sup&gt;</td>
<td>There is no evidence that retrieval potentials with a computer are on a different level than can be obtained with card catalogs.</td>
</tr>
<tr>
<td>Points of measurement&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Tests of index language structure and design should be differentiated from tests of effectiveness with which indexing is utilized.</td>
</tr>
<tr>
<td>Question analysis&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Different viewpoints on selection of questions for the test resulted in test sets more suited to one of the systems than the other.</td>
</tr>
</tbody>
</table>


<sup>c</sup>National Science Foundation, Scientific Information Notes, VI, No. 1 (February-March, 1964), p. 15.

urement. The transition from exploratory to descriptive study came in two stages: (1) the extension of situation analysis resulted in fully developed case studies and (2) the use of secondary data led to use of statistical method for descriptive studies. In both of these stages the performance measurements attempted were conditioned by suggestions of sponsors and experiences of center managers operating in widely varying work environments and phases of institutional growth. Results obtained were meaningful but unstandardized, and possibilities for bias existed. A number of the more important studies of this era are listed in Table 22, on page 136.

Experimental studies were first used in connection with performance measurements for indexing and retrieval functions. These functions offered opportunities for immediate collection of data structured to identify changes in technique and resulting outcomes. Experimental designs for these subfunction studies used criteria based on judgment of the experimenters as to what constitutes effective performance. Independent appraisal was not ordinarily involved. Considerations of cost, time span, and operability seem to have delayed use of experiments reflecting total center performance under conditions of unrestricted demand. Some experimental designs confound factor effects—typical of real-life situations. Even when confounded effects are subsumed under total performance, obtaining a condition of ceteris parabus with respect to the environment is not usually possible. As a result both random and systematic errors are encountered. As the evaluators get further away from the specifics of case analysis and base their studies on random data, bias should be reduced. Improved precision will come, how-
## TABLE 22

**EXAMPLES OF EXPLORATORY, CASE-METHOD, AND STATISTICAL STUDIES OF CENTER PERFORMANCE**

<table>
<thead>
<tr>
<th>Center STUDIED</th>
<th>Study Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBM Data Systems Division Technical Information Centera</td>
<td>Expository review of system features such as mechanization, compatibility, reversibility, controls, simplicity, and user orientation.</td>
</tr>
<tr>
<td>Defense Documentation Center and other government information servicesb</td>
<td>Questionnaire survey on field-office service, quality of bibliographies and abstracts, document legibility, formats, indexes, and need for changes.</td>
</tr>
<tr>
<td>Center for Application of Sciences and Technology, Wayne State Universityc</td>
<td>Descriptive study of origins, objectives, and first-year operations; reviews system design, activities, products, and plans for future work.</td>
</tr>
<tr>
<td>Chemical-Biological Coordination Center of the National Research Councild, e</td>
<td>Case analysis of operations followed by review of factors resulting in discontinuance.</td>
</tr>
</tbody>
</table>

---


d Richard M. Dougherty, "The Scope and Operating Efficiency of Information Centers as Illustrated by the Chemical-Biological Coordination Center of the National Research Council," *College and Research Libraries* (January, 1964), pp. 7-12, 20.

ever, only with refined techniques, replications, auxiliary measurements, and blocking of sample data. The present state of the art in experimental techniques for these evaluations appears typical of early social-psychological research in general, and the outlook for improvement is good.27 A survey and analysis of work in this field has recently been published as a result of contract research sponsored by the National Science Foundation. A review of 49 studies of document-center performance was tabulated according to research goals, nature of system and study environment, subject matter of the research, research method and research reporting.28 The detailed list of "dimensions" under these categories is shown in Appendix C of this study, which provides reproductions of tables on the "review frame" and frequency of studies. Conclusions reached by this study are that further work on method is needed along the following areas:

Selection of areas and approaches
Improvement in criterion methodology
Analysis of transmission of information
Determination of how relevance judgments are made
Functional steps in the query chain29


29 Ibid., pp. 61-68.
Viewpoint of performance evaluations

Viewpoint of performance measurement involves the question of the relationship of the evaluator to the center. The great majority of evaluations attempted to date have been conceived and carried out by management personnel of the centers under study. This work benefits from the close familiarity of the investigator with the situations under study and offers excellent opportunities for the introduction of improvements suggested by the outcomes. In these respects, sponsors' objectives are being supported. To the extent that self-evaluation permits bias and strengthens defense mechanisms, suboptimization is likely to occur with respect to sponsors' objectives. Performance measurements based only on systems checks are more introspective in nature than those which take into account users' opinions. Even though conceived and directed by management personnel of the centers themselves, studies which take the user into account introduce a second party viewpoint. Inadvertent bias may be uncovered and corrected as a result of this influence. Greater independence of the performance measurement problem is achieved when outside, evaluators are used. If these investigators are compensated by or through center management, however, some possibility remains that any bias originating with this management may be felt in the outcome. Only when sponsors or users support independent evaluators' measurements will the influence of center managers be minimized. At that point, the question remains as to whether sponsors and users can contribute their influences without overriding the technical
judgment of the information centers themselves. This investigation is an independent study of a center where the investigator is not involved as a user or sponsor. However, the investigator has a continuing relationship with the center under study in other functional areas which offer an opportunity for the admission of bias. In this case, the advantages of familiarity and close association are considered to outweigh disadvantages of possible bias and need for precautionary measures. However, plans for future study will recommend that sponsor support rather than information-center support be obtained.
CHAPTER IV

CONSTRUCTION OF A MEASURE OF EFFECTIVENESS

The Objectives of Performance Measurement

Performance measurement is a vital link within the control function of the management process. Its primary objective is to reflect results in a manner suitable for exercise of control. Implicit within the control function are various goals, performance standards, and criteria which predice the kind of information sought for performance-measurement purposes, and the general form of its expression. When performance-measurement data relate directly to specific objectives, the work of supporting the control function is simplified. Control also implies (1) the use of corrective action for deficiencies, (2) adaptation to externally imposed changes, and (3) exploitation of productive factors. To support the action-taking aspect of the control function, performance measurement should lead to the identification of causative factors and provide a basis for formulation of the policies, directives, and other management dicta needed. In cases where the organizational objectives relate to physical outputs which can be counted, performance measurement may be simply the enumeration of acceptable output units, with defects classified by probable point of origin. To the extent that statements of objectives are less
tangible, the performance-measurement strategy may require more complex information to be gathered. In these cases, the elements of fulfillment of objectives, cause analysis, and formulation of action are unlikely to resemble statements of goals or the forms of activity records maintained. These performance-measurement data and figures of merit must be relatable through some defined repeatable process to organizational objectives and cause identification.

Criteria for a Sponsor's Measure of Effectiveness

Both objectives of performance measurement and the situational context involved provide a basis for criteria which can be applied to establish the scope and operational characteristics of a sponsor's measure of effectiveness. They also influence the choice of experimental design to be used in testing the measure. However, they do not limit the characteristics of either to a single set of characteristics. Many choices can be identified as to variations in technique which would satisfy the desired characteristics.

Necessity

The first criterion selected for the sponsor's measure of effectiveness is that the information provided be necessary to the purpose or objectives of performance measurement. It must serve either the estimation or quantity of output, the rating of output as to suitability, the matching of output quantity or quality to organizational objectives, the approach to identification of causal factors, or the approach to formulation of corrective measures. If additional goals are identified for the performance-measurement process, they can be a basis for
gathering additional data. Depending on goal definitions, cost data as described in Table 15, page 119, are unlikely to be necessary for measurement of effectiveness. Data implied in Table 14, page 116, are likely to be necessary.

Sufficiency

The second criterion adopted for the sponsor's measure of effectiveness is that the combination of information gathered be sufficient to estimate quantity and quality of output. Several necessary measures taken together might present an incomplete picture, or they might fail to tie the performance measure to other aspects of the control function. Sufficiency for purpose of this study is comprised of the following elements: (1) estimates obtained must be quantitative; (2) confidence levels are to be established; and (3) information obtained must be relatable to organizational objectives, cause identification, and formulation of corrective measures. Although sufficiency can be redefined if other performance-measurement objectives are selected, it still represents good fulfillment. Necessity represents only the support of goals.

Optimal Structure

A third criterion is that the information obtained represent an optimal amount and variety of data. The criterion of sufficiency can be interpreted to include or exclude redundant information. The criterion of optimal quantity and variety of information admits redundancy to the extent that it enhances efficiency and effectiveness of the measurement
process. Thus, more than one estimate of some key factor such as relevance may be desirable. Limiting factors defining optimal information structure include extent of need for additional and confirming data, costs, and time required. Performance measurements based on a single criterion have not reflected optimal structure. Composite ratings offer a better approach, but may not reveal the significant change of a key variable within the composite. Multiple criteria are more likely to represent an optimal structure.

Suitability

The fourth criterion is that of suitability. The generalized model of origin and flow of scientific and technical information presented in Chapter II of this study provides a basis for determining suitability. Factors which must be considered include demands placed on the center, functional scope across which the measure is taken, and the center’s position within the context of the model. All of these factors involve making the measure true to life. First, the situational context of center performance should be recognized. Then the work produced and adaptation to the changing environment can be studied.

Universality

A fifth criterion relates to generality with which the measure can be applied. In order to provide comparative ratings of centers, the measure should fit a general case as described in the model. It should also be capable of adaptation to variations within the general case. These variations include document centers versus information-analysis
centers, centers of different size, and centers serving different technical fields. Even though the measure is designed to cover the total functional scope of the most complex center, it should also apply to centers representing incomplete functional combinations. Values obtained through measurement should be relatable from center to center, either through direct comparison or conversion to index numbers.

Independence

The sixth criterion for the sponsor's measure of effectiveness relates to independence from unsought influences exerted by either center managers or sponsors of centers. This desired characteristic may involve the use of independent audit or measurement of customer satisfaction. If corroborative performance measurement by center managers and sponsors are available, an independent evaluation is useful for comparison purposes. In the event this measurement is the only one made, its independence is all the more important for avoidance of bias in the evaluation process.

Comparability

A seventh and final criterion for the measure is that it provide a comparative base. Some alternative means of accomplishing results obtained through center functions might be used as a base. The center can then be described as doing a given job either equally well or some number of times better or worse than the alternative approach. Perhaps the simplest point of comparison is the case of flow of scientific and technical information in the absence of use of the center's output. The
model in Chapter II recognizes a set of functions which can be allocated either to centers or to the technical community-at-large, permitting comparisons of this type.

**Description of the Derived Measure**

Based on the criteria adopted, the sponsor's measure of effectiveness involves comparison of usefulness of output of the study vehicle as compared to usefulness of the open literature. Secondarily, the measure considers completeness of the center's outputs. Output quality is measured in terms of relevancy and pertinency of information. The attributes of entropy and timeliness are also considered for inclusion in the measure. Of these two factors, a limited test is planned with respect to entropy, but work on the attribute of timeliness is deferred to the plan for future research.

The multiple-factor structure provides for evaluation by users of simplified approximation of the following attributes:

- Pertinency
- Relevancy
- Entropy
- Completeness

The significance of each of these factors to the sponsor's measure of effectiveness is discussed in the ensuing paragraphs of this section. Their relationship to the criteria developed in the preceding section is shown by Table 23, on page 146.

In the field of information storage and retrieval, pertinency is generally considered to mean direct applicability of information to a
<table>
<thead>
<tr>
<th>Criterion</th>
<th>Pertinency</th>
<th>Relevancy</th>
<th>Entropy</th>
<th>Completeness</th>
<th>Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Necessity</td>
<td>A use-oriented</td>
<td>Relevancy may be attribute of best</td>
<td>Concentration</td>
<td>If measurable, is an aspect of</td>
<td>Each item is a necessary condition of</td>
</tr>
<tr>
<td></td>
<td>attribute, has</td>
<td>available answer</td>
<td>affects usefulness</td>
<td>effective work</td>
<td>effectiveness</td>
</tr>
<tr>
<td></td>
<td>highest priority</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sufficiency</td>
<td>Covers only a part</td>
<td>Covers query orientation but not</td>
<td>Shows concentration but not</td>
<td>Not measurable</td>
<td>No subset is adequate; timeliness may be</td>
</tr>
<tr>
<td></td>
<td>of output</td>
<td>direct usefulness</td>
<td>other qualities</td>
<td>enough to be sufficient</td>
<td>necessary</td>
</tr>
<tr>
<td>Optimal Structure</td>
<td>Not applicable to</td>
<td>Not applicable to single factors</td>
<td>Not applicable to single factors</td>
<td>Not applicable to single factors</td>
<td>Some redundancy is acceptable and necessary</td>
</tr>
<tr>
<td></td>
<td>single factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suitability</td>
<td>Requires value</td>
<td>Usually query oriented</td>
<td>Better formulations needed</td>
<td>Perfect induction implied</td>
<td>To be inferred from test</td>
</tr>
<tr>
<td></td>
<td>judgments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Universality</td>
<td>Common to all center</td>
<td>Common to all center evaluations</td>
<td>Common to all center evaluations</td>
<td>Common, difficult to apply</td>
<td>Set has universal applicability</td>
</tr>
<tr>
<td></td>
<td>evaluations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Independence</td>
<td>User evaluation</td>
<td>User evaluation needed</td>
<td>User evaluation</td>
<td>User may not be competent  to</td>
<td>Outside evaluators appear desirable</td>
</tr>
<tr>
<td></td>
<td>needed</td>
<td></td>
<td>needed</td>
<td>judge</td>
<td></td>
</tr>
<tr>
<td>Comparability</td>
<td>Can be structured</td>
<td>Can be structured in percentage</td>
<td>Can be structured in percentage</td>
<td>Can be in percentage or index form</td>
<td>Comparisons on full subsets are feasible</td>
</tr>
<tr>
<td></td>
<td>in percentage or</td>
<td>or index form</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>index form</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
need. If the need is adequately expressed by a question, pertinent data represent a complete or partial answer to that question. Pertinent documents are those which include material usable in the work to be accomplished. If the data or references provided require significant amounts of work for additional development of information, synthesis, or drawing of conclusions, the data or references are less than pertinent. Information which has a close relationship to the answer sought represents a borderline case. If a liberal view is taken, it may be pertinent. In a narrower sense, it is something less than pertinent. If a scientific and technical information center is doing a good job, its output should be more pertinent than the alternative source—the open literature. Since degrees of pertinence are not well defined or agreed upon, the concept is taken in an absolute sense for this study. It is either present or not present. With respect to a given body of information, some percentage of the total is pertinent. Thus, the center output and the open literature can be compared with respect to percentage of pertinent content. This factor will be referred to in a measurement process by use of the following symbols:

\[ P = \text{Pertinency} \]

\[ P_C = \text{Pertinency of center output (percentage of center output considered pertinent)} \]

\[ P_L = \text{Pertinency of open literature (percentage of open literature considered pertinent)} \]

\[ P_D = P_C - P_L \]
Relevance implies information bearing on the need but unsuitable for direct use. Such information is important, particularly if it is the nearest thing available as compared to pertinent information. It will either be assimilated through some research, design, or engineering process, or it will likely be retained for future use. The notion of degrees of relevance is being developed through various studies which support the evaluation process. At this point in time, however, basic problems such as units, scaling, and ranging are not established. As a minimum two classes can be used—low and high relevance—in the absence of precisely defined degrees of relevance. Some percentage of center outputs and total literature will fall into each of these classes. The following notation has been adopted for symbolic reference to relevancy in this study.

\[ R = \text{Relevance} \]

\[ R_C = \text{Relevance of center's outputs (percentage of center output deemed relevant)} \]

\[ R_{C1} = \text{Percentage of center's outputs having comparatively low relevance} \]

\[ R_{C2} = \text{Percentage of center's outputs having relatively high relevance} \]

\[ R_L = \text{Relevancy of open literature (percentage of total considered relevant)} \]
The characteristic of completeness can be viewed in at least three ways. First of all a complete answer to a question might be the standard of performance. Such a standard is unsatisfactory for performance measurement of a scientific and technical information center when the needed information simply does not exist. However, if the center is charged with responsibility for original data development, this concept of completeness is meaningful. It should be of interest to sponsors in any case as it indicates a need for additional data development regardless of where the research is to be conducted. Since the sponsor's measure is limited to those factors necessary to evaluate performance, this aspect of completeness is not sought in testing the measure. A second way of defining completeness would be to use the judgment of the center's management. The professional personnel involved should have an adequate appraisal of the state of the art and know what information should be available. This concept of completeness, however, tends to beg the issue, because the center's outputs are usually as complete as they can be made by center personnel. Additionally, this viewpoint of completeness lacks independence—a criterion which has been adopted for construction of the measure. A third concept of completeness involves users' reactions to the information provided. Assuming that the center's outputs have been presented with qualifying statements relating to

\[
R_{L1} = \text{Percentage of open literature with low relevance} \\
R_{L2} = \text{Percentage of open literature with high relevance} \\
R_D = R_x - R_y \\
R_R = \frac{R_x}{R_y}
\]
the scope of source material used and effort expended, the user is in a position to express an opinion as to whether a reasonably complete job was done. This approach may be somewhat unsatisfactory from the standpoint of user qualification to judge completeness. The user may be less informed than information-center personnel as to the extent of information in being which relates to his needs. Conversely, his search may have revealed hitherto unknown sources and also have given him an appraisal of availability. In the absence of some more precise concept of completeness, the alternative used will be that of whether the user thinks a reasonably complete job has been done. At this point in time, completeness is used in the sponsor's measure of effectiveness with respect to center outputs but not comparatively with respect to the open literature. The plan for future work provides for comparative study. Completeness is represented symbolically in this study as follows:

\[ C = \text{Completeness of information} \]
\[ C_c = \text{Completeness of center outputs} \]
\[ C_L = \text{Completeness of literature coverage} \]
\[ C_D = C_c - C_L \]
\[ C_R = \frac{C_c}{C_L} \]

The concept of entropy in the information sciences derives its name from the thermophysical property.¹ In 1948, Dr. Claude Shannon of Bell Laboratories formulated equations for describing the quantity of

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¹Y. S. Touloukian, The Concept of Entropy in Communication, Living Organisms, and Thermodynamics (Lafayette, Indiana: Purdue University, 1953).
information in a channel or the information content of a message. Some of these mathematical statements were recognized as isomorphs of expressions for the thermophysical property entropy which is an expression of the unavailable energy within a thermodynamic system.

The mathematical identity between information and physical entropy has led to the designation of information as the negative of entropy and consequently an increase of information being equivalent to a decrease in entropy. This concept is quite compatible with the physical nature of entropy since physical entropy is later shown to be proportional to the logarithm of the probability.

According to the concept of information entropy, the significance or content of a message is determined by the presence of unexpected units of information. Elementary units are usually binary digits or bit. If the bit distribution of a message is homogenous and therefore expected as in the case of a carrier tone, no information is present. This situation has some rather general analogy to the case of maximum entropy in thermodynamics. Shannon's use of the term entropy has been questioned by those who prefer the term negentropy to indicate the presence of significant information.

In connection with the discussion just completed it is rather disturbing to find that in the literature on information theory there is an apparent contradiction between the major work of Shannon and others. This apparent contradiction, which has aroused much debate in the literature, is the result of a confusion in terminology. In order to avoid this confusion it is necessary to distinguish carefully between the information at the transmitter and the information at the receiver. While in the above presentation we have referred to the information gained by the receiver and equated it to the negative of entropy, Shannon on the other

---


3 Touloukian, op. cit., p. 16.
hand equates the information produced by a source to a positive entropy. In essence, Shannon uses the entropy simply as a measure of the statistical characteristics of a source of information, not as a step towards finding the information value of any given signal with respect to the receiver of the signal. Therefore, in Shannon's terminology the entropy of a message source is proportional to the number of different combinations (messages) which that source can produce.¹

The entropy criterion has been suggested as a measure of effectiveness for information systems. This approach is generally recommended where effectiveness and efficiency are equated, or where the measure combines aspects of both effectiveness and efficiency. Since the entropy measure indicates the portion of available capacity used for significant (unexpected) information, it is more properly a measure of efficiency (percentage utilization) than effectiveness. Another question as to its merits as a measure of effectiveness relates to whether either user needs or organizational objectives recognize a value in redundant information. A data-center output may state that no information is available, or it may confirm through repetition information already in the hands of the user. These two cases might not qualify as unexpected within the entropy concept. Yet, they have value for justifying data-development programs or for increasing the confidence level of the starting conditions upon which basic activities are undertaken.

Although the entropy measure does not represent a sufficient measure within the context of this study, it does indicate the portion of center outputs which constitute a unique or original contribution from the standpoint of a user. For this reason it will be included as

¹Touloukian, op. cit., p. 17.
a factor within the first measure and applied to center outputs only. Entropy evaluation of the open literature would be a highly subjective and imprecise estimate on the part of users, as indicated by findings reached through use of the interview guide. If an experimental design to test the measure can include personnel of the center itself as a comparison group, their appraisal of open-literature entropy can be compared to user's appraisal of center output entropy. Symbolic representation adopted for this factor is as follows:

\[
S = \text{Information entropy}
\]

\[
S_C = \text{Entropy of data center outputs as appraised by users}
\]

\[
S_L = \text{Entropy of open literature as appraised by center personnel}
\]

\[
S_D = S_C - S_L
\]

\[
S_R = \frac{S_C}{S_L}
\]

The factor of timeliness has been recognized as an important candidate for inclusion in the sponsor's measure of effectiveness. Timeliness implies getting needed information to the user in time to satisfy his need without incurring costly or unwarranted delay. Another interpretation of the term involves currency (sometimes recency) of the information provided. Since the currency aspect of timeliness is implied under the completeness concept, the term will be used only in the sense of response time for purposes of this study. Both the interview-guide findings and the analysis of inquiries during the first year of center operations indicate that timeliness is not a problem of any
significance with respect to the center under study. Additionally, the
appraisal of timeliness would be difficult for users. Records available
do not reflect critical-path activities at this level of detail (i.e.
awaiting response from an information center). The factor of timeliness
is sufficiently important, however, that it will be recommended for in-
clusion in an expanded measure in the plan for future work.

In summary, the proposed sponsor's measure of effectiveness for
scientific and technical information centers is a five-factor appraisal
of center outputs with comparison to alternative methods (direct use of
open literature) for each of these factors. The initial application of
this measure will be limited to four factors for data center outputs and
and comparison to open literature alternatives will be made on two of
these four factors. A summary description of the factorial content of
the measure is shown in the following table.

TABLE 24

FACTORIAL CONTENT: PROPOSED SPONSOR'S MEASURE

<table>
<thead>
<tr>
<th>Factor</th>
<th>Item Evaluated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pertinency</td>
<td>Center Outputs and Open Literature</td>
</tr>
<tr>
<td>Relevancy</td>
<td>Center Outputs and Open Literature</td>
</tr>
<tr>
<td>Completeness(^a)</td>
<td>Center Outputs</td>
</tr>
<tr>
<td>Entropy(^a)</td>
<td>Center Outputs</td>
</tr>
<tr>
<td>Timeliness(^a)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Further development of the factors is called for in the plan for
future research in Chapter VIII.
Anticipated Results of Measurement

Anticipated results can be described in two ways: (1) in terms of problems to be encountered which may affect the outcome, and (2) in terms of expected values. The general effect of most problems would be to reduce the precision of measurement and the confidence levels attached to the scores assigned. The use of anticipated scores, although poorly based prior to the initial measure, will assist in the analysis of results and evaluation of the measure itself. Both the anticipated problem areas and expected scores have been developed on the basis of interview-guide information and experiences noted in the literature survey.

Difficulties, Alternatives, and Modifications

Anticipated During Use of the Measure

Problems attendant upon application of the measure involve abridgment of factor definitions and possible failure of respondents to understand definitions or to give realistic appraisals. A fundamental difficulty involves the use of comparisons which are not based on mutually exclusive alternatives. Respondents are not being offered either data-center products exclusively or open-literature search exclusively. Rather, they can use both sources to enrich their research efforts to a greater scope. There is no basic limitation such that some total number of information units are available and the choice has to be made in terms of some combination from the two sources. The abridgment resulting from this situation requires the adoption of an assumption which is fairly well recognized as reasonable but cannot be proved. This
assumption is that subjective utility ratings can be applied to both the information content of the open literature and to data-center outputs in the absence of an alternative substitution requirement, and that the ratings so assigned are on some comparable scale suitable to determining approximate relative values and inequality relationships involved. This approach follows von Neumann's axiom 3A without requiring that indifference-curve analysis apply. Yet it seeks to use real-number measurement scales, which do not generally apply to qualitative criteria wherein the evaluator may revise scores as more alternatives are considered, and the aspiration level may change. In summary, the idea of personal utility structures for system users is sufficiently well founded to apply in effectiveness measurement, but more conceptual work on this point will be suggested by the plan for further study.

Other factors which will require abridgment are the definitions of pertinency, relevancy, and entropy. Particularly with respect to relevancy, the preference for using query-oriented versus need-oriented


definitions will depend on how the measurement process is affected. Research on basic entropy patterns is now in process, indicating the relative immaturity of the concept for performance-measurement purposes. The definition of completeness is simply left to the respondents although their qualifications and viewpoint to make such a judgment are not fully known. Instead of a strict definition of pertinency, the idea of how much information was applied in actual use will be substituted. No serious effects are anticipated from this translation of the pertinency concepts into everyday language. Relevancy is somewhat more difficult to convert to simple terms. The terms close relationship and moderate relationship taken together should indicate relevance, as should the selective retention of material for possible use. Remote relation, no relation, state-of-the-art awareness, and passed over should be equivalent to very little or no relevance. Entropy is an even more complex concept in the measurement situation. First of all, the selection of a base representative of "channel capacity" is operationally difficult, even though page length, word count, and similar measures could be compiled. Estimation of the total volume of open literature is also open to question even in the face of research conducted by the center under study in the accomplishment of its planning functions. Secondly, the mass or universe within which entropy is being measured is not defined as a single file or channel. The nearest


approximation to a common-sense figure which should correlate well with
the entropy rating is expressed by the question, "How much of the inform-

ation provided was new to you?" Finally, the factor of timeliness is

simply omitted from the first application of the measure because of

situational aspects previously noted.

As a result of problems in factor definition and respondent

reliability, enumerations obtained for even broad classes (such as high

and low) will be more like close approximations than precise counts.

Some test should be made of the effects of varying the class intervals

or changing factor definitions. If possible, some comparative test

should be provided of the effect on outcome of measuring a factor in

more than one way (for example through the use of two definitions of

relevancy of center output). Finally, significant differences should

be so designated only on the basis of a stringent test.

Expected Outcome

Expected outcomes have been developed through operational analy-

sis of center activities and use of the interview guide with a number

of users of the center. The predicted ratings represent extrapolations

based on very small sample statistics conditioned by experience and

opinions of individuals experienced in the field. A further basis for

prediction of outcome is the sponsor's rationale which dictates the

primary organizational objective. The center must represent a better

approach to acquiring information and solving problems than previous

methods by order-of-magnitude proportions if continued funding is to be

made available. The following table shows values of expected outcomes

estimated prior to the initial test of the measure. It should be noted
TABLE 25

ANTICIPATED OUTCOME FROM TEST OF THE MEASURE

<table>
<thead>
<tr>
<th>Factor</th>
<th>Anticipated Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open Center</td>
</tr>
<tr>
<td>Pertinency</td>
<td>33 1/3%</td>
</tr>
<tr>
<td>Relevance</td>
<td>66 2/3%</td>
</tr>
<tr>
<td>Completeness</td>
<td>50 %</td>
</tr>
<tr>
<td>Entropy</td>
<td>50 % new</td>
</tr>
</tbody>
</table>

that the points of measurement cover open literature—input prior to processing at the center—through output in the hands of users. The difference in quality created between these points represents the effect of center performance. Specific estimates appearing in Table 25 above represent a consensus of predictions by data-center personnel, users interviewed in depth, and users participating in pretest of the questionnaire.
CHAPTER V

DESCRIPTION OF THE STUDY VEHICLE: AIR FORCE
MACHINABILITY DATA CENTER

Based on model and measure characteristics, candidates for use as a study vehicle in testing the measure were screened. As centers qualified to be study vehicles were identified, more detailed criteria were used to make a final selection. The center selected was reviewed in terms of field of interest and functions performed. Next, its first-year operations were studied to provide data supporting the design of an experiment to test the measure. Users were described through review of records and use of the interview guide, and are used to provide evaluations in the experimental design. Finally, interaction of the study vehicle and the proposed test was predicted based on compatibility with the model, information availability, and users' reactions. Use of the Air Force Machinability Data Center operated by Metcut Research Associates, Inc., Cincinnati, Ohio, as a study vehicle is expected to result in a meaningful test of the proposed measure. In addition, this test will provide an evaluation of first-year operations of the center.

Development and Application of Selection Criteria

Choice of a suitable study vehicle is based on considerations of field of endeavor, technical community served, functions performed, type
of output or service, skills required by the task structure, and record availability. Selection of a single center as a study vehicle poses difficult questions. Many interesting and excellent centers must be eliminated from consideration. Possible restriction of applicability of the study results to the field in general must be taken into account. The process of elimination and selection leading to choice of the Air Force Machinability Data Center as the study vehicle is accomplished through the application of criteria relating to suitability and feasibility for this study. The extent to which conclusions can be drawn on about all centers in the population domain of this class depends on the extent to which the Air Force Machinability Data Center is representative of the general function model shown on page 74. This center is representative with respect to types of functions performed, as shown on page 170. However, the functional composition (relative amount of time spent on each function) varies considerably from center to center. In summary, this selection appears to provide a study vehicle which will provide benchmark results within a reasonably short period leading to further and perhaps continuous studies of a more refined nature.

Selection Criteria

The selection criteria adopted are stated in terms of characteristics of a study vehicle which would contribute to the effectiveness and efficiency of this study. Each should support one or more of the study goals: (1) to construct a sponsor's measure of effectiveness for scientific and technical information centers, (2) to conduct an experiment using the measure, (3) to evaluate the measure and the center under
study, and (4) to initiate planning for continuing research in this field of study.

Characteristics desired in the study vehicle are:

1. Functional specialization as a scientific and technical information center, as opposed to specialization in other activities such as library work and performance of some incidental amount of center functions.

2. Functional scope including information analysis in addition to document services (document services may be either an internal support process, or a direct service to users).

3. Subject-matter specialization within a well defined area of science or engineering.

4. Widespread use representing a situation of virtually unrestricted demand.

5. Completeness of documentation as to internal activities, inquiries, responses, and other details of center operation.

6. Availability of the center for study, including cooperation by the management and convenient geographical location.

7. Stability of specialized effort on the same goals or objectives.

8. Accessibility of both internal and external points of measurement.


10. Comparability of costs of output with costs of achieving equivalent results by alternative methods.
(11) Susceptibility of total volume of literature in the field to estimation.

(12) Modularity of information elements and sets to provide fairly well defined units for counting.

(13) Relatability of the total-volume-of-literature estimate to counts of information sets and elements.

(14) Unifying purposivity in requisition of information sets and elements (as opposed to accidental or custodial aggregations).

A sequential application of the first six criteria eliminated almost all centers reported in the literature from detailed consideration, as shown in the following table.

**TABLE 26**

**ELIMINATION OF STUDY CANDIDATES DURING PRELIMINARY SCREENING**

<table>
<thead>
<tr>
<th>Criterion Applied</th>
<th>Number of Centers Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total reported</td>
<td>10,000 +</td>
</tr>
<tr>
<td>1</td>
<td>1,000</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>3 - 6</td>
<td>10</td>
</tr>
<tr>
<td>7 - 14</td>
<td>1</td>
</tr>
</tbody>
</table>

The final selection was then made on a scoring system for the few remaining candidates. Weightings assigned for scoring are arbitrarily scaled to provide general evaluations on each criterion, as shown below.
Elimination of centers by critical factors after use of the first six criteria is summarized in Table 27, on page 165.

**Field of Interest and Function of the Selected Center**

Operating under contractual sponsorship, the Air Force Machinability Data Center provides technical information primarily to manufacturing engineering personnel, the majority of whom work in companies which are suppliers to the Department of Defense. Effort is allocated commensurate with priorities, but an attempt is made to satisfy all requests for information. Almost any establishment in the United States engaged in material-removal operations qualifies as potential suppliers to the Department of Defense. Foreign firms may secure information if their inquiries through diplomatic channels receive Department of Defense approval.

**Field of Interest**

The Air Force Machinability Data Center is concerned with machinability (material removal) data and related information to increase manufacturing capability and reduce costs of material removal.
TABLE 27

ELIMINATION OF STUDY VEHICLE CANDIDATES ON FINAL SUMMARY

<table>
<thead>
<tr>
<th>Criteria (pp. 162-63)</th>
<th>Centers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
</tr>
</tbody>
</table>

Function
Scope
Field
Demand
Documentation
Availability  x  x  x
Stability  x
Accessibility  x
Economics  x  x  x
Comparability
Literature
Modularity
Relatability  x
Acquisition

\[a\] Electronic Properties Information Center
\[b\] Mechanical Properties Information Center
\[c\] Defense Materials Information Center
\[d\] Radiation Effects Information Center
\[e\] Thermophysical Properties Research Center
\[f\] Prevention of Deterioration Center
\[g\] PLASTEC (U. S. Army Plastics Information Center)
\[h\] Ceramics and Graphite Information Center
\[i\] Air Force Machinability Data Center
This information includes starting conditions on difficult as well as routine machining situations. Over 30 conventional and alternate classes of metal removal operations are described for thousands of material family groups and specific alloys of various hardnesses and processing conditions. Associated information includes part geometry, machine tool descriptions, cutting tool geometry and material, cutting fluid, results in terms of metal removal (or work done) and tool life, predicted sources of new information, bibliographical references and specific values for variables such as speeds and feeds. The focal concept for acquisition, interrogation, or presentation of information is the machining situation. A machining situation may be defined as a single metal removal operation conducted on a specific alloy having a definite set of physical and mechanical properties. Machining situations may be defined in further detail in terms of part geometry or configuration, machine tool on which the operation is carried out, tool geometry, tool material, cutting fluids, and significant variables. The significant variables include combinations of speeds, feeds, metal removal rates, tool life, etc.

Machining situations may be described in a manner such that relevant information can be grouped to satisfy the need represented by an inquiry. For example, a minimal description of a machining situation should be permitted to allow wide range in search, and successively finer or more specifically descriptive statements of the machining situation should be permitted in order to select the exact set of data points for immediate starting conditions. In addition, any parameter on the machining situation, such as material hardness or identification
of material worked, should be capable of description as a variable, or a range within limits. This flexibility in the allowable manner of describing a machining situation is necessary because of the widely varying kinds of inquiries which are encountered. Search capability can also recognize the values of significant variables. Field definition in the form of classification headings and examples of terms used by the center is provided as Appendix D of this study. This technical-field orientation involved use of management, engineering, and system personnel in the design of the center. These same individuals, described in Table 28, appearing on page 168, participate in operation and management of the center.

Economic perspective of the field of interest is provided by an estimate made during the center's design study. The high cost of aerospace materiel is generally recognized, and the remaining industrial base is probably an order of magnitude greater than the aerospace subsector. Based on surveys regarded as authoritative by the U. S. Department of Commerce, numbers of machine tools in use were used as the basis for estimating economic magnitude. The annual aerospace subsector material-removal cost is related mainly to material-removal equipment operated in establishments of the prime contractors themselves. A larger cost segment for aerospace use is incurred through operation of equipment located in subcontractor establishments. Although no allocation between subcontractor equipment for aerospace versus other production can be established, the center's technology dissemination will affect both classes of production. Estimates of costs in these areas are probably valid only for order-of-magnitude appraisals of the economic
TABLE 28
EXCERPTS FROM SKILLS PROFILE OF DESIGN TEAM,
AIR FORCE MACHINABILITY DATA CENTER¹

<table>
<thead>
<tr>
<th>EXPERIENCE FIELDS</th>
<th>MACHINING AND RELATED ENGINEERING</th>
<th>SYSTEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FT = Full Time</td>
<td>FT = Part Time</td>
</tr>
<tr>
<td></td>
<td>FT = Full Time</td>
<td>FT = Part Time</td>
</tr>
<tr>
<td></td>
<td>FT = Full Time</td>
<td>FT = Part Time</td>
</tr>
<tr>
<td>Manufacturing Technology (Machining)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Machining Research, Testing and Development (Work materials, tools, fluids, and systems)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>B. Machining (On-the-job production machining experience)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C. Machine Tool Operation</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>D. Design and Building of Machine Tools</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>E. Machine Tool Research, Testing and Development</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>F. Production Engineering</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>G. Technical Consultation and Information Services</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Manufacturing Technology (All Others - including casting, forging, welding, forming, fabrication, powder metallurgy, etc.)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Basic Engineering - (Application and Professional Practice)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Aeronautical</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>B. Mechanical</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>C. Metallurgical</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>D. Chemical</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>E. Electrical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F. Civil</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>G. Industrial (Including value engineering)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Pure Science - (Education and Application)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Chemistry</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>B. Physics</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>C. Mathematics</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>D. Material Science (Including metallurgy)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Systems Design and Operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Operations Analysis</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>B. Information Storage and Retrieval</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>C. Commercial and Industrial</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>D. Logistics</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>E. Engineering Data</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>F. Manual Processing</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>G. Semi-Mechanized</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>H. Punch Card Equipment</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>I. Automatic Data Processing</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>J. Scientific Computer</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Planning</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>B. Organization and Control</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C. Research Supervision</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>D. Financial</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>E. Consultation</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

subsectors where some productivity change may result from use of outputs.
The annual aerospace subsector material-removal cost estimate is shown
in Table 29, below.

**TABLE 29**

COST ESTIMATE MADE BY METCUT RESEARCH ASSOCIATES, INC.
RELATING TO STANDARD INDUSTRIAL CLASSIFICATION
NUMBERS 3271, 3722, 3723, AND 3729 a

1. Number of units as noted in the 1963 American
   Machinist Inventory of Metalworking Equipment
   a. Complete Aircraft, SIC 3721 40, 651
      (metal cutting machines only)
   b. Aircraft Engines and Parts,
      SIC 3722, SIC 3723, and SIC 3729 145, 994
   TOTAL 186, 645

2. Average labor cost + overhead = $8.00 per hour
3. Average working day = 8 hours
4. Number of working days per year = 250
5. Average number of direct labor
   personnel per machine = 1
6. Cost of labor + overhead =
   $8.00 x 8 x 250 x 186, 645 =
   $ 2, 986, 320, 000
   or about  $ 3, 000, 000, 000


Since subcontracting structures bring most industrial concerns within
potential relationship with the aerospace group, information provided
by the center should affect a much larger sector. Estimated annual
material-removal costs for this larger sector are shown in Table 30, on
page 170.
### TABLE 30

**COST ESTIMATES MADE BY METCUT RESEARCH ASSOCIATES, INC. FOR OPERATING METAL CUTTING MACHINE TOOLS IN THE METALWORKING INDUSTRIES**

1. Total number of metal cutting machine tools in the metalworking industries
   
   2, 137, 497

2. Average number of direct labor personnel per machine = 1

3. Cost of labor + overhead = $8.00 x 8 x 250 x 2, 137, 497
   
   = $34, 199, 952, 000
   
   or about $34, 000, 000, 000

---


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**Functions of the Center**

The following functions are provided for in the organization, personnel, and facilities of the Air Force Machinability Data Center.

- The first—testing activities—is being performed by the contractor under separate contractual sponsorship rather than as part of the data-center operation. Application assistance has been of limited scope because of cost considerations and limited demand.

- Testing activities to confirm validity of data in those cases where theoretical analysis is inconclusive, and to maintain professional capabilities of technical personnel working in the center.

- Surveillance of the over-all field of interest to assure an active information-acquisition program.

- Document acquisition and selection of input materials to assure completeness of coverage and rejection of unsuitable materials.

- Technical review and evaluation of inputs, including source qualification, completeness, and accuracy of incoming information.

- Indexing of inputs to provide retrieval capability and standard scales and numeric codes for ease of machine processing.
Maintenance of a physical store of information, including entire documents, abstracts, and tear-sheets, mechanized files, and suitable indexes.

Search formulation by technical personnel of the center interposed between the user and the system itself.

File processing for retrieval, including both the manipulation of indexes to provide references and the handling of content to provide specific answers for users.

Technical review and evaluation of search results prior to release of information to assure adequacy and suitability of information.

Format arrangement and copy preparation after technical content selection to provide an acceptable product to the user.

Assistance in use of information where direct assistance may be necessary.

Refinement or addition to existing data generated by technical personnel of the center as inputs and outputs are reviewed.

Purging of obsolete or superseded information on a continuous basis with every review of output.¹

Most of the center's output is in the form of answers to questions in a convenient format. Starting recommendations for machining situations are the most common type. Typically, a machining manual or handbook helps to answer many questions, including specific problems, without involving the time and cost of contacting the center. This type of product is well suited for handling concise, frequently used information. Other product formats, such as machining instructions and special reports, require tailoring output rather than referencing of manuals. Timely releases of new information may be provided so that use may be made of recent accomplishments. In addition to numerical data, the center may put out information in the form of text (explanations, detailed instruction, and case histories) or graphic and pictorial material. The subunits of information in tables can be counted easily, but the analysis of the number of information elements in text and

graphic material requires setting up certain assumptions. The following arbitrary rules will be applied in future work to estimate quantity of information.

1. In the case of text, a detailed topic outline will be derived for counting purposes.

2. Graphic information yields a count based on number of series or curves presented, plus number of scales and number of information points intended for or taken off by the user.

3. Counting of information supplied by means of pictorial information is limited to the specific items intended to be shown or used.

First Year Operation of Air Force
Machinability Data Center

On October 1, 1964, the Air Force Machinability Data Center came into being as an Air Force sponsored scientific and technical information center. The contractual period expired on January 31, 1966, and was replaced by a subsequent contract still in effect. The term of the first contract is considered to represent approximately one full year of actual operations in view of start-up, and during the first year the center worked to find users and provide them with service while building up an information repository. The community itself cooperated in making the first step possible. The publishers of Metalworking News, Machinery, Materials in Design Engineering, Steel Magazine, American Machinist, Cutting Tool Engineering, Machine and Tool Blue Book, Western Machinery and Steel World, Missiles and Rockets, Materials Evaluation, and others, helped to publicize the center. Additional information was released by
Air Force Materials Laboratory (particularly the Manufacturing Technology Branch), the National Referral Center of the Library of Congress, and other technical information centers, institutes, societies, and associations.

Review of Operations

By the end of 1964, a total of 22 inquiries had been received and answered; the data repository had its initial material, and a growing effort was under way to maintain current awareness of world literature on machinability. Retrospective coverage went back to 1960 and selectively to much earlier dates. The center needed more data contributors, both inside and external to the center; and it needed to reach more users. As it started into 1965—the first full year of normal operation—a User List and Part Time Evaluator Program were set up and given major emphasis during the year. The User List establishes communication links through which the center can provide regular services. Once the channel is in being, use is prompted by recognition of need on the part of using individuals. Based on user characteristics defined during the design study, directories were acquired of establishments where such individuals are most likely to work. For the first year's program, the following approach was followed in compiling names of organizations and people.

1. World Space Directory, Fall 1964, lists 72 major manufacturers under which there are various divisions. All divisions received a letter explaining the Users List program, together with forms for listing names of appropriate individuals who should be interested in using the center.

2. A request was made to the Air Force Project Monitor to review Section A-1 of the same directory and indicate the
appropriate Government offices which should receive a User letter. In addition, distribution lists from current machinability contracts were screened by the monitor.

3. Colleges and universities having metallurgical or mechanical engineering departments were contacted, based on membership in the Engineering Council for Professional Development. The member groups of the Engineering Council include:

American Institute of Aeronautics and Astronautics, Inc.
American Institute of Chemical Engineers
American Institute of Mining, Metallurgical, and Petroleum Engineers
American Society of Civil Engineers
American Society for Engineering Education
American Society of Tool and Mechanical Engineers
The Engineering Institute of Canada (foreign contacts withheld for now)
The Institute of Electrical and Electronics Engineers, Inc.
National Council of State Boards of Engineering Examiners

4. All closely related centers such as Defense Materials Information Center and the National Referral Center were contacted.

5. The Materials Advisory Board (MAB) Committee on Manufacturing Requirements for Aerospace Materials and the Ad Hoc Committee on Aerospace Manufacturing Requirements was contacted for additional names.

The response to this program yielded a list of over 2,300 individuals designated as communicators for their organizations. Inquiries were also used as a source for names to be added to the Users List. The list represents over 800 establishments, nearly two-thirds of which are industrial as contrasted to government, professional, academic, and other nonindustrial. A count of individuals also shows about two-thirds in the industrial category. Users range from one-man activities to very large corporations, some of which have over 50 individuals set up as communicators.

Classification of Inquiries and Outputs

Quantitatively, the work of the center can be expressed in both physical units and dollars. For example, the average cost of the year's 595 inquiries can be given, or the amount of time by time of skill which went into the processing of any one could be examined. The kinds of detail available for activity measurement are shown by the cost accounting structure and statistical processing counts of the center attached as Appendix E. Of the first 595 inquiries, 25 per cent represented repeating establishments, and almost 20 per cent represented individuals with more than one inquiry. Examples of organizations making frequent inquiries are listed below. Their distribution

| TABLE 31 |
| EXAMPLES OF ORGANIZATIONS MAKING SEVEN OR MORE INQUIRIES |

| October 1, 1964 Through January 31, 1966a |

<table>
<thead>
<tr>
<th>Organization</th>
<th>Number of Requests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerojet-General Corporation</td>
<td>10</td>
</tr>
<tr>
<td>Boeing Company</td>
<td>7</td>
</tr>
<tr>
<td>Cincinnati Milling Machine Company</td>
<td>11</td>
</tr>
<tr>
<td>Curtiss-Wright Corporation</td>
<td>7</td>
</tr>
<tr>
<td>General Electric Company</td>
<td>54</td>
</tr>
<tr>
<td>Holley Carburetor Company</td>
<td>7</td>
</tr>
<tr>
<td>International Business Machines Corp</td>
<td>7</td>
</tr>
<tr>
<td>Lockheed Aircraft Corporation</td>
<td>8</td>
</tr>
<tr>
<td>Martin Company</td>
<td>9</td>
</tr>
<tr>
<td>North American Aviation</td>
<td>16</td>
</tr>
<tr>
<td>Sandia Corporation</td>
<td>7</td>
</tr>
<tr>
<td>TRW Inc.</td>
<td>18</td>
</tr>
<tr>
<td>Wayne State University</td>
<td>7</td>
</tr>
<tr>
<td>Westinghouse Electric Corporation</td>
<td>10</td>
</tr>
<tr>
<td>Wright-Patterson Air Force Base</td>
<td>21</td>
</tr>
</tbody>
</table>

by Standard Industrial Classification matches that of the total Users List distribution, and is shown in Table 32, on page 177. As set forth in the center's design study, the following description shows the user as a well defined type of engineer.

The user of a machining information center emerges as a person in manufacturing engineering, industrial engineering or manufacturing who is continuously attempting to optimize and improve performance in a number of complex machining situations being conducted simultaneously. This individual may be supporting such functions as: preparation of estimates; determination of production rates (including time standards); development of machine tool requirements; measurement and analysis of labor and production costs; determination of floor space requirements; direction of purchasing policies of machine tools, materials, cutting tools, and fluids; layout of detail procedures including machining instructions for operators, solving machining problems, and meeting production schedules. His needs are for comprehensive, current, specific elements of information which bear upon his problems. These elements of information fall into two general classes: first, the identification of a machining situation; and second, the recommended values which can be used with confidence to control variables under his jurisdiction as well as the results which can be expected from the use of recommended values.\(^3\)

The significance of user characteristics to this study is that they establish the type of sample composition required during test of the proposed sponsor's measure. Studies have indicated that all users of these centers have some characteristics in common, but that individual needs vary according to role, discipline, project, and environment.\(^4\)

If these variations are pronounced, stratified sampling might be required. The group under study, however, reflects great similarity of

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\(^4\)COSATI, pp. 8-2--8-16.
### TABLE 32

AIR FORCE MACHINABILITY DATA CENTER SUMMARY OF SPECIFIC INQUIRIES BY STANDARD INDUSTRIAL CLASSIFICATION CODE

<table>
<thead>
<tr>
<th>SIC Number</th>
<th>Major Group</th>
<th>No. of Inquiries</th>
<th>Per cent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>91</td>
<td>Federal Government</td>
<td>77</td>
<td>13.0</td>
</tr>
<tr>
<td>27</td>
<td>Printing, Publishing, and Allied Industries</td>
<td>9</td>
<td>1.5</td>
</tr>
<tr>
<td>28</td>
<td>Chemicals and Allied Products</td>
<td>11</td>
<td>1.8</td>
</tr>
<tr>
<td>29</td>
<td>Petroleum Refining and Related Industries</td>
<td>8</td>
<td>1.4</td>
</tr>
<tr>
<td>32</td>
<td>Stone, Clay, and Glass Products</td>
<td>17</td>
<td>2.8</td>
</tr>
<tr>
<td>33</td>
<td>Primary Metal Industries</td>
<td>39</td>
<td>6.5</td>
</tr>
<tr>
<td>34</td>
<td>Fabricated Metal Products, Except Ordnance, Machinery, and Transportation Equipment</td>
<td>16</td>
<td>2.7</td>
</tr>
<tr>
<td>35</td>
<td>Machinery, Except Electrical</td>
<td>156</td>
<td>26.0</td>
</tr>
<tr>
<td>36</td>
<td>Electrical Machinery, Equipment and Supplies</td>
<td>20</td>
<td>3.3</td>
</tr>
<tr>
<td>37</td>
<td>Transportation Equipment</td>
<td>150</td>
<td>25.0</td>
</tr>
<tr>
<td>38</td>
<td>Professional, Scientific and Controlling Instruments; Photographic and Optical Goods; Watches and Clocks</td>
<td>4</td>
<td>0.7</td>
</tr>
<tr>
<td>39</td>
<td>Miscellaneous Manufacturing Industries</td>
<td>4</td>
<td>0.7</td>
</tr>
<tr>
<td>50</td>
<td>Wholesale Trade</td>
<td>8</td>
<td>1.4</td>
</tr>
<tr>
<td>7391</td>
<td>Research, Development and Testing Laboratories</td>
<td>21</td>
<td>3.5</td>
</tr>
<tr>
<td>8221</td>
<td>Colleges, Universities and Professional Schools</td>
<td>35</td>
<td>5.9</td>
</tr>
<tr>
<td>86</td>
<td>Nonprofit Membership Organizations</td>
<td>8</td>
<td>1.4</td>
</tr>
<tr>
<td>8911</td>
<td>Engineering and Architectural Services</td>
<td>7</td>
<td>1.1</td>
</tr>
<tr>
<td>8921</td>
<td>Nonprofit, Educational and Scientific Research Agencies</td>
<td>4</td>
<td>0.7</td>
</tr>
<tr>
<td>1</td>
<td>Individual</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>595</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

structures. The center's outputs are replies to the inquiries, and include additionally a handbook on machining data for titanium alloys. Approximate volumes of output items are listed below in Table 33.

**TABLE 33**

**OUTPUT PRODUCTS OF THE AIR FORCE MACHINABILITY DATA CENTER**

**OCTOBER 1, 1964 THROUGH JANUARY 31, 1966**

<table>
<thead>
<tr>
<th>Type of Item</th>
<th>Approximate Quantity Distributed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bibliographies and abstracts</td>
<td>12</td>
</tr>
<tr>
<td>Summary reviews on processes, tools, industrial practices, etc.</td>
<td>150</td>
</tr>
<tr>
<td>Copies of articles, books, and other documents</td>
<td>250</td>
</tr>
<tr>
<td>Tables or excerpts of specific data on machining variables</td>
<td>500</td>
</tr>
<tr>
<td>Titanium handbooks</td>
<td>3, 200</td>
</tr>
<tr>
<td>Announcements</td>
<td>5, 000</td>
</tr>
</tbody>
</table>

These outputs were based on normal system input in most cases. As shown in Table 34, page 179, the kind of information sought by users varies widely. In cases where little or no information had been processed into the system, *ad hoc* inquiries were made of sources identified by the center's management and sponsors. Since results of these special acquisition efforts became inputs to the center as well as answers to inquiries, they are considered within the normal functional span. Total volume of input on which outputs were based is shown in Table 35, on page 180.
## TABLE 34

**KINDS OF INFORMATION SOUGHT BY USERS FROM THE AIR FORCE MACHINABILITY DATA CENTER**

<table>
<thead>
<tr>
<th>Kind of Information</th>
<th>Number of Inquiries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommendations for a specific machining situation</td>
<td>73</td>
</tr>
<tr>
<td>Starting recommendations for an extensive group of machining situations</td>
<td>118</td>
</tr>
<tr>
<td>Information pertaining to new machining processes, equipment and tools</td>
<td>45</td>
</tr>
<tr>
<td>Coordination and potential use of AFMDC</td>
<td>77</td>
</tr>
<tr>
<td>Visits to the Center</td>
<td>60</td>
</tr>
<tr>
<td>Requests for specific documents, reports, books, papers, etc</td>
<td>70</td>
</tr>
<tr>
<td>General information such as safety practices, names of firms having certain machining capabilities, tool material properties etc.</td>
<td>48</td>
</tr>
<tr>
<td>Requests for bibliographies and abstracts</td>
<td>12</td>
</tr>
<tr>
<td>State-of-the-art information and reports</td>
<td>14</td>
</tr>
<tr>
<td>Special inquiries and reports for U.S. Air Force, Manufacturing Technology Division</td>
<td>12</td>
</tr>
<tr>
<td>Evaluation, translation and review of reports, books, papers</td>
<td>14</td>
</tr>
<tr>
<td>Request for information on beryllium</td>
<td>11</td>
</tr>
<tr>
<td>Comparison of one process or material with another</td>
<td>15</td>
</tr>
<tr>
<td>Information pertaining to cutting fluids</td>
<td>15</td>
</tr>
<tr>
<td>Information on machinability research</td>
<td>11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>595</strong></td>
</tr>
</tbody>
</table>

TABLE 35

VOLUME OF INPUTS OF THE AIR FORCE MACHINABILITY DATA CENTER
October 1, 1964 through January 31, 1966¹

<table>
<thead>
<tr>
<th>Description</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Documents Entered into the System</td>
<td>8,718</td>
</tr>
<tr>
<td>Evaluated Documents:</td>
<td></td>
</tr>
<tr>
<td>Final Technical Evaluation Completed</td>
<td>276</td>
</tr>
<tr>
<td>Preliminary Technical Evaluation Completed</td>
<td>2,422</td>
</tr>
<tr>
<td>Inquiries Entered as Documents with Evaluation Completed</td>
<td>400</td>
</tr>
<tr>
<td>Machining Situations Evaluated and Ready for Coding</td>
<td>24,946</td>
</tr>
<tr>
<td>Machining Situations in Storage</td>
<td>20,380</td>
</tr>
<tr>
<td>Cards Punched</td>
<td>38,447</td>
</tr>
<tr>
<td>Unit Costs:</td>
<td></td>
</tr>
<tr>
<td>Per Document Entered</td>
<td>$14.47</td>
</tr>
<tr>
<td>Per Document Evaluated</td>
<td>40.71</td>
</tr>
<tr>
<td>Per Machining Situation (Data Points) Evaluated</td>
<td>2.78</td>
</tr>
</tbody>
</table>

TABLE 35

AIR FORCE MACHINABILITY DATA CENTER SYSTEM INPUT
OCTOBER 1, 1964 THROUGH JANUARY 31, 1966

<table>
<thead>
<tr>
<th>Type of Item</th>
<th>Number of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Documents Screened</td>
<td>8,716</td>
</tr>
<tr>
<td>Documents Evaluated</td>
<td>3,098</td>
</tr>
<tr>
<td>Machining Situations Evaluated</td>
<td>45,326</td>
</tr>
</tbody>
</table>


Expected Interaction of Study Vehicle and Proposed Test

Use of the Air Force Machinability Data Center as a study vehicle was intended to provide a suitable test of the proposed measure. This center is highly compatible with the generalized model of origin and flow of scientific and technical information. Used as a guide for both construction of the measure and selection of the study vehicle, this model conditions the entire test. Some lack of precision in measurement is expected, however, because of the kinds and quality of information available. Formal activity and accounting records concerning relationship with the center are not maintained by users. Yet the outputs are usually retained and can speak for themselves. Attitude of the technical community toward the contractor operating the center may also affect the outcome. Possible effects in this area include: (1) user bias based on popularity or personal friendships, (2) inadequate appraisal due to length of operational period, (3) tendencies of professional personnel in some cases to take controversial positions, and
reaction to novelty of a government-sponsored service without charge in this area.

Extent of Compatibility With the Generalized Model

The generalized model emphasizes importance of basic activities within the technical community. These include primary and secondary research, together with related steps leading to state-of-the-art advancement. The data center is responsible for current awareness and understanding of activities of the technical community as a means for anticipating needs and planning for an effective operation. Ability to communicate effectively depends on adaptation to the socio-cultural influences involved in the basic activities of the field of interest and the derivative information-handling functions. Unless these conventions are met by the center's management, losses in communication will occur. This problem can be acute during the introduction of new institutions and other changes into large loosely organized groups characterized by extensive interaction of heterogeneous subgroups.

The firm operating the Air Force Machinability Data Center is in a position to provide the technical background and adherence to group standards necessary for effective performance. Personnel who designed the center (shown in Table 28, pages 167 and 168) now participate in its management. These individuals have published reports on the technical subject matter of the center in leading journals and periodicals for over three decades. The data they have originated and compiled since 1940 constitute the substantive content of the U. S. Air Force machining data development report series and the Army manual (now in two editions) providing machining starting conditions for use in the
arsenals. A partial list of publications of the key personnel appears as Appendix F to this study. In addition to carrying out research in the field, the firm is engaged in the practice of engineering and test activities on a commercial basis. Review of project files shows over 10,000 completed jobs since the firm's beginning in 1948. Performance of the information-flow functions of the generalized model has been demonstrated by the review on page 74. Since the center bases its output on an internal document-retrieval system and can provide document-type service if needed, it includes the functions of both information-analysis and documentation centers. To some degree, all features of the model are represented by this center.

Kinds and Quality of Information Available

Success of the test of the proposed measure hinges on availability of information. Within the center, itself, adequate source data exists from the basic design study to current cost and activity records. All documents, including inquiries and responses, are under machine-index control within the classification scheme and standardized term list used by the center. Background data on using firms and individuals are maintained. A network of audit trails is provided covering performance costs, inputs, outputs, user reactions, and related factors. The center's appraisal of the state of the art and its planning are expressed in contractual reports and milestone projections. No difficulty is anticipated in receiving analytical information from internal sources.

External data present several problem areas. The interview guide used for exploratory investigation and case description during this study was designed to find areas where adequate and inadequate informa-
tion exists. The questionnaire developed to survey users reflects findings as to kinds and quality of information available. The major problems with respect to external data, some of which have already been mentioned are as follows:

1. Formal records are not available covering relationships of users with the data center.

2. The question of timeliness of service evokes no pronounced favorable or unfavorable reactions.

3. Over-all research progress and source identification is not always maintained in enough detail.

4. Appraisals of material obtained (from any source) versus need or assumed potential availability are rather general in nature.

5. Although general reading habits are well identified, details as to publication sources and content of individual articles tends to be obscure.

6. Volume counts of material obtained from all sources are rough approximations.

7. Many potential search sources are not recognized by a substantial portion of the community.

8. The idea of a "free" service of this type is difficult for some of the respondents to comprehend fully.

Within limitations imposed by condition of external data, measurement appears feasible. The value-judgments of actual and potential users can be taken as subjective appraisals of satisfaction and, in turn, performance.
Relationships With the Technical Community Served

Effects based on relationships of data-center personnel with the technical community will operate both for and against this study. Reputation of the contracting firm may result in a favorable bias toward its performance. For this reason, no reference to the firm's identity appears in the questionnaire survey. Conversely, the competition among advanced professional workers may stimulate an intensive critical review by some. Survey questions are structured to avoid controversy insofar as possible. The activity of the data center itself may tend to put users under some feeling of obligation concerning cooperation toward its future support. For this reason, the survey was posed as a basis for planning without reference to implications of justifying existence. The major influence of these effects is expected to be relatively heavy response to the survey, regardless of motivating factors behind the interest. This influence should aid in stimulating efforts at realistic appraisal and reduction of misleading role playing on the part of the respondents.
CHAPTER VI

EXPERIMENTATION TO TEST THE SPONSOR'S
MEASURE OF EFFECTIVENESS

The initial test of the proposed sponsor's measure of effectiveness for scientific and technical information centers involves choice of experimental design, sample selection, questionnaire preparation, gathering of data, and preparation of preliminary tabulations. Since each of these steps can affect the outcome of the test and in turn the evaluation of the measure, any deviations from the structure of the measure or opportunities for error must be closely controlled. An account of the techniques used during this phase of work is contained in the following section.

Exploratory Research

Exploratory research consisted of part of the literature search reported in Chapters I and II, visits to centers listed on page 56 of this report, and visits to industrial establishments engaged in aerospace production. During visits to manufacturing establishments the interview guide (Appendix B) was used to gather detailed information from manufacturing-engineering personnel representing both users and nonusers of the center. Plants visited included the following:

- Aerojet General Corporation, Downey, California
- Aerojet General Corporation, Azusa, California
- General Electric Company, Evendale, Ohio
These visits provided examples and suggestions which were helpful in setting up the experimental design and expected outcomes. Other material from exploratory research affecting experimentation is that on which the interview guide was based. Prior experience with use of questionnaires for survey was also considered.

Experimental Design

The choice of experimental design is conditioned by the following factors:

1. The experimental variable should be some attribute of data-center performance.

2. Prior information obtained may be adequate for prediction of expected outcomes, but it is unsuitable as a "before" measure because of sample size and composition.

3. Because of recency of availability of data center output, a time interval between conventional "before" and "after" measures may encompass a shift in attitudes unrelated to the experimental variable which could affect outcomes without being detected.
4. As the time base lengthens and additional tests are made, initial data obtained should be suitable for use as a "before" measure.

5. Although the enumerations to be taken do not involve mutually exclusive choices, cause-and-effect attribution will be attempted in the interpretation of differences in ratings received by center outputs as compared to the open literature.

These considerations lead to the choice of a single sampling operation and manipulation of the data obtained into experimental form for the initial test. Although it has been criticized as a quasi-experimental design rather than a true experiment,¹ the *ex post facto* design satisfies all of the conditions enumerated including that of upgrading the procedure into panel design.² Assignment of sample members to experimental and controlled groups on the basis of measured characteristics can provide all of the data necessary. The "before" measure is simply inferred from the distribution obtained in the "after" measure. This inference permits a more formal elucidation in testing the hypotheses than would the "after"-only experimental design. Information from operations analysis of the data center and from prediction of results based on the interview guide permits basic *ex post facto* design to be expanded by the inclusion of a comparison group. The significance of this modification is that the comparison-group judgments reflect goals which management might set in advance of actual


performance measurement. Another modification of the basic experimental design is the reiteration of some factors for more than one definition or class interval. The modified design adopted for this test is shown on Table 36, on page 190.

**Questionnaire Preparation and Testing**

Based on results of using the interview guide and other research, a brief questionnaire was prepared and tested to secure information in support of the experimental design. Some of the more important factors considered in preparation of the questionnaire are as follow:

1. Because of the wide geographic dispersion of users and potential users of the Air Force Machinability Data Center, the only economically feasible means of gathering a sample of sufficient size would be a mailed questionnaire.

2. To win an adequate response, the mailed questionnaire should offer brevity, anonymity of respondents, and ease of handling.

3. To support the use of *ex post facto* experimental structure, the questionnaire should identify each respondent as to experimental-group or control-group classification.

4. As shown by the interviews, most of the individuals to be contacted are unfamiliar with the technical vocabulary of information storage and retrieval systems. Specialized terminology of this field should be avoided.

5. Within the subject area of machinability data, inquiries and potential areas of interest represent such a wide diversity of subjects that no single typical or generalized machining situation is suitable for reference in the questionnaire.
### TABLE 36

**EXPERIMENTAL DESIGN FOR TEST OF THE PROPOSED SPONSOR'S MEASURE**

<table>
<thead>
<tr>
<th>Process</th>
<th>Experimental Group</th>
<th>Comparison Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Before&quot; Measurement</td>
<td>((P_L)_1)</td>
<td>(P'L_1)</td>
<td>((P''_L)_1)</td>
</tr>
<tr>
<td>Experimental Variable</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>(center output)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;After&quot; Measurement</td>
<td>(P_C_2)</td>
<td>(P'_C_2)</td>
<td>(P''_L_2)</td>
</tr>
<tr>
<td></td>
<td>(P_L_2)</td>
<td>(P''_L_2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(R_C_2)</td>
<td>(R'_C_2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(R_L_2)</td>
<td>(R''_L_2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(S_{C_2})</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(C_{C_2})</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Effect of Experimental Variable** = \(P_C_2 - P_L_1\); \(R_C_2 - R_L_1\);

Other factors are noncomparative measurements during the initial test.

Values in parentheses are inferred: \(P_{C_1} \approx P_{C_2}\)

\(P_{L_1} \approx P_{L_2}\)

\(P''_{L_1} \approx P''_{L_2}\)

\(R''_{L_1} \approx R''_{L_2}\)

Actual Measurements are \(P_{C_2}, P_{L_2}, P'_{L_2}, P''_{L_2}\)

\(R_{C_2}, R_{L_2}, R'_{C_2}, R'_{L_2}, S_{C_2}, C_{C_2}\)
6. As a minimum the questionnaire should permit development of pertinency and relevancy scores for both the open literature and the center outputs, and a completeness rating for center outputs.

7. Information should be provided on several characteristics to permit matching of the experimental group and control group.

8. In view of the plans for future studies, some means of respondent identification would be desirable if more detailed analysis are to be attempted.

9. Since the measure is being applied to the first year of center operations, length of use and frequency of use may be atypical. Provision should be made for adjusting frequency of use to an annual rate and for testing the effects of annualized use rate on user satisfaction.

Each of the questions used, its contributions to analysis, and any unusual features involved are described in the following review.

1. Have you used the Air Force Machinability Data Center—or materials which it disseminates—as a source of information in connection with your job?

   never (skip 2, 3, and 4) total number of references to date

The control group is comprised of all individuals indicating "never." Remaining respondents constitute the experimental group, and the reported number of uses is the unadjusted usage rate.

2. How long have you used the center's outputs?

   30 days or less over 6 up to 9 months
   over 1 up to 3 months over 9 up to 12 months
   over 3 up to 6 months over 1 year
Time-increments are presented for the convenience of the respondent in enough detail to adjust frequency-of-use data from Question 1. The placement of this question serves to focus the attention of experimental group members on their entire span of experience with the center prior to asking that they form a judgment relating to center outputs.

3. How does the material received to date from AFMDC relate to the questions you asked or encountered? (check one blank in each column)

_____ directly usable  ____ apparently complete
_____ close relation  ______ reasonably comprehensive
_____ moderate relation  ______ good coverage of question
_____ remote relation  ______ fair coverage of question
_____ no relation  ______ poor coverage of question

The lefthand response column provides a basis for determining pertinency and relevancy of center outputs. For rigorous evaluation within the experimental design, the category "directly usable" is considered to mean pertinent information, and to be directly comparable with a similar category in Question 6 relating to direct use of information from the open literature. The effect of a more lenient definition of pertinency--of including close relation--can also be considered in evaluating center outputs, although not enough information is available from the questionnaire to apply this modification to open-literature rating. The pertinency rating established by this question is part of the "after" measure. Based on the different levels of relevance indicated by the structure of this column, a relevancy score will be developed for center output. This score is obtained for
comparison to that from Question 4, rather than as a primary indicator. The righthand column for Question 3 provides a basis for scoring completeness of the center outputs.

4. Of material received from AFMDC, what percentages are

_____ new to you?  _____ discarded?
_____ not new to you?  _____ retained?

Question 4 provides another basis for determining relevance of Center outputs using retention of material as a criterion. It is part of the "after" measure of the experimental design. It also provides information for testing novelty as an approximation of entropy. The value of redundant information confirmation could qualify such material as relevant, in spite of a weak entropy rating.

5. Even though accuracy of estimate may be only approximate, how much reading and reference do you do in a typical or average week relating to machinability, considering all sources you use other than AFMDC? (check one blank in each column: specify amount if first or last)

<table>
<thead>
<tr>
<th>Pages Per Week</th>
<th>Hours Per Week Reading Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>____ up to 20</td>
<td>___ up to 2 ___</td>
</tr>
<tr>
<td>____ over 20 to 40</td>
<td>___ over 2 to 4 ___</td>
</tr>
<tr>
<td>____ over 40 to 60</td>
<td>___ over 4 to 6 ___</td>
</tr>
<tr>
<td>____ over 60 to 80</td>
<td>___ over 6 to 8 ___</td>
</tr>
<tr>
<td>____ over 80 ___</td>
<td>___ over 8 ___ ___</td>
</tr>
</tbody>
</table>

This question provides information for matching characteristics of control-group and experimental-group members. It also interrupts the response of experimental-group members so that their rating of open literature is discontinuous with respect to their rating of center out-
puts. It is intended to focus the attention of all respondents on their total reading habits prior to forming any judgments as to the usefulness of the open literature. Characteristics matched based on this question are total reading time and amount of reading per week. This question is regarded as a key element in the experimental design. If center outputs have caused a change in users' aspiration levels, reading habits may change. A similar interpretation is involved with respect to Question 6.

6. Please provide the following information concerning your general reading program relating to machinability information, not including AFMDC material (total need not equal 100%)

   ______ percentage actually applied in use (sooner or later)
   ______ percentage retained in some form for possible future use.
   ______ percentage noted for general state-of-the-art awareness
   ______ percentage covered trying to find useful material (not including above 3 percentages)

Appraisal of the open literature as a source of machinability data is obtained for both the control group and the experimental group. As a result this question can be used for matching the two groups on each of the four factors covered. Poor matching may indicate a change in aspiration levels on the part of the experimental group as a result of exposure to center outputs. It also provides pertinency and relevancy scores for the open literature for the experimental group as key measurements for inference of the "before" measure in the experimental design. Information actually applied in use is considered pertinent, and material retained or noted for state-of-the-art awareness is
considered relevant. Amount of material retained from the open litera-
ture by the experimental group provides an additional factor for inclu-
sion in the experimental design. Material passed over in an attempt to
find information of value is considered to have only remote relation-
ship by virtue of its presence in the documents covered and lack of
suitability for retention, state-of-the-art surveillance, or applica-
tion. Unlike the scoring system in Question 3, response in Question 6
is in the form of percentage estimates. These estimates are converted
to the form of data provided by Question 3 for comparative use in the
experimental design.

7. Did you receive this questionnaire from ____ AFMDC directly
or from ____ a colleague?

The initial selection of names for the Air Force Machinability Data
Center User File defined the universe from which this sample is taken.
Question 7 provides confirmation that the respondents are actually mem-
bers of the universe being studied. Secondarily, when related to other
information such as that from Question 8, it provides a key to possible
further study outside the scope of this test.

8. Statistical processing number ____

At the time of sample selection, address cards of the Data Center User
File were numbered sequentially to facilitate and verify the random
selection process of using every sixth name in a file alphabetically
arranged by company. The numbers so assigned are the "statistical
processing numbers." The first major section of some 1,500 names repre-
sents industrial users from the corporate standpoint. All of the job
titles in this file are oriented toward use of machinability data for
creation of form utility in a product, whether in estimating, material selection, design improvement, process improvement, or other engineering functions within aerospace industry. No effort is made to distinguish use of information for actual as opposed to proposed projects because of difficulties in securing such information. The second major section of over 800 names in the User File represents people who handle machinability data in carrying out an informational function but who are not oriented directly by their corporate affiliation to the production of form utility. The institutions involves include universities, professional societies, research institutions and other nonindustrial classes. This question is used for matching characteristics of the control group and the experimental group to verify their comparability. It can also be used as a basis for analyzing effect of additional factors in planned future work.

The questionnaire was tested with five individuals who had cooperated on use of the interview guide and with 25 additional persons listed on the user file from the local area but not within the sample group. Based on this test, a number of revisions were made and the quality and quantity of response estimated. Although some differences of opinion as to interpretation of question 6 were anticipated, these ambiguities were expected to distribute themselves in a random manner such that effects on matching characteristics and average scores for relevancy and pertinency would be largely self-cancelling. A summary of the use to which each question is put is summarized in Table 37, on page 197.
### Table 37

**Relationship of Questionnaire and Experimental Design Factors**

<table>
<thead>
<tr>
<th>Question</th>
<th>Factor</th>
<th>Group Separation and Matching</th>
<th>Edit and Audit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PC</td>
<td>PL</td>
<td>SC</td>
</tr>
<tr>
<td>1</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

The structure of hypothesis and expected outcomes from the test are shown in Table 38, on page 198.

**Sample Composition**

The sample composition for this study appears to be typical of users of scientific and technical information centers generally, as well as representative of the total User File of the center. The simplest available characteristic for describing composition appears to be organizational Standard Industrial Classification Code. Composition of the group receiving questionnaires as well as respondent-group and subgroup compositions shows no significant difference in the types of
TABLE 38

HYPOTHESES USED FOR TEST OF SPONSOR'S MEASURE AND EXPECTED OUTCOME

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Expected Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary</strong></td>
<td></td>
</tr>
<tr>
<td>( P_{C2} \approx P_{L1} )</td>
<td>( P_{C2} &gt; P_{L1} ), reject</td>
</tr>
<tr>
<td>( R_{C2} \approx R_{L1} )</td>
<td>( R_{C2} &gt; R_{L1} ), reject</td>
</tr>
<tr>
<td>( C &gt; )</td>
<td>Accept</td>
</tr>
<tr>
<td>( S_C &gt; 50% )</td>
<td>Accept</td>
</tr>
<tr>
<td><strong>Comparison</strong></td>
<td></td>
</tr>
<tr>
<td>( X'<em>{2} \approx X'</em>{1} )</td>
<td>Accept</td>
</tr>
<tr>
<td>( P_{L2} \approx P_{L2} )</td>
<td>Accept</td>
</tr>
<tr>
<td>( P'<em>{C2} \approx P</em>{C2} )</td>
<td>Accept</td>
</tr>
<tr>
<td>( R'<em>{L2} \approx R</em>{L2} )</td>
<td>Accept</td>
</tr>
<tr>
<td>( R'<em>{C2} \approx R</em>{L2} )</td>
<td>Accept</td>
</tr>
<tr>
<td><strong>Matching</strong></td>
<td></td>
</tr>
<tr>
<td>( P''<em>{L2} \approx P</em>{L2} )</td>
<td>Accept</td>
</tr>
<tr>
<td>( R''<em>{L2} \approx R</em>{L2} )</td>
<td>Accept</td>
</tr>
<tr>
<td>( T_{EG} \approx T_{CG} )</td>
<td>Accept</td>
</tr>
<tr>
<td>( V_{EG} \approx V_{CG} )</td>
<td>Accept</td>
</tr>
<tr>
<td>( A_{EG} \approx A_{CG} )</td>
<td>Accept</td>
</tr>
</tbody>
</table>

Where \( T \) = Hours per week reading time  
\( V \) = Number of pages read per week  
\( A \) = Organizational affiliation pattern  
\( EG \) = Experimental Group  
\( CG \) = Control Group

and relationships of factors may be in terms of scores, 
Chi-square tests, or statistical parameters
organizational affiliations of these scientists and engineers. The mailing list includes 250 individuals affiliated with production organizations and 135 others having some active relationship to the production establishments or to the technical community. At the time of sample selection, inquiries had been received from nearly 30 per cent of these individuals. The sample composition is expected to contain at least 60 individuals who have actually made inquiries as compared with some larger number who have established their status in the User File but who have not yet used the center's outputs. If equal response is received from those who have made inquiries and those who have not, the control group will be approximately three times the size of the experimental group. In such a situation, control-group replication can be undertaken for confirmation of homogeneity of the sample. Such an outcome is unlikely, however, because people who have made inquiries are likely to have greater interest in the center and to provide a heavier response than control-group members. In any case, the total sample obtained should be more than adequate to provide experimental and control groups with 31 or more degrees of freedom. Further checks on the homogeneity of the response sample are provided by the group of matching factors set up in the questionnaire.

Response to Questionnaire

From a mailing of 385 questionnaires, 199 replies were received, representing a response of 52.5 per cent. A total of 35 replies were unsuitable for counting in either the experimental group or the control group because of use of write-in comments instead of estimates requested. These comments typically covered reasons why the respondent felt that
his reply would be atypical or why completion of the questionnaire by the
the right people in his organization would not be convenient. Replies
were assigned to experimental and control groups on the basis of use of
center outputs covered in Question 1. As shown in Table 39 below, less
response was received from control-group members than had been antici-
pated. This disproportionate response is interpreted to result from a
higher degree of interest on the part of users because of more pressing
needs and possibly a satisfactory relationship with the center.

TABLE 39
ASSIGNMENT OF QUESTIONNAIRE RETURNS TO
CONTROL AND EXPERIMENTAL GROUPS

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of Returns</th>
<th>Expected Number of Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>67</td>
<td>120</td>
</tr>
<tr>
<td>Experimental</td>
<td>97</td>
<td>60</td>
</tr>
<tr>
<td>Control Rejects</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Experimental Rejects</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>199</td>
<td>180</td>
</tr>
</tbody>
</table>

Frequency of Reference

Control-group member identification included number of references
to center outputs made to date. These references may be separate in-
quiries or multiple use of single outputs. A distribution by frequency
of use is shown in Table 40, on page 201. A separate treatment is pro-
vided to adjust reported frequency to an annual use rate based on data
from Question 2. Half of the users are covered within the frequency of
TABLE 40
FREQUENCY OF USE OF CENTER OUTPUTS BY EXPERIMENTAL GROUP

<table>
<thead>
<tr>
<th>Frequency of Reference</th>
<th>Number of Respondents Reporting</th>
<th>Number of Respondents Annualized</th>
<th>Number of References Reported</th>
<th>Number of References Annualized</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>7</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>27</td>
<td>21</td>
<td>54</td>
<td>42</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>8</td>
<td>39</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>17</td>
<td>28</td>
<td>68</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>2</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>13</td>
<td>48</td>
<td>78</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>3</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>7</td>
<td>8</td>
<td>56</td>
</tr>
<tr>
<td>10</td>
<td>9</td>
<td>8</td>
<td>90</td>
<td>80</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>4</td>
<td>12</td>
<td>48</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>22</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>24</td>
<td>1</td>
<td>0</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>1</td>
<td>2</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>48</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>48</td>
</tr>
<tr>
<td>50</td>
<td>1</td>
<td>1</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>100</td>
<td>2</td>
<td>2</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Total</td>
<td>97</td>
<td>97</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
four for either reported or annualized data. Half of the references are covered just after the frequency of ten for both series. A convenient breaking point for "low" versus "high" frequency of use can be set with seven or more references representing the "high" set. The mean frequency lies between three and four references, with the mode at two. Obviously skewed toward low frequency of use, a graph of the data resembles a Poisson rather than a Gaussian probability distribution function. Isolated lumpiness toward the high frequencies could indicate more than one universe based on application of ranging techniques. These characteristics of the data favor use of rather broad class intervals for cross-tabulation and estimation of differences based on Chi-square analysis rather than parametric statistics. A note in passing which may be of interest is that high-low intervals were used for frequency-of-use analysis of attitudes of scientists toward a specialized information center, with seven times a year as the beginning point for the high-use set.\(^3\) While the practice cannot be taken as normative, it offers a convenient and workable segmentation of sample data obtained for this study.

Length of Use

The length-of-use data applied to annualized frequency of use were obtained from Question 2. Less than one third of the respondents had under six months' experience with the center, so that a relatively

minor adjustment was involved in converting to annual reference rates. Response to Question is shown in Table 41, below.

TABLE 41
LENGTH OF TIME FOR USE OF CENTER OUTPUTS

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 days or less</td>
<td>6</td>
</tr>
<tr>
<td>over 1 to 3 months</td>
<td>8</td>
</tr>
<tr>
<td>over 3 to 6 months</td>
<td>14</td>
</tr>
<tr>
<td>over 6 to 9 months</td>
<td>9</td>
</tr>
<tr>
<td>over 9 to 12 months</td>
<td>17</td>
</tr>
<tr>
<td>over 1 year</td>
<td>43</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>97</strong></td>
</tr>
</tbody>
</table>

Although yielding an unequal number of sample points for the two subgroups, the cross-tabulation categories selected under "length of use" are simply "low" (up to six months) and "high" (six months or over). The "low" set contains 28 members—a sample size reasonably close to the desired 31 or more degrees of freedom.

Most of the replies came from individuals addressed by name in the mailing. Of the 164 replies, only 14 indicated that the questionnaires were received from colleagues. Verification of organizational identity was made through use of the statistical processing numbers. In all of these 14 cases, relatively large organizations with substantial numbers of manufacturing engineering personnel were involved. It appears reasonable that the designated communicators had acted on
behalf of others in making inquiries and then handed the questionnaires to those in a position to make the evaluation. In any case, it is concluded from Questions 7 and 8 that the response is in fact from the universe studied. The referral responses were distributed proportionately between the control and experimental groups.
CHAPTER VII

OUTCOME OF THE EXPERIMENT

Experimental results were used to compare group structures, measure performance in terms of comparative quality of output, provide a performance rating for the study vehicle, and appraise the measure. Findings in each area are considered in development of the plan for future work in Chapter VIII. Much of the analysis consists of comparisons of distributions to find significant differences. For each of these comparisons, the Chi-square test was applied using the .001 significance level where a significant difference would imply favorable performance, and a .10 significance level where matching of subgroup characteristics is attempted. These criteria of significance are intended as rigorous tests to challenge differences in group composition and to demand that performance differences be pronounced. In the case of 2 x 2 contingency tables with only one degree of freedom, expected values are all in excess of five so that no serious inaccuracies are anticipated.

Matching of Subgroups

The logic of "before" measurement inference rests on equivalence of the control and experimental subgroups at the time of the "after" measure. If the experimental group composition is significantly different—or if its aspiration levels have been affected by exposure to
center outputs—the appraisal suffers. The choice of characteristics for matching depends on the need for assurances as to compatibility:

(1) Do the experimental-group members read less from the open literature in terms of volume read and time spent? (2) Do the experimental- and control-group members rate the open literature differently? Even if there is no change in aspiration level or reading efforts, do members of the two groups reflect similar organizational affiliations in terms of form-utility versus information-transfer orientation? The answers to these questions help to establish relative acceptability of the evaluations obtained.

Reading Patterns

Reading patterns are described in terms of pages and hours involved in weekly reading for the field of interest. The choice of time period involves need for a short span to aid in realistic appraisal with enough length to cover a typical activity cycle. Although the week may seem short, pretest indicated that a "typical week" concept arises spontaneously with the respondents and that unusual activity periods are automatically rejected. The distribution from Question 5 for reading habits in terms of pages per week is shown in Table 42, on page 207. A \( \chi^2 \) value of 2.5083 with 4 degrees of freedom indicates approximately a 65% probability that differences could be due to chance alone. Since the criterion of 10% (\( \chi^2 = 7.779 \)) is well past the actual value of \( \chi^2 \), no significant difference exists between control- and experimental-group reading volumes. The matching hypothesis \( V_{EG} \approx V_{CG} \) is accepted.
TABLE 42
NUMBER OF PAGES PER WEEK READ BY SAMPLE SUBGROUPS

<table>
<thead>
<tr>
<th>Number of Pages</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Group</td>
</tr>
<tr>
<td>up to 20</td>
<td>41</td>
</tr>
<tr>
<td>over 20 to 40</td>
<td>12</td>
</tr>
<tr>
<td>over 40 to 60</td>
<td>6</td>
</tr>
<tr>
<td>over 60 to 80</td>
<td>5</td>
</tr>
<tr>
<td>over 80</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>67</td>
</tr>
</tbody>
</table>

The remaining data from Question 5 show amount of time per week spent in reading. This distribution confirms that of reading volume. The value of 2.79468 for $\chi^2$ with four degrees of freedom indicates about a 60% probability that differences could be due to chance alone. The distribution of hours per week spent reading literature on machinability is shown in Table 43, on page 208. The matching hypothesis $T_{CG} \approx T_{EG}$ is accepted.

Response on both reading time and volume showed that most of the sample group do relatively little reading in the field. In view of the large number of journals and periodicals available, this behavior may reflect difficulty of using open literature as a source of information. During use of the interview guide, a list showing a majority of the sources covered by the center was shown to respondents. Included
TABLE 43
HOURS PER WEEK READING TIME BY SAMPLE SUBGROUPS

<table>
<thead>
<tr>
<th>Hours Per Week</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Group</td>
</tr>
<tr>
<td>up to 2</td>
<td>40</td>
</tr>
<tr>
<td>over 2 to 4</td>
<td>16</td>
</tr>
<tr>
<td>over 4 to 6</td>
<td>7</td>
</tr>
<tr>
<td>over 6 to 8</td>
<td>2</td>
</tr>
<tr>
<td>over 8</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>67</td>
</tr>
</tbody>
</table>

in Appendix B, this list identifies 87 periodicals which individually have relatively low concentration of information as viewed by center personnel. Reading coverage of even the high-yield subset would require considerably more than two hours a week.

Organizational Affiliation Patterns

Comparability of organizational affiliations was checked in terms of manufacturing versus nonmanufacturing orientation. The data obtained are summarized in Table 44, on page 209. The $\chi^2$ value of 1.26806 for a contingency table with one degree of freedom indicates a 32% probability that differences could be due to chance alone. While this test accepts the hypothesis of similar composition, it is closer to the criterion by half the distance of the reading-pattern
TABLE 44

SUBGROUP ORGANIZATIONAL AFFILIATIONS

<table>
<thead>
<tr>
<th>Type of Organization</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Group</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>48</td>
</tr>
<tr>
<td>Nonmanufacturing</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>67</td>
</tr>
</tbody>
</table>

outcomes. After-the-fact review of user file establishment procedures showed a four-month time lag in solicitation of interest on the part of nonmanufacturing establishments. This condition suggests that the experimental group would show a higher percentage of manufacturing affiliations, which is indeed the case. Accordingly, the matching hypothesis $A_{EG} \sim A_{CG}$ is accepted.

Rating Patterns

When application in use is the test of pertinency, subgroups can be matched according to percentages of open literature actually used. Data on this point from Question 6 will also be used to develop scores for use in testing the primary hypothesis $P_{C2} \sim P_{L1}$. The data obtained are shown in Table 45, on page 210. There is about a 63% probability that differences could be due to chance alone based on a $\chi^2$ value of 2.63270 for a contingency table with four degrees of freedom. Accordingly, the matching hypothesis $P_{L1}^{''} \sim P_{L2}$ is accepted. A preliminary
TABLE 45

PERCENTAGE OF OPEN LITERATURE APPLIED IN USE

<table>
<thead>
<tr>
<th>Percentage Applied</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Group</td>
</tr>
<tr>
<td>0 - 20</td>
<td>55</td>
</tr>
<tr>
<td>21 - 40</td>
<td>7</td>
</tr>
<tr>
<td>41 - 60</td>
<td>4</td>
</tr>
<tr>
<td>61 - 80</td>
<td>0</td>
</tr>
<tr>
<td>81 -100</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>67</td>
</tr>
</tbody>
</table>

finding with respect to the primary hypothesis concerning pertinency is that this rating toward the low end of the scale leaves room for significantly different performance by the center.

The comparative measure of relevancy offered by the experiment is related to retention of material for future use. This concept substitutes "close interest" or "recognition of potential value" for the query-oriented relevancy of most prior tests. Data obtained from Question 6 on this point are tabulated in Table 46, on page 211, showing retention. The $\chi^2$ value of 2.83515 for a contingency table with four degrees of freedom indicates about a 58% probability that differences could be due to chance alone. Again, the relatively low selective retention of open literature offers an opportunity for different source material to reflect substantially different performance. Based on the lack of significant differences between control and experimental groups with respect to
Table 46

PERCENTAGES OF OPEN LITERATURE RETAINED

<table>
<thead>
<tr>
<th>Percentage Retained</th>
<th>Control Group</th>
<th>Experimental Group</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 20</td>
<td>46</td>
<td>58</td>
<td>104</td>
</tr>
<tr>
<td>21 - 40</td>
<td>8</td>
<td>19</td>
<td>27</td>
</tr>
<tr>
<td>41 - 60</td>
<td>7</td>
<td>14</td>
<td>21</td>
</tr>
<tr>
<td>61 - 80</td>
<td>5</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>81 - 100</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>67</td>
<td>97</td>
<td>164</td>
</tr>
</tbody>
</table>

open literature, the matching hypothesis $R''_{L2} \approx R_{L2}$ is accepted.

An alternative view of relevancy might accept information relating to the work without regard to physical retention. The idea of significance for state-of-the-art awareness is also a characteristic on which control and experimental groups can be matched for similarity. Data on this characteristic obtained from Question 6 are presented in Table 47, on page 212. The $\chi^2$ value of 3.80125 shows about a 41% probability that differences could result from chance alone for a contingency table with four degrees of freedom. This outcome is considered to support the idea that the groups are comparable, including the matching hypothesis $R''_{L2} \approx R_{L2}$.

A final test of group similarity involves the rejection rate or estimate of amount of noise in the channel. Not all of the respondents
attempted to answer this question, and some indicated on the questionnaires a lack of understanding of its meaning. Results for 125 respondents attempting a specific estimate are shown below.

<table>
<thead>
<tr>
<th>Percentages Notes</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Group</td>
</tr>
<tr>
<td>0 - 20</td>
<td>25</td>
</tr>
<tr>
<td>21 - 40</td>
<td>16</td>
</tr>
<tr>
<td>41 - 60</td>
<td>13</td>
</tr>
<tr>
<td>61 - 80</td>
<td>6</td>
</tr>
<tr>
<td>81 - 100</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>67</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percentages Covered</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Group</td>
</tr>
<tr>
<td>No response</td>
<td>18</td>
</tr>
<tr>
<td>0 - 20</td>
<td>28</td>
</tr>
<tr>
<td>21 - 40</td>
<td>10</td>
</tr>
<tr>
<td>41 - 60</td>
<td>9</td>
</tr>
<tr>
<td>61 - 80</td>
<td>1</td>
</tr>
<tr>
<td>81 - 100</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>67</td>
</tr>
</tbody>
</table>
A probability of approximately 77% that differences could be due to chance alone is indicated by the \( \chi^2 \) value of 2.76696 for a contingency table with five degrees of freedom. Because of incomplete response, this distribution includes the additional category; a separate \( \chi^2 \) test of response only leads to similar results. Since this test clearly relates to nonpertinent nonrelevant material, acceptance of matching hypotheses \( P'_{L_2} \approx P_{L_2} \) and \( R''_{L_2} \approx R_{L_2} \) is confirmed through complementary data.

**Inference of "Before" Measures for Open Literature Pertinency and Relevancy**

Use of ex post facto experimental design requires that the "before" measures be inferred. This relationship might be taken as an assumption based on implicit simultaneity and identity of sample members. However, if the sample data themselves are not representative, an actual "before" measure might be significantly different from that inferred. This problem is minimized in the case of the comparison group—personnel of the center itself. Operational analysis data maintained by the center reflect uniform selection rates during both preliminary (relevancy level) and final (pertinency level) technical evaluation of inputs over the entire period studied. Hence, the hypothesis \( X'_{2} \approx X'_{1} \) is accepted, where \( X \) denotes either \( P \) or \( R \) and the "prime" notation identifies the association of the factor with the comparison group.

In the case of open-literature appraisal by control and experimental groups, the limits of the "before" measure can be estimated with some selected confidence level. For this study the confidence level...
of 95% has been adopted so that the difference between the true population mean $\bar{X}_p$ and the sampling mean $\bar{X}_s$ does not exceed $2 \sigma_M$.

where $\sigma_M^2 = \frac{\sigma_P^2}{n} (1 - r)$ and $\sigma_s$ is taken as an approximation of $\sigma_P$. For the total sample, the ratio $r$ is $n$ (sample size, 164) compared to $p$ (population size, 2,300) or about $722; 2 \sigma_M$ for the various factors and its effect on inferred values are shown in the table below. Appropriate values of $n$ and $r$ for subgroups are used.

### TABLE 49

<table>
<thead>
<tr>
<th>Factor Measured</th>
<th>$\bar{X}_s$ Percentage</th>
<th>$2 \sigma_M$</th>
<th>Inferred &quot;Before&quot; Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Upper Limit</td>
</tr>
<tr>
<td>$R_{L_2}$</td>
<td>23.10</td>
<td>3.52</td>
<td>26.62</td>
</tr>
<tr>
<td>$R''_{L_2}$</td>
<td>22.19</td>
<td>5.10</td>
<td>27.29</td>
</tr>
<tr>
<td>$P_{L_2}$</td>
<td>16.20</td>
<td>3.36</td>
<td>19.56</td>
</tr>
<tr>
<td>$P''_{L_2}$</td>
<td>14.13</td>
<td>3.16</td>
<td>17.29</td>
</tr>
</tbody>
</table>

If center-output pertinency and relevancy are compared to the upper limit of open-literature scores, a more conservative appraisal will be obtained.
Ratings of Center Outputs

Outputs of the Air Force Machinability Data Center were rated according to which of a set of descriptive terms was most accurate. This technique was adopted to disguise the intended comparison. It requires that a conversion be made to compare these ratings with those of the open literature. The simplest scheme is to compare the weighted average percentage scores of the open literature to the percentages of respondents choosing an equivalent alternative from the descriptive set in Question 3. At first thought, this technique may appear to shift the statistical base. However, each unit of center output is prompted by a need represented by an inquiry, or reference. These units are individually either pertinent, relevant, or otherwise; and the percentage of respondents using equivalent descriptions is equivalent to the percentage of material in each category. Open literature, however, represents a different compilation or presentation where unit contributions are bound together. For a given set, only a percentage will be pertinent, relevant, or otherwise. The class equivalencies are shown in Table 50, on page 216. Since retention has been used as indicative of pertinency for open literature, a directly comparable category for center outputs has been included in Question 4. Other factors rated with respect to center outputs are completeness (as judged by users) and novelty (as an approximation of entropy). These outcomes are shown in Table 51, page 216.
### TABLE 50

RELATION OF RESPONSE CATEGORIES FOR CENTER OUTPUTS AND OPEN LITERATURE

<table>
<thead>
<tr>
<th>Factor</th>
<th>Response Category</th>
<th>Center Outputs</th>
<th>Open Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pertinency</td>
<td>directly usable</td>
<td></td>
<td>applied in use</td>
</tr>
<tr>
<td>Relevancy (high)</td>
<td>close relation</td>
<td></td>
<td>retained</td>
</tr>
<tr>
<td>Relevancy (medium)</td>
<td>moderate relation</td>
<td></td>
<td>noted</td>
</tr>
<tr>
<td>Relevancy (low)</td>
<td>remote relation</td>
<td></td>
<td>covered searching</td>
</tr>
<tr>
<td>Noise</td>
<td>no relation</td>
<td></td>
<td>(no category)</td>
</tr>
</tbody>
</table>

### TABLE 51

RATINGS OF CENTER OUTPUTS

<table>
<thead>
<tr>
<th>Factor</th>
<th>Question</th>
<th>Number of Respondents</th>
<th>Rating (Percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{C_2}$</td>
<td>3</td>
<td>38</td>
<td>39.2</td>
</tr>
<tr>
<td>$R_{C_2}$ (high)</td>
<td>3</td>
<td>42</td>
<td>43.2</td>
</tr>
<tr>
<td>$R_{C_2}$ (medium)</td>
<td>3</td>
<td>17</td>
<td>17.6</td>
</tr>
<tr>
<td>$R_{C_2}$ (low)</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Noise</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$R_{C_2}$</td>
<td>4</td>
<td>97</td>
<td>75</td>
</tr>
<tr>
<td>$C_{C_2}$</td>
<td>3</td>
<td>97</td>
<td>66</td>
</tr>
<tr>
<td>$S_{C_2}$</td>
<td>4</td>
<td>97</td>
<td>54</td>
</tr>
</tbody>
</table>
Since novelty (entropy) ratings were given in percentages, the score $S_{C_2}$ is simply the weighted average of the response. Completeness scoring required conversion of data from descriptive categories to a score based on the following plan.

**TABLE 52**

**DERIVATION OF COMPLETENESS SCORE FOR CENTER OUTPUT**

<table>
<thead>
<tr>
<th>Response Category</th>
<th>Assigned Value</th>
<th>Weight (Responses)</th>
<th>Score Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparently complete</td>
<td>90</td>
<td>23%</td>
<td>21</td>
</tr>
<tr>
<td>Reasonably comprehensive</td>
<td>70</td>
<td>37%</td>
<td>26</td>
</tr>
<tr>
<td>Good coverage</td>
<td>50</td>
<td>35%</td>
<td>17.5</td>
</tr>
<tr>
<td>Fair coverage</td>
<td>30</td>
<td>5%</td>
<td>1.5</td>
</tr>
<tr>
<td>Poor coverage</td>
<td>10</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td></td>
<td><strong>66</strong></td>
</tr>
</tbody>
</table>

With ratings available for both center outputs and open literature, the primary hypotheses can be tested. Since equivalent distributions were secured for relevancy scores, the $\chi^2$ test can be applied. The $\chi^2$ value of 137.70 indicates a significant difference in Table 53 for a .1% criterion of 18.465 under four degrees of freedom. The pertinency-rating ratio $P_{L1}: P_{C2} = 39 : 15 = 2.6$ is also considered to be a significant difference. Number of respondents rating center outputs and open literature as "highly pertinent" versus "less pertinent" is shown in Table 54, on page 218. The $\chi^2$ value of 16.134 (criterion
TABLE 53

DISTRIBUTION OF EXPERIMENTAL GROUP RELEVANCY PERCENTAGES
FOR CENTER OUTPUTS AND OPEN LITERATURE

<table>
<thead>
<tr>
<th>Percentage Retained</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open Literature</td>
</tr>
<tr>
<td>0 - 20</td>
<td>53</td>
</tr>
<tr>
<td>21 - 40</td>
<td>19</td>
</tr>
<tr>
<td>41 - 60</td>
<td>14</td>
</tr>
<tr>
<td>61 - 80</td>
<td>4</td>
</tr>
<tr>
<td>81 - 100</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>97</td>
</tr>
</tbody>
</table>

= 10.8) shows a significant difference at the .1% level under one degree of freedom for the contingency table. Thus, the enumeration data confirm the pertinency scores previously developed.

TABLE 54

DISTRIBUTION OF EXPERIMENTAL GROUP PERTINENCY PERCENTAGES
FOR CENTER OUTPUTS AND OPEN LITERATURE

<table>
<thead>
<tr>
<th>Percentage Pertinent (Applied in Use)</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Open Literature</td>
</tr>
<tr>
<td>Over 50%</td>
<td>13</td>
</tr>
<tr>
<td>50% or less</td>
<td>84</td>
</tr>
<tr>
<td>Total</td>
<td>97</td>
</tr>
</tbody>
</table>
Based on these tests, two hypotheses shown below are rejected:

\[ P_{L_1} \approx P_{C_2} \]

\[ R_{L_1} \approx R_{C_2} \]

**Comparison Group-Estimates**

Expected outcomes shown in Table 25, page 108, were based on observations of personnel working within the center. These individuals can be considered as a comparison group for relating the experiment to the expectations of center management. A fairly low estimate was made with respect to direct application of outputs for reasons developed in the design study and subsequent reports by the center. Basically, the center outputs represent starting conditions which will permit successful but unoptimized operation. Yet the experience of the center indicates that a substantial number of users apply starting conditions directly and make no attempts to optimize. Based on these observations, an estimate was made that approximately one-third of the output material would be used directly without modification. A broader definition of pertinency would raise the score by approximately the amount of the "close relationship" category to more than double. The appraisal of open-literature pertinency by center personnel is reflected by the yield of evaluated data from final technical evaluation. Based on coverage of all identifiable and obtainable literature for current and retrospective material, this yield will not exceed ten per cent. By concentrating on a high-yield subset users may achieve a higher yield figure, but their average for the universe should be under ten per cent.
Relevancy involves other problems in estimating for center personnel. In a sense, all of the material provided is relevant. Yet the user may feel that a reference to a source document or other center is not relevant per se. Others may feel that data on a similar case (e.g., involving a different material from that of the inquiry having a partial set of like properties) is not really relevant. Its relationship to the query is more "something similar to" than "information concerning." Because of the necessity for using such material when no other is available, center personnel anticipate a relevancy rating from users of about 75%. The 25% reduction allows for discard of references and some portion of data after examination. Estimates of current-literature relevancy by center personnel is based on the amount of material sent to final technical evaluation after preliminary screening and preliminary technical evaluation. Approximately 25% of the material reviewed is highly relevant to the major areas of current need and interest.

Although completeness may be difficult for users to estimate, center personnel have a reasonably good basis for estimation. During and since the center's design study, continuing surveillance has been maintained of the world's sources of information in this field. From this work, an estimate is available as to the actual volume of information potentially available, the extent of redundancy in the various sources, and the percentage coverage represented by the center's collection. As of the end of a year of operation, the center was still making acquisitions and processing an input backlog. Although no one group could be expected to make substantial inroads on the problem of
creating a comprehensive data bank in that short time, the center had substantial assets. All of the material collected and reviewed during the design study and operational test of the center was still in hand. In addition, the machinability research and engineering studies of the company were available to the center, including current and continuing progress reports. By supplementing these assets with a program of highly selective direct acquisitions, the center was able to amass a substantial amount of information relating to areas of greatest current interest. Therefore, a completeness rating of not less than 50% was expected from users.

The idea of informational entropy was related to encounter of new information. Some users of the center have access to excellent sources and make inquiries for purposes of confirmation and determination of availability. Even though the redundant reply is sought, it may offer nothing new. In working at the technological frontier in machining, center personnel gain an awareness of unique information, much of which is unpublished. From this insight into recency of information origin, center personnel expect at least half of output material to be new to users.

When the comparison group estimates are checked against actual response, a fair level of agreement is found. Table 55, on page 222, recapitulates the pertinent elements. Similarity of rating patterns is indicated by a $\chi^2$ value of 2.01537 when the ratings are treated as a contingency table with five degrees of freedom. Differences shown could result from chance alone about 84% of the time, so that the rating distributions are considered highly similar. This agreement in
TABLE 55

COMPARISON GROUP ESTIMATES VERSUS EXPERIMENTAL GROUP
RESPONSE ON CENTER OUTPUT RATINGS

<table>
<thead>
<tr>
<th>Factor</th>
<th>Comparison Group</th>
<th>Experimental Group</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P_{L_2})</td>
<td>10</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>(R_{L_2})</td>
<td>25</td>
<td>23</td>
<td>48</td>
</tr>
<tr>
<td>(P_{C_2})</td>
<td>33</td>
<td>39 (Q 7)</td>
<td>72</td>
</tr>
<tr>
<td>(R_{C_2})</td>
<td>67</td>
<td>75 (Q 4)</td>
<td>142</td>
</tr>
<tr>
<td>(C_{C_2})</td>
<td>50</td>
<td>66 (Q 3)</td>
<td>116</td>
</tr>
<tr>
<td>(S_{C_2})</td>
<td>50</td>
<td>54 (Q 4)</td>
<td>104</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>235</strong></td>
<td><strong>272</strong></td>
<td><strong>507</strong></td>
</tr>
</tbody>
</table>

Pattern together with observation of similarity of rating pairs leads to acceptance of the following hypotheses:

\[ P'_{L_2} \sim P_{L_2} \quad R'_{C_2} \sim R_{C_2} \]
\[ P'_{C_2} \sim P_{L_2} \quad C_C > 50\% \]
\[ R'_{L_2} \sim R_{L_2} \quad S_C > 50\% \]

**Interaction of Factors**

Although major decisions on all study hypotheses have been taken as predicted, some consideration should be given to interaction of factors for which data are available. The following points are of interest and susceptible to some degree of resolution at this time.
1. Extent to which frequency of use is a function of length of use.

2. Whether frequency of use and level of user satisfaction are related.

3. Whether satisfaction is related to novelty (entropy) of material received.

4. Whether high rate of use of open literature is related to high rate of use of center outputs.

The question of frequency versus length of use can be examined through a contingency coefficient in terms of $\chi^2$ (Table 56).

**TABLE 56**

**LENGTH OF USE VERSUS FREQUENCY OF USE**

<table>
<thead>
<tr>
<th>Frequency of Use</th>
<th>Number of Respondents by Length of Use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (Under 6 months)</td>
</tr>
<tr>
<td>Low (up to 6 times a year)</td>
<td>24</td>
</tr>
<tr>
<td>High (7 or more times a year)</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
</tr>
</tbody>
</table>

The $\chi^2$ value of 9.0751 at one degree of freedom indicates a significant difference at the .01 level. The data show a relatively greater increase in "high use" response with movement of length from "low" to "high." Frequency of use, therefore, is partly a function of length of use.
User satisfaction may prompt repeated use. The test for this relationship involves both the usefulness and the completeness rating. When tabulated according to relative frequency of use, the completeness appraisals are as shown in Table 57, below.

**TABLE 57**

**FREQUENCY OF USE VERSUS COMPLETENESS**

<table>
<thead>
<tr>
<th>Frequency of Use</th>
<th>Completeness Ratings by Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reasonably Complete</td>
</tr>
<tr>
<td>Low</td>
<td>39</td>
</tr>
<tr>
<td>High</td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td>56</td>
</tr>
</tbody>
</table>

The \( \chi^2 \) value of 0.8281 indicates about a 38% probability that differences could be due to chance alone. An opposite conclusion can be drawn from examination of data on usefulness presented in Table 58.

**TABLE 58**

**FREQUENCY OF USE VERSUS USEFULNESS**

<table>
<thead>
<tr>
<th>Usefulness Ratings</th>
<th>Frequency of Use by Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Directly Usable</td>
<td>23</td>
</tr>
<tr>
<td>Close Relation</td>
<td>31</td>
</tr>
<tr>
<td>Moderate Relation</td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td>71</td>
</tr>
</tbody>
</table>
Here the $\chi^2$ value of $34.3079$ with two degrees of freedom is significant even at the .001 level. Because usefulness is considered more important than completeness, the latter conclusion is accepted. Concentration of difference toward the high-use-high-satisfaction sector supports the idea that satisfaction leads to frequent use.

Effects of novelty (or entropy) can be tested in a similar way. Since percentage ratings were obtained from respondents, the distributions of these percentages by level of satisfaction can be compared.

**TABLE 59**

NOVELTY (ENTROPY) VERSUS SATISFACTION LEVEL

<table>
<thead>
<tr>
<th>Novelty (Entropy) Percentage Rating</th>
<th>Number of Respondents by Satisfaction Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Satisfaction</td>
</tr>
<tr>
<td>0 - 20</td>
<td>4</td>
</tr>
<tr>
<td>21 - 40</td>
<td>2</td>
</tr>
<tr>
<td>41 - 60</td>
<td>7</td>
</tr>
<tr>
<td>61 - 80</td>
<td>2</td>
</tr>
<tr>
<td>81 - 100</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
</tr>
</tbody>
</table>

The $\chi^2$ value of $1.82639$ with four degrees of freedom indicates about a $77\%$ probability that differences can be due to chance alone. Since there is no significant change in satisfaction level with changes in novelty (entropy), outside factors are probably controlling.

Some people may simply use more data, regardless of source, than others. A simple test of this possibility is shown in Table 60.
TABLE 60

HIGH VERSUS LOW USE (APPLICATION) OF CENTER OUTPUTS AND OPEN LITERATURE

<table>
<thead>
<tr>
<th>Frequency of Use (Application)</th>
<th>Respondents by Source of Data</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Center Outputs</td>
<td>Open Literature</td>
</tr>
<tr>
<td>High</td>
<td>29</td>
<td>12</td>
</tr>
<tr>
<td>Low</td>
<td>40</td>
<td>57</td>
</tr>
<tr>
<td>Total</td>
<td>69</td>
<td>69</td>
</tr>
</tbody>
</table>

Since the $\chi^2$ value of 10.865 exceeds the .001 criterion at one degree of freedom, there is very little probability that differences could be due to chance alone. Hence, there is no discernible tendency toward nondiscriminate heavy use.

While other relationships might be tested, the foregoing are deemed most meaningful to this evaluation. Other tests may be developed for future work, as the details on strong, weak, and conflicting indications of factor relationships are analyzed.

Conclusions

The conclusions of this study are based on recapitulation and review of experimental outcomes. Evaluation of the center, the measure, and the experiment itself are feasible. These factors confirm the validity of undertaking further work and the need for a plan incorporating changes based on experience.
Experimental Recapitulation

Substitution of measurement values in the experimental design form facilitates calculation of difference in ratings as a function of source. It purports to show introduction of center outputs as a cause of changes in rating of that segment of source material as compared to open literature. Table 61, below, provides the recapitulation.

<table>
<thead>
<tr>
<th>GROUP AND FACTOR</th>
<th>&quot;BEFORE&quot; MEASURE</th>
<th>&quot;AFTER&quot; MEASURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P''</td>
<td>(11% to 17%)</td>
<td>14%</td>
</tr>
<tr>
<td>R''</td>
<td>(19% to 27%)</td>
<td>22%</td>
</tr>
<tr>
<td>EXPERIMENTAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>(16%)</td>
<td>16%</td>
</tr>
<tr>
<td>R</td>
<td>(23%)</td>
<td>23%</td>
</tr>
<tr>
<td>P'</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P''</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R''</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMPARISON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P' L</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>R' L</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>P' C</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>R' C</td>
<td>75%</td>
<td></td>
</tr>
<tr>
<td>C' C</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>S' C</td>
<td>50%</td>
<td></td>
</tr>
</tbody>
</table>
The effects of the center performance are shown by the following:

Pertinency Difference \( = P_{C_2} - P_{L_1} = 39\% - 16\% = 23\% = P_D \)

Relevancy Difference \( = R_{C_2} - R_{L_1} = 75\% - 23\% = 52\% = R_D \)

Ratio of Pertinencies \( = \frac{P_{C_2}}{P_{L_1}} = \frac{39\%}{16\%} \approx 2.5 = P_R \)

Ratio of Relevancies \( = \frac{R_{C_2}}{R_{L_1}} = \frac{75\%}{23\%} \approx 3.0 = R_R \)

In summary, the measurement outcome was anticipated fairly closely.

Different values based on changes in definitions of factors or class intervals can be recapitulated in the same format. Such a manipulation would show some changes in the final differences and ratios derived. However, they would not change any of the actions on the hypotheses nor the nature of inequality relationships involved. For this reason, they are not tabulated in this section.

Center Evaluation

The over-all performance rating of the Air Force Machinability Data Center appears to be quite satisfactory. Significant differences have been noted by users with respect to pertinency and relevancy of materials received as compared to open literature. Favorable ratings on entropy (novelty) and completeness were obtained. The suggestion that frequency of use may be a function of satisfaction level offers an area for study in connection with improvement of performance. Presumably, increases in ratings for the four factors tested will raise the satisfaction level. An analysis of high-use relationships may highlight performance attributes which can be applied to more users. Conversely, lack of use by previous users could be a basis for analysis leading to introduction of changes.
Independent appraisals are becoming available on center performance which corroborate these findings. During 1965 and 1966, an increasing number of unsolicited letters have been received by the center indicating high levels of user satisfaction. In addition, the center is starting to follow up some of the more important inquiries to see whether problem areas can be identified. This work is leading to a relationship where users become contributors of data, further indicating attitudes of satisfaction and trust. Finally, the sponsoring agency of the center surveyed users of eight centers using the outline shown in Figure 8 on page 230. This approach was followed by a survey as to what the users would be willing to pay for these services if sponsorship were reduced. The center under study appears to have fared about as well as other centers, all of which have had longer operational histories than the Air Force Machinability Data Center. Although these independent appraisals are still in process, the preliminary indications are that they will tend to confirm ratings obtained during this study.

Measure Evaluation

Evaluation of the proposed sponsor's measure of effectiveness at this point in time can only be tentative. It shows enough promise to justify further work which will provide a more final evaluation. Some of the conclusions formed about the measure are as follow:

1. The measure appears to meet the criteria on which it was based.

2. The measure can be used to support the control function.

3. The measure should be expanded to the five-factor comparative form suggested at the time of its design.
FIGURE 8
SPONSOR's SURVEY OUTLINE

EVALUATION OF INFORMATION RECEIVED FROM ____________________________ CENTER

A. Effectiveness of System

1. Relation of material received to question asked

<table>
<thead>
<tr>
<th>Estimated</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close Relation</td>
<td>%</td>
</tr>
<tr>
<td>Moderate Relation</td>
<td>%</td>
</tr>
<tr>
<td>Remote Relation</td>
<td>%</td>
</tr>
<tr>
<td>No Relation</td>
<td>%</td>
</tr>
</tbody>
</table>

2. Material was new to me

Material was not new to me

B. Effect of material received

1. Effect on work done

   Changed course of work
   Affected Choice of Contractor
      (or subcontractor)
   Indicated some anticipated work was unnecessary
   Only effect was time required to check material
   Other (please specify)

2. Please give estimates of the value (indicate if negative) of the information received $________________ or ____________ manhours.

C. General Information

1. Please identify agency that benefited from this service

   Air Force
   AEC
   FAA
   Army
   NASA
   ARPA
   Navy
   OTHERS

2. Status of work for which information is to be used

   Proposal
   Active Contract
   Company Sponsored Project

3. Please identify known relevant information not received in this service.
4. Definitions of factors should be reviewed and revised before further application.

5. Independent estimates of value or cost saving by users are needed in order to determine economic impact of performance changes shown by the measure.

6. Completeness is likely to remain the most difficult factor to appraise, and entropy seems to offer the least contribution to meaningful evaluation.

Experiment Evaluation

Evaluation of this experiment indicates that it provided enough information for testing and planning purposes. Deficiencies are also noted. The following points should be considered in extending the work beyond this point:

1. Expansion of the experimental design to panel design should also include replication of subgroups.

2. Data gathering should be integrated with the performance cycle as much as possible.

3. Questions should be rewritten for clarity and restructured for better cross-checks and comparable coverage of factors.

4. Scales and intervals should be analyzed for revisions.

5. The pattern of outcome analysis and the selection of tests and criteria can be modified to take advantage of improvements in sample data as population characteristics stabilize.

6. Volume data would be preferable to percentage estimates in many cases, and units of measure should be defined and standardized.
CHAPTER VIII

PLANNING FOR FUTURE RESEARCH

This study was undertaken because of recognition of a need for better measures of effectiveness for scientific and technical information centers. The increasing interest in these centers implies that the need for measures of effectiveness will continue to grow. Although the study has demonstrated that such measures can be constructed and applied, it has also shown that almost all of the work on the problem still lies ahead. Additional types of measures are needed. With respect to the measure developed and tested for this study, results to date are sufficiently encouraging that more work is planned. The measure itself can be improved by extending the completeness measurement to the open literature and by adding a timeliness rating. Application of the measure can be improved by analysis of ambiguities and interpretations reflected by response to the questionnaire, followed by further improvement of survey techniques. The center already evaluated can be evaluated again for the beginning of time-series measurement. With very little modification, the measure can be applied to additional centers, so that comparative performance indices can be obtained and analyzed. Finally, the general model can be reappraised and modified where desirable, after which the effectiveness measure can be extended in depth to provide ratings for subfunctions shown in the model.
The Planning Environment

Planning for future work in this field must take into account two major trends: (1) the natural evolutionary response of new institutions in adapting to the demands placed on them, and (2) attempts at planning on a national scale within the federal government and agencies associated with government planning. The history of the information storage and retrieval movement is recent. The idea of an information crisis has been described as a myth carefully nurtured by vested interests. Conversely, the weight of evidence reported in Chapter I and II of this study is that a new era in availability and use of information has been entered. This technological frontier demands better performance of functions through use of new institutions. Performance-measurement capabilities are essential to achievement of goals newly assigned to these institutions.

To what extent does the idea of evolutionary trends and performance of individual centers affect the outlook? Somewhere within the pronouncements of need and claims of panaceas lies the structure of future institutions. Today's centers are the initial and early approximations of that structure. They lack the organizational strength predicted by visionaries, but they represent the facts of performance. Somewhere, a strong "indigestible" unit may have already evolved which carries the pattern of the future. Group dynamics of a closed set of users may be the key to achievement. It is likely that the approach

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1Yehoshua Bar-Hillel, "Is Information Retrieval Approaching a Crisis?" American Documentation, XIV (April 1963), p. 98.

to future advancement must be made through analysis of effects resulting from many of these attempts. It also appears that the specialized information industry of the future will consist of survivors within a competitive environment where the interplay of competitive forces act on the sponsor rather than directly on the institution itself. In summary, the evolving unit is the basis for learning and progress—with or without the assembly of these units into a federally planned and subsidized program.

How will attempts at planning on a national scale affect planning for future work in performance measurement of these centers? Interest on the part of government agencies and their co-operating nongovernment allies can expand and possibly accelerate efforts in this area through financial sponsorship and arrangements for institutions to participate. The attitude of national planners has been expressed by the most recent major report on their proposals.

Information centers are a permanent part of an national system(s) for handling scientific and technical information. New information systems are currently coming into being; some are under design, and a few, at the national level, are in the process of experimental operation and modification. It is important that both costs and effectiveness of these new communication systems be recorded and evaluated from their very beginnings. The cost and the effectiveness should be compared between various new systems, as well as with existing traditional and evolving systems.3

Actually, almost all national planning efforts and proposals seek to capitalize in some way on the existence of high performance individual centers. Even those plans which call for national centers usually

recognize the likelihood of existence of many additional units in some form of network.

We have noted that scientists and engineers have information needs, that these are satisfied either by resort to the formal or informal networks (possibly both) and that there are a multiplicity of special libraries, document centers, information centers and data centers loosely linked and coordinated within a national information system by the Office of Science Information Services of the National Science Foundation, the National Referral Center, Science Information Exchange, etc.

How adequate is the network? how can it be improved? The overall problem has been considered by the President's Science Advisory Committee, the Science Information Council, Congressman Pucinski's Ad Hoc Subcommittee on a National Research Data Processing and Information Retrieval Center, Senator Humphrey's subcommittee, et alia. Proposals have been made for centralization, coordination and a mixture of both. A "system of systems" has been proposed. Julius Cahn, Senator Humphrey's staff assistant, argues that the "hour is late, the need is great." Others argue for a mammoth centralized information center with a battery of computers linked by coaxial cable to decentralized satellite centers servicing local needs.

One movement illustrative of work toward national systems is that concerning a proposed national engineering information system. Advocated by the Engineers Joint Council, it envisions a national coordinating center bringing individual units into a system. The advocates of this plan anticipate accelerated developments in the field.

I fully expect that the beginning made nearly four years ago will be amplified and accelerated during the next few years. I confidently predict that a sound engineering approach to defining the structure of the nation's information systems and to developing the economic justification of new systems will turn out to be the crucial prerequisite to national programs of any kind.

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A review of some of the key statements concerning national planning appears in Table 62, on page 237.

Additional Supporting Studies

One of the most important aspects of planning for further work in the field of effectiveness measurement is the formulation, refinement and maintenance of guidelines for research method. A single test or experiment may be expected to utilize only a very small portion of the tools and techniques available to the evaluator. In many cases the specific application will require modification and abridgment of some fairly general method. Experience in the application of evaluation techniques and research on method are progressing concurrently. A partial listing of evaluation techniques and research projects on evaluation methodology was presented in Chapter III of this study. As indicated in the references cited, additional studies are under way.

Leading organizations concerned with these two important areas (performance measurement and improvement of performance-measurement methods) include the National Science Foundation, the Committee on Scientific and Technical Information, and a substantial number of individual organizations and institutions such as the Systems Development Corporation, American University, Pennsylvania State University, Aslib, Western Reserve Institute, Stanford Research Institute, Drexel Institute, and various contracting organizations of the several sponsoring agencies. Although the experience base in this field is relatively small, the rates of learning and change in method are relatively high. A basic requirement for continuation of the performance-measurement process is that the evaluators maintain proficiency and current awareness for their
TABLE 62
EXAMPLES OF PROPOSALS FOR NATIONAL PLANNING FOR SCIENTIFIC AND TECHNICAL INFORMATION

<table>
<thead>
<tr>
<th>Source and Year</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baker Panel, 1958&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Federal coordinating service for existing programs</td>
</tr>
<tr>
<td>Western Reserve University, 1961&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Mechanized Information Service Network with central coordinating center</td>
</tr>
<tr>
<td>Crawford Task Force, 1962&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Establishment of central authority with respect to federal government information activities</td>
</tr>
<tr>
<td>Weinberg Panel, 1963&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Each federal agency should assume responsibility for information activities (no central agency or center)</td>
</tr>
<tr>
<td>Battelle, 1963&lt;sup&gt;e&lt;/sup&gt;</td>
<td>Centralized agency concept</td>
</tr>
<tr>
<td>COSATI, 1964&lt;sup&gt;f&lt;/sup&gt;</td>
<td>Centralized agency concept</td>
</tr>
</tbody>
</table>


<sup>e</sup>G. S. Simpson, Jr., "A Pentagon of U. S. Scientific and Technical Information and Data Service," working paper (Columbus, Ohio: Battelle Memorial Institute, 1963).

<sup>f</sup>COSATI, op. cit.
work. A listing of examples of current studies is presented in Table 63, on page 239, showing that improved techniques can be expected to emerge during the planning projection period.

**Suggested Revisions of the Sponsor's Measure of Effectiveness**

The proposed sponsor's measure of effectiveness attempted to measure an average performance level in terms of pertinency and relevancy of center output as compared to the same attributes for the open literature. Without comparison to the open literature, it included a basis for entropy measurement and for estimation of completeness as viewed by users of the center output. Suggested revisions to the proposed sponsor's measure lie in two general areas: (1) the provision of a comparative base for entropy and completeness with respect to the open literature; and (2) the addition of a timeliness rating for both the center output and the open literature. As these measures are applied sequentially through additional tests or experiments, the original ex post facto experimental design becomes a panel design, wherein each successive measure is the "after" measure of the current cycle and the "before" measure of the next cycle. Considering the five principal factors recommended for the revised measure, the experimental design expression of the proposed sponsor's measure of effectiveness is that shown in Table 64, on page 240.

The use of effectiveness measurement—other than for decisions as to continuation of sponsorship—assists in two major areas: (1) exploitation of factors and circumstances conducive to favorable results, and (2) avoidance or correction of conditions leading to
### TABLE 63

**CURRENT STUDIES WHICH MAY AFFECT PERFORMANCE-MEASUREMENT TECHNIQUES**

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Subject of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr. Gerhard L. Hollander, Hollander Associates&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Criteria for Adaptive Systems (system-independent assessment and evaluation measures)</td>
</tr>
<tr>
<td>Nartronics System Support Department&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Methods for Predicting System Performance (sensitivity to various stresses)</td>
</tr>
<tr>
<td>Technical Operations, Inc.&lt;sup&gt;b&lt;/sup&gt;</td>
<td>System Exercising and evaluation Techniques (normative exercising of initial designs)</td>
</tr>
<tr>
<td>Auerbach Corporation&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Quantitative Methods for Information Processing Systems Evaluation</td>
</tr>
<tr>
<td>International Electric Corporation&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Computer System Evaluation</td>
</tr>
<tr>
<td>Dikewood Corporation&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Techniques for Hypothesis Generation and Testing</td>
</tr>
<tr>
<td>Massachusetts Institute of Technology&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Quantum Theory Applied to Cognitive Processor Organization</td>
</tr>
<tr>
<td>Air Force Cambridge Research Laboratories&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Information Presentation Research (display to obtain clearest picture of the effectiveness of the processing operation)</td>
</tr>
<tr>
<td>System Development Corporation&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Information Processing Potentials in Large Scale Operations (specification of policies and command behavior in precisely observable and measurable terms)</td>
</tr>
</tbody>
</table>

<sup>a</sup>Rowena Swanson, *op. cit.*, pp. 52, 13.

TABLE 64

EXPANDED EXPERIMENTAL DESIGN FOR THE PROPOSED SPONSOR'S MEASURE

<table>
<thead>
<tr>
<th>Process</th>
<th>Experimental Group (^a, b)</th>
<th>Comparison Group (^a)</th>
<th>Control Group (^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Before&quot; Measurement</td>
<td>(infer)</td>
<td>(infer)</td>
<td>(infer)</td>
</tr>
<tr>
<td>&quot;After&quot; Measurement</td>
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</tr>
<tr>
<td>Experimental Variable</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>(center output)</td>
<td></td>
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<tr>
<td>PC</td>
<td>P(_C)'</td>
<td>P(_L)'</td>
<td>P(_L)</td>
</tr>
<tr>
<td>R(_C)</td>
<td>R(_C)'</td>
<td>R(_L)'</td>
<td>R(_L)</td>
</tr>
<tr>
<td>S(_C)</td>
<td>S(_C)'</td>
<td>S(_L)'</td>
<td>S(_L)</td>
</tr>
<tr>
<td>C(_C)</td>
<td>C(_C)'</td>
<td>C(_C)'</td>
<td>C(_L)</td>
</tr>
<tr>
<td>T(_C)</td>
<td>T(_C)'</td>
<td>T(_L)'</td>
<td>T(_L)</td>
</tr>
</tbody>
</table>

1 Cycle repeats after standard interval such as one year to establish time series

\(^a\) For each center in study group.

\(^b\) Parts of panel rotation may be desirable after each measure.

\(^c\) Some form of replication is desirable.
unfavorable performance. This practical and important use of effectiveness measurement requires that the measure be segmented or stratified to permit isolation and identification of individual causative factors. As changes are introduced or discovered in each of the broad functional areas covered by the model, changes in a time series plot of measurement indices can be identified. Additional levels of detail will be necessary for identification of specific changes. At this point two further steps are needed for analysis. The first step is the use of multi-level factorial analysis to determine where significant differences in over-all performance have resulted concurrently with factor change effectiveness. The second step is the construction of more detailed individual measures—experimental and otherwise—for verification of causal relationships and for more precise evaluation of magnitude of effects. This general pattern of detailing the work of performance measurement is both methodical and exploratory in nature. As the functional and procedural map for a given center becomes more detailed, subjects of specific interest will continue to emerge; however, the basic strategy of change detection, cause isolation, and appraisal of the magnitude of effects characterizes a continuing process.

In summary suggested revisions of the sponsor’s measure of effectiveness relate to scope in terms of factors measured, comparative base, time series extension, and application to subfactors. Any or all of these revisions can be considered for the next test. Depending on the study vehicles selected, any or all can be adopted. Aside from changes in the measure itself, revisions may also be made in the choice of data series selected to apply the measure.
Multiple Center Test Program

The general applicability of the proposed sponsor's measure of
effectiveness to the entire class of scientific and technical informa-
tion centers can be demonstrated only when several centers are evaluated
by use of the measure. Even though the measure was developed on the
basis of a generalized model representing centers of this class, its
operability for more than one center is yet to be demonstrated. One
of the main topics of interest in a multiple-center test is whether
some average figures of merit for comparative pertinency, relevancy,
entropy, completeness, and timeliness are applicable to more than one
center. In the event that different centers necessarily achieve dif-
ferent performance rating scores, the scores over a period of time for
each center can be converted to index numbers so that inter-city com-
parisons of performance trends can be made. It appears plausible that
centers of similar size, functional composition, nature of technical
orientation, and types of communities served might tend to have equiva-
 lent scores for a similar performance. Conjecture about performance-
rating scores for highly dissimilar centers must await the availability
of direct evidence.

The first multiple-center test might well be oriented toward
determination of the scatter of performance rating scores for centers
of various classes. More than one center of each class is needed so
that the effect of similarity may be determined. Additionally more than
two classes should be represented so that the comparative base for
observation of differences is enlarged. If only a limited number of
factors for center classification are used, the number of centers to
be studied can be kept within some reasonable upper limit such as 10 or 15 centers. Some of the classification factors to be considered in viewing study candidates are as follow:

1. Functional scope, as in the case of document centers versus data centers.

2. Magnitude of operation, as in the case of annual budgets above and below some figure of demarcation such as $300,000 annually.

3. Technical field construct, such as science versus engineering, physical versus life sciences, or specific versus hybrid fields.

4. An important characteristic of user community, such as professional versus nonprofessional, or industrial versus nonindustrial users.

**Correlation With Other Measures**

Sponsors and operating managers of scientific and technical information centers collect a great deal of information concerning costs, collection sizes, and volume of activities. Insofar as physical counts of documents analyzed, items indexed, inquiries answered, and outputs generated are meaningful, many effectiveness ratios can be developed. During the multiple-center test, this information can be reviewed versus performance-rating scores so that direct and inverse relationships can be uncovered between performance-rating scores and other factors.

Another class of measures for which information is generally available involves attempts at self-appraisal by individual centers on performance of key functions. Indexing and search are perhaps the two most salient and widely studied examples of such functions. As in the
case of systems covered by the Aslib-Cranfield studies, different
techniques and procedures may be involved when one center is compared
to another. Performance-measurement scores can be analyzed in the
light of existing effectiveness and efficiency ratings on key functions,
as well as in the light of differences in techniques employed.

A third group of other measurements which should be available is
the independent attempts of sponsors to evaluate performance of these
centers as a basis for funding support. Many prior attempt at measure-
ment have had inclusive results. Some prior and pending studies of
interest are listed in Table 65, on page 245. Application of the pro-
posed modified measure might provide clarification or greater certainty
in a given situation. In instances where a good basis for evaluation
has been established, known performance ratings can serve as a check on
the reliability and accuracy of the proposed sponsor's measure of effec-
tiveness. In summary, maximum use should be made of existing cost
records, workload data, and independent evaluations during the future
research program.

Relation of This Measure to Trends in Management of
Scientific and Technical Information Centers

Some of the trends emerging or prevailing in management of scien-
tific and technical information centers noted during the course of this
study and previously discussed at some lengths are as follow:

1. Tendencies toward standardization, functional synthesis, and
possible network integration of scientific and technical information
centers.
<table>
<thead>
<tr>
<th>Investigator</th>
<th>Subject of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Stephen Juhasz</td>
<td>Evaluation of mechanized and announcement techniques for Applied Mechanics Reviews</td>
</tr>
<tr>
<td>American Society of Mechanical Engineers</td>
<td></td>
</tr>
<tr>
<td>Dr. William Goffman</td>
<td>Evaluation of models of two concepts of epidemic theory to improve search strategy in information retrieval</td>
</tr>
<tr>
<td>Western Reserve University Center for Documentation Research</td>
<td></td>
</tr>
<tr>
<td>Dr. Y. S. Touloukian</td>
<td>Evaluation of machine-processing techniques for reference text production</td>
</tr>
<tr>
<td>Purdue University</td>
<td></td>
</tr>
<tr>
<td>Dr. John O'Connor, ISI</td>
<td>Tests of feasibility of indexing natural language texts by machine</td>
</tr>
<tr>
<td>Drs. Garfield and Sher</td>
<td>Evaluation of the citation index as an objective measuring tool for tracing the use of reports and communications by scientists</td>
</tr>
<tr>
<td>ISI (Institute for Scientific Information)</td>
<td></td>
</tr>
<tr>
<td>Dr. Frank B. Cannonito</td>
<td>Design and simulation of a model combinatorial information-retrieval system</td>
</tr>
<tr>
<td>Hughes Aircraft Company</td>
<td></td>
</tr>
<tr>
<td>Dr. F. Sommers, et al.</td>
<td>Measurement of information capacity of a language, efficient coding methods</td>
</tr>
<tr>
<td>New York Research Group</td>
<td></td>
</tr>
<tr>
<td>Dr. Granino A. Korn</td>
<td>A study of performance, design, and organization of hybrid computer systems</td>
</tr>
<tr>
<td>University of Arizona</td>
<td></td>
</tr>
<tr>
<td>Dr. Robert J. Audley</td>
<td>Tests of an experimental technique using a stochastic model of choice behavior</td>
</tr>
<tr>
<td>University College (London)</td>
<td></td>
</tr>
<tr>
<td>Dr. Bernard A. Galler</td>
<td>Analysis of automatic programming languages</td>
</tr>
<tr>
<td>University of Michigan</td>
<td></td>
</tr>
</tbody>
</table>

*aBased on Rowena Swanson, op. cit.*
2. Increasing funding stringency and pressures for development of a market where centers earn their way.


4. Expected emergence of a second-generation class of professional managers as compared to founding innovators.

Each of these trends affects the validity and usefulness of the proposed measure. Basically, an additional set of criteria for design evolution of the proposed measure can be developed on the basis of these trends. These criteria partially overlap the set shown on pages 141 through 144, used to develop the initial version of the proposed measure. This element of redundancy is taken as evidence of suitability of the proposed measure from the outset. The additional criteria are as follow.

1. Standardization of units of measure, terms, definitions, scales, and intervals is needed in the measure.

2. Functional classification and grouping should be provided by the measure based on some detailed synthesis of operations and processes.

3. Additive properties are needed for some of the ratings to permit network analysis.

4. Relatability to estimates of costs, values, and savings is necessary for future funding justification.

5. The measure should be decision oriented at sponsorship level.

6. The measure should be understandable in substance and principle without requiring high professional competence in contributing disciplines such as information theory, systems design, library science,
or field of technical specialization. The proposed measure appears to offer a basis for adaptation to the additional criteria. Based on these and other planning considerations developed in this chapter, a detailed work plan can be developed as the first stage of future work.
APPENDIX A

SEQUENCE OF RESEARCH AND REPORTING ACTIVITIES

As indicated in Chapter I, the research activity included both primary and secondary investigation, as well as definitional, analytical, design, measurement, and reporting activities. The interaction of these tasks can be indicated as follows.

<table>
<thead>
<tr>
<th>Affected Activity</th>
<th>Initiating Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Definition</td>
<td>a b c d e</td>
</tr>
<tr>
<td>b. Research</td>
<td>a c d f</td>
</tr>
<tr>
<td>c. Design</td>
<td>b d</td>
</tr>
<tr>
<td>d. Measurement</td>
<td>a b c d e</td>
</tr>
<tr>
<td>e. Analysis</td>
<td>b c d f</td>
</tr>
<tr>
<td>g. Reporting</td>
<td>a c e</td>
</tr>
</tbody>
</table>

This extensive interaction reflects the heuristic nature of the project. Initial discoveries caused redefinition and reorientation. As more factors became known, progress became more direct.

These activities are relatable to the study objectives and report structure. Shown below are the study objectives as stated in Chapter I (page 44). Opposite each is the identity of the principal activities supporting the objective and the chapters in which the work is reported.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Supporting Activities</th>
<th>Chapters where Reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct the measure: background</td>
<td>a b c</td>
<td>I II</td>
</tr>
<tr>
<td>design</td>
<td>c e</td>
<td>III IV</td>
</tr>
<tr>
<td>Conduct the experiment</td>
<td>d e</td>
<td>V VI</td>
</tr>
<tr>
<td>Evaluate the measure and center</td>
<td>e</td>
<td>VII</td>
</tr>
<tr>
<td>Initiate planning</td>
<td>a c e</td>
<td>VIII</td>
</tr>
</tbody>
</table>

Figure 9 (page 249) is a flow chart of the main work sequence.
FIGURE 9
FLOW CHART OF PROCEDURE FOR DESIGN AND TEST OF A SPECIALIST'S MEASURE OF EFFECTIVENESS FOR THE SCIENTIFIC AND TECHNICAL INFORMATION CENTER

<table>
<thead>
<tr>
<th>Definition</th>
<th>Research</th>
<th>Design</th>
<th>Measurement</th>
<th>Analysis</th>
<th>Reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Select Field of Interest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management Functions and Usefulness in the Field of Scientific and Technical Information</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1. Narrow Field for Study</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Sponsor's Measure of Effectiveness</td>
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<tr>
<td>6. Identify Basic Problem for Study</td>
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<tr>
<td>Construct and Test a Sponsor's Measure</td>
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<tr>
<td>7. Select Sources for Detailed Study of Key Literature</td>
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<tr>
<td>5. Evaluate Prior Surveys and Studies</td>
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<tr>
<td>National Science Foundation</td>
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<tr>
<td>Ohio State University</td>
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<tr>
<td>New York University</td>
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<tr>
<td>Stanford University</td>
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<td></td>
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</tr>
<tr>
<td>3. Literature Review I</td>
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<td></td>
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</tr>
<tr>
<td>9. Describe Environment and Major Functions</td>
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<tr>
<td>10. Write Chapter 1</td>
<td></td>
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<tr>
<td>11. Derive General Functional Model</td>
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<tr>
<td>14. Criteria for a Measured Model</td>
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<tr>
<td>15. Define the Measure</td>
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<tr>
<td>12. Model: Research Findings</td>
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<tr>
<td>13. Set Up Criteria for Design of a Measure</td>
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<tr>
<td>8. Literature Review II</td>
<td></td>
<td></td>
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<tr>
<td>16. Defined Measure: Selected Criteria</td>
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<tr>
<td>20. Select Study Candidates (Centers)</td>
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<tr>
<td>21. Visit Key Centers</td>
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<tr>
<td>25. Select Center for Study Vehicle</td>
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<tr>
<td>22. Center Candidates: Selection Criteria</td>
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<tr>
<td>23. Write Chapters II and III</td>
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</tbody>
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FIGURE 0 — c o n tin u e d

Analytic

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Mail Survey

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APPENDIX B

INTERVIEW GUIDE

During the introductory phases of the interview, the following materials are handed to the respondent:


2. A copy of the respondent's inquiry on a standard form (IF-1) used by the center. This item may be retained by the respondent.

3. A copy of the design study made prior to establishment of the center opened to Figure 29, page 85, accompanied by a discussion of the "machining situation" concept and how to estimate the individual data element volume involved. This item is retrieved by the interviewer.

4. A copy of a complete set of machinability data tables previously prepared by Metcut Research Associates for use by the U. S. Army arsenals and generally available to the industry. This item is retrieved by the interviewer.

---


5. Examples of recently completed work on U.S. Air Force machinability studies. This item is retrieved by the interviewer.

6. A list of articles and other materials representing typical sources of input to the data center (copy of this list appears at the end of this Interview Guide).

7. Copy of the output material used for this individual inquiry.

8. Summary information on number of inquiries to date by Standard Industrial Classification Code, materials groups, and kinds of machining operation (in case of questions or discussions in this area).
Name: ________________________________

Job Description Title: ________________________________

Organizational Position Title: ________________________________

Extent to which duties are supervisory: ________________________________

Total time in present position (by type of work): ________________________________

Total time in directly related work: ________________________________

HIGHER EDUCATION:

<table>
<thead>
<tr>
<th>DEGREES</th>
<th>MAJOR SUBJECT</th>
<th>YEAR RECEIVED</th>
<th>SCHOOL</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>NON-DEGREE COURSES</th>
<th>MAJOR SUBJECT</th>
<th>YEAR TAKEN</th>
<th>SCHOOL</th>
</tr>
</thead>
</table>

253
PART I  The Inquiry and Response

1. How did you first learn of AFMDC?
   ___ AFMDC announcement sent direct to you
   ___ AFMDC announcement reaching you indirectly
      (How? _________________________)
   ___ Through AF or other DoD personnel
      (NAME: ____________________________)
   ___ Through another user (NAME: ____________________________)
      (ORGANIZATION: ______________________)
   ___ Publicity (MEDIUM: ____________________________)
   ___ Other: ____________________________

2. In view of the fact that only a reasonable portion of all current machining information can be fully processed at this time, does the information received provide a fairly comprehensive coverage of your current needs in the field on which you requested information?
   ___ Yes   ___ No

3. Would you have found additional title listings or abstracts useful to read first in order to help you select material to read in detail?
   ___ No, wanted only detailed information
   ___ Title listings desired
   ___ Abstracts desired
   ___ Both titles and abstracts desired
   ___ Either (no preference)
   ___ Already used either or both
4. From the time you needed this information or started to search for it, what was the actual time it took to get it?

5. Briefly, could you tell me what specific machining operations you thought would be involved in this job?

6. Do you feel that the AFMDC response to your question was
   ____ reasonably prompt?
   ____ too slow?
   ____ could have been faster?

7. Would you have preferred to receive material covering a broader area than that selected to answer your specific question?
   ____ Ordnance Data Book
   ____ Other (Describe)

8. Did you receive machinability data or other information from AFMDC which you consider not to be
   ____ pertinent to your problem
   ____ relevant to your area of interest
9. How did you use the material received?

____ To keep up with what is going on in the field
____ For leads indicating work being done on your problem elsewhere
____ To avoid possible duplication in conducting machining experiments
____ To avoid duplication in submitting machining development proposal
____ To use in developing a proposal

Type of Item: ____________________________________________________________

____ To set up a reference system
____ For estimating

Type of job: _____________________________________________________________

____ For developing standards

Example(s): _____________________________________________________________

____ To verify data you already had
____ To modify data you already had
____ To obtain starting conditions for a job
____ Other than the above

Specify: __________________________________________________________________

10. Functional areas supported by this information are:

____ Research
____ Exploratory Development
____ Advanced Development
____ Engineering Development
____ Operational System Development
____ Reliability / Quality Control
____ Manufacturing

____ Other (Specify): _____________________________________________________
11. Was this particular job
____ assigned
____ self generated
____ joint decision
____ other (specify): ______________________________________________________

12. What was the date you
____ started this task
____ completed this task

13. Did you secure data or information additional to that from AFMDC?
____ Yes  ____ No
If yes, did you arrange to send this information to AFMDC, or will you do so?  ____ Yes  ____ No

14. What needed machinability data did you get along with the task assignment?

15. Did any information come to you informally, that is, information you may have gotten orally from a colleague, phone call, etc.?

16. Did you obtain information during the task that you did not use by the end of the task?
____ From AFMDC
____ From other sources
17. Was there any information that you wanted at the beginning or during the task that was not obtained by the end of the task? Describe:

18. Did you learn of other projects involving (_____ the same) (_____ Similar) problems
   _____ directly from AFMDC
   _____ indirectly through using or following up AFMDC information
   _____ through other sources, including your own professional work

19. Can you describe how the overall machinability data package needed was received by you in terms of media (journals, texts, etc), quantity of media (number of pages, roughly), and percent of total received from each source?

20. Do you normally refer to the above media or persons when confronted with the problem of obtaining this kind of information?
21. What was the first organization or person you contacted to start getting this information?

____ Received with task assignment
____ Supervisor
____ Assigned information acquisition to subordinate
____ Consultants (outside)
____ Colleague
____ Librarian or technical researcher
____ Library (search by self)
____ Departmental bookcase or files
____ Own collection
____ Information or Data Center(s)
____ Manufacturer, Supplier, Vendor
____ Other (specify): ____________________________

22. What was the principal reason you used this first source?

____ Received with task assignment
____ Most authoritative
____ Only source known
____ Availability (ease of access)
____ Knew information was at this specific source (personal recall)
____ Found it helpful previously
____ Other (Specify): ____________________________
23. Do you feel that the AFMDC

- is making a significant contribution
- is not yet making a significant contribution but probably will
- must operate along entirely different lines to contribute
- probably will never contribute very much
- is too new to be the subject of well founded opinions

24. Do you have any comments or suggestions to improve AFMDC service?

25. Can you describe briefly any machinability problems still needing solution?

26. Who else in your organization should be contacted for additional comments on the machinability data situation and AFMDC?

27. This list shows articles which have appeared in one or more technical journals or similar media within the last year. Without trying to remember where you saw the articles, please mark the list as follows:

  V you noticed the article but did not bother to read it
  - you think you may have read the article or one similar to it
  * you are reasonably certain you have read the article
28. Here is a list of some of the many journals and periodicals which contain some amount of machinability data. Will you please mark the list as follows:

- subscribed but may be marginal
* popular and widely used

29. Do you use other sources of machinability data which we have not listed here or already discussed?

___ Handbook ___ DDC TAB
___ Latest reports on ___ NASA STAR developments
___ Survey of field ___ AEC TID
___ Library accession ___ SIE Lists
___ ARTS ___ Abstracting Journals (List): ___

___ Other (List):

30. Can you estimate the amount of material (even if approximate) you review in the "other sources" just discussed?

___ estimated pages a year ___ estimate of accuracy of estimate

31. Can you give an approximate figure for the amount of machinability data you derive from journals and periodicals such as we have discussed?

___ number of machining situations (reasonably complete description)
___ number of data points concerning key machining variables
___ percent of material read important to machining practice
___ percent of material read which is used for specific problem
___ percentage noted for general state-of-the-art awareness

32. During the past year, did you have any serious trouble obtaining or locating machining information needed in your work?
   If YES, describe the difficulty:

Could you offer a solution to this problem?

33. For finding out what an article is about, what methods of abstracting do you prefer?
   ___ Complete sentences lifted from the original
   ___ Complete phrases lifted from the original
   ___ Selected facts (data) taken from the original
   ___ Selected facts (data) taken from multiple sources and evaluated
   ___ Coherent narrative written by (___ author) (___ independent expert) summarizing the main points covered in original
   ___ Coherent narrative written by (___ author) (___ independent expert) summarizing results or conclusions from original
   ___ Key words taken directly from the original based on frequency of use
34. How many hours a week does the "average" or "typical" individual in your profession spend reading technical material?
   _____ to stay current
   _____ looking for specific information

35. If time were available, how many hours a week would the person in your situation spend reading technical material?
   _____ to stay current
   _____ looking for specific information

36. Does this organization have or participate in any type of local program for development of machinability data?

37. If so, how many people are involved in this program?

38. When was the program actively started?

39. Have specific funds been set aside to support this program?

40. Is your program advanced enough to recognize any positive results?

41. Describe briefly any significant problems in machinability which have been successfully overcome.
42. Indicate actual and required specialized subject-matter knowledge available in personnel performing this activity:

<table>
<thead>
<tr>
<th>SPECIALTY</th>
<th>NUMBER OF PERSONNEL TO DO THIS WORK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ACTUAL</td>
</tr>
<tr>
<td></td>
<td>REQUIRED</td>
</tr>
</tbody>
</table>

43. For any experimentation you are conducting in machinability please provide the following information unless restricted by security or proprietary reasons:

<table>
<thead>
<tr>
<th>PRINCIPAL INVESTIGATOR</th>
<th>GOALS</th>
<th>APPROACH</th>
</tr>
</thead>
</table>
44. Estimate the number of projects which cannot be discussed at this interview for the following restrictive reasons:

SECURITY   PROPRIETARY   BOTH

45. What means are used by this organization to inform others of your potential as a source of machinability data?

46. What technical information resources related to machinability are maintained by your organization? Describe:

47. For this activity as performed in-house, what is the time interval between receipt of various items for processing and availability at the point of use?

48. For this activity, how many items are now either in process or waiting to be processed?

49. What is the average number of items reviewed per week?
50. What is the average number of documents referred to in the course of creating or reviewing an input item?

51. What aids, other than documents, are used in reviewing an input?
   - Review board meetings
   - Consultation with other specialists
   - Commissioned literature searches
   - Other (specify)

52. What factors are considered in reviewing each input item used?
   - Validity
   - Uniqueness or Novelty
   - Completeness
   - Pertinence
   - Logical organization
   - Suitability of technical level for intended audience
   - Security
   - Adequacy of illustrative material (charts, graphs, etc.)
   - Length
   - Adequacy of bibliographical references
   - Accuracy of terminology
   - Propriety
   - Patentability
53. What methods are used for announcing the arrival of new items:

- book jacket display
- actual item display
- item routed to selected users
- accession bulletins
- accession bulletins with abstracts
- none
- Other (specify):

54. What method of indicating subject matter interest is used?

- key words
- broad subject categories
- none
- other (specify):

List of Journals and Periodicals

for Use with the Interview Guide

Aero/space Engineering
Aircraft Production
American Machinist/Metalworking Manufacturing
ASME Transactions
Australasian Manufacturer
Canadian Metalworking
Cutting Tool Engineering
Design Engineering
Engineering (British)
Engineering (U.S.)
Engineering Journal
Engineering Materials & Design
Fansteel Metallurgy
General Motors Engineering Journal
Grinding and Finishing
Grits and Grinds
Indian Machine Tool Journal
Industrial Finishing (British)
Industrial Finishing (U.S.)
Institute of Metals Journal
International Science & Technology
Iron Age
Iron Age Metalworking International
Iron and Steel Institute Journal
Journal of Aeronautical Science
Journal of Applied Mechanics
Journal of Metals
Journal of Nuclear Metals
Light Metal Age
Lubrication Engineer
Machine
Machine and Tool Blue Book
Machine Design
Machinery
Machinery (London)
Machines and Tooling (Translations)
Magnesium Products
Mass Production
Materials in Design Engineering
Mechanical Engineering
Metalbewerking
Metal Progress
Metal Removing
Metallurgical Society AIME, Transactions
Metallurgie
Metals (Japan)
Metalworking
Metalworking News
Metalworking Production
Metalworking Review
Mill and Factory
Missiles and Rockets
Modern Machine Shop
Modern Metals
Nickel Topics
Plastic
Plastics Technology
Powder Metallurgy
Product Engineering
Production
Production Engineer
Refractories Journal
Rem-Cru Titanium Review
Research and Engineering
Research, Journal of Sciences and Its Application to Industry
Revue de Metallurgie
Reynolds Review
Ryan Reporter
SAE Journal & Preprints
Science and Engineering
Scientific and Industrial Research Journal
South African Mechanical Engineer
Space Aeronautics
Stanki i Instrument
Steel
Steel (Translation)
Steel Founders Society of America, Research Reports
Steel Horizons
Tool and Manufacturing Engineer
Tooling and Gaging
Tooling and Production
Ultrasonic News
Union Carbide Metals Review
Vestnik Mashinostroenila
Welding and Metal Fabrication
Western Machinery and Steel World
Western Metalworking
APPENDIX C

CATEGORIES FOR ANALYSIS: NATIONAL SCIENCE FOUNDATION STUDY

As reported in Chapter III, the National Science Foundation sponsored development of a method for study of document-retrieval systems through contract NSF #C-418. Categories for analysis used during this study reflect better study method than that of other research reviewed. These categories are likely to be significant for purposes of further study of data centers as well as document centers, since document centers can also be described within the generalized model used for this project (Figure 7, page 74). For this reason, the categories for analysis developed under the National Science Foundation study are reported in their entirety below.

The 15 review dimensions are defined on the following pages. Under each dimension, questions which were asked in reviewing each study are indicated. Subclassifications are provided under most of the dimensions. These should be thought of as tentative; they do not preclude the addition of other items under the same dimension.

1. Study Objectives

What are we trying to achieve or find out by performing this study? We can meaningfully differentiate between the following types of study objectives:

(a) Study of Variables: Their effects and interactions.
(b) Comparative Evaluation: Specific procedures, specific systems or subsystems.
(c) Descriptive Evaluation: Single systems or subsystems.

Note that the statement of objectives usually includes a specification of the subsystem (system) and/or variables to be studied. (Dimensions 6, 7.)
2. Research User Perspective

Who is the user of the research? Whose information needs is the study attempting to meet? Possible users of the research are:

(a) System designer/evaluator
(b) System buyer/manager
(c) System operator
(d) System user/customer
(e) System scientist/researcher

The specific user perspective will have strong and important implications for how many studies are planned and conducted. This is especially important in respect to selection of criteria (discussed in a later section).

3. System and Subsystem Objectives

What is the objective of the system or subsystem considered in this study? What is it supposed to accomplish, achieve, or satisfy? One way in which system objectives vary is illustrated by the following classification scheme:

(a) System Level:
   (1) Meeting information requests stated by the users.
   (2) Satisfying the user's requirements and needs for particular information.
   (3) Providing informational support to meet the organizational goal(s)
   (4) User satisfaction.

(b) Subsystem Level: The specific objective of each functional step.

A statement of the objectives of a particular system should include specification of the system user and/or type of information. The specification of the objective of the system or subsystem studied is of obvious importance to the formulation of criteria to evaluate how well the system (Subsystem) achieves its objective.

4. System Stage

In what stage of development is the system under study? Is it being designed, is it in operation, etc.? Commonly used categories are:

(a) Conceptual
(b) Design
(c) Development
(d) Test and installation
(e) Operational
(f) "Non-system specific"—refers to studies of variables which may be performed in the laboratory without reference to an actual system

The system stage is important because it determines what kind of data is available or can be collected about the system and what kind of methods are appropriate.

5. Research Setting

What is the setting in which the study takes place? The following types should cover most possibilities:

(a) Normal operational environment (e.g., a library).
(b) Manipulated operational environment (e.g., an experimental library).
(c) Laboratory physical simulation (e.g., recreation of a portion of a library in a laboratory).
(d) Laboratory phenomenological simulation (e.g., simulating the events but not the physical aspects of a part of the library).
(e) Mathematical simulation (e.g., computer simulation).
(f) Systems analysis--description (e.g., a flow chart representation

Limitations in the research setting will influence the kinds of studies performed and the kinds of measures which may be taken. When there are no prior restrictions on setting, then the choice of setting will be determined in part by the other study dimensions.

6. Subsystem studied

What functions or subsystems of the document retrieval system are under study or involved in the investigation? In terms of the model (Appendix A), one or more of the following functional steps will be involved:

(a) Document acquisition
(b) Document acquisitions selection
(c) Document selections analysis
(d) Document analysis indexing
(e) Document indexing processing and filing
(f) Query acquisitions
(g) Query acquisitions selection
(h) Query selection analysis
(i) Query analysis indexing
(j) Query indexing processing and matching

The study may pertain to one or more of these functional steps and be oriented toward alternative methods of performing them within the same system. Or it could evaluate two or more whole systems as alternatives, each of which includes all functional steps.

7. Independent or Manipulated Variables

What variables are manipulated? What are the variables whose effects or relationships are being studied? Document retrieval system variables can be classified as follows, using as a point of reference the subsystem or system under consideration.

(a) Input Variables: The ways in which the things that come into the subsystem may vary.
(b) System Variables: The ways in which the system components and operations may vary.
   (1) Personnel
   (2) Procedures
   (3) Equipment

8. Criterion Measures

What measures are used to evaluate outputs or effects? Criterion measures should be judged in terms of:
(a) **Appropriateness**: Are they relevant to the systems objectives and outputs?

(b) **Freedom from Bias (Contamination)**: Are they influenced by variables other than the independent variables?

(c) **Reliability**: Are the results consistent when the study is replicated and in terms of intra- and inter-judge agreement?

In the planning stage, the researcher should also judge the measure in terms of the practicality of obtaining the measure.

9. **Design Comparisons**

   What is being compared? What comparisons must be analyzed and evaluated to give the answers? Design comparisons can be described in terms of groups, experimental conditions, etc., depending on the specific study.

10. **Controls**

   What variables are controlled, either experimentally or statistically, to minimize extraneous influences? These variables can be classified in the same manner as were the "independent or manipulated variables" mentioned above.

11. **Analyses and Statistics**

   What methods and techniques are used to evaluate the data? The many specific methods can be grouped into three main headings:

   (a) **Descriptive**: Description of observed events in the sample studied.

   (b) **Observational Inference**: Generalization from observed events to larger population.

   (c) **Experimental Inference**: Evaluation of results of experimental manipulation.

12. **Measurement Sensitivity (Scaling)**

   How sensitive are our measurement techniques? How precisely can we measure the various items (e.g., independent variables, criteria, etc.) we are measuring? What kinds of scales do we have or need? In a typical evaluation study, numbers will be assigned to identify the "goodness" of performance (the criterion) or the ways in which people or things vary. The precision, fineness or sensitivity of our measuring devices determine what mathematical manipulations may be performed and influence how well one can detect relationships between variables under study and the criteria.

   Levels of measurement may be classified as follows:

   (a) **Nominal**: Different names may be assigned to different "things"; the judgment made is "same" or different.

   (b) **Ordinal**: Things may be placed in rank order (e.g., $A < B < C$).

   (c) **Ordered Metric**: In addition to ranking things as above, the distance between adjacently ranked things may be ranked.

   (d) **Higher Ordered Metric**: In addition to ranking things, all distances between objects may be ranked.
(e) **Interval**: Scale value may be assigned numbers such that differences (intervals) between values are equal (e.g., the difference between 1 and 2 is the same as between 3 and 4).

(f) **Ratio**: Scale values have the same properties as numbers including a zero point and may be manipulated as are numbers.

For a further consideration of levels of measurement and appropriate statistical tests the reader is referred to Siegel (1956).

13. **Sampling**

How are the cases (subjects, events, etc.) selected? What methods were used to determine which cases would be included in the study? Possibilities include:

(a) None (used entire population)
(b) Accidental (uncontrolled)
(c) Purposeful controlled (stratified, matched, etc.)
(d) Random

14. **Research Description**

How is the research reported? What should be included in the description? Does the description permit replication?

15. **Research Interpretations and Conclusions**

What kinds of interpretations and conclusions can be drawn?  

---

APPENDIX D

FIELD OF INTEREST DESCRIPTION

AIR FORCE MACHINABILITY DATA CENTER

1. Minimum Situational Identification
   a. Machining operation
      basic operation, sub-operation, and variation
   b. Material hardness (workpiece)
      hardness scale identification and actual value
   c. Material condition
      primary processing state and secondary processing state
      (such as heat treatment or surface treatment)
   d. Material group
      grouping based on usage, composition, or structure

2. Specific data coverage
   a. Material description
      most commonly used, industry-accepted identification
   b. Part configuration
      part shape, dimensions, and required tolerances
   c. Machine tool
      type, size, manufacturer, model number, spindle horsepower,
      year of manufacture, condition, type of modifications, and
      special characteristics
d. Tool material
composition of cutting-tool material in terms of industry
and manufacturers' designations

e. Cutting fluid
coolant, electrolyte, abrasive slurry, dielectric,
etchant, or gas as applicable, in both industry and
manufacturers' designations

3. Control information
a. Input characteristics
source identification, type, quality, availability, and
accessibility of detailed information

b. Set designators
links which relate all members of sets according to a wide
variety of set designators

4. Detailed information
a. Numerical data for machining variables
cutting speed, feed rate, depth of cut, and other data in
specific units relating to the operation reported

b. Tool geometry
complete engineering information on tool design

c. Unit terms
key words further describing significant relationships

d. Graphic information
microfilm aperture cards showing special features such as
part drawings, tooling details, set-up characteristics, and
production engineering documentation
5. Bibliographic information
   complete, standard elements of information for reporting of
   sources and preparation of specialized bibliographies

6. Potential source identification
   source-and-subject listings used to maintain current awareness
   of new developments relating to the state of the art
APPENDIX E

COST CONTROL DATA AND OPERATIONS ANALYSIS

INFORMATION AVAILABLE ON THE AIR FORCE MACHINABILITY DATA CENTER

1. Cost-accounting categories

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>DIRECT LABOR</td>
</tr>
<tr>
<td>1100</td>
<td>Inquiries</td>
</tr>
<tr>
<td>1110</td>
<td>Engineering Supervision</td>
</tr>
<tr>
<td>1111</td>
<td>Inquiry strategy and inquiry approval</td>
</tr>
<tr>
<td>1120</td>
<td>Machining data analysis</td>
</tr>
<tr>
<td>1121</td>
<td>Answering inquiries</td>
</tr>
<tr>
<td>1130</td>
<td>Data processing</td>
</tr>
<tr>
<td>1131</td>
<td>Keypunching</td>
</tr>
<tr>
<td>1132</td>
<td>Verification</td>
</tr>
<tr>
<td>1133</td>
<td>Sorting, collating, tabulating, etc.</td>
</tr>
<tr>
<td>1134</td>
<td>Coding</td>
</tr>
<tr>
<td>1135</td>
<td>Decoding</td>
</tr>
<tr>
<td>1140</td>
<td>Data control</td>
</tr>
<tr>
<td>1141</td>
<td>Forms and document handling</td>
</tr>
<tr>
<td>1150</td>
<td>Data acquisition</td>
</tr>
<tr>
<td>1151</td>
<td>Special acquisition for inquiries</td>
</tr>
<tr>
<td>1160</td>
<td>Reproduction</td>
</tr>
<tr>
<td>1161</td>
<td>Xerox</td>
</tr>
<tr>
<td>1162</td>
<td>Ozalid</td>
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<tr>
<td>1163</td>
<td>Ditto</td>
</tr>
<tr>
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278
<table>
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<td>1181</td>
<td>Manufacturing Technology Division (Air Force)</td>
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<tr>
<td>1182</td>
<td>Others</td>
</tr>
<tr>
<td>1200</td>
<td>Original data entry</td>
</tr>
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<td>1210</td>
<td>Engineering supervision</td>
</tr>
<tr>
<td>1211</td>
<td>Technical planning</td>
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<td>1220</td>
<td>Machining data analysis</td>
</tr>
<tr>
<td>1221</td>
<td>Preliminary screening</td>
</tr>
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<td>1222</td>
<td>Preliminary technical evaluation</td>
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<td>Final technical evaluation</td>
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<td>Sorting, Collating, tabulating, etc.</td>
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<tr>
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<td>Ozalid</td>
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<td>Drawing of data sheets, etc.</td>
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<td>Technical institutions, professional societies</td>
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<td>Machinability laboratories</td>
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<td>Data acquisition by technical personnel</td>
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<td>1281</td>
<td>Plant visits</td>
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<tr>
<td>1282</td>
<td>Telephone, TMX, telegram</td>
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<td>1283</td>
<td>Letters</td>
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<td>1284</td>
<td>Technical meetings (machinability)</td>
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<td>1285</td>
<td>Technical meetings (information science)</td>
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<tr>
<td>Code</td>
<td>Description</td>
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<td>1286</td>
<td>Foreign plant visits</td>
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<tr>
<td>1287</td>
<td>Foreign technical meetings</td>
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<td>1290</td>
<td>Data storage</td>
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<tr>
<td>1291</td>
<td>Document file</td>
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<tr>
<td>1292</td>
<td>Support information (books, etc.)</td>
</tr>
<tr>
<td>1300</td>
<td>General dissemination of machinability data and center information</td>
</tr>
<tr>
<td>1310</td>
<td>Publication in technical literature</td>
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<tr>
<td>1311</td>
<td>Presentation at technical meetings</td>
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<tr>
<td>1320</td>
<td>AFMDC exhibits</td>
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<tr>
<td>1330</td>
<td>Trade and technical newspapers and magazines</td>
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<tr>
<td>1340</td>
<td>User list (technical aspects)</td>
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<td>1350</td>
<td>User list products</td>
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<tr>
<td>1360</td>
<td>AFMDC pamphlets, announcements, etc.</td>
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<tr>
<td>1370</td>
<td>Special reports (state of the art, etc.)</td>
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<tr>
<td>1380</td>
<td>Bibliographies</td>
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<tr>
<td>1400</td>
<td>AFMDC system reports and meetings</td>
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<tr>
<td>1410</td>
<td>Monthly (Manufacturing Technology Division)</td>
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<tr>
<td>1420</td>
<td>Quarterly (Manufacturing Technology Division)</td>
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<tr>
<td>1430</td>
<td>Annual (Manufacturing Technology Division)</td>
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<tr>
<td>1440</td>
<td>Operations manual</td>
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<tr>
<td>1450</td>
<td>Detailed code book</td>
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<tr>
<td>1460</td>
<td>AFMDC meetings</td>
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<tr>
<td>1470</td>
<td>Manufacturing Technology Division and Information Branch meetings, reports, and conferences</td>
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<tr>
<td>1480</td>
<td>Special reports for Manufacturing Technology Division, Department of Defense, etc.</td>
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<tr>
<td>1500</td>
<td>Machining data verification, experimental planning</td>
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<tr>
<td>1502</td>
<td>testing</td>
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<td>1503</td>
<td>reports</td>
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<tr>
<td>1600</td>
<td>System modifications</td>
</tr>
<tr>
<td>1610</td>
<td>IBM 1130 computing system</td>
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<tr>
<td>0000</td>
<td>INDIRECT LABOR</td>
</tr>
<tr>
<td>0101</td>
<td>General repair, cleaning, painting</td>
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<tr>
<td>0102</td>
<td>Training</td>
</tr>
<tr>
<td>0103</td>
<td>Sickness or excused absence</td>
</tr>
<tr>
<td>0104</td>
<td>Holiday</td>
</tr>
<tr>
<td>0105</td>
<td>Acquisition of major facilities and equipment</td>
</tr>
<tr>
<td>0106</td>
<td>Acquisition of minor facilities and equipment</td>
</tr>
<tr>
<td>0108</td>
<td>Absence without pay</td>
</tr>
<tr>
<td>0116</td>
<td>Proposals and setting up programs</td>
</tr>
</tbody>
</table>
2. statistical program for analysis of center effectiveness

a. inquiry analysis

All processed inquiry cards are designated as completed and maintained by:

major—standard industrial classification

intermediate—inquirer

minor—minimum requirements data (see Appendix D)

Monthly, quarterly, and annual analyses are available to show number of inquiries, source of inquiries, type of inquiries, type of data requested, degree of reply proficiency, and manhours expended on inquiries.

b. original data entry analysis

All new suspense cards generated by establishment of new data cells are available by data classification, source, and minimum requirements. Periodic reports can provide information on number of data cells established, type of data cells, source of data, classification, and manhours expended.
c. Data review analysis

Suspense cards which have matured and resulted in completed work by matching data analysts are available for data-cell review and potential-source analysis. Data-cell review is conducted in the same categories as original data entry analysis (item b). Potential source breakdown is the same as that used for inquiry analysis (item a). Periodic reports can provide information on number and type of data cells reviewed, classification of system data, and degree of review effectiveness. Number of repeated contacts, source of repeated contacts, type of data needed by the system, and manhour expenditures are also available.

d. Summary reports

Percentages of total manhours for inquiries, original data entry, system data review, and potential source data. Total and unit manhours for inquiries, original data entries, data cell review, and potential source contacts.
APPENDIX F

EXAMPLES OF TECHNICAL ARTICLES AND REPORTS
WRITTEN BY PERSONNEL OF METCUT RESEARCH ASSOCIATES, INC.


"Tooling for Ceramics, Tool Engineer, June, 1958.


"Machining of Metals for Advanced Aircraft and Missiles," ASTE Paper at Western Tool Show, Los Angeles, September, 1958.

"Microstructure as it Affects Machinability, ASTE Collected Papers, Volume 58.


U.S. Air Force Machinability Reports, Volumes I through VI, published by the Air Force during the period 1950 through 1956, together with additional interim reports on the current continuing work on this series.
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________. "Evaluating the Effectiveness of Information Retrieval Systems," a paper read at the IFIP Congress, Munich, Germany, August 27-September 1, 1962.

________. "Measuring the Reliability of a Subject Classification by Men and Machines," American Documentation, XV, No. 4 (October, 1964).


Green, John C. "The Information Explosion--Real or Imaginary?" Science, CXLIV, No. 3619 (May 8, 1964).


Ross, Laurence W. "A Note on Value Functions," American Documentation, XVI, No. 2 (April, 1965).


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"The Management of Scientific Intelligence," Recurring Presentation to visitors at Defense Metals Information Center, Battelle Memorial Institute, from working papers in files of the investigator.

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No. 3. 1962

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1961.

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in the Field of Electronics, 87th Congress, 1st session. 1961.

Documentation, Indexing, and Retrieval of Scientific Information:
A Study of Federal and Non-federal Science Information

Reports

Prepared by the Technical Staff, Air Force Materials Laboratory,
Wright-Patterson Air Force Base, Ohio, 1965.

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Atherton, Pauline (ed.). Classification Research. Proceedings of The
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1965.

Auerbach Corporation. DOD User Needs Study: Phase I. Washington, D.C.:

Interview Guide Handbook for the DOD Study to Determine How
Scientific and Technical Information Is Acquired and Used by R


Beveridge, Gerald W., and Maloney, Clifford J. The Biological Laboratories Information Retrieval Program. Frederick, Md.: Biological Labs., 1962.


Davis, Charles J. Annex C to the Army Study System: Study Documentation and Information Retrieval, Volume II. A Report Prepared by the Systems Analysis Division, Office Director of Coordination and Analysis, Office of Chief of Staff, 1963.


Goldwyn, A. J. *Purpose and Objectives of the Comparative Systems Laboratory*. Cleveland: Western Reserve University, 1964.


Hillman, D. J. *Study of Theories and Models of Information Storage and Retrieval (9 reports)*. Bethlehem, Pa.: Lehigh University, 1962-1964.


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**Unpublished Material**


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CEIR, Inc. Proposal, Lecture Notes, and Questionnaires for The Army Research Office Scientific and Technical Information Survey (working papers in the files of the investigator).


Science Information Exchange, Smithsonian Institution. Questionnaire on The Notice of Research Project (NRP) (unpublished papers in the files of the investigator).
