Science, Government, and Information

The Responsibilities of the Technical Community and the Government in the Transfer of Information

A REPORT OF
THE PRESIDENT'S SCIENCE ADVISORY COMMITTEE

THE WHITE HOUSE
January 10, 1963

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STATEMENT BY THE PRESIDENT

One of the major opportunities for enhancing the effectiveness of our national scientific and technical effort and the efficiency of Government management of research and development lies in the improvement of our ability to communicate information about current research efforts and the results of past efforts.

This report of the Science Advisory Committee draws attention to the importance of good communication to modern scientific and technical endeavor. It makes a welcome contribution to better understanding of the problems of scientific and technical communication both within the Government and outside of Government and of the steps that can be taken to meet these problems.

As the report points out, strong science and technology is a national necessity and adequate communication is a prerequisite for strong science and technology.

The observations of the Committee deserve serious consideration by scientists and engineers engaged in research and development and by those administering the large Government research and development programs.

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SUMMARY AND MAJOR RECOMMENDATIONS

Transfer of information is an inseparable part of research and development. All those concerned with research and development—individual scientists and engineers, industrial and academic research establishments, technical societies, Government agencies—must accept responsibility for the transfer of information in the same degree and spirit that they accept responsibility for research and development itself.

The later steps in the information transfer process, such as retrieval, are strongly affected by the attitudes and practices of the originators of scientific information. The working scientist must therefore share many of the burdens that have traditionally been carried by the professional documentalist. The technical community generally must devote a larger share than heretofore of its time and resources to the discriminating management of the ever-increasing technical record. Doing less will lead to fragmented and ineffective science and technology.

These are the major findings and recommendations of this Panel. In arriving at these conclusions, the Panel has tried to understand the information transfer process itself, and to identify those problems in information handling that have been magnified by the accelerating growth of science and technology. The first two parts of the following report therefore describe some attributes of the information process and of various information handling systems.

Since strong science and technology is a national necessity, and adequate communication is a prerequisite for strong science and technology, the health of the technical communication system must be a concern of Government. Moreover, since the internal agency information systems overlap with the non-Government systems, the Government must pay attention to the latter as well as to the former.

The Government must be concerned with our non-Government communication systems for another, less obvious reason. The technical literature with its long tradition of self-criticism helps, by its very existence, to maintain the standards, and hence the validity, of science, particularly of basic science. The Government, as the largest supporter of basic science, has a strong interest in keeping viable this mechanism of critical review of the science it supports.

The Government's concern with technical communication is complicated by the impact of modern science and technology on national defense. Criteria for guarding information that should not be divulged in the national interest must be established and must be kept up to date. This Panel has not analyzed in detail these difficult problems of secrecy and classification; they may well bear further thought and analysis by another group.

Since both the Government and the technical community are involved with our technical communication system, the Panel, in making detailed recommendations that elaborate upon our general recommendations, has addressed itself both to the technical community and to the Federal agencies.

A. *Recommendations to the Technical Community*

1. *The technical community must recognize that handling of technical information is a worthy and integral part of science (pp. 14, 27, 29).*

We shall cope with the information explosion, in the long run, only if some scientists and engineers are prepared to commit themselves deeply to the job of sifting, reviewing, and synthesizing information; i.e., to handling information with sophistication and meaning, not merely mechanically. Such scentists must create new science, not just shuffle documents: their activities of reviewing, writing books, criticizing, and synthesizing are as much a part of science as is traditional research. We urge the technical community to accord such individuals the esteem that matches the importance of their jobs and to reward them well for their efforts.

2. *The individual author must accept more responsibility for subsequent retrieval of what is published (pp. 14, 24–26).*

Individual scientists and engineers must participate in the information transfer process, rather than leaving the entire responsibilty to the professional documentalist. We therefore urge authors of technical papers to—

a. Title papers in a meaty and informative manner (p. 24)

b. Index their contributions with keywords taken from standard thesauri. Societies and editors are urged to establish such thesauri wherever this is practical (p. 25).

c. Write informative abstracts (p. 25).

d. Refrain from unnecessary publication (pp. 25–26).

3. *Techniques of handling information must be widely taught (p. 28).*

Familiarity with modern techniques of information processing is necessary for the modern scientist and engineer. Our colleges and universities must provide instruction in these techniques as part of the regular scientific curriculum. They must also educate in the art of handling information more professionals who can lighten the burden of the technical man and can invent new techniques of information retrieval.

4. *The technical community must explore and exploit new switching methods (p. 30).*

The information transfer network is held together by an array of switching devices that connect the user with the information (as contrasted with the documents) he needs. As the amount of information grows, more ingenuity will be needed to find effective switching mechanisms, if only because the capacity of the human mind places a limit on how much information can be assimilated. The technical community must courageously explore new modes for information processing and retrieval. Among the schemes that ought to be exploited more fully are:

a. Specialized Information Centers (pp. 14, 32–33, 43). The Panel sees the specialized information center as a major key to the rationalization of our information system. Ultimately we believe the specialized center will become the accepted retailer of information, switching, interpreting, and otherwise processing information from the large wholesale depositories and archival journals to the individual user. The Panel therefore urges that more and better specialized centers be established.

We believe the specialized information center should be primarily a technical institute rather than a technical library. It must be led by professional working scientists and engineers who maintain the closest contact with their technical professions and who, by being near the data, can make new syntheses that are denied those who do not have all the data at their fingertips. Information centers ought to be set up where science and technology flourish. We believe that the large, Government-supported laboratories could become congenial homes for groups of related specialized information centers.

b. Central Depositories (pp. 30–32). The central depository to which authors submit manuscripts that are announced and then distributed on request may ease the technical problems of switching documents quickly and discriminatingly between user (particularly the specialized center) and source. Central depositories are now being used by several Government information systems, and there is little question of their practicality. The Panel, though recognizing the difficulties of replacing the traditional techniques of communication via conventional journals, nevertheless urges technical societies to experiment with central depositories, or some variant thereof (as is done by the American Physical Society), for at least some of their literature.

c. Mechanized Information Processing (pp. 20–21, 34–35). The Panel recognizes that mechanical equipment offers hope for easing the information problem. Commercially available equipment is not the remedy in every case; economics, size, frequency of use, growth rate, depth and sophistication of indexing must be examined in detail for each collection before a specific system is to be mechanized. There is a need for equipment specifically designed to retrieve documents from very large collections. The recent study under the auspices of the Council of Library Resources, recommending automation of the Library of Congress, should be evaluated with a view toward its implementation both as a means of improving the services offered by the Library and of advancing the art of automatic retrieval.

d. Development of Software (p. 35). Hardware alone is not a panacea for difficulties of information retrieval. Software, including methods of analyzing, indexing, and programing, is at least as necessary

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for successful information retrieval. The Panel wishes to call the attention of the technical community to a promising new method of access to the literature called the citation index: a cumulative list of articles that, subsequent to the appearance of an original article, refer to that article.

5. *Uniformity and compatibility are desirable (p. 36).*

Since the entire information system is a network of separate subsystems, rapid and efficient switching between the different elements of the system is essential. Such switching will be fully effective only if the different subsystems adopt uniform practices toward abstracting and indexing. We commend the Office of Science Information Service (OSIS) of the National Science Foundation for trying, through the National Federation of Science Abstracting and Indexing Services, to encourage order in a chaos of non-uniformity. We believe that Government, by virtue of the financial support it gives to private information services, should exert leverage in persuading societies to adopt more uniform practices.

B. *Recommendations to Government Agencies*

We preface our recommendations to the Federal agencies with the statement that Government information activities must not be allowed to swamp non-Government activities. The special sensitivity of non-Government, decentralized information services to the needs of the user as well as the variety of approaches offered by these services is precious and must be preserved. Support by Government does not necessarily mean domination by Government but this danger must always be guarded against.

1. *Each Federal agency concerned with science and technology must accept its responsibility for information activities in fields that are relevant to its mission. Each agency must devote an appreciable fraction of its talent and other resources to support of information activities (pp. 44ff).*

Since the information process is part of the research and development process, agencies that support research and development in fields that are relevant to their missions accept responsibility for supporting and otherwise carrying out information activities in these fields. Each of the mission-oriented agencies ought to become "delegated agents" for information in fields that lie within their missions. In these fields the agencies should maintain a strong internal information system and should support non-Government information activities, always striving to blend the Government and non-Government systems into a consistent whole.

2. *To carry out these broad responsibilities each agency should establish a highly placed focal point of responsibility for information activities that is part of the research and development arm, not of some administrative arm, of the agency (p. 45).*

We stress that the technical information activities of an agency must be part of research and development, not part of administration.

3. *The entire network of Government information systems should be kept under surveillance by the Federal Council for Science and Technology (p. 46).*

We applaud the recent action of the FCST in establishing an interagency Committee on Science Information. Among other matters, this committee will be expected to prevent overlaps and omissions as the agencies become delegated agents in various fields of science and technology.

4. *The various Government and non-Government systems must be articulated by means of the following information clearinghouses:*

a. Current Efforts Clearinghouse (pp. 46–47). We recommend that the Science Information Exchange (that provides information on who does what where) be strengthened and that it receive separate support rather than depending on voluntary contributions from the agencies it serves. A Technological Efforts Exchange, either as part of SIE or working in close collaboration with it, should be established.

b. Report Announcement and Distribution (p. 47). We recommend that the Office of Technical Services of the Department of Commerce be made a complete technical reports sales agency. It should be given enough support so that it can announce promptly and supply inexpensively a copy of any declassified Government technical report.

c. Retrospective Search and Referral Service (pp. 47–48). We approve the recent action of NSF and the Library of Congress establishing a National Technical Referral Center as part of the Library of Congress.

In addition, the National Referral Service should maintain and make available a directory of Specialized Information Centers and a register of formal technical meetings.

5. *Each agency must maintain its internal system in effective working order (pp. 38–43).*

The internal communication system is based largely on informal technical reports. We offer the following recommendations for improving the dissemination and retrieval of information contained in the technical reports:

a. Technical reports should be refereed or otherwise screened before they enter the internal information system (pp. 39–40).

b. Agencies must insist that their contractors live up to their contractural obligations for adequate technical reporting. We believe that proprietary interests sometimes serve as barriers to proper flow of information. We recommend that the whole matter of defining what are and what are not proprietary rights in Government contracting be subjected to a Government-wide study (pp. 41–42).

c. Although the Panel sees no cause for alarm in the way classification is now handled by Government agencies, this impression is largely an intuitive one. We therefore recommend that problems of security and declassification be studied by an ad hoc group of the Federal Council's Committee on Information (pp. 41–42).

d. Since the report literature is often poor, critical reviews of the report and related literature play an important role. Critical review journals published under Atomic Energy Commission auspices have been generally successful; we urge other agencies, notably National Aeronautics and Space Administration and Department of Defense, to undertake similar review ventures in fields of interest. Such review journals might well become a most important product of the specialized information centers.

e. We believe that the large central agency depository should concentrate on being a document wholesaler, and that, where specialized centers exist, the job of preparing state-of-the-art reviews, and otherwise interpreting the literature, should be the responsibility of the specialized information center (pp. 43–44).

f. Since these latter activities are so important to the effective transfer of information, we believe that the agencies concerned should actively sponsor and support additional specialized information centers at appropriate establishments (pp. 33, 43).

6. *Problems of scientific information should be given continued attention by the President's Science Advisory Committee (p. 51)*.

The problems of scientific information are very complex and they will continue to be with us. We therefore recommend that scientific information, and particularly the balance between Government and private activities, be given continued attention by the President's Science Advisory Committee.

Part 1

THE NATURE OF THE INFORMATION PROBLEM

Science and technology can flourish only if each scientist interacts with his colleagues and his predecessors, and only if every branch of science interacts with other branches of science; in this sense science must remain unified if it is to remain effective. The ideas and data that are the substance of science and technology are embodied in the literature; only if the literature remains a unity can science itself be unified and viable. Yet, because of the tremendous growth of the literature, there is danger of science fragmenting into a mass of repetitious findings, or worse, into conflicting specialties that are not recognized as being mutually inconsistent. This is the essence of the "crisis" in scientific and technical information.

Inasmuch as the Federal Government now supports three-fourths of all science and technology of the United States, it has a responsibility to prevent our scientific-technical structure from becoming a pile of redundancies or contradictions simply because communication between the specialized communities or between members of a single community has become too laborious. Moreover, since good communication is a necessary tool of good management, the Federal Government, as the largest manager of research and development, has a strong stake in maintaining effective communication.

The problem of course is not the Federal Government's alone. Science and technology are the business of many who are outside Government: the professional technical societies, the universities, private industry. Each of these communities has developed methods to cope with the difficulties in communication, some (notably the physical scientists) more successfully than others; yet because these communication systems have grown up in isolation, they too often tend to further fragment our already disjointed scientific structure. The Federal Government alone interacts with all of the elements of our information systems; it is uniquely able to examine the overall problem from a properly general viewpoint and to guide and otherwise support measures for unifying our communication and so preserving that unity of science and technology that is indispensable to their effective pursuit.

Another reason for the Federal Government's interest in maintaining the health of our scientific communication systems has to do with the validity of our science. Modern science and technology cost our society dearly, and our society is justified in demanding its money's worth. Much of the return from science and technology is tangible and obvious: better defense, better food, more abundant energy. But the many technical activities that do not directly lead to tangible gains must also justify their existence to the society that supports them. Here the process of scientific communication, with its long tradition of ruthless self-criticism, plays an indispensable role. The existence of a healthy, unified, impartial, and sophisticated system of scientific communication—indeed, of scientific criticism—helps to assure society that the science it supports is a responsible and worthwhile undertaking and not merely an avenue of self-expression for an elite group.

The Government's attitude toward dissemination of scientific information is necessarily affected by the influence of science upon our national posture. The idealistic motivation for science and the most compelling one for the creative individual is intellectual curiosity; a society that ignored this motivation would still achieve some material progress for a brief interval, but would have stifled the spark of the deepest human aspirations. But science is not pursued solely for human edification or even for improvement of our social and material well-being; parts of research and of development are aimed at maintaining our military strength to keep the peace. Results from these technical efforts cannot be transmitted as freely as can non-military science and technology; on the other hand, within the circle of military research establishments, quick, discriminating communication of discoveries is essential. The conflicting demands of secrecy and of free exchange, reflecting as they do the diversity of our technical and scientific goals, complicate the problem of effective communication.

Both the legislative and the executive branches of the Federal Government have already devoted considerable attention to the mounting problem of handling information. On the legislative side, the Senate Committee on Government Operations and its Subcommittee on Government Reorganization and International Organizations have studied the problem and have issued several reports dealing with it. On the executive side a previous Panel of the President's Science Advisory Committee (PSAC) under the chairmanship of W. O. Baker has examined the question of whether the Federal Government should establish a single all-encompassing centralized science information service, similar in scope to the U.S.S.R.'s All-Union Institute of Scientific and Technical Information, as a means of coping with the threatened breakdown in scientific communication. The Baker Panel concluded that no such drastic action was called for at the time, but that the National Science Foundation's role as a coordinator of science information services ought to be strengthened. Central to the recommendation of the Baker Panel was the establishment of the Office of Science Information Service (OSIS). The OSIS has been in existence since 1959 and has performed many of the functions envisioned for it by the Baker Panel. This Panel also urged the independent professional societies to participate aggressively in an expanded science and engineering communication system.

The scope of the present Panel study is somewhat broader than that of the earlier PSAC Panel since, among other things, the present Panel can assess how the earlier recommendations have turned out. In addition to considering the role of the Federal Government and the relation between the Federal Government's information systems and the non-Government systems, we have tried to examine the scientific communication process itself: how information is generated, stored, retrieved, summarized. Our report and recommendations are addressed therefore not only to the Federal agencies but also to private agencies, and to individual working scientists and engineers. We hope to apprise scientists and technologists of the current information problem and to arouse them to personal as well as group action in dealing with it.

A. *How Much Communication Is Needed?*

Everyone engaged in science—the working scientist, the scientific administrator, the head of a scientific agency—recognizes that scientific communication is necessary; the question is: how much is necessary? To expand an information system or to establish one where none now exists takes money and manpower. Since there are no unequivocal criteria for deciding what is a sufficient information system, why should one decide to spend more on communication, especially if it means spending less on something else or if one's efforts are useful mainly to someone else? How does the head of a Federal agency decide the appropriate size of his information service? How does a professional society through its publication committee decide on a new journal? For that matter, how does a working scientist decide whether to spend more time in the library? Because of the elusive quality of scientific communication, because there are few criteria available to decide how much communication is enough, such decisions are generally made intuitively if not haphazardly. To the working scientist or engineer, time spent gathering information or writing reports is often regarded as a wasteful encroachment on time that would otherwise be spent producing results that he believes to be new. To the scientific administrator, the need for scientific communication is one of many competing needs—to be weighed against the need for additional computing equipment, or for more scientists, or for more stenographers.

It is no wonder that the scientific administrator, especially at the highest level in Government, so often fails to be impressed with the urgency of the communication problem or with the necessity of spending more to improve the situation. He is importuned on every hand by professional specialists to each of whom the situation in his specialty appears to be in a state of crisis that can be eased only by more spending. Communication is only one such professional specialty; it suffers by comparison with other services, such as, say, computing, in that the output of a computer as a rule demonstrably affects the course of a technical enterprise, whereas the output of an information system usually affects the course of a technical enterprise less directly and over a longer period.

We have been unable to make much progress in deciding how much communication is about right. Evidently, some knowledge is better re-created than retrieved. For example, most scientists recompute the square of a number rather than looking it up in Barlow's Tables. On the other hand, even in a well-equipped laboratory one would ordinarily look up the melting point of LiF rather than measure it. Thus the question of when to re-create a scientific result and when to use the information system is a matter of relative cost and familiarity with the system. A scientist resorts to the information system if he believes it is easier, or more illuminating, to consult the written record rather than to do the experiment himself. Yet the scientist's own estimate of what he wants by way of information may be inconsistent with what he should have to pursue his work most effectively. The anomalies of our information system have conditioned some scientists to active resistance to being informed.

An operational analysis of the process of technical discovery made by the Panel suggests that the individual theoretical scientist will, on the average, maximize his overall productivity if he spends half of his time trying to create new scientific information and half of his time digesting other work and communicating his own. This result seems to be rather insensitive to the values of the parameters that were used to characterize the processes of information retrieval and creation. We would therefore suspect that mathematical models of similar flavor might throw some light on the question of how much effort ought to be put into an information system, whether an individual's, a professional society's, or a Government agency's. But this is a speculation that further work can verify or deny. In the meantime, we have only commonsense to tell us that considerable effort—in most cases more than is now expended—must go into scientific communication, and that the effort required will grow.

B. *Good Scientific Communication Is No Substitute for Good Management*

Because information about what is going on is necessary for making management decisions, improvement in scientific information systems is sometimes represented as a panacea for bad management of research and development. Though it is true that poor management can and does occur with the best of communication systems, poor communication almost always leads to bad management.

We belabor this point because some articulate and concerned spokesmen have, at least by implication, confused the problem of communication with the problem of management of research and development. In some discussions of the advisability of establishing a single Department of Science, deficiencies in the scientific communication system have been invoked to help justify the merging of all Government science into a single department. But this is surely an oversimplification of a perplexing problem. Whether bringing the Government's total information system under a single organizational roof would improve communication is in the first place conjectural;

in any case, even if the desired improvement were thereby achieved, better management of research and development would not automatically follow. Information is one of many tools that the manager of research and development must have; the *use* to which he puts the information—indeed, the diligence and responsibility he shows in unearthing needed information—is determined only by his own skill as a manager. To expect miracles of management to follow from centralization of the information system is unjustifiably optimistic, especially since many important aspects of research and development management are, and must remain, decentralized.

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Part 2

ATTRIBUTES AND PROBLEMS OF THE INFORMATION TRANSFER CHAIN AND OF INFORMATION SYSTEMS

The information problem is many separate problems because the information process is many separate processes. Moreover, information is handled in many different systems, and each information system serves many different communities, each with its own interests and outlook. In this part of our report we shall describe some attributes, and the corresponding problems, of information processing and of the systems, governmental and nongovernmental, that have evolved to handle scientific and technical information. Suggestions for solving the problems, both by individual and Government action, will be considered later.

The basic scientist, the technologist, and the administrator see the dimensions and nature of the scientific communication problem differently. Most basic scientists confine their interests to one or a few rather narrow specialties; the extent of each specialty is largely determined by the effectiveness of the scientist's communication system. If communication with a neighboring field becomes too difficult, the basic scientist imperceptibly narrows his interest to those matters on which he believes he can keep himself informed. Thus the information dilemma appears relatively remote to the basic scientist. But even in basic science, narrowing of the scientist's interests is a dangerous course. As we have already said, science is really indivisible; if it fragments into a host of wholly unconnected specialties, each specialty narrowing and the number of specialties increasing with time, science as an instrument for probing nature will be greatly weakened. Moreover, in spite of the obstacles to proper communication, modern science tends to become more and more interconnected. Though a scientist chooses to narrow his specialty, science itself creates an ever-increasing number of potential points of contact between the scientist's narrow specialty and the surrounding fields. As time goes on, successful pursuit of a narrow specialty requires effective contact with more and more diverse parts of the literature.

The technologist is at the other extreme from the basic scientist. He cannot afford the luxury of accommodating the size of his field of interest to what his information system can handle. His job is to design a rocket or a communication system or a reactor, and his customer will not be satisfied with inadequate design because some knowledge was out of his field. He must be receptive to cues from all fields of science and technology. He ignores related art at great peril, especially when the hardware that he creates is expensive. The problem of information access falls upon him more heavily than it does upon the basic scientist.

The information needs of the technical administrator overlap those of the scientist and the technologist, but the emphasis is different. He too must encompass large segments of technical information; yet the manager needs not only the technical results of a given investigation but also knowledge of what is being done by whom, and who is available for doing what. This kind of information we shall call "scientific intelligence." At every level of management, either in Government or in a research organization, scientific intelligence is used by the administrator when he draws up a research program, proposes a new project, or decides to cut back on an old one.

In a sense, every individual scientist or technologist is a research manager. At the beginning of a new research he must decide on his strategy (including allocation of his personal resources); he must even decide whether or not to do the research. In making such judgments, he too uses scientific intelligence; since these judgments are divided among so many more people than those made by the full-time research manager, his needs for scientific intelligence, though equally important in the aggregate, are not so clearly felt.

A. *The Information Transfer Chain*

The information process comprises separate steps or "unit operations": generation, recording and exposition, cataloging, storage and dissemination, retrieval and exploitation by the user. Since the steps are linked in the sense that the later steps depend on the earlier, the entire information process is chainlike; we shall call it the Information Transfer Chain. The first two steps in the chain—generation, and recording and exposition—are performed by the technical man and the organizations that support him, the later steps by the professional documentalists and the organizations that handle information, as well as by the users.

The information chain operates like a switching system. The ultimate aim is to connect the user, quickly and efficiently, to the proper information and to only the proper information. But perfectly precise switching is neither possible nor desirable. One cannot define in advance exactly what information is proper; the switching system must always allow for some browsing in neighboring areas. Moreover *the capacity of the user to absorb information limits the system.* Evidence is accumulating that the amount of scientific literature the user will pay attention to is limited; one survey conducted by *Biological Abstracts* suggests that on the average a biologist can scan journals or titles or abstracts involving 5,000 papers per year. Thus the information switching system, to be effective, must be more than a passive switch: it must select, compact, and review material for the individual user so that he *actually assimilates* what he is exposed to, and he is not exposed to too much that is unimportant or irrelevant. Its fundamental task is switching *information,* not documents.

Most of what is written about the information problem is concerned with the later steps in the information transfer chain; that is, analyzing information for the purpose of identification, placing information in its proper place in a classification system, storing information, alerting, and matching stored information with requests for information. The elaborate automated systems described in the popular press and the art and science of librarianship are concerned exclusively with these later steps in the handling of information already generated and not at all with the initial generation of information. It is our belief that the information problem is aggravated by this separation between what is done by the documentalist and what is done by the author: that the earlier and later steps in the chain are not as separate as tradition holds them to be, and that improvement in the former, especially with a view toward subsequent retrieval, would undoubtedly ease the latter.

B. *The Information Process as Part of the Research Process*

Carrying further the thread of argument of the previous paragraph, we come to perhaps the most essential attribute of the information process: *the information process is an integral part of research and development.* Research and development cannot be envisaged without communication of the results of research and development; moreover, such communication involves in an intimate way all segments of the technical community, not only the documentalists. The attitudes and practices toward information of all those connected with research and development must become indistinguishable from their attitudes and practices toward research and development itself. This is the central theme of our report.

We place special stress upon what seems an obvious point because, in the early days of science, the problem of communication could be managed casually. Each individual scientist could work out his own private communication system, suitable to his own needs, and, since the requirements were relatively small, the whole matter could be treated rather incidentally. But with the growth of science a casual attitude toward communication can lead only to insufficient communication. Scientists individually, technical societies, agencies supporting research and development, will have to recognize that adequate communication no longer comes free. Communication cannot be viewed merely as librarians' work; that is, as not really part of science. An appreciable and increasing fraction of science's resources, including deeply motivated technical men as well as money, will inevitably have to go into handling the information that science creates.

Science can ultimately cope with the information expansion only if enough of its most gifted practitioners will compact, review, and interpret the literature both for their own use and for the benefit of more specialized scientists. The Panel believes that such activities may eventually achieve a position in the science of the future comparable to that of theoretical physics in modern-day physics. Recognition of the importance of such scientific middlemen is discernible in the proliferation of the so-called specialized information center where information is digested and interpreted. The Panel views the specialized information center as one key to ultimate resolution of the scientific information crisis.

C. *The Discipline-Mission Duality*

Information generated for one purpose is often useful for quite different purposes. The documentalist is therefore faced with a difficult problem of classification: according to what *fundamental* scheme ought he to label a segment of knowledge so as to make it available to all who need it, yet avoid redundant announcing, abstracting, and identifying?

Scientific knowledge, by the middle of the 19th century, was divided into classical disciplines such as chemistry, physics, physiology, etc., each with its own communication system. As long as there were few points of contact between the disciplines, each disciplinary system operated in fairly strict isolation from the systems of other disciplines. As science has become interdisciplinary and as the literature has grown, the weaknesses in the strict disciplinary classification of knowledge have become apparent. Chemists as well as physicists used information on the infrared spectra of hydrocarbons; abstracts of the same articles on infrared spectra began to appear therefore in both *Chemical Abstracts* and *Physics Abstracts*. The secondary literature expanded, and thus added to the information problem.

The growing importance of interdisciplinary fields has caused some duplication in information systems. However, much more overlapping has resulted from the extraordinary growth of mission-oriented science, especially science supported by Government agencies with fairly well-defined missions. Thus research and development supported by the National Aeronautics and Space Administration furthers the applied mission of the agency; namely, the exploration of space. The work itself falls into almost all the traditional disciplinary fields—chemistry, physics, astronomy, biology, etc. The workers in the field are *space* scientists or engineers, dedicated to achieving the mission of NASA; they are also rocket chemists, guidance physicists, weightlessness physiologists, and the like. The information collected by these diverse specialists very properly should be collected, disseminated, and controlled in a mission-oriented (in this case, space) information system, since what the physiologists learns about weightlessness affects the engineer's design of a space capsule. But the knowledge discovered by the physiologist about weightlessness is also useful to the basic physiologist interested in the kinesthetic sensory system. The basic physiologist is not likely to read, nor should he be expected to read, the space literature; hence the information contained in the mission-oriented NASA system must also appear in the discipline-oriented American Physiological Society system. Obviously the situation is reciprocal: in many cases the information originating in the discipline-oriented system must also find its way into the mission-oriented system. Thus we recognize a fundamental mission-discipline duality in information systems that is familiar to all who have worked in a large laboratory where a related duality often goes under the name of systems-components. The technical community itself has responded to the mission-discipline duality by organizing itself into horizontal discipline-oriented societies such as the American Physical Society and into vertical mission-oriented societies such as the American Rocket Society. A physicist working on rockets will ordinarily belong to both the American Physical Society and the American Rocket Society. He will communicate the same results to his colleagues in both societies, in the one case flavoring his communication with more physics than rocketry, in the other case with more rocketry than physics.

The mission-discipline duality, even though it has evolved gradually and is inherent in modern scientific communication, imposes many complications upon the information switching system. In the first place, it implies a duplication of effort, albeit a necessary duplication. The same individual must often present his paper twice, once to his discipline-oriented colleagues and once to his mission-oriented colleagues. This places a burden not only on the communicator but also, after publication, on his ultimate audience. For the literature has now grown by two papers instead of one, and retrieval has become more complicated. Secondly, the compacted literature—that is, abstracts, keyword indexes, titles—of the one system must eventually appear in the other. This inevitably introduces delays. Finally, even though a mission system overlaps with several discipline-oriented systems, the overlap is incomplete. Would the physicist interested in nuclear structure find better coverage in the nuclear section of *Physics Abstracts* or the physics section of *Nuclear Science Abstracts?* Not knowing the answer a priori, many physicists consult both.

The mission-discipline duality also raises fundamental questions concerning the Government agency information systems. Government agencies usually have fairly well-defined applied missions. Presumably all the technologists or research and development administrators who work for the agency are united by a single interest—achievement of the agency's mission. For this technical audience, held together by a common purpose, a mission-oriented internal information system run by the Government agency makes good sense. But what about Government agencies whose mission is so broad (as for example the Department of Defense) as to comprise almost all science as well as many, many sub-missions? What of the Government agency such as the National Science Foundation whose primary mission is support of basic research in all fields? In the case of the National Science Foundation, just who would be served by an information system, complete with abstracting service and bibliographic controls that covered only those parts of basic research that are paid for by NSF and almost every useful item of which would ultimately appear in the standard disciplinary systems? Source of support is no valid criterion for bibliographic classification. Aside from the practical fact that agency systems are usually quicker than disciplinary systems, information systems based on the criterion of source of support can have relatively little use to the basic scientist unless the source of support is so broad that the information system brings the great bulk of a scientific field under its control. Thus the NSF supports only a small part of all the American work in nuclear physics, and an information system that covered only what NSF supported would be of little use to a nuclear physicist; on the other hand, AEC supports most of the country's work in nuclear physics, and an AEC information system, especially when not wholly confined to AEC-supported research, can be quite useful to the nuclear physicist, both inside and outside AEC.

But there are other than purely scientific uses to which Government information systems are put. To the administrator, research and development manager, company trying to get a contract, or congressional investigator who wishes to know what is going on—not because he can make detailed scientific use of the material but because he needs the information to form management judgments—such collections of information are invaluable. The collection, however, is then being used as a source of scientific intelligence, not of scientific information, and ought to be so recognized. Many research institutions as a matter of custom and etiquette periodically present their work as a whole, even though the work lies in many different fields; such "reports to the trustees" are traditional in the scientific world. To some extent the agencywide information system, especially in the basic sciences, is a continuing report to the agency's management, giving the management an idea of what is being done by whom. As an effective bibliographic tool in the basic sciences, such reports, because of their limited coverage, are at a serious conceptual disadvantage.

The agencywide system generally has much more validity in technology than in basic science, since technology is itself strongly mission oriented and depends upon many disciplines. An information system oriented around the same mission as the technology is therefore natural and proper. Moreover, the technological literature generally is less well organized than is the purely scientific; technological literature, being often in the form of informal reports, may find no bibliographic home outside an agency information system. Were they not collected in agency systems, many specialized technical reports would never be recorded and would be lost forever.

D. *The Relation Between the Various Information-Handling Communities; Financial Problems*

The diversity of information systems raises many jurisdictional, and financial, questions. As we have seen, information is generated and handled by many different communities: the technical societies, Government agencies, private publishers, technically oriented companies. The functions of many of these organizations overlap, partly because some of the groups are organized around a mission and some are organized around a discipline, partly because in a free society, overlap and blurring of sharp lines is inevitable. Thus some Government agencies act in many respects like a full-fledged technical publishing house. For example, AEC arranges for the publication of books, monographs, and journals that it deems to be relevant to atomic energy. Again in the field of atomic energy, parallel publication efforts have been launched by numerous private publishers: in English, there are now three series of monographs on atomic energy of which one is originated and partially subsidized by AEC, two are issued by private publishers. Similarly, where a mission-oriented technical society has sprung up to meet the requirements of people working for a given Government agency, the communication programs of the technical society and of the Government often overlap. For example, when all of atomic energy was classified, all communication in the field—reports, meetings, even journals—was published by AEC. Now that large parts of atomic energy are unclassified, much of the communication process has been taken over by the mission-oriented societies that cluster around atomic energy—the American Nuclear Society, the Health Physics Society, the Radiation Research Society, the Society of Nuclear Medicine. But the takeover is not complete; AEC continues to keep the whole literature of nuclear science under bibliographic control, and to provide other information services that are not available from non-Government sources.

Overlapping of private and public services, in this case information systems, is traditional in our society. Can we identify criteria according to which we decide which segment of the information system ought to be the Government's direct responsibility, which parts ought to be subsidized by the Government but remain under private control, which parts ought to be completely private? The Government agency information systems have evolved without any Government-wide policy concerning the relative roles of the private and public enterprises, and some guidance on this tricky issue is needed.

Many Government information systems are better financed than non-Government ones—at least the Government is often better able to absorb the expense of an information system that does not visibly pay its own way than is a private institution, either profit or nonprofit. In the hands of a vigorous information system director and a sympathetic agency administrator, Government information systems therefore could well be more expansionist than are the non-Government ones, and this expansion by Government could aggravate the financial distress of the non-Government systems. We must ask whether such encroachment exists, and if it does, is it, on the whole, desirable—is the overall result a more effective or a less effective information system?

Not that the financial distress of our non-Government information organs is in any real degree caused by Government competition; the main cause is that the volume of information has grown too fast. *Chemical Abstracts* in 1930 contained 54,000 abstracts; a private subscription cost $7.50 per year, an institutional subscription cost $12 per year. In 1962 *Chemical Abstracts* published 165,000 abstracts and the 1963 price will be $500 per year to American Chemical Society members and to colleges and universities, and $1,000 per year to all others. Though these prices fully pay for publication of *Chemical Abstracts,* they leave nothing to pay for badly needed experimentation in new ways of abstracting and indexing chemical literature. Insofar as the Federal Government is the main sponsor of both basic and applied research, it has responsibility for the financial viability of the communication network whether it is within or without Government: if *Chemical* or *Biological Abstracts* were about to cease publication because they had no money to continue, the Federal Government could not idly stand by.

Finally we come to a most delicate, and perhaps crucial, issue in the discussion of the relative role of Government in the technical communication system. The traditional communication channels, organized generally by discipline, are strongly under the control of the practicing technical people. A communication system controlled by the people it serves may in some respects be less efficient than a monolithic government system; it has, however, the overriding merit of being sensitive to the needs of its customers. It was as much as anything to preserve this essential quality of the present rather haphazard information system that the Baker Panel recommended against establishing an all-encompassing, Government-operated information system in which control, however well meaning and beneficent its intent, is removed from the practitioners. Much thoughtful attention must be given to the point raised by the Baker Panel before one embarks on a great expansion of the Government's own information system. Nevertheless, we must recognize that our primary concern is to maintain the strength of our science and technology. We must search for the means by which we can improve the efficiency of our communication system without sacrificing the values inherent in our traditional methods and organizations.

E. *The Emergence of the Report and Preprint Literature*

To many professional librarians, especially those who became librarians before informal research and development reports assumed their present dominant position, the technical report is the crux of the current information crisis insofar as the Government is concerned. And the professional librarian has real cause for alarm. About 100,000 informal Government reports, of which 75,000 are unclassified, are written each year in the United States as compared to 450,000 papers in standard American technical journals. Material that appears in standard journals is kept under bibliographic control; it is generally abstracted and made part of the permanent record. This is too infrequently the case with research and development reports, most of which record work done for the Government either in its own laboratories or under contract. The documentation community has taken an equivocal attitude toward informal reports; in some cases the existence of these reports is acknowledged and their content abstracted in the abstracting journals. In other cases informal reports are given no status; they are alleged to be not worth retaining as part of the permanent record unless their contents finally appear in a standard hard-copy journal. Whether this position is tenable even in the basic sciences is open to question; it certainly is no longer tenable in technological development. Here the in-

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formal report, rather than the formal paper, has always been the main vehicle of publication. Most companies doing development had fairly elaborate internal report systems long before the war-born deluge of Government reports. Because so much development is now done by Government, a large fraction of all technical, especially development, information is now contained in the Government report literature: what was a minor problem when Government development was minor has become a major headache now that Government-sponsored development dominates all development.

Some basic scientists see in a variant of the formal report—the preprint—the beginning of the breakdown of the basic-science communication system. In many highly competitive, fast-moving fields of basic science, such as molecular biology, the machinery of publication in standard journals moves too slowly to serve fully the needs of the scientific community. It has therefore become customary for scientists to circulate preprints of articles among their colleagues. Such informal circulation, which harks back to the earliest days of science when new results were communicated by personal letter, has the advantage of speed. But it also has within it the seeds of serious disorders for science; for such distribution of scientific knowledge is controlled neither with respect to content nor bibliographically (to the point where many librarians are unaware of its existence). The distribution list for preprints usually consists of a few hundred of the author's colleagues, and this militates against the publicness of science. A preprint does not have to pass a critical referee; the preprint "literature" is therefore irresponsible, and cannot serve, as does the refereed literature, to assure society that the science it supports is a responsible enterprise. Altogether the preprint system has created an information problem in some parts of basic science which, in its way, is as serious as the problem created by the informal report system: in both cases the product is unedited; it is privately distributed; it is not abstracted; and it is difficult to retrieve. The scientific community must devise ways of retaining the timeliness of the preprint and yet reducing its privateness and irresponsibility. Rapid publication of preprints in standard journals and discarding of preprints that have been already printed are practices that would obviously help.

F. *Development of Information-Handling Technology*

The growth of published information has fostered the invention of many new handling and searching techniques and concepts. Best known are the retrieval systems based on automatic machinery. In addition, there are imaginative new ways of listing titles; for example, permuted titles,* of gaining access to the literature (citation indexes), of preparing abstracts or translations (by machine), of compacting the physical size of the record (microfilm and microfiches), of duplicating printed material.

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* The earliest reference found to this principle appears in A. Crestadoro's *Art of Making Catalogs of Libraries,* London, 1856.

The invention of the new retrieval methods is beginning to affect our traditional modes of communication. The traditional forms of the book, journal, and reprint may eventually give way to the machine storage of graphical and digital information and machine-generated copy. The technical publishing business may gradually be transformed into the *information handling* business in which the printing press as a means of mass production of identical documents no longer plays a dominant role.

The mechanical devices are divided into two types, graphical and digital. The former handle photographs of documents directly, and they require human interpretation (i.e., reading) to retrieve the information contained. The devices which handle information in digital form cover a wide spectrum.

At one extreme, the automated index compacts the intellectual content of a document into a few index or keywords that are stored in the machine. These systems can retrieve mechanically the desired information if the query can be represented adequately in such primitive terms. However, the human effort required to index in depth any significant body of information (e.g., 10,000 man-years of work by B.S. chemists would be needed to index all U.S. chemical patents) is a serious shortcoming of such systems.

At the other extreme, the whole text could be put into digital form, say from the monotape used to prepare a book. Practically nothing has been accomplished in developing adequate search strategies for purely mechanical retrieval from such a store, although there is likelihood that such methods will be developed in the next decade.

A characteristic of any nontrivial information retrieval system is the large volume of information in terms of bits of storage required and the small amount of processing (relative to numerical data processing). Equipment directed to these characteristics is not yet available, although it is technically feasible.

Because most of the schemes and devices for handling information are so new, their limitations are still not fully understood; in particular, it is not usually appreciated that the new systems generally retrieve *documents* rather than *information*. The proponents of new systems often urge them on the information community with zeal and enthusiasm, and the documentalist or administrator must decide how much to accept and how much the reject. Elaborate automation systems have been bought both within and without Government before the real usefulness of the systems has been assessed. It will therefore be important to understand the promise and limitation of automatic information retrieval systems. Administrators and documentalists will have to improve their grasp of modern information-handling technology so that they do not look upon elaborate and expensive computers as magical panaceas for their information-handling woes.

G. *The Student*

The size of the information problem as well as the developments in information-handling techniques place new burdens upon the student. He must learn much more about his subject and he much learn more about how to keep in touch with his subject than did students of earlier generations. Would we not ameliorate the information problem if we required each new scientist or technologist to understand the techniques of communication just as we are beginning to require him to understand computer-technology? Courses in the use of literature and in technical communication have been sporadically offered in many schools of science and engineering. Would more such courses and further modernization of course content help to keep up with new technologies? These questions will be pursued in Part 3 of this report.

H. *International Aspects of Scientific Information*

Finally we touch briefly on problems created because science and technology are international enterprises. Historical accident has fragmented the world politically, and this political fragmentation is fundamentally inconsistent with the unity of science. Nevertheless scientists have through the years developed rather effective methods for overcoming their political and geographic isolations—they have formed international unions, they exchange reprints, they hold many international meetings. But the burgeoning of science has complicated the workings of the international instruments that have grown up to help scientists in one country exchange views with those in another. All the problems that beset domestic communication beset international communication, but with certain additional complication; most obvious is the diversity of languages. Considerable progress is being made in machine translation of scientific material, and the Panel believes that machine translation may reduce the need for learning languages.

Geographic fragmentation further complicates the mission-discipline duality: superposed on the information systems organized by mission and discipline are information systems organized by geographic division, and switching between the systems is cumbersome. Thus each of the atomic energy commissions—the French, the British, the Russian, for example, as well as the American—has its own information system. Unclassified reports generated within the French and British, and to some extent within the Russian, systems are eventually collected and abstracted in the American system, and vice versa; but the foreign reports sift into the domestic system relatively slowly and there is much duplication. What is true of the atomic energy information system is even more true of information systems in fields that have a long tradition of independent national publication: there is overlapping, duplication, and general inefficiency. A step toward improvement worthy of study would be to establish a number of technical depositories abroad, comparable to the 12 regional depositories being established in the United States with the cooperation of the Department of Defense, National Aeronautics and Space Administration, Atomic Energy Commission, and National Science Foundation. These centers furnish convenient facilities for reference to Government reports, and would help unify our existing information facilities in many countries.

One aspect of the international communication system gives it a unique importance. Science as one of mankind's common undertakings has great potential as a generator of international good will. The international scientific organizations, like the international unions, were originally created to cope with the problem of scientific communication; and, in general, international cooperation in the sciences has meant primarily cooperation in communication of scientific results. Any further rationalization of the international system of scientific communication will go right to the center of the whole matter of international cooperation in science and will have a corresponding effect in fashioning science into a stronger instrument of international understanding.

Part 3

SUGGESTIONS: THE TECHNICAL COMMUNITY

In the previous section we identified several unsolved problems of our information system. In this and in the next section we offer suggestions to the technical community and to the Government agencies for correcting some of the deficiencies we have identified. Our suggestions to the technical community will be concerned mostly with rationalizing the information transfer process itself insofar as this process depends on the written, rather than the spoken, word; our suggestions to the Government will be aimed at strengthening the Government organizations that handle information.

A. *Authors Must Accept More Responsibility for Information Retrieval*

We have seen that the information transfer chain can be split into those parts carried out by the author (initial generation) and those parts carried out by the documentalist and the user (dissemination, cataloging, storage, and retrieval). Traditionally, authors have assumed little responsibility for the later links in the information transfer chain. This sharp separation of tasks aggravates the difficulties of information retrieval: authors ought to prepare their papers with much more sensitive regard for subsequent dissemination and retrieval than has been their custom. The managers of primary publication (editors, publishers, technical societies) must likewise do their part to ease retrieval of the information they publish.

The individual author can help in many ways. Thus the title of a technical paper should be one of the simplest and most effective devices for announcement and retrieval; yet titles, particularly of patents, are often meaningless. The value of a title as a bibliographic device depends on how well, and how succinctly, it conveys the sense of the papers. Authors should use specific and meaty words that would be positively helpful to a person trying to judge the content of a paper from its title. Referees, journal editors, and patent examiners often demand that poorly written papers or patents be rewritten; they must demand that poorly titled papers or patents be retitled.

Closely related to titles are keywords and thesaurus classifications. Many journals now require their authors to label their articles with keywords taken from an assigned thesaurus. In some fields, notably nuclear spectroscopy, the data fall into such well-defined and unvarying categories that authors, by assigning keywords, can provide a very complete index to the content of their papers. Even in such broad fields as engineering, keyword indexing is being undertaken with considerable success. The American Institute of Chemical Engineers now requires keywords on each article, and the Engineers' Joint Council is preparing an engineering thesaurus. Some fields, especially those that have strong interdisciplinary implication, do not lend themselves as well to keyword classifications; nevertheless, the utility of keywords, particularly for retrieval by computer, encourages their widest possible use.

What is true of titles and keywords is also true of abstracts; no one can abstract an article as economically as can the author; yet many journals do not require an author abstract. We would suggest that every paper be accompanied by an author abstract that is acceptable to the editor of the journal, and that each editor insist (perhaps by detached reviewing) on abstracts the form and characteristics of which best serve the users in the particular field served by the journal.

B. *Unnecessary Publication Should Be Eliminated*

A simple but urgent suggestion to authors is to refrain from unnecessary publication. The literature has been and always will be cluttered with poor and redundant articles. In final analysis the quality of what is published reflects the taste and judgment of the individual author. Admonition to authors to restrain themselves from premature, unnecessary publication can have little effect unless the climate of the entire technical and scholarly community encourages restraint and good taste. But there are many pressures to publish quantity, fewer pressures to publish quality. Those supporting research can much more easily judge how many papers have been published than they can judge how good the papers are. When the volume of publication in a field becomes so great that many of the papers remain unread, the prestige that can be properly assigned to the writing of a paper diminishes; the technical paper as a unit of currency for measuring the merit of a scientists becomes devalued, and administrators must consider this when they insist on frequent publication.

Inadequate means of switching between information systems also encourages redundant publication. If those who will be interested in specific results of a scientist do not belong to the readership of some one journal, there is pressure for the scientist to publish similar material not once but twice or even more. As the information transfer network now exists, with main emphasis on journals to switch the information, such duplication is essential if the information is to be transferred to those who need it. The need for duplicate publication can be reduced by improving alerting systems of all kinds so that they will be more dependable and more widely used.

Some duplicate publication will always be necessary; in particular, because of the mission-discipline duality, the same material must, one way or another, be readily available to users of both the mission-oriented and discipline-oriented systems. But the needs of the users of both kinds of systems could more frequently be served by publication in only one system if the switching devices—title announcements, abstracts, referral services—between the two systems were fast and efficient. Improvements in switching mechanisms, for example, in fast exchange of permuted title lists, are even now technically feasible and they should be widely used.

Many Government agencies have tried to avoid publication of the same primary material in both their report system and in overlapping technical society systems by encouraging primary publication in the open (usually, discipline-based) literature. Reprints of material so published are acquired by the agency system and the reprints are recorded and announced in the agency system's regular title or abstract journal. The scheme works well where the paces of the agency system and of the discipline-oriented systems are comparable. Unfortunately, especially in technology, a fast-moving agency cannot gear the pace of its information system to that of an archival, discipline-oriented, technical society. Nevertheless, agencies should rely upon *open* literature for primary publication to the greatest extent feasible, and they should be ready to adopt better switching mechanisms between their system and the open literature as those become available.

C. *American Technical Books Must Be Improved*

The previous suggestions relate to those parts of the information transfer chain in which the overlap between author and documentalist is clearly recognized. In other parts of the chain the auhor's job does not overlap so clearly with the job of the documentalist; these parts have to do with the content and manner of expression of what the author seeks to communicate, whether it be information already available or new information. Briefly, we believe that clearer and more succinct writing will in itself smooth the avenues of communication and the mechanisms of retrieval.

We are convinced that too many scientific books are written hastily and with much less care than the subjects deserve. Writing a good book takes an immense amount of time and work. It implies the clarification of many ideas that one has been willing to leave alone for awhile; the review of a large, repetitious, and often unclear literature; and the careful arrangement and rephrasing of the whole subject. A major task facing our American technical community is to write not only more books but better books.

One way to get better books would be to commission their writing by recognized authorities, and to pay the authors really well for their efforts. We would urge agencies, both governmental and non-governmental, to sponsor the writing of surveying and summarizing books in the same way as they now sponsor research. We believe agencies ought to adopt policies regarding the reimbursement of authors that encourage, rather than hinder, the writing of books by competent people who are supported by the agencies. In particular, we believe Government-sponsored fellowships for research and training grants should be available for the writing of books.

D. *The Technical Community Should Give Higher Status to the Reviewer*

Scholarly reviews, articles, and critical bibliographies also play an important part in easing the information crisis. They serve the special needs of both the established workers in a field and the graduate student entering the field, as well as the general needs of the nonspecialist. Review writing is a task worthy of the deepest minds, able to recast, critically analyze, synthesize, and illuminate large bodies of results. The relation of the reviewer to the existing but widely scattered bits of knowledge resembles the relation of the theorist to available pieces of experimental information. In order to emphasize the growing importance of the reviewer and also the growing difficulties that he faces, scientific and technical societies should reward his work with good pay and with the regard that has been reserved heretofore for the discoverer of experimental information. Those asked to write reviews or to give invited papers reviewing a subject should be selected by the scientific societies with the same care as are recipients of honors or of appointments to the staff of a university.

Hand in hand with the increasing recognition of the review author should go an increasing realization by him of his growing responsibilites. He should view his subject dispassionately, paying equal attention to his own contribution and to the contributions of others. He should search for remaining problems and the most fruitful areas of further work as diligently as he emphasizes existing accomplishments. He should also point to areas where further work is necessary.

E. *Modern Psychological Insights Into Communication Should Be Exploited*

New information could be made easier to assimilate, and in this sense easier to retrieve, if authors wrote better. We do not understand the communication process well enough to know how our natural language can be made into an instrument for the most effective presentation of scientific and technical information, but progress is being made. Advances in our understanding of the communication process should become known to authors and to the information-handling community, and should be put to work in the improvement of our technical writing. Nor should devices other than improvements in the natural language be ignored. Recognizing the danger of creating too many highly specialized languages, we point out nevertheless that symbols or conventions to replace wordly clichés or to describe commonly used methods of instrumentation could reduce the volume of the literature and help ease its retrieval. Or judiciously used journalistic techniques, such as different type fonts, display boxes, different colors, might help to make the technical literature easier to assimilate. Many of these techniques might be repugnant to those brought up in the conservative scholarly tradition, yet if further study and experiment shows them to be effective, the technical community ought to consider their adoption.

F. *Our Scientists and Engineers Must Express Themselves Clearly*

Much more obvious than any deficiency in our understanding of the communication process itself, or in the possible application of journalistic techniques, is our inability to use natural English properly. This Panel is gravely concerned, as are many others who have written on the information problem, that so many American scientists and technologists can neither speak nor write effective English, that the new language of science and technology is turgid, heavy, and unclear. This is a problem that goes beyond what the Panel has set out to do. The seeds of articulateness are sown in the home and at the elementary and high school level. Nevertheless we strongly suggest that science and engineering departments demand much more expository writing as part of regular courses, and that ability to communicate well be made a firm requirement for graduation from our technical schools.

G. *The Technique of Handling Information Must Be Widely Taught*

But our schools and colleges will have to do more than insist on proficiency in handling the language. They will also have to insist on some proficiency in the techniques of information retrieval. The technical man, as an author, contributes to the information explosion; as a user of information, he is overwhelmed by the explosion. He must therefore be able not only to express himself clearly and succinctly and with proper regard for subsequent retrieval of what he writes; he must also be acquainted with the new tools and techniques of information handling. Imparting such skills to our new generation of technical people is the job of our colleges, universities, and technical schools. They will have to teach, much more aggressively than they have in the past, the techniques of technical communication.

Schools of science and technology have offered some training in use of the literature and in the techniques of communication, but their efforts have been sporadic. Only in those fields, notably chemistry, where the information crisis has been clearly discerned, has much formal training in literature retrieval been given. Some chemistry departments have for years required their students to take short courses in the use of the literature, and many have adopted the more effective procedure of making active use of the literature a necessary part of the work in such courses as Qualitative Organic Analysis. It is probably no accident that the practicing chemist subsequently demonstrates greater proficiency in using the literature than do most of his colleagues in other disciplines. Engineers, on the other hand, receive virtually no training in literature techniques, and they pursue their daily work unmindful of the powerful resources awaiting their call. We are glad that the Engineers' Joint Council has recognized this serious lack and is formulating plans to fill the need. We would go a step further and suggest that all professional societies in the sciences and in engineering adopt an official policy calling for training in the preparation and use of literature as part of the curriculum. Accreditation teams should subsequently inquire not only into the adequacy of the library, as in the past, but also into the ways in which its use is promoted and facilitated. This has been done for many years by the American Chemical Society's Committee on Professional Training. Government agencies supporting research at a university should recognize support of the library as a legitimate expense.

Attempts to provide more adequate training in scientific communication and information retrieval encounter several problems. The support of the college administration and department heads must be gained. There are too few professors who are themselves sufficiently knowledgeable in the use of the literature to be able to teach the modern techniques effectively. Students themselves must acquire enthusiasm for learning how to cope with the information problems they will surely encounter in their careers. It should not be overlooked that neophytes in the scientific and engineering professions usually pattern their professional behavior after the behavior of the professional tutor. Only if the technical community itself becomes information minded will its students become information minded.

We recognize and support NSF's programs aimed at training teachers in the field of scientific documentation. We also urge that more teaching material, especially books, be prepared as texts for courses in technical communication. It is true that books on this subject are already available. However, most of them were written at a time when the scientific information problem was less critical than it now is; they generally aim at helping the author put across his ideas and his personality. What are needed in addition are books that cover the author's entire role in the information transfer chain, and that describe recent developments both in information-handling technology, and in those parts of psychology and information theory that bear on the communication problem.

H. *The Technical Documentalist Must Be Recognized and Supported*

Even though the individual scientist and engineer becomes more proficient in handling the literature, there is obviously more published literature than the average individual can master in all its detail. The technical man therefore needs the continuing and growing support of professionals who really know how to exploit the literature fully, and who are able to invent imaginative new approaches to the techniques of information transfer.

We therefore strongly support NSF's efforts to develop college and university programs aimed at attracting more science and engineering students to careers in technical information. A science or engineering degree with an option in technical documentation may be an appropriate pattern. We also recommend that secondary school guidance officers learn more about career opportunities in modern technical librarianship. The library profession has so far given only a token nod to the challenge presented by the radically new systems for organizing, storing, and retrieving technical information. We believe this shortcoming would be overcome if more able scientists and engineers went into technical librarianship.

I. *New Switching Methods Must Be Explored and Exploited*

In the previous paragraphs we have proposed some measures that authors could take to smooth the transfer of information from author to user. We consider now what can be done to improve those steps in the information transfer chain that are more directly under the control of the documentalist and the user; these include dissemination, storage, and retrieval.

As we have already said, the basic problem of literature access can be considered a switching problem—switching information, not documents. The basic need is to connect each customer, as nearly as possible, to the information he needs, plus a little more. The information-handling community has come up with many inventions, both in hardware and in technique, that hold promise in this connection. Some of these schemes, such as citation indexing, or issuing a daily scientific newspaper, have either not been tried, or are being tried on a small scale. Permuted title indexes are beginning to spread with *Chemical Titles* and the indexes in each issue of *Biological Abstracts* leading the way. Data and information centers have caught on widely. In the following paragraphs we shall discuss some of these new switching methods. Our main purpose is not so much to recommend one specific scheme over another as it is to emphasize the need for innovation, imagination, and courage. New techniques must be tried and new attempts supported. Mistakes, some of them costly, will occur. Yet to do nothing new is perhaps the worst mistake; the flood of undigested information will surely engulf our science and shatter it into isolated fragments unless we change the traditional methods that we use to handle the flood. Some societies, notably the American Physical Society and the American Chemical Society, have shown admirable initiative in trying new schemes; others have been much less venturesome. We urge all organizations concerned with technical information to investigate the new techniques and ideas and to take a sympathetic attitude toward innovation in handling of information. We wish especially to commend the NSF for its support of research in this field, and in particular for its support of practical tests of new modes of technical communication.

J. *Centralized Depositories Are an Attractive Possibility*

An attractive *technical* solution to the problem of the dissemination and retrieval of documents is the centralized depository. This would acquire documents in a field of its responsibility; it would broadcast abstracts in a regular announcement bulletin; copies of the full texts would be available on order from the depository. Papers sent to the depository would be freely available for journal publication, thus encouraging journals to continue and to expand their vital function of selection and quality leadership. This system is now in partial effect for Government reports put out by AEC, DOD, and NASA. Individual grantees and contractors of these agencies also participate in it, especially for the dissemination of technical reports not published elsewhere.

The central depository has some advantages as a substitute for, or better, as a supplement to, conventional publication. It is extremely fast; it rationalizes the preprint; it compacts the circulating literature; it funnels the accumulation from a given field in one place for efficient retrieval. By relieving the conventional journals of their implicit obligation to process every contribution that might be conceivably useful to science, it can leave them with the more creative and manageable responsibility of selecting and encouraging the best contributions for wide distribution. Centralized facilities can also be the focal points for the development of automatic processing techniques that are uneconomical for widely scattered services. The Atomic Energy Commission and the Armed Services Technical Information Agency (ASTIA) repository systems have already proved their effectiveness for technical reports. ASTIA fulfills requests for documents in 3 to 6 days and soon plans to give faster service. The quality of print retrieved from microfilm with new copying equipment used by the large depositories is close to that of the original document.

Despite the technical and possibly even the economic advantages of a switching center based on a central depository, a number of problems must be solved before this method can be considered seriously as the primary method of dissemination. Perhaps the main obstacles to its more general adoption may come from the attitudes of some elements of the technical community itself. It is not certain how scientists would react to the establishment of such a system, since all previous experiments (for example, the American Documentation Institute) have lacked some features essential to a successful central depository: adequate coverage; broadcast announcement; auxiliary select journals and retrieval services; adequate financial support; approbation by scientific and governmental leadership. Some members of the Panel are more optimistic than others about the facility with which the hard-copy journal, with the prestige that purportedly goes with publication in the conservative traditions, can be led to share its functions with the depository, even on the grounds of broader concern for the unity and effectiveness of science. In any event, coordinated systems developed on the initiative of scientific societies are preferable, for many reasons, to those based on centralized judgment of a Government bureaucracy. In fact, in fields such as basic physics and chemistry, in which strong scientific societies have evolved, the outlook for effective communication systems involving the gradual evolution of a depository approach is relatively optimistic. These efforts should be given every possible encouragement as answers to the communication problem in which scientists play the most effective part.

We are much impressed with the ingenious "halfway solution" to the central depository problem that the American Physical Society has devised. The society divides its contributions into those that are very timely and particularly important and those that are less timely and more archival. The former are published in abbreviated form with less than a month's delay in *Physical Review Letters.* The latter are published in extenso in *The Physical Review* with a 4 to 6 months' delay; abstracts of articles appearing in *The Physical Review* are distributed as an abstract bulletin with *Physical Review Letters. The Physical Review* is becoming a sort of central depository; more and more physicists read only the abstract bulletin, and consult the full articles in their library, or obtain reprints from the author. In another experiment the American Chemical Society has reported the outstanding popularity of an advance reprint service for *Industrial and Engineering Chemistry;* contributions to the journal are promptly announced and reprints are made available even before articles are published. From these arrangements to the full-fledged depository appears to us to be a relatively small step. Once individual scientists become accustomed to consulting abstract or title bulletins for the purpose of current awareness, the magic of the unique hard copy, with its very long delay, ought to disappear.

The outlook in other fields, for example, in biology and medical research, is dimmed by the complex interrelationship of the subjects with which biologists deal and the lack of comprehensive technical organizations comparable to the American Chemical Society or the American Physical Society. The problem of communication in this field may not be solved until the workers in the field evolve, possibly with Government support, comparably strong central organizations.

K. *More and Better Specialized Information Centers Are Needed*

The centralized document depository is primarily a clearinghouse for documents; in general, it does not try to glean information from the documents it handles, but merely provides appropriate documents to users. But retrieval of documents is not the same as retrieval of information; a technical specialist really needs the information contained in the published literature, not the published literature itself. To retrieve information, as contrasted to documents, the technical community has devised the specialized data and information center.

A specialized information center makes it its business to know everything that is being published in a special field—such as nuclear spectroscopy or the thermophysical properties of chemical compounds; it collates and reviews the data, and provides its subscribers with regularly issued compilations, critical reviews, specialized bibliographies, and other such tools. Its input is the output of the central depository. There are now in the United States about 400 such centers; the net number is growing, though some specialized information centers can and should die because the fields of science they serve cease to be active. As originally conceived, the centers compiled data as opposed to ideas or knowhow; one of the earliest *data* centers compiled the *International Critical Tables.* Many of the data centers have evolved into *information* centers that not only compile data but also keep abreast of all developments in a field.

We believe that the specialized information center, backed by large central depositories, might well become a dominant means for transfer of technical information. It therefore behooves the technical community, at this early stage in the proliferation of specialized centers, to learn what makes a good specialized center, and to plan new centers accordingly.

Specialized information centers, to be fully effective, must be operated in closest possible contact with working scientists and engineers in the field. The activities of the most successful centers are an intrinsic part of science and technology. The centers not only disseminate and retrieve information; they create new information. Making a discriminating selection of data, as was done in preparing the *International Critical Tables,* requires scientific insight of high order, and is itself an essential scientific activity. The process of sifting through large masses of data often leads to new generalizations. The Nuclear Data Center that collects and distributes information on the static properties of nuclei contributed notably, for example, to the development of the shell model of the nucleus, one of the major theoretical underpinnings of modern nuclear physics. What is true of the Nuclear Data Center is undoubtedly true of other centers. In short, knowledgeable scientific interpreters who can collect relevant data, review a field, and distill information in a manner that goes to the heart of a technical situation are more help to the overburdened specialist than is a mere pile of relevant documents. Such knowledgeable scientific middlemen *who themselves contribute to science* are the backbone of the information center; they make an information center a technical institute rather than a technical library. The essence of a good technical information center is that it be operated by highly competent working scientists and engineers—people who see in the operation of the center an opportunity to advance and deepen their own personal contact with their science and technology. Proliferation of the specialized information centers will therefore require many such "information scientists": dedicated and knowledgeable technical men who help interpret and assimilate the literature for others working in the field.

Since the technical information center in this sense must be part of science and technology, it is natural that it be located where relevant science is flourishing. The Panel therefore urges that new information centers be established at public and private technical institutions, not as adjuncts of general libraries, or of publishing ventures, or of central depositories. Where research and development is done for the Government—at Government laboratories, national laboratories, universities, or industrial laboratories—information centers in related fields ought to find a congenial atmosphere. We note with approval that AEC has already established about a dozen such centers at its national laboratories, and we believe this practice should be encouraged by other Government agencies.

L. *Mechanization Can Become Important But Not All-Important*

Emergence of the information center with its emphasis on retrieval of information as contrasted with retrieval of documents does not mean that document retrieval is unnecessary. On the contrary, the growing volume of publications places more and more pressure on the technical community to come up with ingenious schemes for switching documents efficiently—if not to individual users, then to information centers. In fact, the proliferation of the information centers will undoubtedly increase the pressure on the general document wholesalers—libraries and Government agencies—to strengthen and rationalize their document-retrieval systems.

Retrieval of documents requires both "hardware" and "software." Hardware connotes those mechanical devices (ranging from edge-punched cards to elaborate digital computers) that identify labels for, and may even deliver originals or copies of, documents once the documents have been properly indexed or otherwise identified. Software connotes the increasing variety of ways by which retrieval systems may selectively reach the document: conventional catalog entries, keywords, abstracts, permuted title indexes, citation indexes, etc.; and the programing systems that would let us take full advantage of such modes of access. Without adequate software, hardware cannot help and sometimes can hurt.

Where the software exists or can be made available in time, the possibilities of hardware improvements are indeed impressive, but the demands are also impressive. The Library of Congress, for example, contains over 10 million identified accessions, corresponding to 10^{13} bits of recorded information. Each accession requires some 2,000 bits of information to catalog it. A memory of several tens of billions of bits' capacity is required to store the catalog alone. Current use requires 200 accesses a minute, from 200 simultaneous users. An easily attainable improvement in service would require a tenfold increase in capacity (e.g., more cross-referencing) and could accommodate a tenfold increase in use. These characteristics are not met by existing commercially available equipment, but are now technically feasible.

Although a system for the Library of Congress could cost as much as $50 million, we believe that, since the advance in the technology of retrieval achieved by automating the Nation's largest library or at least its Division of Science and Technology will be available to all libraries, such an expenditure could be well worth while. We therefore recommend that the recent report recommending automation of the Library of Congress, prepared under the auspices of the Council of Library Resources, be reviewed carefully with a view to possible implementation of its findings.

The NSF, recognizing that a central advisory service where documentalists and others concerned with information problems can go for impartial advice as to what computers can and cannot do would be very helpful, supported the setting up of such a service at the National Bureau of Standards in 1959.

We urge documentalists, especially within the Government, to consult this service before committing themselves to very expensive and complicated automatic document-retrieval systems. Insofar as Government information services are concerned, there is a need to provide information about other, less exciting but very important aspects of retrieval hardware such as reproducing and microphotographing equipment; we are pleased to note that the Bureau offers information on such devices as well as on computers. The Panel urges that the Bureau's services be widely used and perhaps better publicized.

M. *Citation Indexing Should Be Useful*

Along with development of hardware, much ingenious thought must obviously go into software; i.e., indexing and other preparation of the documents for subsequent retrieval. Of the new approaches to software, the Panel is particularly impressed with the citation index; we wish to call the technical community's attention to this apparently powerful, though relatively little used, new searching tool.

All of us are familiar with lists of references at the end of an article. Such lists enable the reader to trace backward in time the antecedents of the article being perused. Every scientist has used such lists to delve more deeply into the subject he is studying. But reference lists only go backward in time; they give no hints as to the influence a given article has had on the development of the subject after the article appeared in print. The citation index is a list of the articles that, subsequent to the appearance of an original article, refer to or cite that article. It enables one to trace forward in time the same sort of interconnections with the literature that, by means of lists of references, one now traces backward in time. Because the indexing is based on the author's, rather than on an indexer's, estimate of what articles are related to what other articles, citation indexes are particularly responsive to the user's, rather than to the indexer's, viewpoint.

Lawyers have used a citation index, Shepard's Citations, for more than 100 years. Each year Shepard's lists all appellate decisions that have cited any previous cases. Since the law is unified in somewhat the same way as is science in that the rule of precedent connects what happens later with what happened earlier, it is not surprising that a bibliographic tool so useful to the lawyer could also be useful to the scientist.

The National Science Foundation is sponsoring trials of citation indexing in genetics and in statistics and probability. The genetics index, for example, will cover all the genetics literature from 1959 through 1963 and will be published in a single volume; it will be kept up to date by yearly supplements. The Panel believes that citation indexing, particularly in combination with permuted title indexing, will come to be used widely, and that its use will further alter both the way in which we think of the technical literature and the way we manage it.

N. *The Importance of Compatibility*

Growth in amount and diversity of literature will inevitably bring us more major switching elements, divided between specialized information centers, abstract journals, central depositories, and technical libraries; and an increased flow of documents, abstracts, title and keyword lists, divided between conventional journals, letter journals, reports, and deposited manuscripts. As the system grows, obstructions to easy flow will become more and more disabling. The greatest of these obstructions is incompatibility.

Overlapping information systems can surely gain by replacing exactly synonymous keywords by identical ones. And the identical abstract may be usable in two or more abstract journals. As larger and larger parts of the information system are considered, the problems become more difficult. How widely can the same principles for the selection of keywords or the writing of abstracts be used? When must two systems analyze the same paper from different points of view?

The National Science Foundation, recognizing the importance of uniform abstracting and indexing, has sponsored the National Federation of Science Abstracting and Indexing Services (NFSAIS). This forum of some 20 different nonprofit and Government services works to achieve more uniformity among the many overlapping services. Because most services developed their own habits and traditions in isolation, NFSAIS has encountered understandable difficulties in achieving uniformity. Nevertheless the Panel believes that much can be done, and it commends both NSF and NFSAIS for undertaking to create more order in a chaotic sea of nonuniformity.

Gains from either mechanization or compatibility are greater when the other is present. To the extent to which editors, of both primary and abstract journals, can agree on compatible formats and can assign page numbers to articles before they are printed, photographic reproduction in abstract journals could be used to bring many abstracts out as soon as, or even before, the papers are published. Exchange of lists of titles and keywords between mechanized systems is easy when title formats and keywords are compatible—i.e., easily intertranslated—and very difficult otherwise. Exact agreement offers still further gains, though not as much as for hand systems. Transfer and merging of compatible title and keyword lists can be greatly speeded by mechanization; if mail exchange of tapes proves inadequate, direct communication between rapid access memories is possible. Actual trials, such as the Medlars (Medical Literature Analysis and Retrieval System) scheme for switching between the National Library of Medicine and satellite centers in specialized fields of medicine, will soon help to guide us as to how far and fast we should move toward such complete mechanization. The Panel believes that adequate means for rapid switching, the first among which is compatibility, can greatly ease the burden caused by overlapping systems—agency with discipline, agency with agency, or discipline with discipline.

O. *Non-Government Technical Publication Will Require Government Support*

How shall we pay for our non-Government information systems? Obviously, since the Government now supports three-fourths of all scientific and technical work, publication even in non-Government media will eventually be largely paid for by Government. One question is how to choose the fairest means for transferring Government money to the technical publications. In particular, which is sounder public policy—to allot Government funds directly to a nonprofit publication, or to allot the money indirectly via the page charge?

The Federal Government, through the Federal Council for Science and Technology, has already taken a stand in favor of page charges. As yet, not all technical societies have accepted the principle of page-charge financing. To many scientists the page charge is repellent because it represents a change in a comfortable and longstanding custom. To many in industry it appears to be in conflict with the fundamental assumption of the patent system that the discoverer of technical information should be rewarded for making the information public. This view is contrary to the one we have emphasized in this report. We believe information is part of research: that the links in the information transfer chain are welded together, and that in this age of information crisis, the creator of information must assume as much responsibility as possible for subsequent dissemination and retrieval of the information he creates. The page charge imposes on the technical author a financial responsibility that is consistent with this view of the information transfer chain. We therefore urge technical societies, regardless of their tradition, to turn to page-charge financing.

The page charge does not serve the needs of secondary publication—abstracting and indexing. Article charges (perhaps a flat fee per article) that would go to support abstracting and indexing by related secondary media have been suggested as a way of supporting media of secondary dissemination. At first glance, since foreign abstracts account for almost half of the content of many American abstract journals, it might seem that article charges would be an unfair way to provide such support. But when we consider that each article, if carefully prepared, has already drawn upon the efforts of secondary publications, article charges appear much more reasonable. In any case, except in the few cases where subscriptions pay the actual cost of abstracting, we see no other alternative to direct Government subsidy of secondary media. Such subsidy might cost as much as $30 million per year by 1970.

Part 4

SUGGESTIONS: THE GOVERNMENT AGENCIES

The Federal Government is confronted with two separate, though related, information problems: it must maintain an effective *internal* communication system; and it must see that an effective *overall* communication system is maintained. The Government's involvement with the entire information system has, in turn, two distinct aspects. (1) The Government and non-Government systems are interwoven; hence the Government must pay close attention to the non-Government systems if it wishes to keep its own system effective. (2) Since information is part of research, Government must assume responsibilities even toward those parts of the non-Government system that do not overlap with its own, simply because Government has assumed such heavy responsibilities toward research. Our suggestions to Government are therefore aimed, on the one hand, at improving its internal information system, and on the other hand, at clarifying Government's responsibilities toward the non-Government information systems, and improving the connections between Government and non-Government systems.

THE INTERNAL INFORMATION SYSTEM

Four-fifths of the Government research and development dollar goes into development; of the development dollar, more than 90 percent is spent by three agencies, the Department of Defense, the Atomic Energy Commission, and the National Aeronautics and Space Administration. Most of the information flowing out of these activities appears in about 100,000 informal technical reports each year. The essence of the internal technical information problem faced by the Government is control and dissemination of the information and the intelligence contained in such reports. More specifically, the Government must preserve what is valuable; it must reject what is worthless; and it must summarize, index, abstract, and distribute its holdings promptly and efficiently.

The burden of keeping up with Government-sponsored reports falls much more heavily on the technologist and the technical administrator than on the basic scientist. That is not to say that the report literature is the only problem, or that basic scientists would not benefit were the Government to handle and retrieve its documents more effectively. The various information systems operated by Government agencies, by specialized centers, and by technical societies are interwoven; improvements in one system help every other system. Some Government-sponsored development is reported in conventional literature, at technical meetings, by informal word of mouth as well as in reports. But relative to the report literature, these other media present a less urgent problem. The incompletely controlled flood of reports creates an internal information problem, and since this flood is superposed on the conventional literature, it aggravates appreciably the overall information problem.

A. *What Is Useless Must Be Kept Out*

First, what can the Government do to assure that reports it collects are worth saving? It can be argued that, except as limited by security, all research and development paid for by the Government ought to be published, since the fruits of Government research belong ultimately to the people. Some administrators believe therefore that every research and development effort paid for by the Government must be recorded and disseminated. One result of this attitude is that the Government's internal report system is burdened with material that ought not to be part of the permanent record.

The Panel believes that Government should publish all significant research and devolpment information, but that it should not clutter its system with information that is half-baked or that is better re-created than retrieved. We realize that it is extremely difficult a priori to decide what to re-create, what to retrieve—i.e., what should be kept, what should be forgotten. The usual response is to keep everything. Yet this is surely not a complete answer. The human user is part of the retrieval chain; his ability to absorb information imposes a limit on the retrieval system that no amount of elegant automatic machinery can overcome. An information system badly overloaded with irrelevant documents will be less likely, not more likely, to find the right information for the right user. The problem is how to select, from the jumble of research reports, patents, design studies, engineering drawings, and other non-conventional research and development documents paid for by the Government, the material that is worth disseminating and retrieving, and to keep the remainder out of the system.

Report literature differs from the conventional literature in one essential respect: conventional papers, generally speaking, are formally refereed, reports are not. Even though the information flood may have lowered the standards of the conventional literature, there is little question that reports, in general, are not written as well as conventional papers. On the other hand, reports are timelier, and often are more voluminous, if not more complete, than papers. The report was originally conceived, and still is conceived, as a working tool and was not intended to become part of the common archival literature; what was permanently useful, especially in a terminal report, was eventually to be extracted and published conventionally. But the necessary growth of the Government information systems has tended to formalize the informal report; it is now given an archival status beyond what was originally intended, but the quality of the informal report has not improved accordingly.

Can we improve the *quality* of report literature without sacrificing its timeliness or its completeness? The Panel believes much can be done, and we put forward the following possibility: that each agency handling large numbers of reports, notably AEC, DOD, and NASA, establish resident referees at the major contractor and in-house sites to review reports *before* they are forwarded to the agency system in much the same spirit that referees traditionally review material intended for conventional publication.

The resident referees should be competent technical employees of the contractor who would be expected to understand the central information system as well as the technical matters in question. Over the years one could expect the resident referees among an agency's contractors to develop an esprit de corps, and to come up with many suggestions for improving the quality of technical reports. The system need not work perfectly, but we believe that its mere existence will help give to the Government technical report some of the tradition of excellence and value that is now generally enjoyed by the better conventional literature.

Refereeing the report literature need not slow the system seriously. Referees will learn that in some cases speed is more important that polish and, unlike referees for archival journals, they will learn to use criteria such as timeliness in making their judgments. A scheme that has some of the aspects of the technical report referee already exists. AEC now accredits responsible reviewers at each major contractor site who decide which reports are declassifiable, and the system has worked for years with little delay.

Competent research establishments generally review critically all material emanating from them. Establishments, such as the older NASA laboratories or the National Bureau of Standards, that visualize their missions to be creation of information, have maintained the highest standards for their technical reports. On the other hand, contractors whose mission is to build a piece of hardware are much less likely to review their reports critically.

The resident referee imposes a critical review of a report early in the information transfer chain. Though prior review is desirable, there is precedent for refereeing informal reports after the reports have left the authors' control. Several agencies now screen reports after they have been submitted to the agencies' central depositories. In 1949 all captured German technical reports were refereed by several hundred American experts under contract to the Office of Technical Services (OTS). Only 20 percent of the reports survived the scrutiny of the referees and entered the OTS system. Various other mechanisms for technical screening of the report literature will undoubtedly occur to the managers of technical information systems. We urge mainly that such screening is needed, and that it be done by competent working technical men who are in contact with the author.

B. *What Is Useful Must Be Located and Kept*

The problem of the report literature is not merely how to keep worthless material out. It is also how to get all that is worthwhile in. Thus ASTIA, the information service of the Department of Defense, estimates that it receives no more than 40 percent of the information generated at DOD expense. We must therefore devise ways of encouraging contractors to submit complete and accurate accounts of all parts of their activities not adequately covered by conventional publication, in forms that are conveniently retrievable.

The referee scheme which we have described, insofar as it improves the quality of the material going into the Government systems, ought to increase the information content if not the volume of the reports entering the system. Moreover, the usefulness of many reports, particularly periodic general progress reports, could be enhanced if their contents were classified or even physically separated according to discipline. Such reports, covering as they do a great variety of topics, are almost ideally suited to make bibliographic control difficult. We do not treat an issue of a learned journal as a single document: insofar as broad summary reports are sources of information rather than intelligence, there is no stronger reason to treat them as single documents.

But improving quality and accessibility is not enough. Barriers do exist in the flow of reports and other documents from contractor to Government, and these must be discovered and removed. Perhaps most important, many contractors and lower level administrators consider reports as only incidental to the development of a piece of hardware. If the hardware works well, why bother about the report? The contractor is selling equipment, not information, and the project officer is judged by the result, not by the report. Moreover, large development projects are usually led by engineers whose tradition for written communication is relatively weak. We therefore note with approval that DOD now withholds 10 percent of a contractor's fee until the reporting requirements of the contract are fulfilled. We believe that the contract officer himself, in administering this requirement, will have to be given enough technical help to enable him to judge whether or not the material submitted indeed gives an adequate account of what was done. In making such judgments, the contract officer would be expected to work closely with the contractor's resident referee.

A second possible barrier to full dissemination of information within the Government is too rigid an interpretation of security regulations. The Panel is aware of the asymmetry that exists between the way the Communist and the non-Communist worlds handle information. We believe, on balance, that our more liberal policy leads to more security, not to less. Nevertheless we do not believe it to be in the public interest always to push automatically for more dissemination. Each case must be decided on its merits. Our general impression is that security regulations, as now interpreted by AEC and DOD, have not imposed a serious burden on the Government's information system nor have they allowed too much information to be divulged; however, these conclusions are based on intuitive judgments, and we have not analyzed closely what criteria for classification would best serve the interests of the nation. We would recommend that an ad hoc group of the Federal Council's Committee on Information examine this question further. A related problem, the "need-to-know" regulation, has apparently been ameliorated by recent action of ASTIA.

Finally, in many cases contractors invoke alleged proprietary rights to keep useful material out of the information stream. Proprietary rights in Government contracting pose tangled, difficult legal questions that go beyond the matter of information transfer. The Panel believes that the present efforts to develop more uniform Government-wide policies on patent rights in Government research and development contracting should be expanded to cover proprietary, nonpatentable rights. Such policies would help contract administrators decide whether a contractor is justified in withholding information. We note with approval that DOD has recently turned its attention to this question. However, we believe this is a Government-wide matter that demands attention from the Federal Council for Science and Technology.

C. *Technical Reviews of Report Literature Will Help*

Because there are so many technical reports, and most of them are unrefereed and of uneven quality, reviews of technical reports can be particularly useful as discriminating guides to the literature. The reviewer of the report literature must not only tell a coherent story; he must also serve as referee, weeding out what he believes to be wrong from what he believes to be right. Moreover, to make his review fully useful he must cover relevant open literature.

Experience has already demonstrated the value of *critical* reviews of report literature and the related open literature. The Atomic Energy Commission issues five quarterly review journals, *Nuclear Safety, Power Reactor Technology, Nuclear Materials, Reactor Fuel Processing,* and *Isotopes and Radiation Technology.** These reviews, written by working experts, have been received enthusiastically by the technical community. What has worked so well in atomic energy ought to work well in other areas where Government agencies lead in the development of technology, such as space and military technology. Therefore, we commend NASA's plan to establish such critical review journals, and we urge DOD to do the same in appropriate fields. Where non-Government groups are able to publish such review journals, they should be encouraged to do so.

Such journals would be expected to thrive best near specialized information centers; indeed, the journal itself may prove to be the most important product of the specialized information center. Since writing reviews is difficult and time consuming, the specialized information center often needs

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*First issue of *Isotopes and Radiation Technology* scheduled for publication April 1963.

help from its parent institution in preparing the journal. This again illustrates that the specialized information centers, and particularly the report review journal, ought to be located at large centers of technical research and development rather than at a technical depository or a publishing house.

D. *The Agency Depositories Should Be Document Wholesalers*

Even if the information systems of Government agencies contained all valuable and well-conceived research and development reports, and only these, effective switching of information contained in the reports to the host of potential users would remain a formidable task. The Panel believes that eventually the main task of switching information (as contrasted to documents) to individual users should be the job of the specialized information centers. Thus again we return to organizing the information system in a hierarchy with the specialized centers occupying a key position between the large Government or other depositories and the individual users. For such a scheme to work, the number of special centers would have to increase greatly, generally with the support and encouragement of Government. Such a development would require a much greater allocation of scientific resources to manipulation of information than is now the case, but, as we have repeatedly insisted, this is inevitable if we are to preserve a viable science and technology.

Large Government central depositories such as DOD's Armed Services Technical Information Agency (ASTIA) or AEC's Division of Technical Information Extension (DTIE) or NASA's Office of Scientific and Technical Information (OSTI) would, in this scheme, become primarily document distributors. They would concentrate on supplying documents to specialized centers and technical libraries, rather than to individuals; they would not try to create new information nor critically review the material they disseminate. Such an ultimate division of labor between the Government depository and the specialized centers makes good sense to us for the following reasons. In the first place, critical processing of information is a job of the scientist, not of the documentalist. Scientists best able to cope with this job are likely to find the specialized center a more congenial home than the Government depository. In the second place, as the volume of literature grows, the announcement media of the central depositories become less and less useful to the individual; thus the Department of Commerce's OTS bimonthly keyword index, that covers all Government publications, is useful to the librarian or to the information scientist *because* it covers such a wide field, but for the same reason, it overwhelms the individual user interested in a special project or discipline. Moreover the large Government depository often collects only reports of work supported by a particular agency, whereas the specialized center collects reports relevant to its discipline or mission regardless of source of support. The individual user, whether mission or discipline oriented, is more likely to find what he needs in the announcement bulletins of the specialized center than in those of the central depository. So to speak, the interests of the specialized center match more discriminatingly those of the individual user, and it therefore is a more efficient switching mechanism for him than is the large depository.

E. *Agencies Must Become Information Minded* *

Though we expect that the specialized centers eventually will assume a central role, we cannot say with assurance when they will acquire this status. In the meantime the agency systems will have to continue to alert individuals, as well as libraries, and retrieve intelligence for contract administrators and information for technical specialists. How well are the agencies doing these different jobs for their customers: collecting, disseminating, and retrieving agency-generated documents? Can the agencies do these jobs better? Few generalizations can be made; the agencies differ widely in the way they disseminate their information and, more importantly, in their attitude toward the information. This is to be expected partly because the subject matter generated by the agencies' research programs is so diverse, partly because information is part of the statutory mission of some agencies and not of others. Thus NSF, dealing primarily with basic research, most of which appears in the standard literature, makes no announcements of papers issued by its contractors or grantees; DOD, dealing mostly with hardware developments, announces those of its technical reports that enter the ASTIA system. The law directs some agencies, notably AEC, Department of Agriculture, and NASA, to disseminate information; others, such as DOD, do not have such statutory directives. Naturally, agencies that consider information to be part of their mission take its dissemination more seriously than do agencies without this assigned responsibility.

Whether prompted by differences in congressional directive or by differences in subject matter, the agencies vary most strikingly in the fraction of potentially useful material they cover. We have already mentioned that ASTIA, the DOD's technical report information agency, collects not more than 40 percent of the reports that are byproducts of DOD's research and development programs. DTIE, the AEC counterpart of ASTIA, includes not only all AEC-generated reports but also all publications—from the open literature and from non-AEC technical reports—that deal with nuclear science and technology. So to speak, DTIE is a "delegated agent" for all documents it interprets as relating to nuclear science. NSF makes no special attempt to collect and make available on request papers that grow out of research it sponsors. Such research is published as part of the regular literature and is communicated through the usual channels of the learned societies.

There are inconsistencies between the practices of the various agencies, even in what appear to be similar situations. AEC supports much research

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*In this and the following section the Panel draws heavily on the work of a special study group consisting of J. H. Crawford, Jr., Chairman, G. Abdian, W. Fazar, S. Passman, R. B. Stegmaier, Jr., and Joshua Stern. The Panel acknowledges with gratitude the very important contributions of this group.

that is as basic (and as little mission oriented) as anything supported by NSF; why should results of such research be kept and disseminated in the AEC system, whereas results of NSF research are not found in any agency system? Or again, NASA and DOD both support development of large rockets—yet the information generated in the NASA-supported program is more likely to find its way into the NASA system than is similar material supported by DOD to find its way into the DOD system.

Inconsistencies between agency practices are not confined to the choice of what to cover. Take the matter of initial distribution; some agencies customarily distribute as many as 1,000 copies to other organizations adjudged to be potential user; others, handling the same kind of material, distribute less than 100 copies. Again, each of the agency systems has its own system of announcing, indexing, and abstracting reports. Some of the keyword indexing systems are mutually compatible, some are not; some do not use keywords.

The technical and mechanical inconsistencies between agency information systems—differences in format, in indexing, in compatibility of abstracting, in initial distribution and the like—are rather detailed matters that, under guidance of NSF's Office of Science Information Service, are gradually being remedied. On the other hand, inconsistencies in the *attitude* of agency managers toward information are another matter; as long as information is considered important by some agencies, but unimportant by others, some agencies will have an aggressive technical information system, others a weak one.

Our fundamental recommendation to each Government agency therefore is that it take information seriously; that all agency managements recognize information per se as an essential product of their agency's operation whether or not Congress has so directed; and that they recognize control and dissemination of information to be a vital part of research and development. Each agency ought to establish a *focal point of responsibility* for technical information—a highly placed official who will see to it that information activities in his agency are both sensible and vigorous. Such a focal point of responsibility must be a part of the agency's technical, not of its administrative, management. The highly placed official would decide how much and what kind of information processing should be done; he would be expected to compare his agency's information activities with those of other agencies; in short, he would insist on proper handling of the technical literature for which his agency is responsible.

F. *Interagency Cooperation Is Necessary*

When each Government agency doing technical work has established a highly placed focal point of responsibility for information, and has endowed the person in charge with enough authority to act, we shall expect a gradual improvement in the way the Government agencies handle the information they generate. But action by the agencies acting separately is not enough. Because the information handled by one agency is useful to another, interagency cooperation and consultation is needed; we therefore applaud the Federal Council for Science and Technology for establishing a Committee on Information that will, among other things, try to establish Government-wide standards for handling information. This committee will also have to draw attention to many of the obvious inconsistencies in the way different agencies handle comparable problems; to ask, for example, why AEC should be a delegated agent with respect to nuclear science and engineering, but NIH not a delegated agent in molecular biology; or why the amount spent on information by different agencies, per dollar spent on research and development, should vary so much. Such questions are not easily answered, nor is the correct answer always to spend more on information services. In addition, there are many technical details that, if handled more uniformly by the various agencies, would result in easier transfer of information between the different agency systems. Such details will undoubtedly require continued attention from the Committee on Information.

The work of the Committee on Information will be supported by the NSF's Office of Science Information Service. This office knows the most about Government and non-Government information problems, and it will continue to play the important role defined in title 9 of the National Defense Education Act in rationalizing the Government's information services. However, since NSF is itself a Government agency on the same level as the other agencies, it can mainly persuade, not direct, other agencies to comply with Government-wide standards or to accept appropriate responsibilities for handling their information.

Government-wide leadership must come, in the first instance, from the Federal Council for Science and Technology, largely through its Committee on Information, in part through its staff support, and where necessary through its Chairman, the President's Special Assistant for Science and Technology. As a consequence, staff responsibility for problems of scientific and technical information must be a specifically assigned responsibility within the new Office of Science and Technology.

G. *Government-Wide Information Clearinghouses Are Needed*

Government-wide clearinghouses will also be needed to integrate the agency systems with each other and with the non-Government information systems. Foundations for the needed clearinghouses are in existence, but a general strengthening is necessary.

1. *Current Efforts Intelligence*

One needed clearinghouse is a more adequate specialized center for scientific intelligence that could answer the question: who is doing what research where? Such an exchange should begin by covering only Government-sponsored research, but might eventually cover, on a voluntary basis, non-Government efforts. The current efforts clearinghouse would most appropriately be an expanded and strengthened form of the present

Science Information Exchange (SIE). The SIE now keeps track of about 75 percent of federally supported biological research, and has just begun to cover the physical sciences. We believe this exchange should be expanded so that it covers all the physical and biological sciences sponsored by Government as well as non-Government; that a technological efforts clearinghouse (as part of or adjoining to the SIE) ought to be established; and that the Exchange should receive support through separate funding rather than through voluntary contributions from participating agencies. All Government agencies concerned with research and development can do much to help the Exchange by using diligence and care in collecting current efforts intelligence, and in forwarding it, suitably packaged, to the Exchange.

2. *Report Announcement and Distribution*

Government reports and other technical documents are now announced and sold to the public through the Office of Technical Services of the Department of Commerce and through the Superintendent of Documents of the Government Printing Office. The GPO announces and sells only material that it prints. On the other hand, although it sells only those documents not handled by GPO, OTS, through its bulletin, *U.S. Government Research Reports,* announces titles of all technical reports made available from research and development agencies, mainly AEC, NASA, and DOD, as well as those GPO documents with technical content. OTS has been handicapped in the past because not all agencies have contributed their material to OTS, and because it needs more money to carry on its business properly. We believe that OTS should be given enough support so that it can announce promptly and supply inexpensively a copy of any declassified Government technical report to any customer—in short, that it should become a complete Government technical reports sales agency.

3. *Retrospective Search and Referral Service*

The technical information network is already an intricate array of agency collections, technical libraries, specialized centers, and private services; as our technology grows, the whole system will become even more complicated. How does a seeker of information know where to start a search on a particular subject, and what help can he expect in making the search? If the searcher is knowledgeable about Government agencies and his question clearly pertains to a specific agency, the problem may be simple. But most inquiries cannot be handled simply. The casual user of the Government information system is unlikely to know that material on bioagricultural research is kept not only in the National Library of Agriculture, but also in the National Library of Medicine, in the Library of Congress, in the Atomic Energy Commission's Division of Technical Information Extension, and in many other places. A national referral service which could direct all inquirers to the proper library or information service is an obviously needed switch in what would otherwise be a poorly articulated system of information systems. The Panel therefore strongly approves the recent joint action of the National Science Foundation and the Library of Congress to establish a National Technical Referral Center as part of the Library of Congress.

The proposed National Referral Center should keep track of all specialized information centers and should put prospective users in touch with the appropriate special centers. In view of our prediction that the numbers of specialized information centers are likely to grow markedly, we believe this to be a particularly important activity of the Referral Center.

We would suggest also that this Center maintain an up-to-date register of all formal technical meetings, and that it publish periodically announcements of such meetings, preferably classified by field.

THE RELATION BETWEEN GOVERNMENT AND NON-GOVERNMENT INFORMATION SYSTEMS

Where does the Government's responsibility for handling information, either as "wholesaler" or as "retailer," end? With respect to informal reports or documents put out entirely by the Government or its contractors, there is no question; obviously the Government is responsible for disseminating and retrieving its own report literature. One question that needs clarification is how much further does the Government's responsibility go—how should it deal with information, other than its own reports, that is relevant to its mission?

We have seen the diversity of attitude among the agencies with respect to this central issue. At the one extreme are AEC and NASA; these agencies are delegated agents in atomic anergy and space technology. They interpret their responsibilities very broadly; AEC's DTIE therefore tries to keep track of all information on atomic energy whether it is generated within the Atomic Energy Commission or elsewhere. Its abstract journal and technical reviews cover both the Government and the non-Government literature, and it runs a full-fledged atomic energy information service, not merely a technical reports depository; in addition, it encourages non-Government communication in atomic energy. At the other extreme is DOD whose central information system, ASTIA, handles only DOD reports. Should agencies other than AEC and NASA become delegated agents for dissemination of documents in their respective fields; i.e., should they collect and disseminate in their central depository *all* the information relevant to their missions, whether or not it stems from work they support?

One obvious advantage of a single agency's becoming the delegated agent for a particular field is the great convenience to the users; a space scientist or information center need look only at the tools supported by NASA, since NASA, by melding its own announcement service with that of the non-Government Institute of Aeronautical Sciences, covers all space literature. On the other hand, where the agency's mission confines it to only a small segment of a field, it would be unnatural and unwise for the agency to preempt the entire field. Thus each case must be examined in detail.

The Atomic Energy Commission and NASA already are delegated agents in atomic energy and in space. We believe this is justified and works well. Obviously DOD, because of its size and diversity of interests, cannot become a delegated agent for all technology. Yet we believe that DOD could and should become a delegated agent in each of certain mission-oriented areas—for example, in undersea warfare, in radar, in civilian defense. In these areas DOD ought to supply the same kinds of bibliographic tools and services as AEC does in atomic energy, or as NASA does in space. It should actively encourage non-Government information activities, and it should interweave its own services with those of the non-Government agencies. On the other hand, where the area is very broad and not clearly mission oriented, as, say, chemistry or physics, then DOD obviously cannot serve as a delegated agent—even though the headings "chemistry" and "physics" should continue to appear in the ASTIA announcement bulletin.

We believe that our recommendation to the Department of Defense could well be applicable to the National Institutes of Health: that NIH might identify special areas that are particularly germane to the work of its separate institutes, and that each institute consider establishing what would amount to a very elaborate specialized information center with services available to the entire biomedical community. The whole complex of NIH information centers might be serviced by the National Library of Medicine and, particularly, by the Medlars system. The focal point of responsibility within NIH would be expected to eliminate overlaps and omissions in this complex.

A. *Agencies Must Accept Broad Responsibilities*

In becoming a delegated agent for a given field, an agency must assume many responsibilities beyond merely collecting, announcing, and abstracting relevant material. The agency must help establish and support specialized information centers in the field; it must support worthy publishing ventures that would otherwise not receive support; and it must generally take active leadership in encouraging better communications in the field both within and without the Government. In effect, we are proposing that agencies, as delegated agents, do for communication in the fields they cover what NSF–OSIS does for scientific communication in general. Nor is this without logic. Communication is an essential part of research; if an agency sponsors research in support of the agency mission, it ought also to allocate resources to support the communication necessary for effective conduct of that research.

The division of responsibility between NSF and the agencies parallels the mission-discipline duality that we discussed in Part 2. The agencies would support mission-oriented information activities; NSF would do the same for the discipline-oriented activities. For example, if the American Institute of Physics wished to experiment with a central depository, and if it needed Government support, it would go to NSF; if the American

Nuclear Society needed similar support, it would go to AEC. A specialized information center in crystallography would be the responsibility of NSF, in viruses, of NIH. The separation between mission and discipline is not sharp, and some overlap between NSF and other agencies is to be expected. The FCST's Committee on Information would have to be sensitive to just such overlapping or omissions and would help keep the whole arrangement sensible and effective.

Government involvement in scientific communication is going to grow, just as Government involvement in science and technology is growing. Can this growth be so guided that user-sensitive non-Government systems are not swamped by elaborate Government systems that are relatively less user sensitive? The user sentitivity of the better technical society information systems is a precious thing; we should not lightly replace such systems with ad hoc systems conjured up by Government bureaucrats. We believe that the recommendations we have made will avoid this danger. In the first place, we have insisted that the focal point of responsibility in each agency be part of the agency's research and development management. Much of the user insensitivity of Government information systems results, we believe, from their being part of administration rather than of research. Secondly, by delegating responsibility for mission-oriented information handling to mission-oriented agencies, the Government will be represented by agency technical men who are usually members of the technical community that centers around the agency's mission. They would be expected to speak both languages, the technical community's and the documentalist's; when they sponsor information activities they could be expected to temper any expansionistic predilections of the Government with an understanding of what the field really needs. Finally, we point out that *support* of an activity by Government does not necessarily mean domination by Government. We envisage that much of what an agency spends for information handling would be spent by contract to non-Government institutions. The NSF–OSIS has set desirably high standards for support without domination of scientific information activities.

B. *Communication Is a Continuing Problem*

Coping with the problems of communication posed by the growth of science and technology requires the help of all technical people, not only of the information specialists; it requires the help of all Government agencies with investments in science and technology, not just the agencies that have been specifically designated by Congress to support information activities. In this report we have therefore stressed two primary and simple points: first, that information is part of research and development; and second, that *all* those involved in research and development—individual scientists and engineers, private institutions, industry, and Government agencies—must become information-minded and must devote more of their resources to information.

But, even though our advice be taken seriously, problems of communication will remain. We therefore believe that the President's Science Advisory Committee, either by recurrent appointment of ad hoc panels or through a small standing panel with rotating membership, should give continued attention to scientific and technical information. Such a panel would have to consider matters that have been touched only lightly by us: for example, the establishment of standards as to the amount of information needed; or the evaluation of the technical merit of specific schemes for handling information; or the further pursuit of the relationship between our national information system and the international system. Above all, continuing attention must be given to the balance between Government and private activities. We must always seek to insure, on behalf of both the Federal Government and the technical community, that the Federal information system remains adequate but does not overwhelm the existing non-Government systems, and that our Government and non-Government systems continue to develop into an effectively interwoven instrument that is always responsive to the changing needs of our science and technology.

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