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ABSTRACT

Over the past 30 years, science has placed great stress on the importance of scientific and technical information (STI) to the individual scientist. The Baker, Crawford, Weinberg, SATCOM, Greenberger, and Conference Board reports extended this objective by emphasizing the need for new supporting methodology and by pointing up the critical importance of STI to the nation as a whole. A review of the recommendations of these studies and reports and the implications of the new directions of science suggest that we need: (1) a locus of responsibility for making science information policy at the national level; (2) a dynamic, federally funded research and development program; and (3) a voluntary organizational mechanism for coordinating STI activities in the public and private sectors. The office of the President's Science Advisor would be a natural home for (1) a Panel on Science Information Policy responsible for examining STI policy issues affecting the public and private sectors, and (2) an institute with which STI elements in the public and private sectors could voluntarily affiliate. The National Science Foundation's Division of Science Information should be charged with explicit national research and coordination responsibilities for STI, including explicit research priorities consistent with national priorities and the new directions of science. (Author/PF)

A NATIONAL APPROACH TO SCIENTIFIC AND TECHNICAL INFORMATION IN THE UNITED STATES

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TABLE OF CONTENTS

PREFACE

This study articulates the federal government's responsibilities in providing for the dissemination of scientific and technical information (STI). It is one of four studies that were recently commissioned by the Division of Science Information (formerly known as the Office of Science Information Service) of the National Science Foundation (NSF) as part of a systematic review of its research-funding programs. The review is the first of its kind to be undertaken by the National Science Foundation since the science information function was established in NSF in 1958. The other three reports deal respectively with the past impact of Division of Science Information (DSI) research programs,[1] current research priorities of professionals in the field of science information,[2] and science information needs in light of forecasted technological and social change.[3]

Included in a separate document are eight internal working papers, written throughout the past year, that provide background information in support of the study's conclusions. There is also an experimental 25-minute color film, "Science Information and Science Policy", provided as an offshoot of the investigation.[4] It captures participants in a day-long conference on science information held on June 26, 1975, at the University of California, Los Angeles. Using a new technique of group discussion called "Generative Graphics," conferees rapidly achieved consensus on a number of issues relevant to the study. The film received the Outstanding Movie of the Year award from the American Society for Information Science on October 28, 1975.

I wish to express my appreciation to a number of people who helped me. Harvey Marron and Joshua I. Smith of the American Society for Information Science gave me the opportunity to understand the research priorities of the information science community by making me an

active participant in their research work. Russell L. Ackoff and Martin Elton of the Wharton School, University of Pennsylvania generously shared the results of their on-going research into a National Scientific Communication and Technology Transfer System (SCATT). Dr. Lee G. Burchinal, Mr. Robert S. Cutler, Col. Andrew A. Aines, and others of NSF's Division of Science Information offered their assistance. Numerous professional colleagues, throughout the country, reviewed the manuscript and contributed constructive criticism. Finally, other members of Becker and Hayes—Ms. Marion Rice, Ms. Carole Bailey, Ms. Nancy Culver, Mr. Jamshid Faryar, and Mr. William S. Becker—worked on the project with me, and gave me new ideas and better ways of putting old ones. I am especially indebted to Mr. Joseph Brunon, Dr. Barnett Addis, and the staff of the Behavioral Sciences Media Laboratory at the Neuropsychiatric Institute, UCLA, for shooting and producing our award-winning film.

6

I. INTRODUCTION

Many different individuals and institutions in the public and private sectors generate, access, and use science information. But, although science information is everyone's concern, it is presently no one's responsibility. In the United States there is no "system" of scientific and technical information. Instead, our pluralistic society has fostered a diverse collection of science information activities composed of loosely coupled units in the public and private sectors.

This study develops a rationale and sets forth a framework for a national program of scientific and technical information compatible with the perceived new directions of science and our free enterprise system. It deals with both information science and science information. It is important to distinguish between the meanings of these two phrases. *Information science* is concerned with *means*. It is concerned with the way man creates, organizes, and communicates information in all forms. *Science information* is the set of *ends* involved. It is at once the main product and the main ingredient of scientific endeavor. Science information is therefore intrinsic to every scientific discipline—including information science.

The organizations in the public and private sectors which engage in science information activities are often referred to collectively as the scientific communication enterprise. Individually, they are members of the scientific and technical information community. They vary in size and function. Some have limited information responsibilities while others, like the scientific and technical societies, operate extensive science information systems and services in behalf of their members and the public.

The scientific and technical information community in the United States has four main components: (1) the discipline-oriented systems of the professional societies—each concentrating on the systematic organization of knowledge in a particular domain of basic science; (2) the mission-oriented information systems of the federal agencies, e.g., for astronautics in NASA, for atomic energy in ERDA, for medicine in the National Library of Medicine; (3) the specialized information activities of private institutions and of industry such as special libraries, information analysis centers, indexing and abstracting companies, data base services, etc.; and, (4) the information files and other resources that are maintained by our institutions of higher learning. An increased supply of scientific and technical information has been assured by the so-called knowledge explosion. This may be seen in the exponential expansion of scientific knowledge, knowledge-producing professions and industries, research and development organizations, information services and machines, and the media of communication themselves. It is symbolized in the spectacular spread of electronic computers, and the greater ease of obtaining and processing information has induced more information consciousness among professionals and executives. It is the accumulation of scientific knowledge and the continuous integration of this knowledge into the mainstream of national life that provides the principal force for national progress. And, it is generally recognized by Congress [5] and others, that the efficient management of our nation's scientific knowledge resources by the scientific communication enterprise is related in a vital way to the quality of science and engineering work in the U.S., to the ability of our national economy to exploit new knowledge arising from science, to the competitive posture of the U.S. in world markets, and to the maintenance of our national security. If one accepts this premise, then there is a concomitant obligation to husband and protect the scientific communication enterprise, and the scientific knowledge which it possesses, as one would any important national resource.

It would be easy to allow the scientific communication enterprise to develop haphazardly, but if we really believe that the accumulation and application of scientific knowledge is the handmaiden of progress, then we must begin now to treat scientific and technical information as a national resource and to make a special effort to achieve additional convergence among related programs. A national program would bring about such a convergence not so much by federal regulation as by a judicious application of research funds towards the development of standards, uniform practices, and informal coordination of the scientific and technical information community to serve the public interest.

On May 11, 1976, the President signed into law P.L. 94-282, the National Science and Technology Policy, Organization and Priorities Act of 1976. This new law reaffirms government policy with respect to the scientific communication enterprise by stating that "It is the responsibility of the Federal Government to promote prompt, effective, reliable, and systematic transfer of science and technology information by appropriate methods ..." and by recognizing the Federal Government's responsibility "... not only to coordinate and unify its own science and technology information systems, but to facilitate the close coupling of institutional scientific research with commercial application of the useful findings of science."[6]

9

II. AN HISTORICAL PERSPECTIVE

Full and open communication of research results among scientists is a practice which dates back to the establishment of the scientific academies in the seventeenth century. At first, most scientific communication occurred by word-of-mouth exchanges of information. Over the years, this was rapidly supplemented by informal correspondence, printed proceedings, journals, and books. As the scientific enterprise expanded, scientific information proliferated and the patterns of communication among scientists grew more complex. The increasing difficulty of searching the literature and keeping up with relevant developments was quickly recognized as a serious communication problem within science. It precipitated the development of various science information systems.

The professional societies were first to be concerned with fostering efficient science information systems. After World War II the American Chemical Society was a pioneer in what was at the time called scientific documentation. The Society began applying punched cards, microfilm, and, later, computers to the processing of chemical literature. Other societies followed this lead, so that today virtually every professional society has reexamined its methods of handling scientific literature. As a result, each basic scientific discipline has developed its own STI system to support its own specialized interests.

A milestone in the development of science information in the United States occurred at the national level when Congress established the National Science Foundation in 1950.[7] From its inception, NSF was urged to take new initiatives in support of basic research in all scientific disciplines, to upgrade science education, and to increase the exchange of science information. Of this latter charge, the present Division of Science Information in NSF is a direct consequence. It and its now defunct advisory body, the Science Information Council, were created in 1958.[8]

After the first Soviet space shot in 1957, a great many changes were made in Washington following a major review of American scientific and technical research and development. Three White House science information studies appeared in rapid succession, and their recommendations set policies that still prevail today. William O. Baker prepared a report which resoundingly affirmed the principle that the free flow of scientific information was indispensable to the advancement of science.[9] J. H. Crawford, in a report prepared for the Federal Council on Science and Technology, recommended that each agency of government have one office alone responsible for its science information activities.[10] Alvin Weinberg, in a report in 1963 for the President's Science Advisory Committee, asserted it was not enough for the government merely to make information on completed research available; it had an equal responsibility for communicating information about research in progress.[11]

The Weinberg report had a great impact on the evolution of scientific and technical information systems in the federal government. So much so, that the Federal Council on Science and Technology, attached to the White House, assigned special functions to the Committee on Scientific and Technical Information (COSATI)[12] to coordinate scientific and technical information services among the federal agencies and to reduce duplication of effort. The Federal Council was moved to do this because it wished to derive maximum knowledge and value from the huge investment which the agencies were making in scientific and technical research and development.

COSATI helped focus the attention of government agencies on the need for better information systems and the need for standard and common practices among them. While each agency had line authority to improve and expand its own specialized information facilities, none possessed the responsibility for developing programs of common concern. It was here that COSATI made numerous and meaningful contributions. COSATI's role was that of coordinator of federal information activities. It provided a forum for discussion of the information function in federal programs, it helped establish certain standards that facilitated information exchange among the federal agencies, and it served as a rallying point in Washington for consideration and deliberation of policy issues brought to light as a result of changes in government programs or other new developments affecting the national information scene. One of its major contributions in the private sector was the encouragement it gave to the development of information science.

By the mid 1960s, information science began to be recognized by some as a separate profession. As an interdisciplinary science, it drew on such fields as mathematics, logic, linguistics, psychology, computer technology, operations research, the graphic arts, communications, library science, management science, and others. Today, it has emerged as a definite field of science responsible for building its own literature, theories, principles, and professional applications. The hardware and software tools which accompany most of our operating science information systems are applied and managed, by and large, by information scientists.

COSATI also became interested in giving structure to the total flow of scientific and technical information in the United States. In this connection, it commissioned a study in 1963 [13] to examine national systems for the handling and management of scientific and technical documents. In the charge to the study, COSATI called for a review of organizational and functional alternatives for developing a national program. Unfortunately, because of its restricted charter, COSATI did not give the same emphasis to non-government STI systems in its study as it did to the systems of the federal agencies. The study weighed arguments for and against creating a new "capping agency", a new operating agency, or strengthening the present decentralized structure within the federal government.

No specific organizational action was ever taken by the Federal Council on the report. COSATI itself was eventually transferred to NSF and later phased out of existence following the demise of the Office of Science and Technology in the White House.

Another landmark public report on science information policy was published in 1969 by the National Academy of Engineering and the National Academy of Sciences.[14] It is called the SATCOM (Committee on Scientific and Technical Communication) report, and contains the results of a detailed investigation of the present status and future requirements of the scientific and technical community with respect to flow and transfer of information. No less than 200 distinguished scientists joined in this three-year effort. SATCOM principally called for an independent, non-governmental, policy-making body responsible to the National Academy of Science and the National Academy of Engineering. It would be a "Joint Commission", that would be expert in the field of scientific and technical information and capable of providing guidance useful to both public and private organizations in developing more effective science communications. SATCOM further recommended closer cooperation between the public and private sectors, the widest possible dissemination of new information derived from government-sponsored research, immediate attention to the development of cross-disciplinary information systems, greater standardization in science information methodology, and expanded collaboration with science information activities in other countries.

The Conference Board, an independent, non-profit business and research organization, held a series of conferences in 1971 which led to a report on information technology authored by George Kozmetsky and Timothy W. Ruefli in 1971.[15] Unlike earlier reports about scientific and technical information, this one dealt with information as a new resource of critical national and international importance. It points out that the U.S. is the world's first post-industrial society—where the production and processing of knowledge and information is becoming more predominant than the production of goods, and that this is already having profound impact upon our national life. It also states that the information sector of the economy is significant by any standard and that information components of the economy account for a substantial portion of the GNP. The report treats "information technology" in general. It does not concentrate exclusively on the problems of scientific and technical information. The Conference Board's report examined information technology in a comprehensive way and addressed the role of government, education, and industry in fostering the use of information technology in the public interest. It pointed out that the new knowledge industries would soon become the leading edge of many economies and emphasized the strategic value of information in solving the more complex problems facing our society. The report called upon government and industry, as a matter of highest priority, to perceive, assess, and value information in strategic terms for national planning.

In 1972 the Federal Council on Science and Technology and the National Science Foundation commissioned a critical study, known as the Greenberger Report.(16) Dr. Martin Greenberger of the Johns Hopkins University was the Chairman of a special committee which examined the role of the Committee on Scientific and Technical Information (COSATI) of the Federal Council on Science and Technology (FCST). Greenberger's committee took a broader look than before at science information programs and policies. It concluded that the government was not well enough organized to contend with the problems of scientific and technical information facing the country, and recommended a new policy mechanism that would provide the means for strengthening science information programs in and out of government.

Public Law 91-345 dated July 20, 1970 established the National Commission on Libraries and Information

Science (NCLIS). The Commission is a permanent, independent agency within the Executive Branch which advises the President and the Congress on the implementation of national policy concerning library and information services adequate to meet the needs of the people of the U.S. In June 1973 NCLIS voted to direct its energies toward the preparation of a document describing a broad outline of a National Program for Library and Information Services. The Commission issued its report in 1975[17] after taking testimony at regional meetings throughout the country and discussing its concepts at open forums and in the professional press. The proposed national program is aimed at increasing each person's access to the nation's rich knowledge resources whether these resources reside in the humanities or in the sciences. Concern for protecting and improving the knowledge resources in the nation's libraries and information centers is evident throughout the Commission's program document:

> "If our nation is to achieve the most effective use of national information resources and the largest return for funds invested in them, common goals, objectives, methods and standards are needed now for the coordinated development of information facilities. Unless a coordinated program is established on a nationwide level, expenditures, facilities, and efforts will be unnecessarily duplicated, and interconnection will become increasingly difficult as local, state and multistate systems develop without benefit of a common purpose and a common approach."[18]

The Commission's program goal is stated as follows:

> "To eventually provide every individual in the United States with equal opportunity of access to that part of the total information resource which will satisfy the individual's educational, working, cultural and leisure-time needs and interests, regardless of the individual's location, social or physical condition or level of intellectual achievement.
>
> "To make progress toward the attainment of this goal, the Commission ... developed two major program objectives: (1) to strengthen, develop, or create where needed, human and material resources which are supportive of high quality library and information services; and (2) to join together the library and information facilities in the

country, through a common pattern of organization, uniform standards, and shared communications, to form a nationwide network."

It points out that such

"... a program must have incentives strong enough to encourge maximum cooperation and participation, not only by states and local governments, but by interested public and private agencies as well."(19)

Unlike the other reports mentioned previously in this chapter, the document released by the National Commission did not single out science information systems for special attention. It did, however, underscore the importance of creating a nation-wide information structure, including science information, capable of serving all individuals with the information they require in their daily work. The Commission echoed the SATCOM and Greenberger reports by stressing the need for greater coordination between public and private information organizations and it urged the Congress to begin treating information as a national resource.

The U.S. Congress (94th Congress, 1st Session) issued a Committee Print in 1975 dealing with federal management of scientific and technical information with particular emphasis on the role of the National Science Foundation. The report was prepared for the Special Subcommittee on the National Science Foundation of the Committee on Labor and Public Welfare of the U.S. Senate. In the report, the Subcommittee perceived a revitalized mission for NSF based on new requirements and endorsed a national coordinating mechanism for STI. The letter of transmittal from Subcommittee Chairman, Senator Edward M. Kennedy, to Senator Harrison A. Williams, Chairman of the Senate Committee on Labor and Public Welfare, contains the following passage:

"... The importance of scientific and technical information has emerged previously in the congressional examination of science and technology organizations, but only recently have we become aware that international and industrial trends in information networks have enhanced the value of our scientific information resources. This new attention to information as a national resource, however, has also revealed serious weaknesses in our infrastructure for developing and utilizing this valuable resource."[20]

The report also invites recommendations from the scientific community and information specialists before Congress makes new decisions that will reshape future directions of national policy.

Over the past thirty years, science has placed great stress on the importance of science information to the individual scientist. The Baker, Crawford, Weinberg, SATCOM, Greenberger, and Conference Board reports extended this objective by emphasizing the need for new supporting methodology and by pointing up the critical importance of scientific and technical information to the nation as a whole. How much progress has been made?

In general, science information has made real progress in the United States during the past fifteen years. In particular, we have seen a general upgrading of information systems in the various disciplines. These services are founded on broad, consistent coverage of the published literature by the professional societies and their continued development is therefore important to science and to the country. They provide the comprehensive coverage that assures the U.S. a permanent capability to deal with new trends in science and they also enable society to deal with new social problems in a responsible and economical fashion. This is why the federal government overall has an obligation to see to it that these systems remain viable and that they receive developmental funding for their improvement.

During the same period, we have also observed the emergence of commercial STI services in the for-profit part of the private sector. Many commercial indexing and abstracting firms now have computerized STI data bases, and other companies are pioneering new services such as the on-line computer services offered by System Development Corporation and Lockheed. Although the private sector is prepared to take risks, new intiatives require incentives from the federal government to spur their active growth.

The upgrading of science information systems in the federal agencies is further evidence of progress. The medical science information program of the National Library of Medicine (NLM) is one outstanding example. NLM operates the largest, most up-to-date, computerized medical information retrieval service in the world. The spectacular growth of the National Technical Information Service in the Department of Commerce is another example of federal agency initiative.

Much progress has been made from a technological standpoint. Computer technology especially has been used to great advantage. We have seen computers used to print science information electronically, to disseminate it automatically, and to retrieve it on demand. Moreover, computer data bases are proliferating in every branch of science and technology, and the number of computer terminals at the fingertips of scientists and engineers is steadily increasing. Two other information technologies have also made significant contributions to science and technology. The first is telecommunications, which gives science and technology a new freedom for disseminating and networking science information. The second is micrographics, which permits the printed scientific record to be compacted, duplicated, and distributed inexpensively.

The nation's future capability to handle scientific and technical information will, to an important degree, depend on how well and how rapidly we are able to integrate these new technological developments, and others still to come, into the scientific communication enterprise.

From an organizational standpoint, however, progress has been slow. Despite all of the excellent recommendations and good intentions of past reports, there has been a general reluctance in Washington to push forward with a national STI program.

In speaking to a national program, all of the reports urged adherence to the same planning principles in devising a new approach. They agreed that we must at least ensure that science information mechanisms are in place that can effectively stimulate and extend individual creativity; and that all science information activities, whether in government or in the private sector, somehow be made to function together in the national interest.

While each of the reports had an impact on the science information community, their concordant recommendations did not result in major organizational changes within the scientific communication enterprise or the federal government. The persistent question remains—how best to mobilize and unify independent, autonomous units in the public and private sectors around a national program? Within the science information community a general antagonism exists toward imposed solutions and federal control. If a radical transformation is to occur, it most certainly will require that the components of the present system organize themselves voluntarily.

III. THE NEW DIRECTIONS OF SCIENCE

It is surely a mistake to suppose, as some do, that a satisfactory national scientific and technical information program can evolve without reference to the new directions of science. Three new directions of science today pose obvious challenges to scientific communication systems. First is the intense dedication of science to the alleviation of national social and environmental problems. There is a pervasive attempt within the scientific community to apply scientific knowledge and expertise specifically toward solving problems of a societal nature. Another is the continuing trend toward multidisciplinary science. Mainly because science is being redirected to seek breakthroughs in public problems, the established disciplines are expected to become highly interactive in the years ahead. New science information systems will no doubt be needed to share information between the disciplines on particular subjects. Perhaps the most significant new trend will be the development of "real-time" information systems. National and even global monitoring systems will soon be in operation, gathering staggering quantities of data for analysis, interpretation, and retrieval. New approaches to science information wholly different from the classical systems used to process publications will be required to handle the data efficiently.

Problem Solving

Problem solving is the keynote of current research and development. Policy makers alone cannot solve problems like the energy crisis. Both in determining correct policies and in attempting to execute them, they must increasingly rely on the discoveries and techniques of modern science. Not only are certain national problems peculiarly susceptible to the methods of analysis and prediction newly developed by science; in many cases science and technology themselves have created or aggravated these problems. It should come as little surprise that policy makers increasingly look to science to help improve the quality of life.

That the problem-solving trend is increasingly palpable to scientists cannot be denied. Already certain NSF programs have been made to conform with "a shift in national priorities which calls upon science and technology to aid in the solution of major problems that confront our society."[21] At the "Conference to Develop a Rationale for a Science Information Research Program" held by Becker and Hayes in June 1975,[22] almost everyone among the group of science information specialists assembled agreed that the federal government will favor "problem-solving" scientific research in the years ahead. According to the conferees, the new problem-solving orientation of science is betokened especially by the flowering of interdisciplinary think tanks, university research institutes, and urban research centers.

If national policy promotes the use of scientific and technical information to the maximum extent possible for the alleviation of societal problems, existing STI institutions in the public and private sectors can expect to be affected in a number of ways.

First, the wider use of scientific and technical information means that more people will qualify as potential users of existing systems. STI systems have traditionally served as primary clientele the scientists of a particular discipline. However, in a national problem-solving context, the needs of the policy maker, the administrator, the problem specialist, and the public must also be taken into account in the processing of information and the servicing of information needs.

Second, the wider use of STI for the alleviation of societal problems imposes a national, though voluntary, responsibility on each member of the STI community to serve the national interest. This implies that related activities in the public and private sectors should strive to develop coherent systems. It does not mean, however, that they must merge into a monolithic system. A "coherent system" can be one in which the parties agree voluntarily to adopt common standards, protocols, and practices that facilitate the use of their collective files nationally.

Third, such expansion and redirection will add new importance to the public relations and user-education functions of STI activities. More people will have to be made aware, trained, and educated in the purposes, services, access channels, and costs of using STI facilities.

And lastly, increased use of STI facilities will demand that their owner/operators become hard-headed businessmen who can justify costs to users commensurate with the benefits they will receive. In order to enable a free STI marketplace to develop, it will be necessary first to correct certain economic imbalances that exist today between some publicly subsidized STI suppliers and private sector suppliers. Policy clarification here is crucial to the long-term continuity and expansion of private sector STI facilities.

Multidisciplinary Trends

Another direction of science that is bound to have an impact on science information systems of the future is the trend toward multidisciplinary science. As the scientific community dedicates itself to solving society's problems and improving the quality of life, a corresponding need arises to build information bridges across disciplines.

The orderliness of the disciplines is not only in question as a policy, but also as an historical fact. Historian of science Thomas Kuhn noted almost 15 years ago in his celebrated *The Structure of Scientific Revolutions* that science really does not develop by the lockstep accumulation of discoveries and inventions in strictly separated fields. (23) Each field conducts normal scientific research according to "paradigms", or sets of previously accepted rules, tools, and truths, which relate more to areas of phenomena than to preestablished disciplines. These paradigms severely restrict the range of inquiry in a field to those problems which can be expressed and solved within them, in order to allow the most exacting articulation and application of current knowledge. When the old rules begin to require "awkward" stretching for accommodation of new discoveries, perhaps in another field, sometimes a scientific revolution will occur, and a new paradigm will be accepted.

More significantly, the recent inclination of planners and policy makers to take systems approaches to problems has led to the development of new disciplines. Some examples of these "interdisciplines", as Ackoff calls them,[24] are cybernetics, operations research, communications sciences, and systems engineering. There is also pressure on the traditional disciplines to become more interdependent:

> "...In the systems age we tend to look at things as part of larger wholes rather than as wholes to be taken apart... One important consequence of this type of thinking is that science itself has come to be reconceptualized as a system whose parts, the disciplines, are interdependent...a variety of disciplines work together on a problem as a whole."[25]

Building information bridges across discipline lines means greater sharing of the information files extant in the several disciplines. Fortunately, and due mostly to NSF support, the STI files of most of the professional societies and of many indexing and abstracting services are now in machine-readable form. In fact, many scientific bibliographic data bases already reside on a computer and some are even available through on-line communication systems. The sharing of data files to serve multidisciplinary needs implies increased networking of scientific and technical information. While STI data bases exist in the public and private sectors, much work remains to be done in order to integrate them and broaden their availability nationally. Increased networking will heighten the interpersonal communication problem among disciplines and, moreover, ways will have to be found for teaching users in one discipline how to understand the jargon of other disciplines.

Numerical and Real-Time Data Systems

Perhaps the most significant trend in science today is the shift in scientific methodology away from typical laboratory experimentation and natural observation toward highly numerical, real-time information monitoring. It is increasingly likely that government agencies, as well as a number of research institutes in the academic and industrial sectors, will be required by their technical needs to participate in real-time information monitoring, demanding new information systems to support them, and posing great challenges to national science information planning.

It was COSATI, early in 1968, that first recognized the potential impact which numerical data systems would eventually have on science and technology. It commissioned a report describing these emerging systems and providing an inventory of them by type, size, and location.[26]

For a number of good reasons real-time monitoring by communications satellites can become an important tool of science. Monitoring by satellites equipped with multispectral scanners or other optical devices could greatly help the search for energy and resources and also assist us in protecting the environment. Moreover, satellites could facilitate world food management—a scheme recently proposed to alleviate the plight of the new billions that will inhabit Third World countries by the year 2000. Global determination of food supply and demand through remote sensors carried in communication satellites is already under discussion at the United Nations.

The prospect of world food management underscores world weather prediction and control as another objective of science. Here, too, modern information technology based primarily on satellites and computers will be essential.

Werner Von Braun asserts that energy and environmental problems in particular "can only be solved by a global, coordinated systems approach. Successful solutions . . . will require continuous monitoring and surveying of the entire earth, supported by an effective communications system capable of transmitting large quantities of collected data and pictorial information in real-time to a multitude of users. . ."(27) Von Braun predicts that "by the turn of the century, resource satellites will be collecting, as a matter of routine, precise global data on the local and worldwide yield of such food crops as corn, wheat, rye, barley, rice and soybeans, and of fiber crops like cotton and sisal."(28)

The role of real-time information monitoring in the drive towards nuclear disarmament is obvious. Already the Defense Department's SAMOS satellites circle the globe searching for new weapons deployments and providing enforcement of our arms limitations treaties. Further research in satellite sensors could make monitoring of nuclear stockpiles even more precise. Just as important, such innovation might allow us to monitor peaceful nuclear projects as well, and to account for every ounce of plutonium—as some day, inevitably, we must.

Edward Weiss, who has managed the DSI fundamental research program for many years, has observed this trend toward real-time information monitoring systems. He sees such systems as the generators of new reports and foresees a new-style "information explosion". Real-time data, he says, "is not being collected as an end in itself but rather as a means for newer research. It will be manipulated to produce new understandings which will eventuate in new data and reports. We are now confronted by a situation which by virtue of its sheer magnitude is qualitatively different from the information explosion as we have come to know it."(29)

As can be seen, a totally new approach to scientific information handling is implied by the development of information systems which operate in real-time. Conventional scientific documentation systems process books, technical reports, and journal articles. They also provide means for searching bibliographic records, indexes, and abstracts of this material retrospectively. In such cases, it is normal for a user to work through intermediaries like libraries or information centers in order to locate the physical items. Real-time information systems, on the other hand, are different from scientific documentation systems. Real-time information systems imply the closest possible interface between the collection of data and its analysis by a user. They are also totally dependent on the availability of the most advanced forms of computer and communications information technology. Working at a computer terminal, a user can engage his data directly. Furthermore, in certain instances, he interacts with his data while it is being collected and can store it in digital or pictorial form for subsequent analysis and retrieval.

It is plain that these new directions of science will have a profound effect on science information in the years to come. In the twentieth century the field of science information was the instrumentality created to increase the utility of the scientific record. In the twenty-first century it will be the catalytic agent which promotes increased sharing of STI, through communications, among more people. This shift in emphasis must be anticipated in the federal government's research programs now if the changes which are coming are to be accommodated without shock.

IV. PRESSURES ON THE SCIENTIFIC COMMUNICATIONS ENTERPRISE

SATCOM's recommendations concerning broad policy issues at the national level were never implemented, nor were Greenberger's. The pressures which prompted their preparation are still present. What is the current situation, and what can be done about it?

The types of materials and institutions involved in the scientific information transfer process are becoming more diverse. Science information abounds in books, journals and technical reports; in films, audiovisuals, and microfilm; and in digital computer tapes (bibliographical and numerical), analog computer tapes, and video tapes. These forms of science information are produced, processed, and serviced by federal agencies, the publishing industry, indexing and abstracting services, professional societies, information companies, libraries, and information analysis centers in the public and private sectors.

The volume of scientific information continues to expand with the growth of science expenditures and the growth in the number of practicing scientists. Increasingly voluminous scientific data flows from our printing presses daily. This overarching problem has not abated. It is thus little wonder that keeping up with the scientific record has become the main motivation behind efforts by scientists to strengthen science communication processes in the United States.

A recent study by the French economist Professor Georges Anderla for the Organization for Economic Cooperation and Development (OECD) predicted a fourfold to sevenfold increase in information by 1985.(30) In his judgment, no country in the world has yet faced up to the problem of assimilating new knowledge at a rate consistent with its production. Other quantitative studies also indicate that, for all scientific disciplines and for all methods of recording, the volume of information ready for processing in science information systems has been doubling every 10-15 years. The National Academy of Sciences reported the situation this way:

> ". . . Already the figures have become staggering— roughly 40,000 research papers a year in physics, several times that number in chemistry, biology and agriculture, even more in medicine and perhaps as many as 2,000,000 in all fields of science and technology taken together." [11]

Neither Professor Anderla nor the National Academy of Sciences took into account in their predictions the huge quantities of numerical scientific data, as distinguished from printed sources of information, which the United States collects and generates. The amount of this data, acquired by satellite for weather monitoring, environmental monitoring, and other similar programs, is enormous. This "data explosion" was unforeseen in 1958, the year NSF's science information program was established.

There is a growing requirement to use single-discipline information services as generators for satisfying multi-discipline needs. Although many problem-oriented requirements are being met this way, some problems require methods of solution that are often unavailable from any one data base. Each time a new, major multi-discipline information requirement emerges—such as those concerning energy or the environment—it is difficult to assemble a satisfactory data base without considerable delay and expense. Until full compatibility and/or transferability among single discipline data bases is achieved, the demand for independent problem-oriented data bases is likely to persist.

What's more, the number of potential users of scientific information is increasing. Recent statistical projections by NSF [42] indicate that the number of scientists and technicians in the U.S. is rising and will continue to rise during the next decade. To this number must be added the additional millions in business and industry who are secondary users of science information, as well as students engaged in scientific and technical studies. Moreover, scientific and technical information is no longer of interest solely to scientists and engineers. More and more it is being used by decision makers, planners, policy makers, and administrators. This underlies NSF's introduction in 1975, at the request of Congress, of a new program called "Science for the Citizen" to improve the public's understanding of public policy issues involving science and technology.

Another pressure on the scientific communication enterprise is the strong national trend to utilize computers and communications for networking scientific information. Until just recently, computerized discipline-oriented information systems were geographically dispersed in a few large centers and accessed separately. Now, on-line terminals can be used to rapidly interrogate groups of bibliographic data bases through any telephone connection. Studies indicate a 33% annual increase in the availability of individual on-line computer terminals in the U.S. for scientific and other information retrieval applications, from 500,000 units in 1972 to more than 1,500,000 in operation by 1977.[33]

As the number of on-line terminals increase and as greater use is made of shared communication systems, a national scientific and technical information network becomes a tangible reality. Scientists and technicians need information for different reasons at different times. To function effectively, each user must have access, through communications, to that portion of the total resource that is relevant to his immediate needs, whether they coincide with the needs of his stated discipline or not. A national scientific and technical information network which would interconnect discipline-oriented and mission-oriented information systems by electronics could satisfy the diverse needs of users more effectively than can the existing information networks.

There is also a negative argument: unless cohesive development takes place, the separate systems will remain insulated from one another and from their users. Only if maximum communication can be established among them, can the array be converted into a national resource of immense potential value to America's scientific enterprise. To do this, of course, will require development and acceptance of technical guidelines and national standards that will ensure the compatible development of STI networks and their ultimate interconnection. We spend $30 billion/year for scientific R&D; we should thus rank making available the results of R&D as a high public responsibility.

The main agent of this public responsibility is the federal government. Until recently, no authoritative group in the federal government was responsible for shaping science information policy. Nor is there a unit in government charged with research, planning, and coordination functions for STI. We have numerous STI programs in the U.S. which, in the aggregate, constitute a powerful national resource. But, the scientific communication enterprise is not organized to function interdependently in support of American science. Now is the time, then, to devise some means whereby individual efforts in the public and private sectors can voluntarily fall in with a national scientific and technical information program.

V. ORGANIZING FOR NATIONAL DEVELOPMENT

What action can the federal government take now to ensure the harmonious and continuing development of the nation's scientific communication enterprise?

A review of the recommendations of past studies and reports and the implications of the new directions of science suggest we need (1) a locus of responsibility for making science information policy at the national level; (2) a dynamic, federally funded research and development program; and, (3) a voluntary organizational mechanism for coordinating STI activities in the public and private sectors.

Science Information Policy—Creating a National Policy-Making Body

The scientific communication enterprise has never enjoyed a high priority in the competition for national policy attention. But, now the time has come to establish a permanent unit in the federal structure responsible for examining scientific and technical information policy issues, as they arise, and for making informed judgments on how to resolve them. Unless we have an entity which can formulate national STI policy, we will continue to fragment our efforts and to avoid confronting matters which are crucial to the national interest.

An historical step was taken recently that is certain to affect the development of scientific and technical information activities in the United States for years to come. In May 1976, President Ford signed into law the National Science and Technology Policy, Organization, and Priorities Act of 1976. The key provision of the Act establishes a new Office of Science and Technology Policy (OSTP) at the White House to serve the President as an important source of advice on the scientific, engineering, and technical aspects of issues that require attention at the highest levels of government. The Act designates the Director of OSTP as the President's Science Advisor and creates the President's Science Advisory Committee specifying that one of its members will be an expert in "information dissemination". The Act also assigns to the Committee the task of conducting a survey of federal science and technology, including consideration of improvements for handling scientific and technical information in existing federal systems and in the private sector. Thus, the new focal point in government for formulating national science policy and national science information policy rests with the President's Science Advisor and his Committee.

The SATCOM and Greenberger reports, previously mentioned, recommended a high-level policy-making body for STI which included the active participation of the private sector in its deliberations. Since the President's Science Advisor and his staff will be concerned with broad matters of U.S. science policy, *the Science Advisor's office would be a natural home for a Panel on Science Information Policy responsible for examining science information policy issues affecting the public and private sectors.* If, as the Special Sub-committee on the National Science Foundation of the U.S. Senate's Committee on Labor and Public Welfare suggests, we begin at last to treat STI as a national resource, then policy with respect to its long-range development belongs at the highest level of government.

A Panel on Science Information Policy, attached to the Science Advisor at the White House, would discuss policy issues brought before it by the federal agencies and the private sector. It would not operate specific programs but would continually assess the health of the scientific communication enterprise, debate the salient issues from a national perspective, and formulate relevant policy recommendations for the Science Advisor's approval. Its responsibilities would also extend to consideration of national policy in relationship to bilateral and international

STI negotiations. The Panel would be composed of representatives from the public and private sectors including technical experts in STI and individuals who actually use STI services.

The Panel on Science Information Policy would have a full agenda from the very beginning. The field desperately needs high level policy deliberations in several critical areas. For example, from a national viewpoint, what should be the relationship of government STI activities to those of the private sector? What responsibility does the government have for developing or sustaining private sector STI activities, and when is it in the national interest to do so? Should the U.S. give away its scientific information freely or charge a fee? What should U.S. strategy be concerning international STI exchanges with foreign countries? How far should an individual agency go in making STI available to the general public? How can federal agency practices be strengthened with respect to STI? What are the federal government's rights and obligations with respect to STI generated at public expense?

In addition to its primary policy-making function, the Panel would also be assigned responsibilities for: (1) articulating national goals and objectives for the field of scientific and technical information; (2) setting priorities; (3) establishing funding levels for government-sponsored STI research and development; (4) providing a forum for a continuing dialogue with the private sector; (5) encouraging major experiments which can lead to generalizable benefits; and, (6) assisting the federal agencies in the coordination of their science information programs and the resolution of conflicting policies.

At this time, there is no clear national direction for science information programs; the public and the private sector do not always share common objectives. There is a need for strong national leadership, a technological upgrading of scientific and technical information facilities, and a closer integration of public and private STI activities. Most important, is the need to start thinking nationally about our scientific communication enterprise and setting the national policies which accordingly will enable all elements of the enterprise to pull together in the same direction.

Research and Development—Reorienting NSF's R&D Program

During the past twenty years, the federal government has played the major role in sponsoring research and development for the nation's scientific and technical information systems. The programs of the Defense Department and the large mission-oriented agencies were especially significant.

But the unit of government principally responsible for research and development in the scientific communication enterprise is the Division of Science Information of the National Science Foundation. It has given sustained support to the field of scientific and technical information all through its history.

In the last several years the DSI's annual budget has decreased while the budget for the National Science Foundation as a whole has increased. From an annual budget high of $14.4 million in 1968, the DSI budget has dropped to a low of $5 million in fiscal year 1975. (34) This downward trend has prompted the National Science Foundation to reevaluate the mission and function of the DSI in an effort to identify goals and objectives for it which are most explicitly responsive to today's science information needs. Although the recent cuts in the DSI budget implicitly call into question its continuing importance, it should be apparent from "the record" that the DSI has consistently succeeded in enhancing the utility of the national scientific endeavor. It has clearly fulfilled its original statutory charge to induce the effective dissemination of the results of scientific research and development by supporting and encouraging new science information systems. However, because DSI has not been provided with the resources necessary to do the job it has been unable to fulfill all of the responsibilities assigned to it under its original Charter.

It is not clear why the budgetary disparity between science information support and science research support at NSF continues. Certainly there has been no decline in new information problems needing solution nor any lack of evidence of the vital role science information plays in the nation's social and economic well being. In fact, problems of size, cost, compatibility, and complexity of science information systems are growing, not at a constant rate, but at an ever increasing rate. And, science information is being used more and more extensively for the solution of societal problems. Despite these considerations, NSF has been unable to rationalize a useful program for DSI commensurate with the total need. If NSF were to begin to view DSI's research role in the broader context of developing and improving the infrastructure for a national scientific information program, the importance of reversing the existing policy of budgetary restraint might become apparent.

The coming postindustrial, information-oriented society demands just such an office as DSI—with, of course, an enlightened reorientation. In the next five years, the DSI must continue the gearing of its research and support program to national goals by synchronizing its operations with the new directions of science. As we have seen, one of the most significant new directions of science is the reorientation of scientists and facilities for the direct improvement of the quality of life. We have also seen that, in light of the government's broadly-based attacks on problems like the energy crisis, environmental degradation, and hunger, the need for professionals of every stripe to utilize multidisciplinary science information has never been greater.

Science information systems must change accordingly. One might think the best way of satisfying this need is the continued establishment of independent, machine-readable data bases centering on knowledge germane to particular pressing concerns. But this is only part of the answer. What is needed additionally is the intensive investigation of theories and instruments of library and data-base interconnection.

DSI should above all support research that leads to the development of explicit mechanisms for sharing scientific and technical information. Of these perhaps the greatest attention should now be given to on-line, interactive, computer networking systems. These could make our knowledge resources indeed responsive to the protean societal problems we face. Through the distributive power of computers and communications, science information can be made available to many different users simultaneously. The use of on-line computer terminals eliminates geographic restraints, so that specialists in every city can tap the combined science information resources of the country in their own area of specialization. Especially because the networking of discipline-oriented information systems integrates existing systems, spelling a high return on research investment, DSI should fund studies on such matters as networking, disseminating science information among more broadly-based user groups, increasing machine-readable data-base coverage, extending on-line systems and services, and creating standards for facilitating multidisciplinary interconnection.

Considering the new directions of science, and the new methods of science communications, the main priority of DSI must now become applied research for promoting the sharing of science information. Science is being thrust by the public and by policy makers in the direction not of national security, but of national prosperity, health, and well being. For this reason the idea of sharing must not stop with the introduction of mechanisms for sharing between and among libraries and information centers. What is needed additionally are improved means for sharing science information between the scientist, the designer, the implementer, the user, and the public policy maker. Unless the entire chain of communication is enhanced by the sharing process, requirements to improve the quality of life are unlikely to be satisfied. To help ease the application of scientific knowledge to collective national problems, DSI should staunchly support mechanisms for the sharing of science information nationally and internationally.

How can the current framework of DSI research objectives be refashioned to agree with this new, critical priority? Let us first consider the framework. In 1974, the DSI announced that its research program would be directed towards 17 new research objectives. This was an explicit and significant shift away from the policies established earlier. The new objectives are mainly concerned with improving the management, accessibility, and use of STI (see Appendix A). These objectives provide the Division's basis of operations for fiscal years 1975 and 1976.

Generally, the 17 objectives deal with the important issues. The completeness of the list is confirmed by comparing it with a list of objectives culled from the Weinberg, SATCOM, Greenberger, and Conference Board reports. Such an analysis reveals a remarkable degree of overlap and attests to the broad coverage of the current DSI program.

Yet there is mounting evidence that this list of objectives requires further refining, amending, and structuring. For example, six objectives cited in the four above-mentioned reports are not included in the DSI list (see Appendix B). Also, the 17 objectives are not ranked in any order of priority. DSI made a conscious decision not to set priorities in order to give the profession an opportunity to express its own views on the future direction of the research program. Two studies were commissioned. This one, and another from ASIS designed to elicit the views of the information science profession. In a notable effort to tap the judgment and expertise of the technical-community "grass roots", the American Society for Information Science recently subjected the program to the scrutiny of a cross-section of that society's membership. The responses from the information science professionals polled suggest that only the following 5 of the original 17 objectives deserve to be given top priority by DSI:

- Priority 1. To foster the development of networking among scientific and technical information services.
- Priority 2. To encourage use of on-line, interactive STI systems.
- Priority 3. To improve national coordination among scientific and technical information services.
- Priority 4. To encourage the abstracting and indexing of new scientific and technical information.
- Priority 5. To facilitate college-level awareness of scientific and technical information services.

All things considered, however, the list of objectives prepared by DSI represents the first coherent research program to appear in the field of science information. It has been widely publicized and openly discussed in the professional press and at professional meetings. Drawing upon these deliberations, DSI expects to refine the program further and subsequently set priorities. In particular, DSI plans to reformulate those objectives which are most significant in terms of the national welfare or the solution of national problems. Thus, critical analysis of the list provides still more evidence for the need to set new, cogent, research objectives in line with new national priorities.

What are some of the steps the federal government can take to direct and encourage DSI to embark on a new mission, one appropriate to the new directions of science and oriented toward a national program? First, perhaps, should come changes in the statutory basis of DSI.

The National Science Foundation Act of 1950 (Public

Law 507) directed the Foundation,[35] "... to foster the exchange of scientific information among scientists in the United States and foreign countries". In the Act Congress urged the Foundation to strengthen the scientific and technical research apparatus of the nation by (1) taking initiatives in support of basic research in all scientific disciplines; (2) upgrading science education; and (3) increasing scientific information exchange. With the passage of the Act, the Foundation established a Scientific Information Office to meet the third objective.

Later, in conformance with Title IX of the National Defense Education Act of 1958,[36] the Foundation changed the name of the Scientific Information Office to the Office of Science Information Service (OSIS) and in 1976 changed the name again to the Division of Science Information (DSI). A list of all known legislative and executive authorities affecting the responsibilities of NSF for scientific and technical information appears in Appendix C.

Under the terms of Title IX (Sections 901 and 902) of the National Defense Education Act of 1958, the Foundation was directed to establish a Science Information Service which would "(1) provide, or arrange for the provision of indexing, abstracting, translating, and other services leading to a more effective dissemination of scientific information and (2) undertake programs to develop improved methods, including mechanized systems, for making scientific information available." The Act also provided for the establishment of a Science Information Council to advise and make recommendations to the Science Information Service. The statutory life of the Council expired in 1975.

With reference to the first part of the original OSIS mandate—namely, to "provide, or arrange for the provision of indexing, abstracting, translating and other services leading to a more effective dissemination of scientific information . . ."—the Office of Science Information Service scored a number of significant achievements.

Since 1958 it provided direct support to primary publishing and also funded several major experimental research and development projects designed to upgrade—from manual to computer methods—secondary indexing and abstracting services in a number of scientific disciplines such as physics and chemistry. In addition, it established twenty-one new scientific journals and arranged for the systematic translation of relevant foreign scientific literature. With regard to the second part of its mission, it developed six university-based computerized science information systems, supported the computerization of discipline-oriented STI systems, and spurred the growth of a science information industry. All through its history, OSIS has strengthened and extended those activities in and out of government that create, process, organize, and distribute scientific information.

While the wording of its 1958 mandate enabled OSIS to *provide science information services* of its own, and even though it was called the Office of Science Information *Service*, the NSF decided early in its history not to engage in the actual operation of activities that would compete with those of professional societies or commercial interests. Not only that, but in 1971, the Office of Management and Budget directed NSF to phase out its support of even its restricted group of discipline-oriented information services on the grounds that after years of developmental funding they should now be self-sustaining.

The second part of the 1958 mission was to "undertake programs to develop new or improved methods, including mechanized systems, for making scientific information available." Although the word "research" does not appear in this statement, the idea is implicit in it. Based on such an inference, the NSF has served the public and private sectors as a major source of federal funds for basic and applied research work in the general field of information science. It has also supported academic research, specifically in the development of information science as a distinctive discipline. The total investment by NSF in science information research and development activities to support the dual mandate discussed above, for the period 1958-1974, amounted to more than $140 million.(37)

On balance, DSI has made many important advances under its eighteen-year-old charter but more remains to be done. A revision of its mandate is now in order. A new DSI Charter would define "science information" in the broadest terms, making clear that it includes scientific information and data in all formats—whether bibliographic or numerical, printed or audio-visual, digital or analog. Title IX of the National Defense Education Act of 1958 would be amended to direct NSF to establish not a "Science Information Service", as the present law requires, but rather a "Division of Science Information Research and Development". Existing responsibilities to provide indexing, abstracting, and translation services and to investigate new methods for making STI available would continue. Two new explicit responsibilities would be added. The first would be to promote the sharing, exchange, and utilization of scientific and technical information nationally. The second would be to institute a fundamental and applied research program in support of national objectives. Furthermore, if the Charter for DSI should be changed, so should its name. The Division will need a name descriptive of its new responsibilities. Perhaps amending its current name to the "Division of Science Information Research and Development" is most apt under the circumstances.

Thus, the first step which the federal government can take in a national STI context is *to amend the DSI's Charter by charging it with explicit national research and coordination responsibilities for STI.*

In exercising its new responsibilities, DSI would set forth its priority goals for the time-frame 1976-1986. The enlistment of its research program to encourage and develop STI networks within disciplines and between disciplines would have first priority. The program would lead to applied research for the development of voluntary network standards and inter-communication protocols, for creating and sharing machine-readable data base files, for accelerating efforts to convert as much scientific and technical information as possible into machine-readable form, and for bringing on-line computer systems into operation in new subject fields. It would result in greater communication of STI between disciplines and thus enable science to make an impact on the nation's problem-solving capability.

The second research priority would be to increase the utilization rate of STI nationally. It would call for an immediate nationwide campaign to inform and educate potential users, starting in high school and college, about existing and planned STI products, services, and systems in the public and private sectors. A nationwide awareness of present and future STI capabilities, when it occurs, would broaden the exchange of scientific knowledge among scientists and non-scientists alike.

Another step which the federal government can take in support of a national STI program is *to stipulate specific DSI research priorities consistent with national priorities and the new directions of science*. This means NSF would place greatest emphasis on applied research and fund predominantly those projects which imply improvement in STI services nationally through shared resources, cooperative efforts, networks, and other forms of intersystem communication.

Of course, the new DSI program should not neglect its traditional responsibility toward scientific research in the information field. Fundamental research is a long-term investment, not a short-term priority. Information science is a fledgling "interdiscipline" and much of its potential cannot be utilized without deeper studies of its theoretical foundations. Fundamental research in information science is crucial to a national STI program over the long term.

Developing a nationally-oriented research and development program consistent with national priorities and the new directions of science will require more than a restatement of purposes, principles, and priorities by NSF. It means acceptance, on the part of NSF, of a critical responsibility to develop and maintain a clear relationship between the design and operation of science information systems on the one hand and the quality of U.S. science and technology on the other hand.

Coordination—Mobilizing and Unifying the STI Community

As Ackoff points out,(38) the current composition of the STI community represents a "non-system" consisting of a collection of independent, uncoordinated parts. Getting the separate parts of a national STI system to function as a whole will be a Herculean task. Moreover, in our democratic society, it cannot be achieved by federal edict but must come about through voluntary cooperation among all parties.

The STI community is composed of many, independent, autonomous units in the public and private sectors. Each has its own clientele and its own financial base. While one organization may desire to join a larger cooperative in order to form an interdependent national system, it is generally reluctant to do so for fear of losing local control. The alternative then is to seek ways of achieving national objectives through voluntary means.

A unique experiment in voluntary organization of the scientific communication enterprise is already underway. Over the past two years, the Busch Center of the Wharton School of the University of Pennsylvania has been studying STI activities from a whole-system perspective. The project has developed a planning methodology called SCATT (Scientific Communication and Technology Transfer System) which provides an intellectual design framework that permits different "stake-holders" in the STI community to view themselves within the context of a national system. By testing this image with a cross-section of stake-holders, the project expects to initiate and encourage a massive self-organization effort among all parts of the scientific communication enterprise so that their integration is eventually achieved. Through this process, it further hopes to engage the same participants in defining overall objectives that will unify and improve the effect of their respective, individual efforts.

As was indicated in Chapter II, numerous, generally concordant recommendations have been made in the past to establish commissions, advisory councils, capping agencies, and other organizational entities designed to deal with the scientific communication enterprise in a national context. However, none were ever implemented. The reason for this inaction cannot be attributed to a lack of studies of the underlying problem. Everyone connected with science communications agrees the problem exists, that it is important, and that it must be addressed. The trouble has been precisely that high-level officials, whose primary concern is of course with problems other than information, have not been convinced that information problems in a national sense are sufficiently serious to require that anything be done about them. In addition, the inaction probably indicates an aversion by members of the STI community to top-down, imposed solutions, and a general fear of federal control. Rather than continuing to tilt at windmills, perhaps the time has come *to create an Institute, under OSTP auspices, with which STI elements in the public and private sectors can voluntarily affiliate.* Its aim would coincide with the new goals of DSI and its purpose would be twofold: first, to give members of the STI community and the professional societies a continuing voice in shaping the NSF research program; and, second, to provide them with a forum for planning and discussing STI programs from a national perspective. Specifically, it would help in planning and developing the scientific communication enterprise as required to achieve national objectives, and in coalescing the mutual STI interests of the public and private sectors. It would establish a focal point for STI activity now fragmented throughout the government. It would enable the private sector to pool some of its proposals for meeting user needs. It would deal with technical questions like standards and system compatibility, and attempt to develop uniform STI practices and procedures in both sectors. The Institute would essentially replace the now defunct Science Information Council by providing a steady flow of advice and guidance to NSF and DSI. It would operate with a small secretariat supported by the government, but substantive participation by members would be voluntary and self-supporting.

When the marshalling of voluntary, cooperative effort for a specific purpose is in the public interest, there is ample precedent for the federal government to establish a non-profit Institute. Throughout the federal government agencies rely upon voluntary associations not only for research and training assistance but also, in some cases, for the actual administration of certain agency programs. Examples are the services provided by the Institute of International Education to the foreign student program of the Department of State, and the work of the American National Standards Institute (ANSI), established more than fifty years ago by a number of technical societies and the National Bureau of Standards. Similarly, an American Scientific and Technical Information Institute (ASTII) established under the aegis of OSTP with participation from the National Science Foundation could provide the federal agencies, the professional societies, and the information industry, with the organizational framework on which a national program of scientific and technical information could be built. It would also provide the analytical framework within which diverse groups could think about their respective roles and their common technical problems. Membership in the proposed Institute would be drawn from the public and private sector. Organizations like the professional societies, the National Federation of Abstracting and Indexing Services, the Association of Scientific Information Dissemination Centers, the American Society for Information Science the Special Libraries Association, the Information Industry Association, and others, would join the Institute to represent their respective constituencies. The use of nongovernmental organizations to carry out public functions, a rare occurrence before World War II, is now accepted policy in most parts of the government.[39]

VI. EPILOGUE

Just as science itself is undergoing changes in direction, so science information requires changes in policy and organization to meet the problems of the coming decades. Unless the people of post-industrial America begin to manage scientific and technical knowledge more systematically and creatively, we will weaken our ability to apply scientific knowledge to national problems. Moreover, continued fragmented development may lead to costly, overlapping, and unrelated science information systems which can never be made mutually reinforcing. The time has come to put the field of science information in step with the new directions of science. The proposals outlined will go a long way toward this end. They represent practical steps which the federal government can take now, within existing authorities, to support a viable and realistic national program in the field of science information. We do not need a monolithic national scientific and technical information system. What we do need is a national policy, a national R&D program and a national framework within which both diversity and interchange can be voluntarily accommodated.

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34. *Federal Management of Scientific and Technical Information Activities*, *op cit*, p. 81.
35. *National Science Foundation Act of 1950, loc cit.*
36. *National Defense Education Act (1958), loc cit.*
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APPENDIX A

17 DSI OBJECTIVES COMPARED WITH OBJECTIVES CONTAINED IN THE WEINBERG, SATCOM, GREENBERGER, AND CONFERENCE BOARD REPORTS

DSI OBJECTIVES—1974	REMARKS	GREENBERGER—1972
1. *To Measure Benefits From Information Use.* Information managers assert that information services are vital to the advancement of science and technology but factual data to support this thesis are scarce. High priority, therefore, is given to measuring benefits of information services in terms of improved decision making in scientific, technical, managerial, and policy areas.	DSI contends that we need more effective methods for measuring the benefits of information and for justifying the assertion that science information is vital to science and technology, research workers and to decision makers in government and in industry.	Deals with the need to have quantitative means by which to measure information benefits as a function of time and cost to the individual user and his organization.
2. *To Provide Guidance for Improved Management of Scientific and Technical Information Services.* Studies focus on improving the cost-effectiveness and user-responsiveness of services by producing data on the generation, flow, use, pricing, and marketing of information and on ways of promoting the economic viability of public and private services.	Seeks to provide an R&D mechanism for developing guidelines (e.g., on user responsiveness, cost/effectiveness) which, when applied to the nation's STI services will promote their more effective management and economic viability.	Points out the need for similar studies and coordinated development of STI service, emphasizing the importance of identifying economic criteria for management, improving marketing and distribution of STI products and services, and involving the user more actively in the design of systems.
3. *To Strengthen Information Science as a Scientific Discipline.* Support is directed to basic research in the information sciences and to the development of theoretical bases for improving future services.	DSI intent is to support fundamental research that will make information science a discipline in its own right—equivalent in time to chemistry, physics, mathematics, etc.	Assumes the existence of the field of information science and cites the need for research on specific fundamental problems.
4. *To Mobilize Existing Information Resources To Meet National Needs.* Efforts are focused on methods of organizing energy R&D information to test ways to prepare for future critical information needs of the nation.	DSI perceives a need to tool-up quickly in order to meet a crisis in national information requirements, e.g., energy. It implies an interdisciplinary approach to existing files and other resources.	Maintains that the U.S. can no longer afford the luxury of creating new mission-oriented information systems for each crisis situation. It recommends that existing systems be tapped and reorganized whenever the need arises to meet any interdisciplinary requirement.
5. *To Improve National Coordination Among Scientific and Technical Information Services.* Activities include supporting development of national standards for services, assessing the health of the national scientific and technical information enterprise, and stimulating the evolution of national goals and objectives for guiding cooperative, integrated development of scientific and technical information services.	DSI suggests a new advisory body (SIAC) drawn from government and the private sector, to (1) coordinate the "pluralistic society" of STI activities in the U.S., and (2) to assess the health of the STI enterprise each year.	Recommends formation of two groups: one an information policy board to coordinate public and private sector information activities, and, the second a federal technical information committee to coordinate government agency information activities the way COSATI did.
6. *To Increase Return On International Activities.* DSI is seeking performance measures to guide formulation of U.S. objectives for participation in non-governmental as well as governmental international science information programs. Also supported are activities designed to increase the interchange of scientific and technical information between the U.S. and other countries.	DSI stress is to place the U.S. in a position of strength from which it can *gain* from international STI activities.	Decries the absence of a policy-making body to advise the State Department on such matters and confirm agreements. Also, speaks of need for more active policy that would increase availability of U.S. STI to foreign countries.

	CONFERENCE BOARD—1971	SATCOM—1969	WEINBERG—1963
1.	Implies a need to develop measures of information value but also suggests three areas where such measures are directly applicable: profitability, improvement of life style and management efficiency, and decision making.	Because of SATCOM's preoccupation with the private sector, it makes the point that the ultimate test of the benefit of an information service is its survival in the marketplace. It does, however, also call for the development of measures of value for information services.	Assumes information use is essential and seeks ways to increase use, but does not speak specifically of ways to measure benefits.
2.	Encourages [illegible] of public and private efforts to [illegible] and better manage information, including STI, as a [illegible]	Acknowledges the broad value of having a well managed and coordinated set of STI services and calls for marketing and other studies which can provide the economic rationale for management.	Affirms the crucial importance of STI to scientific progress and urges continuing coordination and surveillance over the management of government STI activities. Insists on the need to improve STI management by eliminating poor quality literature, unnecessary redundancy, and other impediments to more effective STI service.
3.	Sees a need for high priority development [illegible] technology [illegible] interdisciplinary program with [illegible] R&D, professional manpower, etc. [illegible] and technology.	SATCOM recommendations never once use the phrase "information science." However, it suggested that organizations "undertake analyses of and experiments on the functioning of the various components of the STI network and other parts of the communication complex." The need for more research in information science can be inferred from this SATCOM recommendation.	The phrase "information science," in 1963, was just coming into vogue. It is nowhere used by Weinberg although many problems of information science are addressed in the report. Weinberg does not suggest that the area be treated as a new, emerging discipline; instead he views the information problem to be part of every discipline.
4.	Stresses the importance of STI in the solution of [illegible] and economic problems [illegible] ways and means to [illegible] technology for [illegible] needs.	While SATCOM does not address the "mobilization" or "crisis" issue, it does discuss the need for promoting interdisciplinary systems. SATCOM also urged the assignment of high priority to new mission-oriented government programs (particularly those dealing with major social problems) and the development of the required information systems.	Calls for creating specialized information centers in areas of national concern in order to have a structure in place for meeting emerging national needs.
5	Recommends a non-profit "center" created by public and private sectors and partly funded by government to clarify national objectives in the field of information technology. The center would formulate and recommend national policies and also perform integrated research.	Recommends a Joint Commission on Scientific and Technical Communication responsible to NAS and NAE. It would be an independent organization under private sector control—to foster coordination of STI programs and represent the STI interests of the country before policy-making groups in government.	Recommends "highly placed focal point of responsibility" in each agency to handle STI. But, also recognizes that separate agency attention will not be enough. Calls for government-wide coordination through the Federal Council for Science and Technology and DSI/NSF. Also recommends government-wide clearinghouses and closer rapport with private sector STI systems.
6	Sees advantages to U.S. in selling and buying information technology internationally. Also urges U.S. to cooperate in R&D programs with other countries in order to strengthen U.S. information technology.	SATCOM makes recommendations on the need for coordination of U.S. collaboration with foreign countries. It stresses the more active involvement of the private sector and urges the U.S. to assist this sector (societies, companies, etc.) in sharing U.S. STI abroad.	Views STI as a strong instrument of international understanding and goodwill. Urges free and open sharing of STI worldwide. Suggests U.S. regional centers abroad to speed transfer of foreign STI to U.S. Does not emphasize the need for net U.S. gain in foreign STI exchange.

DSI OBJECTIVES — 1974	REMARKS	GREENBERGER — 1972
7. *To Promote Use of DSI Sponsored Results* Part of DSI's leadership responsibilities is being carried out by disseminating the results of supported activities To help with this effort, DSI has released an announcement of projects awarded in FY 1974, and is preparing a bibliography of recently completed reports In addition, DSI is sponsoring a series of symposia on problems being investigated with DSI support Symposia are scheduled throughout the year in Washington or in conjunction with other professional meetings	This means that R&D funded by DSI should be both widely disseminated and actively directed to target groups	Neither Greenberger nor SATCOM singles out DSI, but both do encourage U S agencies to improve the means by which all research results stemming from government sponsored programs are made available to the individual scientist and the STI enterprise as a whole
8. *To Foster Publication in Computer Accessible Form* Activities include experiments in electronic publication of ways small publishers can pool resources to computerize their operations.	Pursues the development of technologically advanced publication systems including electronic publishing. Special mention is made of pooling resources among small publishers to enable them to obtain a computer capability.	Makes no specific reference to electronic publishing.
9. *To Promote the Banking of Factual Data* Projects are supported on ways of capturing numerical data in standard form at the point of publication Attention will also be given to data management policies of organizations	Aims at banking numerical and factual data and making it more available. Sees need for inventory of data banks and methods for capturing data in machine form early in the process.	Makes reference to the need for a comprehensive national data base to serve scientists, engineers, *and* the general public. Does not limit the data base to technical information—implies much broader coverage.
10. *To Encourage the Abstracting and/or Indexing of New Information* Work includes demonstrating ways of incorporating data-descriptive records into abstracts of scientific publications, extending abstracting and indexing coverage to the contents of data banks, and eliminating unnecessary duplication among abstracting and indexing services in their coverage of primary literature	Underscores need to index and abstract STI—and to eliminate redundant processing. Implies its interest is limited to computerized systems only.	Agrees with need for abstracting and indexing services and acknowledges overlapping processing, but goes a step further to recommend additional "reprocessing", "repackaging", and "consolidation" of information for different user groups.
11. *To Foster the Development of Networks Among Scientific and Technical Information Services* Efforts are designed to encourage the evolution of a set of linkages that begin with the development of compatibility and resource sharing among abstracting and indexing services and successively incorporate the activities of publishers, data banks, and other distributors into an emerging science information network for searching by users.	Envisages an STI network embracing suppliers, distributors, and users of STI. Encourages establishment of standards, linkages among data bases, and operational compatibility.	Foresees a national information network including government and private components. Stresses the need for standardization to ensure that STI networks will be interconnected eventually.
12. *To Advance User Control in Finding Needed Information* Research includes testing the feasibility of ways users can remotely search dissimilar retrieval systems and extract useful information, first from bibliographic data bases, then from electronic equivalents of today's handbooks and reference materials, and later from the full texts of documents.	Calls for probing new methods of improving access to dissimilar files (full text, data files, and structured files) by remote terminal	No specific mention of "remote terminal access" to files by users, but makes a strong case, in general, for more direct user involvement in information system design and operation.

	CONFERENCE BOARD—1971	SATCOM—1969	WEINBERG—1963
7.	Recognizes that [illegible] of research [illegible] be disseminated in order to be useful, and urges all government agencies to [illegible]. Also recommends a central clearinghouse in government to centralize the documentation of information technology developments sponsored by the federal government.	Neither Greenberger nor SATCOM singles out DOD, but both do encourage U.S. agencies to improve the means by which research results stemming from government-sponsored programs are made available to the individual scientist and the STI enterprise as a whole.	Maintains that each agency of government has a responsibility to communicate the results of the research it sponsors, just as DOD has a responsibility to do the same for its research programs.
8.	Comments briefly on desirability of building data banks early in the information transfer process but makes no specific reference to electronic publishing.	SATCOM encourages major publishers to continue utilizing modern methods of electronic photocomposition. Urges smaller publishers to merge their production activities in order to take advantage of modern technology and achieve economies of scale.	Encourages bibliographic and reference publications in machine-readable form and emphasizes machine retrieval of such information.
9.	Calls for inventorying public and private data banks, for introducing standards, for developing means for measuring data bank effectiveness, and for building a new centralized data bank for government information technology.	Urges agencies which originate STI to accept responsibility for "data compilation", but makes no direct reference to a national data bank. Emphasizes the benefits of common formats in capturing machine-readable [illegible].	Draws the distinction between scientific data and bibliographic data and calls for specialized information centers to collect and organize all data in their assigned fields.
10.	No direct mention of indexing and abstracting.	Puts forward a very strong recommendation for promoting abstracting and indexing services for government-generated R&D, and for providing federal support to societies and private for-profit agencies for abstracting, indexing, and reprocessing STI.	Endorses the preparation of indexes and abstracts in government and private sector. Urges experimentation with new techniques like citation indexing and sees government subsidy of these services as essential.
11.	Calls for development of nationwide information system, including STI, plus increased technological compatibility and appropriate public and private financial support.	Gives top priority to the initiation of experiments on the functioning of different parts of the STI "communication network", but views all forms of communication as part of the "network" (e.g., publications, conferences, telephones, terminals, etc.).	Supports introduction of new technology and systems for communicating information. Sees effective switching and hierarchical organization of STI units as essential and views increased allocation of resources as inevitable to preserve a viable scientific and technical apparatus for the country. The network concept is clearly described in the report although the phrase "STI network" itself does not appear.
12.	No mention of individual scientist per se. But Conference Board's aim is to advance management's access to relevant information. Also speaks of need to improve general public's access to consumer information for diverse social purposes. Calls for user-feedback mechanisms.	Wants a single "file-format language" for machine and human access to dissimilar files. Urges NSF to cooperate with ARPA in this area.	Acknowledges the key role of the user and underscores his need to access different types of material whether using mechanized or manual systems. Sees one principal problem of system design as that of providing enough information to the user but not too much.

DSI OBJECTIVES – 1974	REMARKS	GREENBERGER–1972
13. *To Encourage Computer-Aided Usage of Information.* Users should be able to direct searches, locate and manipulate retrieved information, and proceed to the analysis, interpretation, writing and communication functions using the same equipment, as augmented by powerful and flexible computer capabilities. Development of such capabilities requires research based on the combined efforts of information scientists, computer graphic specialists, and engineers.	Wants to investigate how the user can perform multiple functions on a single terminal and how a terminal (i.e., an intelligent terminal) could assist him.	Speaks of improving "individual effectiveness" in using computers, but doesn't mention performing multiple functions on a single terminal.
14. *To Facilitate College and Graduate-Level Awareness of Scientific and Technical Information Services.* This is being accomplished through development of training materials and curricula suitable for use within science, mathematics, and engineering courses.	Proposes the development of training materials on STI to be incorporated into science and engineering school curricula.	Doesn't address the need for educating students in STI, but speaks frequently of making potential users aware of services.
15. *To Promote On-The-Job Education and Training of Scientists and Engineers.* As with the preceding goal, work is proceeding on the development of short courses and other appropriate training materials.	Aims toward the development of cooperative on-the-job training programs with industry and professional organizations using the newer media.	Implies the need for on-the-job STI training in numerous ways, but doesn't use the phrase "on-the-job".
16. *To Provide Guidelines for Management of Information Services Within Large Organizations.* Two sequential activities are supported: first, analyses for present policies and practices; and second, development and assessment of experimental variations in management of scientific and technical information within large organizations.	Seeks specific guidelines to help managers of R&D organizations to increase STI utilization by their staffs. Special attention is focused on differences in approach to STI by small and large organizations.	Implicit in both reports is the assumption that any way that can be found to enhance user effectiveness is desirable. However, neither report targets the research manager for special training in his administrative responsibility for increasing staff access to STI.
17. *To Provide Guidelines for Establishing Work Conditions that Enhance the Useful Application of Information.* Plans call for analyses of present arrangements and stimulation of experimental variation in the ways information is made available within the working environments of scientists and engineers.	Directs attention to the needs of the individual scientist at the bench and seeks ways to overcome obstacles which inhibit his access and usage of STI.	Wants a coordinated program for increasing "technology transfer" among researchers, practitioners, technicians, and the general public. Promotes the removal of obstacles to STI use.

	CONFERENCE BOARD—1971	SATCOM—1969	WEINBERG—1963
13.	Stresses management's increasing use of information technology and computer-aided systems	Encourages continued experimentation in the design and use of effective combinations of machine and human functions both in storing and retrieving information	Report pre-dates third generation on-line terminal access to computer data but nevertheless encourages computer-aided usage of information
14.	Sees need to design a comprehensive educational program in information technology to develop and maintain the professions managerial talents, and skills essential to an information-dependent society	Recommends the training of all students and faculty in the use of modern library and information services	Strongly suggests the introduction of courses, programs, and other professional training to improve the scientist's and engineer's awareness of and skills in using new information handling techniques and scientific communication.
15.	On-the-job training for all kinds of information usage is implicit in Conference Board's report which presents on- and off-campus education as one of its major propositions	Implies the need for on-the-job STI training in numerous ways, but doesn't use the phrase "on-the-job"	Implies the need for on-the-job training within the context of having the entire technical community become more "information minded" and oriented toward the use of STI in their work.
16.	Gives great emphasis to manager's role in supporting information services and in utilizing information systems to increase staff productivity and competetiveness in the marketplace	Implicit in the report is the assumption that any way that can be found to enhance user effectiveness is desirable. The report targets the research manager for special training in his administrative responsibility for increasing staff access to STI	Speaks of government agency managers and organizations in the private sector having the need to change their "attitude" and devote more resources to information.
17.	Calls for organizations to establish groups to assess implications of information technology on the organization and measure effectiveness of information use. Urges national center with same function. Speaks of encouraging information use by all groups —managers, consumers, professionals, etc	Points out the value of staff exchanges, conferences, sabbaticals, institutes, and other ways of improving STI communication and use by employees	Generally supports this same objective. Suggests the user be involved in STI systems; that he receive data as well as documents; and, maintains he will be more productive through greater use of STI systems.

APPENDIX B

SIX OBJECTIVES FROM THE WEINBERG, SATCOM, GREENBERGER, AND CONFERENCE BOARD REPORTS NOT INCLUDED IN THE 17 DSI OBJECTIVES

1. *Improve the Literature of STI*

   Authors of articles on science information should be encouraged to improve their writing style. The field, in general, needs better abstracts, better reviews, and a better refereeing system.

2. *Embrace R&D for all of the Newer Technologies*

   DSI objectives stress computers but communications, facsimile transmission, and micrographics are three other technologies that deserve equal attention.

3. *Increase Public Understanding of STI*

   It is not enough to improve the education and on-the-job training of scientists and engineers so that they know how to use STI systems and services; there is a concommitant requirement to also inform the more general class of potential users who can benefit from applying STI to problem-oriented situations. A criticism of STI systems is that they serve an elite class of users. (n.b. DSI has no specific research objectives in this area because the National Science foundation supports numerous other programs to improve the public's understanding of science.)

4. *Research the Copyright Problem*

   This is recognized both as a major inhibitor of progress in networking and as the cause of diminishing sales among primary publishers. (n.b. In June 1976, DSI/NSF and the National Commission on Libraries and Information Science co-sponsored a major research study to obtain statistical data on the type and volume of material copied by libraries;

and, to investigate new electronic methods for collecting royalties.)

5. *Establish National Services for STI*

   Weinberg in particular favors establishing a family of specialized information centers and national clearinghouses as an in-place infrastructure for STI. DSI objectives imply no federal responsibility for creating or developing a planned infrastructure.

6. *Improve the Quality and Reliability of Factual Data*

   Science and technology demand that critical data compiled for the individual scientist's use be highly reliable; no mechanism, such as exists for refereeing journal articles, is in place to ensure and guarantee high quality at the time data is entered into an STI system. (n.b. DSI relies on the standard reference data program of the National Bureau of Standards to fulfill this function.)

APPENDIX C

STATUTES AND EXECUTIVE ORDERS AFFECTING THE RESPONSIBILITIES OF NSF FOR SCIENTIFIC AND TECHNICAL INFORMATION:

—National Science Foundation Act of 1950, Public Law 507, 81st Congress, 2nd Session.
—National Defense Education Act of 1958, Title IX, Public Law 85-864, 85th Congress; September 2, 1958 (H.R.13247).
—Executive Order 10807, "Federal Council for Science and Technology," March 17, 1959; which also amended Executive Order 10521, "Administration of Scientific Research by Agencies of the Federal Government," March 19, 1954.
—Presidential Letter to Director, National Science Foundation (Dr. Waterman), dated January 22, 1959.
—Agricultural Trade Development and Assistance Act of 1954, Public Law 83-480 as amended by the Mutual Security Act of 1958, Public Law 85-477 (approved June 30, 1958) and as interpreted by Executive Order 10900, "Administration of the Agricultural Trade Development and Assistance Act of 1954, as Amended," January 6, 1961.

Public Law 507 and Title IX of the National Defense Education Act of 1958 are the principal pieces of legislation affecting the responsibilities of the Office of Science Information Service.

From Public Law 507:

"Functions of the Foundation

"Sec. 3(a) The Foundation is authorized and directed . . .

"(5) to foster the interchange of scientific information among scientists in the United States and foreign countries; . . .

"General Authority of Foundation

"Sec. 11. The Foundation shall have the authority, within the limits of available appropriation, to do all things necessary to carry out the provisions of this Act, including, but without being limited thereto, the authority— . . .

"(g) to publish or arrange for the publication of scientific and technical information so as to further the full dissemination of information of scientific value consistent with the national interest, . . ."