Chapter 5

Framework for a Presidential Initiative on Scientific and Technical Information

An important part of a strategy for scientific and technical information (STI) is leadership-leadership from the science and technology community, Congress, Federal science agencies, and the Executive Office of the President, including the Office of Management and Budget (OMB) and the Office of Science and Technology Policy (OSTP). Leadership is necessary to reach a workable consensus on the outstanding issues of STI dissemination and access discussed in chapters 3 and 4. Leadership is needed to improve interagency coordination and agency organization for STI. How can this leadership be provided? The key is presidential leadership on STI. This can be done in several ways:

1. strengthen the OSTP role;
2. establish an OSTP advisory committee and an interagency coordinating committee on Federal STI;
3. redefine OSTP-OMB working relationships regarding STI;
4. upgrade STI dissemination functions within agency R&D and Information Resources Management programs;
5. develop technical standards and directories for STI dissemination;
6. launch an STI education initiative; and
7. improve international STI exchange programs.

Strengthening the OSTP Role

Congress intended that OSTP be the focal point for STI leadership in the executive branch, and that the OSTP Director (who serves as the President's Science Advisor) designate STI as a priority concern of OSTP.[1] The "National Science and Technology Policy, Organization, and Priorities Act of 1976,"[2] OSTP's organic statute, addresses STI in the declaration of congressional policy. Congress was concerned that STI had received little attention.[3] The Act recognizes that ''effective management and dissemination of scientific and technological information' is part of the U.S. science and technology base. It states that "Federal departments, agencies, and instrumentalities should establish procedures to ensure among them the systematic interchange of scientific data and technological findings developed under their programs. ''4 The legislative intent was to include STI in the OSTP mission implicitly.[5] STI is mentioned in the charter of a President's Committee on Science and Technology that was to consider, among other things, "improvements in existing systems for handling scientific and technical information on a governmentwide basis, including consideration of the appropriate role to be played by the private sector in the dissemination of such informa-

[1] For a discussion of legislative history and options, see U.S. Congress, House, Committee on Science and Technology, Subcommittee On Science, Research, and Technology, Optimizing the Value of U.S. *Scientific* and Technical Information: Legislative Options, report prepared by the Congressional Research Service (Washington, DC: October 1978). For general discussion of science advice in the White House, see W.G. Wells, Jr., "Science Advice and the Presidency, 1933- 1976," dissertation School of Government and Business Administration The George Washington University, Washington DC, 1977; W.T. Golden (cd.), Science Advice to the President (New York: Pergamon Press, 1980); W.T. Golden (cd.), Science and Technology Advice to the President, Congress, and Judiciary (New York: Pergamon Press, 1988); G.J. Knezo, "Suggestions for Collection of Archival Information Pertaining to Presidential Science Advisory Bodies Before 1976," memorandum, Congressional Research Service, Nov. 15, 1989; and statements of Fred B. Wood, OTA; Joseph G. Coyne, U.S. Department of Energy; and Charles R. McClure, Syracuse University, before an Oct. 12, 1989, hearing of the House Committee on Science, Space, and Technology, Subcommittee on Science, Research, and Technology.

[2] U.S. Congress, Public Law 94-282, May 11, 1976.

[3] According t. most observers, the peak of White House interest in STI occurred in the Kennedy and Johnson Administrations, during which time presidential science advisory bodies issued several landmark studies on Federal STI. See, for example, J.H. Crawford, Jr., G. Abdian, W. Frazer, S. Passman, R.B. Stegmaier, Jr., and J. Stem, scientific and Technical Communications in Government, Task Force Report to the President's Special Assistant for Science and Technology (Washington, DC: U.S. Department of Commerce, April 1962); and Federal Council for Science and Technology, Committee on Scientific and Technical Information Recommendations for National Document Handling Systems in Science and Technology (Washington, DC: U.S. Department of Commerce, November 1965).

[4] Public Law 94-282, sec. lo and sec. 102(c)(10).

[5] Earlier legislative proposals addressed STI in more detail. The House committee reports made clear that STI was to have a high priority. See, fOr example, U.S. Congress, House, Committee on Science and Technology, National science and Technology Policy and Organization Act of 1975, Report No. 94-595, 94th Cong., 1st sess. (Washington, DC: U.S. Government Printing Office, Oct. 29, 1975).

> The low profile of OSTP with respect to governmentwide STI policy has, in effect, ceded the dominant executive branch policy role to the Office of Management and Budget.

tion."[6] This provision of the law has not been implemented.[7]

OSTP has provided a modicum of staff attention to STI matters, and has encouraged the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) in some STI matters. The Council, established under Title IV of the Act, is made up of the OSTP Director (chairman), and representatives of the Federal science and technology agencies. The Council created the Committee on Earth Sciences, which has endorsed the work of the Interagency Working Group on Data Management for Global Change. This working group is addressing some of the STI technical and policy issues as they relate to earth sciences and global change. FCCSET also has supported work in the areas of high-performance computing and networking, which relate to STI dissemination.[8] But, neither OSTP nor the FCCSET has given much attention to the dissemination of STI documents or bibliographic databases, to issues involving agencies like the National Technical Information Service (NTIS) and Government Printing Office (GPO) that are responsible for disseminating such materials, or to governmentwide information dissemination issues that relate to STI.

The low profile of OSTP with respect to governmentwide STI policy has, in effect, ceded the dominant executive branch policy role to the Office of Management and Budget. OMB has used its authority under the Paperwork Reduction Act to promulgate governmentwide information policy that covers STI as well as most other types of Federal information (see ch. 3). OSTP has only minimally used its authority under the National Science and Technology Policy Act to get involved in STI policy. Thus the activities of OMB—not OSTP—have had by far the largest impact on STI, and especially on dissemination.

A strengthened OSTP role would help ensure that the special needs and problems of STI are considered, and that the contribution of STI to broader national goals is identified and realized. A stronger role should also improve interagency coordination on STI. The OSTP director may, on his own initiative, give a higher priority to STI matters. This might involve the assignment of OSTP staff to STI issues, and the formal recognition of STI functions within each of the major OSTP programmatic areas. But even so, Congress could seriously consider amending the law to provide stronger congressional guidance. This could be done by adding STI as an explicit, required area of OSTP responsibility and to FCCSET's charter, and perhaps by authorizing OSTP funds specifically for STI activities.[9]

OSTP could prepare and issue a strategic plan on STI, with the advice and assistance of advisory committees and agency officials, as was done in high-performance computing. This recently issued computing plan[10] states the goals, rationale, actions, responsibilities, and budget for implementing the U.S. high-performance computing and networking program. Program leadership is assigned to OSTP, assisted by an FCCSET Committee on Computer Research and Applications and an advisory panel selected by and reporting to the OSTP Director. The FCCSET Committee is responsible for interagency planning and coordination, technology assessment, and preparation of policy recommendations and annual progress reports to OSTP. The advisory panel

[6]Public Law 94-282, sec. 303(a)(2).

[7]For a general review of OSTP performance, see G.J. Knezo, Analysis of the *Office* of Science *and* Technology *Policy*, CRS Report No. 8*-2*5 ' PR (Washington, DC: Congressional Research Service, February 1988) and White House *Office of Science* and Technology Policy *: An Analysis*, CRS Report No. 89-689 SPR (Washington, DC: Congressional Research Service, November 1989).

[8]See U.S. Office of Science and Technology Policy, Executive Office of the President, A Research and Development Strategy for High *Performance* Computing, Committee on Computer Research and Applications, Federal Coordinating Council on Science, Engineering, and Technology (Washington DC: Executive Office of the President, Nov. 20, 1987); and U.S. Office of Science and Technology Policy, Executive Office of the President, TheFederal High *Performance* Computing Program (Washington DC: Executive Office of the President, Sept. 8, 1989).

[9]Congress is considering this approach for high-performance computing. S. 1067, the ''High-Performance Computing Act of 1990,' would mandate and authorize funding for OSTP and FCCSET activities in this area.

[10]U.S. OSTP, *High Performance* Computing Program, 1989, op. cit., footnote 8.

Strategically, the most important STI role for OSTP may be its visible leadership on STI issues coupled with the assessment of STI issues from an integrated cross-cut perspective across agencies and disciplines.

will include scientific, academic, and industry experts, and will provide the OSTP Director and FCCSET with independent assessments of program progress, relevance, and balance. A similar organizational approach could be used for ‘‘a Federal STI Program.’ ‘

An STI strategic plan could, even in its early stages, serve as a focal point for involving OSTP in the ongoing legislative efforts to amend the Paperwork Reduction Act, Printing Act, Depository Library Act, and other statutes that affect Federal STI. OSTP leadership could help develop a strategic vision of: 1) the role of the Federal R&D agencies, NTIS, and GPO in STI dissemination; 2) principles of STI dissemination that encourage use of Federal STI; and 3) updated policies on the open flow of Federal STI that reflect rapidly changing global economic, political, and technological realities.

An STI strategic plan also could integrate STI activities across the several existing Federal policies and programs to encourage technology transfer and industrial innovation. These include, for example:[11]

- the Federal Laboratory Consortium for Technology Transfer, in which about 300 Federal labs participate, that promotes utilization of technical knowledge developed by or for Federal labs;
- The Offices of Research and Technology Applications, located at each Federal lab, that identify technologies and ideas with potential outside application; and
- the Small Business Innovation Development program, that encourages technology development by small companies, including use of federally developed technology and STI in commercial applications.

Other programs encourage a variety of joint ventures and cooperative R&D agreements between the Federal Government, universities, and/or private industry. The proliferation of technology transfer activities has made the need for an STI cross-cut even greater.

Strategically, the most important STI role for OSTP may be its visible leadership on STI issues coupled with the assessment of STI issues from an integrated cross-cut perspective across agencies and disciplines. OSTP leadership would require its collaboration with various STI constituencies-in the science agencies, in Congress, in academia and private industry-for ideas, feedback, and dialog. The last time this happened on STI was in the 1960s.[12]

The National Science Foundation (NSF) supported several STI studies during the 1980s that identified STI problems and possible policy solutions.[13] At that time, OSTP lacked the interest, staff, and high-level support to followup on the STI studies of NSF and other groups. OSTP could not itself perform major STI policy research for lack of resources. But its active involvement can go a long way toward supporting the efforts of others. OSTP certainly can be expected to conduct policy planning

[11] For a general overview, see W.H. Schacht, Technology Transfer: Utilization of Federally Funded Research and Development, IB 85031, and IndustrialInnovation: Debate Over Government Policy, IB 84004 (Washington DC: Congressional Research Service, Aug. 7, 1989).

[12] Presentation of A.A. Aines, former Acting Chairman, Committee on Scientific and Technical Information@ White House Office of Science and Technology, at a CENDI meeting, Dec. 12, 1989.

[13] NSF-sponsored studies include: A.H. Teich and J.P. Weinberg, *Issues* in *Scientific and Technical Information Policy* (Washington, DC: American Association forthe Advancement of Science, Dec. 28, 1982); T.K. Bikson, B.E. Quint, and L.L. Johnson, Scientific and Technical Information Transfer: Issues and Options (Santa Monica, CA: Rand Corp., March 1984); S. Ballard, C.R. McClure, T.I. Adams, M.D. Devine, L. Ellison, T.E. James, Jr., L.L. Malysa, and M. Meo, *Improving* the Transfer and Use of *Scientific* and Technical Information: The Federal Role (Norman, OK: Science and Public Policy Program, University of Oklahoma, September 1986); J.D. Eveland, scientific and Technical Information Exchange: Issues and Findings (Washington, DC: Division of Policy Research and Analysis, NSF, March 1987); NSF Division of Policy Research and Analysis, Scientific Information *Exchange: A* Status Report on *Converting* New *Fundamental* Knowledge Into competitive Products (Washington, DC: NSF, April 1987); and NSF Division of Policy Research and Analysis, Federal Technology Transfer: Mechanisms and Agency Practices (Washington, DC: NSF, May 1987).

and assessments based on the best available STI research.[14]

The extensive, multi-year debate leading up to the establishment of OSTP in May 1976 reflected a strong consensus among leading scientists and engineers on the importance of these OSTP responsibilities to STI.[15] This was followed in 1976-77 by a vigorous debate over OSTP's functions in the Carter Administration. Few of the numerous innovative proposals brought forward[16] were implemented due to President Carter's decision to downsize the entire Executive Office of the President, including OSTP.[17] The Bush Administration (and the appointment of Dr. D. Allan Bromley as the Director of OSTP) is the first real opportunity in 12 years for OSTP to carry out the congressional intent of OSTP's organic Act and fulfill the vision of the scientific and technical community-including a leadership role in Federal STI.

Establishing Advisory Committees on STI

The success of the Committee on Scientific and Technical Information (COSATI) is frequently cited as evidence of the potential effectiveness of high-level advisory bodies. COSATI was formed in 1963 by the former Office of Science and Technology (created in 1962 by executive order) and its President's Science Advisory Committee (PSAC). COSATI and PSAC provided high-level executive branch leadership on STI.[18] With a change of administrations, COSATI was transferred from the Office of Science and Technology to NSF in 1971 and abolished in 1972. The Office of Science and Technology itself was abolished in 1973.[19] OSTP was established by statute in 1976. The new OSTP Director has recently created a President's Council of Advisors on Science and Technology-the equivalent of PSAC—under the President's statutory authority. Functions of the new President's Council of Advisors could be extended to STI and the creation of advisory subgroups such as COSATI.

> OSTP could use FCCSET to help agency STI managers get higher priority for information dissemination and utilization as part of agency R&D programs that collect or create the STI.

Two STI advisory bodies are justified. A COSATI of advisors and experts could report to the OSTP Director. This group might include representatives from major segments of the science and technology community concerned with STI: scientists, scholars, information specialists, large and small business leaders, librarians, State/local government officials, consumer and labor leaders, and the like. A second advisory body comprised entirely of agency STI officials could be established under FCCSET. This group could include representatives from a cross-section of Federal science agencies, including the major Federal science data centers and document clearinghouses, and the governmentwide dissemination and archival agencies.

[14] Both the outreach and policy assessment roles of OSTP are addressed at a general level throughout the enabling statute and legislative history. See Public Law 94-282, op. cit., footnote 2; U.S. Congress, House, Committee on Science and Technology, National Science and Technology Policy and Organization *Act of 1975,* Report, 94th Cong., 1st sess., Rep. No. 94-595 (Washington, DC: U.S. Government Printing Office, Oct. 29, 1975); U.S. Congress, House, Committee on Science and Technology, Science and Technology Policy, Conference Report, 94th Cong., 2d sess., Rep. No. 94-1046 (Washington, DC: U.S. Government Printing Office, Apr. 26, 1976).

[15] See, for example, U.S. National Academy of Sciences, Science *and Technology in Presidential Policymaking: A Proposal* (Washington, DC: National Academy Press, June 1974).

[16] See, for example, statements of Lewis M. Branscomb, "Science and Technology Issues: A Framework" June 14, 1976; Harold Brown, "Science and Technology Organization in the Executive Office of the President," Aug. 23, 1976; and F.B. Wood, V. Coates, J. Coates, R. Ericson, and J. Logsdon, "Early Warning and Policy Assessment Capability To Support Presidential Policymaking/Decisionmaking, ' Jan. 3, 1977; prepared forthe Jimmy Carter Presidential Transition Team.

[17] OSTP was reduced to a minimal staff level of about 15 persons. However, it could have been worse. For example, the White House Office of Telecommunications Policy was abolished, and its functions transferred to the Departments of Commerce and State and the Federal Communications Commission.

[18] See, for example, President's Advisory Committee, Science, *Government, and Information:* The Responsibilities of the Technical *Community* and the Government in the Transfer of Information (Washington, DC: U.S. Government Printing Office, Jan. 10, 1963).

[19] Thomas E. Pinelli, "Chronology of Selected Reports, Related Studies, and Significant Events Concerning Scientific and Technical Information in the United States,' May 1989 draft. For other historical perspectives, see A. Bishop and M.O. Fellows, "Descriptive Analysis of Major Federal Scientific and Technical Information Policy Studies, " in C.R. McClure and P. Hernon, United States Scientific and Technical Information Policies: Views and Perspectives (Norwood, NJ: Ablex Publishing Corp., 1989), pp. 3-55; and A.A. Aines, "A Visit to the Wasteland of Federal Scientific and Information Policy," Journal of the American Society of Information Science, vol. 35, May 1984, pp. 179-184.

OSTP could ensure that Federal science agencies have a role in the STI policymaking process at OMB. OSTP could collaborate with OMB on major initiatives to improve the management of Federal information systems, including agency STI systems.

The lack of an equivalent to COSATI, or a formal FCCSET advisory body on STI, in part led to the creation of CENDI (Commerce, Energy, NASA, NLM, Defense Information). CENDI is an interagency group established by several Federal science agencies (NTIS, DOE, NASA, DTIC, and NLM) to address STI issues. The CENDI agencies represent over 90 percent of the Federal R&D budget. CENDI supports a strong OSTP and FCCSET role in STI.

Compared to CENDI, an FCCSET committee on STI could be upgraded in several ways. First, its scope could be expanded to include the data side of STI as well as the bibliographic and document side on which CENDI now concentrates. Second, the FCCSET committee's membership could be expanded to include other Federal agencies with major STI functions (e.g., USGS, NOAA, USDA, and EPA) that are not presently included in CENDI. Third, staff support and funding could be expanded beyond that now available to CENDI. CENDI has undertaken several new projects in the areas of standards, cataloging, indexing, and technology assessment, but has no regular means of support (participating agencies make voluntary contributions). Fourth, the FCCSET committee could assert leadership in educating government executives on the importance of STI dissemination and governmentwide STI strategies, in a much more vigorous manner than appears possible through CENDI. Fifth, the FCCSET committee could establish strong working relationships with other interagency groups.

Improved coordination is urgently needed among the interagency groups involved in Federal STI, including:

- CENDI;
- Interagency Working Group on Data Management for Global Change;
- Interagency Coordinating Committee on Digital Cartography;
- Special Interest Group on CD-ROM Applications and Technology;
- Federal Publishers Committee;
- Interagency Panel on Numerical Data;
- Interagency Advisory Council on Printing and Publishing; and
- Federal Library and Information Center Committee.

OSTP could take a leadership role on an FCCSET STI committee, to help further offset the natural tendency of all interagency groups to reflect agency-specific rather than governmentwide concerns. OSTP also could help ensure, through FCCSET, that the various interagency groups have adequate administrative and financial support, balanced membership, and an audience for the fruits of their labors. If the FCCSET committee is effective, some of the other interagency groups may no longer be needed.

OSTP could use FCCSET to help agency STI managers get higher priority for information dissemination and utilization as part of agency R&D programs that collect or create the STI. R&D managers have a strong tendency to emphasize the conduct of the research itself, rather than the effective use of research results. OSTP could work with FCCSET to help individual agency STI programs contribute to governmentwide priorities, such as the global change program.

Redefining OSTP-OMB Working Relationships on STI

OMB has a dominant role in executive branch information policy and oversight. The OMB Office of Information and Regulatory Affairs has devoted little attention specifically to STI, and some within OMB strongly support a reactivated STI role for OSTP. But, even if OSTP gives priority to STI, OMB will continue to be a major player for two reasons: first, OMB guidance on general government information policy will also apply to STI (e.g., Circular A-130), unless STI is granted a blanket exemption, an unlikely prospect; second, OMB will still be the primary decisionmaker on budgets for Federal science agencies—including resources allocated to STI.

A new OSTP-OMB working relationship on Federal STI is necessary. OSTP could actively participate in the drafting and public comment process for revisions to OMB Circular A-130 and other circulars that affect STI. OSTP could ensure that Federal science agencies have a role in the STI policymaking process at OMB. OSTP could collaborate with OMB on major initiatives to improve the management of Federal information systems, including agency STI systems. Many criticisms of Federal information systems apply to STI as well. Federal agencies have been criticized for not paying enough attention to the users of Federal information and involving users from the outset of project planning. OSTP and OMB could encourage user outreach activities and provide guidance to the agencies on how to improve outreach.

OMB issues an annual bulletin on "Federal information systems and technology planning' that directs agencies in the preparation of strategic plans. These are developed as part of agency and governmentwide 5-year plans. OSTP could suggest topics for special attention. In 1988, OMB asked agencies to provide details on electronic mapping databases (otherwise known as digital cartographic, geographic, or land information systems). In 1989, OMB asked agencies to provide information on image processing systems and electronic data interchange.[20] These topics all relate to STI. Other possible STI-related topics include: high-density data storage systems; expert systems for information retrieval; machine translation (of foreign language publications); and gateway technologies for multiple remote database access.

OSTP and OMB could help ensure that each Federal science agency is aware of and carefully examines state-of-the-art activities of other agencies. For example, the Defense Technical Information Center (DTIC) prepared a year 2000 strategic plan and is implementing it.[21] DTIC is the clearinghouse for STI developed by or for the Department of Defense (DoD). DTIC operates: an online research database (DROLS = Defense Research On-Line Search); an intelligent gateway to DoD and some other online databases (that eventually will be extended to many Federal agency and commercial databases); and a prototype electronic document system (that uses scanners, optical disks, supermicrocomputers, intelligent work stations, and laser printers for storing and disseminating DoD technical documents).

Other OSTP-OMB joint activities might include:

- cosponsorship of ad hoc interagency committees on specific priority topics, such as improved indexing of Federal STI and other types of information (OMB already has proposed a committee on this topic), management of very large databases (e.g., the Earth Observing System), and quality control of standard reference data (on physical, chemical, and engineering properties).
- cosponsorship of a continuing dialog-through meetings, committees, conferences, and other means—between agency R&D and STI managers to ensure that the Federal investment in STI best serves the R&D user community;
- coordination on appointments to any OSTP and OMB outside advisory committees that maybe established on STI or Federal information;
- cofunding, directly or with agency support, of research projects in targeted cross-cut areas such as user training and STI education;
- OSTP participation in OMB-sponsored interagency groups (e.g., the Interagency Coordinating Committee on Digital Cartography[22]) and vice versa; and
- cosponsorship of conferences that bring together all elements of the STI community, from agencies to libraries to vendors.

The reentry of OSTP into STI activities would open new possibilities for cooperation with OMB in

[20] U.S. Office of Management and Budget, Bulletin 89-17, "Federal Information Systems and Technology Planning," Aug. 22, 1989.

[21] For the original plan, now being updated, see U.S. Department of Defense, Defense Logistics Agency, Defense Technical Information Center, *DTIC 2000:A Corporate Plan for the Future,* DTIC/TR-84/3, July 1984. Also see, for example, T. Lahr and D. O'Connor, An Evaluation *of DTIC's Prototype* CD-ROM (Alexandria, VA: Defense Technical Information Center, August 1989); C.W. Shockley, D.F. Egan, C.H. Groth, Jr., and D.J. O'Connor, Meeting *the* Scientific and Technical Information Challenge, Report DL605R2, contractor report prepared for DTIC (Bethesda, MD: Logistics Management Institute, October 1988); Aerospace Structures Information Analysis Center, Application of New Technologies to DTZC Document Processing, contractor report prepared for DTIC, August 1987; and G.A. Cotter, The DOD Gateway Information System: Prototype *Experience,* DTIC/TR-86/6, April 1986.

[22] This committee was rechartered by OMB in 1989. See memorandum from Richard G. Darman, OMB Director, to Heads of Executive Departments and Independent Establishments, "Coordination of Federal Digital Cartographic Data Program,'' Feb. 28, 1989; also see memorandum from Lowell E. Starr, Chairman, to Participants, Federal Interagency Coordinating Committee on Digital Cartography Governrnenhvide Forum, ''FCCDC Recommendations for an Improved Federal Spatial Coordination Process," Dec. 5, 1989

Technical standards can bridge among different formats so that once the information is in the system, it can be processed, edited, revised, stored, and disseminated in electronic, paper, or microfiche formats.

jointly carrying out executive branch STI policymaking and oversight.

Upgrading Agency STI Management

Agency management of STI needs to be strengthened, and OSTP-OMB cooperation could help.[23] Information dissemination should have a higher priority. Most agencies give scant attention to dissemination, even though dissemination was included in the original Information Resources Management (IRM) program concept, and is referred to in the Paperwork Reduction Act (as amended in 1986). IRM officials and activities are mostly occupied with computers, telecommunications, management information systems, and procurement activities. Job definitions, career paths, and training programs for information dissemination professionals and IRM officials could be revised and strengthened to reflect the importance of STI.

STI dissemination should have higher priority within agency R&D programs as well. STI is the primary product of R&D and is central to agency R&D missions. Several possible actions to upgrade STI deserve consideration:

- the direct participation of STI staff in agency R&D planning and decisionmaking;
- the assignment of technical information officers to major science agency operating units;
- the separation of dissemination as a line item within agency R&D budgets;
- the allocation of at least some minimum percentage of R&D grants, contracts, and operating budgets to STI dissemination, data management, and related areas;
- the participation of R&D program officials in selected interagency STI groups and activities;
- the participation of R&D grantees, contractors, and the like in agency innovation centers designed to share new information about STI dissemination, among other topics;
- the involvement of R&D and STI managers in focus group discussions with and surveys of STI users; and
- the joint sponsorship of independent research on STI dissemination and use (perhaps with cooperation from NSF).

Further research on STI use needs to emphasize the barriers as well as opportunities presented by electronic formats. For example, what conditions—equipment, software, training, experience—contribute to successful use of electronic formats? Is the research on use of online formats applicable to offline formats like compact optical disk? How effective are end users in conducting their own searches of STI databases compared with using intermediaries (e.g., librarians, commercial vendors)? Is existing search-and-retrieval software sufficiently user-friendly to make widespread, decentralized use a reality? Are users able to adapt to the availability of STI in multiple and changing formats? In sum, agencies need to guard against ‘‘technophoria."[24] While electronic formats are well-suited to STI, disseminating agencies should not adopt electronic formats uncritically without a good understanding of the impact on STI users.

Developing Standards and Directories for STI

Technical standards are essential if the government is to make improvements in cost-effectiveness and productivity and assist the private sector to use Federal STI. Technical standards can bridge among different formats so that once the information is in the system, it can be processed, edited, revised, stored, and disseminated in electronic, paper, or microfiche formats. Standards developed for Federal STI should be compatible with those adopted by the private sector and the international standards-setting

[23] For a general critique of agency information management as it relates to STI, see C.R. McClure, A. Bishop, and P. Doty, ‘ ‘Federal Scientific and Technical Information (STI) Policies and the Management of Information Technology for Dissemination of STI,'' in information Technology: Planning *for the Second 50* Years, Proceedings of the 51st Annual Meeting of the American Society for Information Science, Christine L. Bergman and Edward Y.H. Pai (eds.) (Medford, NJ: Learned Information Press, 1989). Also see U.S. Congress, Office of Technology Assessment, *Informing* the Nation: Federal Dissemination in *an* Electronic Age, OTA-CIT-396 (Washington DC: U.S. Government Printing Office, October 1988).

[24] Term coined by C.R. McClure, Syracuse University School of reformation Studies.

organizations. Priority areas for standards-setting include:

- STI indexing and cataloging (standard formats are needed, so that NTIS, GPO, and mission agencies are using compatible approaches);
- STI quality control (especially for preventing or minimizing errors in collecting data and creating documents, and for maintaining data and document integrity throughout the information life cycle);
- STI security (technical and administrative standards for preventing unauthorized use or alteration of Federal STI);
- text markup and page/document description languages (e.g., Standard Generalized Markup Language, which has been issued as an international standard and as a Federal Information Processing Standard (FE%));
- optical disks (there has been significant progress on CD-ROM standards, e.g., for mastering, formatting, and reading, but not yet for search and retrieval software; standards for WORM, Erasable, and CD-I disks are in earlier stages of development); and
- electronic data interchange (EDI), including the open systems interface (OS1) concept (e.g., an OS1 procurement standard has been issued as a FIPS and becomes mandatory in late 1990; a proposed EDI standard has been issued for comment).

STI managers, users, and private vendors generally agree on the need for interoperability among various systems and equipment. The Federal Government can accelerate the development and adoption of the standards needed to ensure interoperability. The National Institute of Standards and Technology (NIST), working with GPO, NTIS, and the Federal science agencies, could help in this standards-setting effort. DoD is important in this process, because it and the defense industry together account for two-thirds of the Federal R&D budget and have invested hundreds of millions of dollars in CALS (Computer-Aided Acquisition and Logistical Support). CALS is designed as a standardized system for the electronic exchange of technical data, drawings, and documents.

Large STI databases—such as in the geographic, space, and earth sciences—must have technical standards for data archiving and exchange, if these resources are to be managed and used effectively. Geographic information systems (GIS) will permit greater data exchange among the Federal science agencies. GIS require the integration of multiple data sets—frequently originating from several different agencies. Most Federal agencies with GIS applications are using data sets from several other agencies.[25] GIS must have standards to ensure interoperability among users in these agencies. Most agencies using GIS have not yet developed standard definitions and/or classifications for the major thematic data categories used in GIS applications and do not have an operational program to collect and manage standardized data.[26] The OMB-chartered Federal Interagency Coordinating Committee on Digital Cartography (chaired by the U.S. Geological Survey) has made progress in developing a standard format for Federal geographic information storage and exchange.[27]

NASA is active in standards for space science data. The Science Data Systems Standards Office (at NASA's National Space Science Data Center (NSSDC)) is responsible for standards development. It works with the national and international standards organizations, validates standards, and disseminates information about standards that are important to space science data collection, storage, and dissemination.

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[25] U.S. Interagency Coordinating Committee on Digital Cartography, Reports Working Group, ''A Summary of GIS Activities in the Federal Government," August 1988, pp. 16-18.

[26] Ibid., pp. 13-15.

[27] See, for example, U.S. Federal interagency Coordinating Committee on Digital Cartography, Standards Working Group, ''Federal Geographic Exchange Format: A Standard Format for the Exchange of Spatial Data Among Federal Agencies, " Dec. 15, 1986, U.S. Interagency Coordinating Committee, "Coordination of Digital Cartographic Activities in the Federal Government,'' Third Annual Report to the OMB Director, 1988. For discussion of the need for a directory to GIS activities and improved Federal/State/local cooperation on GIS, see Lisa Warnecke, ''Georgraphic/Land Information Development Coordination Clearinghouse and Network,'' Syracuse University, School of Information Studies, January 1989, and "Geographic Information Coordination in the States: Past Efforts, Lessons Learned, and Future Opportunities, " in Piecing the Puzzle Together: A Conference on *Integrated Data for Decisionmaking*, proceedings, National Governors Association Center for Policy Research, May 27-29, 1987. For recent updates on GIS standards and related topics, see U.S. Department of the Interior, Study of *Land* Information, prepared in accordance with Public Law 100-409, November 1989 draft; Dec. 5, 1989, memo from Lowell E. Starr, U.S. Geological Survey, on ''FICCDC Recommendations for an Improved Federal Spatial Data Coordination Process," and agency responses thereto. For general background on the Interagency Coordinating Committee, see Memorandum from Richard G. Darman, Director, Office of Management and Budget, to Heads of Executive Departments, Establishments, and Independent Agencies, "Coordination of Federal Digital Cartographic Data Programs," Feb. 28, 1989.

The NSSDC has a generic data storage standard, known as the Common Data Format, that is being beta-tested by NASA laboratories and others.[28]

The standards-setting effort in the earth sciences is being led by the Interagency Working Group on Data Management for Global Change, whose members include NASA, NOAA, NSF, USGS, the U.S. Navy, and the Departments of Energy, Agriculture, and State. The working group has emphasized technical standards to facilitate the exchange of data directory information and data sets. Standards are needed to enable users to access earth sciences data on a variety of computers, over a range of electronic networks. This includes the need for standards on data quality. The working group has involved NIST in its standards-setting activities. The National Research Council's Scientific and Technical Information Board (formerly the Numerical Data Advisory Board) also emphasizes the role of NIST in developing governmentwide standards for a variety of large-scale scientific and technical databases.

Directories to Federal STI are also needed to help users find the information they seek. Some are concerned that a directory or index might be used by OMB to thwart rather than encourage agency information dissemination. But OMB has taken steps to quiet this concern. Under the OMB plan, each agency would maintain a current, comprehensive inventory of information dissemination products and services, including: periodicals, nonrecurring publications, machine-readable datafiles (including compact optical disks), software, online databases, and electronic bulletin boards. Each inventory would serve as an index to agency information and would be submitted to a central collection point and compiled into a governmentwide index.[29] NTIS and GPO could collaborate on preparation of a governmentwide directory, and start by collecting and consolidating available agency-specific directories. OMB intends to establish an interagency group to develop an improved structure and content for agency inventories.

Directories to large-scale scientific databases as well as STI documents should be included in these efforts. The proliferation of space science electronic databases-offline and online-is an example of the importance of directories to users seeking specific information. NASA's Master Directory offers online access to a directory of NASA and other space and earth science data sets and related information. For each data set, the directory includes a descriptive title, abstract, references, contact persons, archival information, storage media, and technical details (e.g., parameters measured, scientific discipline, spatial coverage, time period). The directory allows connection to other information systems or database directories.[30] The NASA directory concept may be applicable to other Federal science agencies, and could be made available to the Federal depository libraries and other Federal information dissemination facilities. NASA is also developing expert "data navigation" systems: software to help users rapidly search, access, manipulate, and display data.

The Interagency Working Group on Data Management for Global change is developing and adapting NASA's master directory into an "interoperable directory" that will provide access to information about global change data. Earth sciences data will be maintained by each agency on a decentralized basis, along with detailed catalogs or inventories of its data sets. Summaries of the data sets will be in a central directory that can route inquiries to the detailed catalogs located at individual data centers and can also transfer data among the various data centers and users. Both online and offline electronic services will be available.[31]

The operational version of the directory will include the following Federal earth sciences data centers or systems: NASA (National Space Science Data Center including the NASA Climate, Ocean, and Land Data Systems); NOAA (National Oceanographic Data Center, National Geophysical Data Center, National Climatic Data Center); and USGS (Earth Science Information Center, Earth Resources Observation Systems [EROS] Data Center, National

[28] U.S. National Aeronautics and Space Administration, Goddard Space Flight Center, National Space Science Data Center, *NSSDC Data* Listings. NSSDC-88-01, January 1988.

[29] See Office of Management and Budget, "Second Advance Notice of Further Policy Development on Dissemination of Information," Federal Register, vol. 54, No. 114, June 15, 1989, pp. 25554-25559.

[30] U.S. National Aeronautics and Space Administration, Goddard Space Flight Center, *The National Space* Science Data Center, NSSDC-88-26, January 1989, pp. 5-6.

[31] U.S. National Aeronautics and Spare Administration, Goddard Space Flighzt Center, National Space Science Data Center, "Report on the Third Catalog Interoperability Workshop, Nov. 16-18, 1989," James R. Thieman, Mary E. James, and Patricia A. Bailey (eds.), March 1989.

Water Data Exchange [NAWDEX], and Earth Science Data Directory, among others).[32] For example, USGS has an Earth Science Data Directory that can be queried from remote computer terminals to identify and locate over 2,000 databases in fields such as geology, hydrology, and cartography. The directory includes: a description of each database; time and geographic coverage of the data; frequency of data updating; type of computer; and person(s) responsible. (USGS does not charge for online access, although users pay their own telecommunication charges.)

The working group and participating Federal agencies are supporting the development of an Arctic environmental data directory to further test the directory concept on a small scale. Arctic climate is thought to be a sensitive indicator of global change. Thus the arctic data directory should have direct utility to the global change research program, and it can also serve as a prototype for a larger earth sciences data directory. CD-ROM is being used for disseminating the Arctic data directory, selected data sets, and reference and bibliographic materials relevant to polar regions.[33]

Launching an STI Education Initiative

Improving U.S. science education is important to renewing U.S. competitiveness. Federal STI can be used to teach students about science and technology and assist them in acquiring basic information search and retrieval skills that are applicable to many careers in the information age.

STI data sets could be used-either online or on disk-for computer models and simulations in science laboratories. Students could use computer-based references and data in their work on topics like energy, environment, health, and space. It is possible to design computer-based enhancements to the science and math curricula that are matched to student skill levels for each year in school.[34]

> Federal science agencies could sponsor pilot projects in local elementary and secondary schools to demonstrate the use of Federal STI in the science curriculum.

Schools and colleges have already made a significant investment in microcomputers; but as yet, aside from the major research universities, STI is rarely used in the classroom. Federal agencies, libraries, and private vendors have limitless opportunities to provide accessible and affordable STI to elementary and secondary schools as well as colleges and universities.[35] There is a pressing need to break the routine of science education, bring more excitement into the program, and involve the students directly.[36] Computer-based STI might help capture the interest and enthusiasm of elementary and intermediate students through more ‘‘hands-on’ science, and strengthen the quality of science education as well. The implications for high school and collegiate science could be profound.

“Hands-on” science means emphasis on observing, critical thinking, and doing rather than rote memorization of facts. Some science education materials already include computer software and could be extended to Federal STI databases online or

[32] See, for example, U.S. Interagency Working Gou, on Data Management for Global Change, “Interagency Session on Data Management for Global Change,” meeting minutes dated Sept. 18, 1987, and Mar. 3, 1989.

[33] See Aug. 8, 1988, memo from Thomas L. Laughlin, Coordinator, Arctic Environmental Data Workshop, National Oceanic and Atmospheric Administration, to Arctic Environment Data Directory Working Group; Douglas R. Posson, ‘‘Arctic Environmental Data System: Results from the Boulder, Colorado, Workshop,” Arctic Research of the United States, Fall 1988, vol. 2; and Feb. 3, 1989, memo from Douglas R. Posson, Chairman, Arctic Environmental Data Directory Working Group, USGS, to Working Group Members.

[34] For a detailed discussion of opportunities for computer-based mathematics education, see National Research Council, Mathematical Sciences Education Board, Reshaping School Mathematics: A Philosophy and Framework for *Curriculum* (Washington, DC: National Academy Press, 1990), and Everybody *Counts: A* Report to the Nation on the Future of MathematicsEducation (Washington, DC: National Academy Press, 1989); and National Council of Teachers of Mathematics, Commission on Standards for School Mathematics, *Curriculum and Evaluation* Standards for School Mathematics (Washington, DC: National Council of Teachers of Mathematics, March 1989).

[35] Some private vendors already offer various Federal STI databases at educational or school library discount prices that range from 25 to 40 percent off the list price.

[36] Al Saley, President, Society of School Librarians International, telephone conversations with F.B. Wood of OTA, October and November 1989.

on disk; many more curricular materials are well suited to the use of Federal STI as course supplements. The range of possibilities is illustrated in table 2.

The degree of difficulty in the course materials could be scaled to the educational level. But the important point would be to include Federal (and other) STI as a component, where appropriate, in student workbooks, teacher supplements, subject matter overviews, and even ''take-home' software packages for use on the family microcomputer or at the local library or science museum.[37]

Several recent studies have focused on the problems and challenges of U.S. science education,[38] but few have considered the role of Federal STI or STI generally. OSTP could provide leadership in this area, perhaps working with FCCSET or other advisory bodies, and launch a science education initiative based on Federal STI, or include Federal STI as part of a broader science education program. An STI education initiative could encompass the following kinds of major activities:

1. Federal science agency STI pilot projects in local schools. Federal science agencies could sponsor pilot projects in local elementary and secondary schools to demonstrate the use of Federal STI in the science curriculum. The various Federal agency data centers could make copies of prototype Federal STI CD-ROMs available at no or nominal charge and perhaps provide start-up training on a pilot basis in collaboration with the educational community.[39] This would help teachers and students better understand the potential of Federal STI in user-friendly electronic formats. Local schools could also experiment with online access to Federal data centers, and with electronic networking for both data (and document) transfer and distance learning.[40]

2. Federal educational programs with STI applications. The Department of Education, Department of Defense, and National Science Foundation have major programs in science, engineering, and mathe-

Table 2—illustrative Use of Federal STI as Science Education Course Supplements

Topic	Application/media
Earthquakes: Land in Motion	Students could analyze the 1989 California earthquake in perspective of long-term trends, other major quakes and their geographic distribution, using data from NOAA's National Geophysical Data Center (CD-ROM).
Earth: The Water Planet	Students could examine current stream flows, lake levels, and precipitation (rain, snow) for regional variations and long-term trends, using USGS water data and NOAA climatic data (online, CD-ROM).
Space: The Last Frontier	Students could explore the solar system through the eyes of space probes such as Mariner and Voyager, using imagery from the NASA National Space Science Data Center (videodisk, CD-ROM).
Toxic Waste: Silent Danger	Students could identify toxic waste dumps in their vicinity, determine the chemicals involved, and analyze the toxicological and environmental effects, using databases from the EPA and NLM (online, CD-ROM).

SOURCE: Office Technology Assessment, 1990.

[37] The National Science Teachers Association and National Council of Teachers of Mathematics both have developed extensive curricular materials that could be reviewed for potential Federal STI applications.

[38] See American Association for the Advancement of Science, Science for All Amen"cans: Project 2061 Report on Literacy Goals in *Science,* Mathematics, and Technology (Washington, DC: 1989); U.S. National Research Council, Everybody *Counts: A* Report to the Nation on the Future of Mathematics Education (Washington, DC: National Academy Press, 1989); and U.S. Congress, Office of Technology Assessment, Educating Scientists and Engineers: *Grade* School to Grad School, OTA-SET-377 (Washington, DC: U.S. Government Printing Office, June 1988).

[39] The US. Geological Survey (in collaboration with NOAA and NASA) is implementing project JEDI—Joint Earth Sciences Educational Initiative-to bring earth sciences information in CD-ROM format to high school students and teachers in northern Virginia. The primary JEDI goal is "to invigorate the teaching of earth science studies in our primary and secondary schools throughout the country. . .through the creation of a stimulating and innovative set of teaching materials.' And NASA is implementing project LASER-Learning About Science, Engineering, and Research-to bring NASA science and technology resources, including STI, to K-12 teachers and students. The project uses teacher workshops, public libraries, audio/visual materials, and mobile laboratories (equipped with computer access to NASA's Spacelink STI system) to enrich science and mathematics education and develop "hands-on" activities that reinforce student interest in science and math.

[40] For general discussion see U.S. Congress, Office of Technology Assessment, Critical Connections.' *Communication for* the Future, OTA-CIT-407 (Washington, DC: U.S. Government Printing Office, January 1990); and OTA, Linking for *Learning:* A New Course for Education, OTA-SET-430 (Washington, DC: U.S. Government Printing Office, November 1989).

matics education.[41] Many of these programs permit and sometimes require the use of computer technology as part of teacher training, curriculum development, and instructional support activities.

The Hawkins-Stafford School Improvements Act of 1988[42] authorizes the use of funds for training math/science teachers in computer use, and for purchase of computer hardware and software. Title VI of the Omnibus Trade and Competitiveness Act of 1988[43] authorizes demonstration programs in technology education to:

- inform students about technology applications;
- develop student skills" in using technology;
- prepare students for life-long learning in a technological society; and
- improve teacher competency in technology education.

Under OSTP coordination, these programs could be reviewed for opportunities to include Federal STI.

Technology-enhanced use of Federal STI is an appropriate topic for teacher training and student projects. The National Science Teachers Association has endorsed science education initiatives to develop curricula to instruct teachers on the use of technology in the classroom, and provide electronic technologies to science teachers at all grade levels.[44]

3. Federal science agency collaborative projects with science museums, associations, and high-tech information companies. Science museums are very successful in the ''hands-on,'' interactive approach to science education. Most science museums use microcomputer-based displays, games, or tutorials, and some provide microcomputer laboratories for intensive computer experience. Computer-based demonstrations of Federal STI applications would be a direct extension of current activities. Federal scientific and bibliographic databases could be operated on a stand-alone basis (e.g., with a dedicated microcomputer using diskette, hard disk, or CD-ROM formats). Science museums with modems could access online Federal STI databases directly from the government and/or private vendors.

Improving the information literacy of U.S. scientists and engineers is one of the most highly leveraged ways to increase the return on the U.S. R&D investment.

Federal STI also could be included in science education programs sponsored by scientific associations and/or private companies. The American Association for the Advancement of Science (AAAS) and a telephone company cosponsor a program to help middle and high school science teachers learn about new communications and information technologies, and how these technologies can be used in science classes. Federal STI would be a natural addition to this type of program.[45] Several private vendors offer substantial educational discounts for off-peak online access to various STI databases, including some Federal STI.

4. Federal collaboration with library and information science professionals. Libraries and the professional library and information science schools offer untapped potential for improving the use of Federal STI. Libraries at the major research universities are well-versed in Federal STI and electronic databases generally. But in many public and school libraries, the use of electronic databases is just beginning. In elementary and secondary schools, the problem is compounded because the role of librarians in facilitating electronic access is only dimly understood.

[41] See C.M. Matthews, Science, *Engineering, and* Mathematics Precollege and College Education, IB 88068 (Washington DC: Congressional Research Service, Nov. 3, 1989) and Science and Engineering Education: The Role of the Department of Defense, Report 89-256 SPR (Washington, DC: Congressional Research Service, Apr. 18, 1989); U.S. Congress, Office of Technology Assessment Educating Scientists and Engineers, op.cit., footnote 39, and Power On: *New Tools* for Teaching *and Learning, OTA-SET-379* (Washington, DC: U.S. Government Printing Office, September 1988).

[42] U.S. Congress, Public Law 100-297, the ''Augustus F. Hawkins and Robert T. Stafford Elementary and Secondary School Improvements Act Of 1988. "

[43] U.S. Congress, Public Law 100-418, Title VI, Subtitle 2, ''Instructional Programs in Technology Education"; see J.B. Stedman, Computers in *Elementary* and Secondary Schools: An Analysis of Recent Congressional Action, Report 88-419 EPW (Washington, DC: Congressional Research Service, June 9, 1988).

[44] National Science Teachers Association "Science Education Initiatives for the 1990s, " position paper, Sept. 7, 1988.

[45] See W. Worthy, ''Diverse, Innovative Programs Revive Precollege Science Math Education," *Chemical* and Engineering News, Sept. 11, 1989, pp. 7-12,

Professional groups such as the Society of School Librarians are attempting to bring new information technologies into the school library setting, and recognize the relevance of Federal STI. Under OSTP leadership, Federal agencies could collaborate with the school librarians to help make this vision a reality.

OSTP and the Federal agencies could reach out to the Nation's schools of library and information science and initiate a dialog on how to improve the collegiate curriculum on STI, working closely with the schools of science, engineering, and technology. The objective would be to educate more librarians and information scientists with a specialty in STI, and upgrade courses on information skills in the academic science and engineering programs. Improving the information literacy of U.S. scientists and engineers is one of the most highly leveraged ways to increase the return on the U.S. R&D investment. Business leaders and academic scholars increasingly recognize this need.[46]

Improving International Exchange of STI

U.S. scientists and engineers are generally not conversant in foreign languages and do not read many foreign language documents. Only a small percentage of foreign language material is translated into English, and even here, U.S. demand for such translations has been weak. The problem is two-fold: many U.S. researchers do not sense the need to consider foreign STI, and do not have the skills needed to do so even if they wanted.[47]

Congress enacted the Japanese Technical Literature Act of 1986 to improve U.S. access to Japanese STI. NTIS is responsible for implementing the act, has agreements with about 50 Japanese information sources, and offers online access to some Japanese databases. OSTP could review how well the act is working, and whether the concept should be extended to other foreign countries. Computer-aided translation offers great promise for enhancing U.S. access to foreign STI. OSTP could examine how progress in this area can be accelerated.

OSTP also could review U.S. bilateral and multilateral science and technology (S&T) agreements to ensure that STI is sufficiently covered. STI is an explicit U.S. objective in implementing the U. S.-Japan S&T Agreement (i.e., to improve the flow of Japanese STI to the United States), and an STI Task Force is focusing on computer-assisted translation of Japanese literature for private industry, academic, and government laboratory users in the United States.[48] OSTP is taking a lead in the U.S.-Japan agreement, a role that could be extended to many other S&T agreements, and to other aspects of U.S. access to foreign STI. These include education and exchange programs for U.S. and foreign researchers, and cooperative agreements between U.S. and foreign STI agencies.

The consensus seems to favor open, reciprocal exchange of STI, with restrictions on access kept to the minimum. OSTP should take the lead in balancing the open flow, national security, and competitiveness concerns that arise in dealing with international STI issues.

The principle of open, reciprocal STI access has been accepted for years in the civilian scientific research community (as contrasted with military or commercial research). Global change research exemplifies the importance of international STI collaboration and the complexities involved. The U.S. Interagency Working Group on Data Management for Global Change recognized from the outset that earth sciences data must be collected and disseminated globally to foster research on global change. The Federal earth science agencies have dozens of international agreements for information exchange, and these could be the basis for an international data network, if data systems are made compatible. The working group is coordinating with several national and international scientific organizations on earth sciences data management, including:

- National Research Council Space Science Board, Committee on Data Management and Computation;

[46]See statement of C.R. McClure, Professor of Information Studies, Syracuse University, before a hearing of the House Committee on Science, Space, and Technology, Subcommittee on Science, Research, and Technology, Oct. 12, 1989.

[47]See C.H. Hill, "Enhancing U.S. Access to Foreign STI: What Should be the Federal Role," in McClure and Hernon (eds.), Federal Scientific and Technical Information, op. cit., footnote 19, pp. 172-192.

[48]See memorandum from D. Allan Bromley, Director, OSTP, to U.S. Members of the Joint High Level Committee on the U.S.-Japan Science and Technology Agreement, Nov. 20, 1989.

A common frustration to those working on international data systems is the lack of a receptive audience at the senior levels of the government. This is beginning to change with regard to STI for global change.

- National Research Council, Numerical Data Advisory Board (recently renamed the STI Board);
- National Research Council, Committee on Geophysical Data;
- International Geosphere/Biosphere Program, Data Management Working Group;
- International Council of Scientific Unions, Panel on World Data Centers;
- Committee on Earth Observation Satellites, Working Group on Data;
- Committee on Data for Science and Technology (CODATA); and
- World Climate Data Program.

A common frustration to those working on international data systems is the lack of a receptive audience at the senior levels of the government. This is beginning to change with regard to STI for global change.

The challenge of managing global change data is mammoth. NASA's Earth Observing System alone will generate an additional terabyte (10^{12} bytes) of data every day. This is equivalent to 10,000 Washington, DC telephone books (white pages) or 520,000 text books (at 200 pages each) per day.[49] Electronic technologies offer the only hope for managing this data (see appendix). The Interagency Working Group has concluded, after several years of effort, that the size and geographic scale of global data require new approaches to data management and international cooperation if the potential of these technologies is to be realized.[50]

Table 3—illustrative Weaknesses in Current Global Change Data Management

Weakness	Explanation
Data quality	Many data sets lack credibility due to inconsistent or poor documentation and quality control.
Data management procedures	There are no established criteria or policies for evaluating, archiving, and updating global data sets.
Data management technologies	New technologies are not applied in a consistent or coordinated manner to global data sets.
Data management infrastructure	The data systems to handle increased observational data are not yet in place.
Global change data sets	Very few data sets have been compiled and processed for the specific purpose of monitoring and detecting climate change.
Satellite data calibration	Despite 25 years of satellite observations, only one satellite data set is sufficiently well-calibrated to document global change.
Data archives	Retrospective data sets are poorly cataloged, inconsistently documented, inaccessible, and subject to an undisciplined publication process.
Data standards	Data formats and exchange mechanisms are inadequately standardized. Standards that exist are not uniformly adhered to.

SOURCE: Committee on Earth Sciences, 1989.

Data management is critical to the success of global change initiatives. The U.S. Global Change Research Program now includes data management in the overall plan, and presents a detailed data management strategy.[51] However, the problems that need attention are daunting, as highlighted in table 3.

While some might question the severity of reported data management problems, the need for international cooperation is compelling. As the Committee on Earth Sciences concluded:

> Data management requires global and international cooperation. . .No one nation, agency, or institution will be able to gather the appropriate data without cooperation from other nations, other agencies, and other institutions. Individual agencies will need the cooperation of others to collect, manage, and preserve data sets systematically for global change and make them accessible across the traditional discipline and agency boundaries.[52]

[49] See R. Kahn, ''Coping With All the Earth Science Data,' EOS, vol. 69, No. 21, May 24, 1988, pp. 609, 612.

[50] U.S. Interagency Working Group on Data Management for Global Change, "Interagency Session, Minutes," June 2, 1989.

[51] U.S. Federal Coordinating Council for Science, Engineering, and Technology, Committee on Earth Sciences, *Our Changing Planet: The* FY *1990* Global *Change* Research Plan (Washington DC: OSTP, July 1989), pp. 91-99.

[52] Ibid., p. 94.