Chapter 6

Computer Modeling, Decision Support, and Government Foresight

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SUMMARY

Advances in information technology are fueling a revolution in computer modeling–both inside and outside of government. The 1980s have been characterized by the expansion of computer modeling, via low-cost microcomputers and user-friendly software, literally into the office of the individual scientist, engineer, analyst, or manager, and, simultaneously via supercomputers, to the new limits of modeling complexity demanded in the scientific, energy, space, climate, and defense sectors. The span and diversity of computer modeling activities in the Federtal Government have never been greater. About 60 percent of Federal agency units responding to the OTA Federal Data Request reported at least some use of computer modeling, with the number of applications ranging up to 2,000 per agency component.

The use of computer-based decision analytic techniques has also increased dramatically. Such techniques typically include computer software that can help decisionmakers or staff analyze a specific problem, possible decision options, and the likely or possible consequences. About 90 percent of Federal agency units report use of spreadsheet software, about one-half use quantitative decision techniques (e.g., linear programming), about one-fourth use forecasting and qualitative techniques (e.g., decision trees), and a handful use decision conferences and computer-conferencing.

Overall, executive branch officials responding to the OTA Data Request believe these techniques to be very useful, even essential, to agency decisionmaking. However, few can document this claim, other than by citing ad hoc examples, because there has been little research on the impact of decision support techniques on agency decisionmaking. The limited research that is available, primarily academic research on model implementation, suggests that models (and, by extension, other decision analytic techniques) can and do have a significant impact on agency decisionmaking. Modeling may become a significant element in the process of negotiation over assumptions and options that is an integral part of agency (and, in general, political) decisionmaking. However, models can be wrong, and models can be misused.

OTA identified several possible actions that could help improve sharing of expertise and learning; facilitate public and congressional access where appropriate; enhance congressional and public understanding of the strengths and limitations, uses and abuses of modeling; and improve the government return on a significant investment. Possible actions include:

- establishing guidelines or standards for model documentation, verification, and validation;
- establishing directories of major modeling applications;
- clarifying procedures on public and congressional access to modeling details;
- conducting further research on the impact of computer modeling and decision support on agency decisionmaking;
- conducting basic and applied research on modeling and decision support methodologies;
- conducting further testing and development of the decision conference technique; and
- bringing computer modeling and decision support clearly within the scope of information resources management.

Information technology-including data collection, archiving, and transfer, as well as mod-

cling techniques-also makes possible improved monitoring, analysis, and, to a lesser extent, forecasting of key national and global trends. Sometimes referred to collectively as foresight capability, this potential is being facilitated by advances in:

- technical monitoring capability (e.g., through remote-sensing satellites, advanced data communication networks, and computerized data centers);
- computational and analytical capability (e.g., through the entire range of computer tools, from microcomputers to supercomputers, related software, and the procedures necessary for documenting and validating models); and
- the scientific knowledge base in the wide range of disciplines that bear on foresight.

Realization of the potential for improved foresight appears to require a synthesis of technical advances, an integration of relevant information, and institutional mechanisms that cut across agency and disciplinary lines. Many of the actions intended to improve decision support would also assist foresight, since foresight can be viewed as one component of decision support. For example, a well-developed model evaluation program built on the prior work of the National Bureau of Standards (NBS), Energy Information Administration (EIA), General Accounting Office (GAO), OTA, and others could help improve the government's modeling activities across-the-board.

The combining of computer modeling, electronic data collection, and various decision analytic techniques used in a decision conference format may be an effective technical approach to improve government foresight capability. This could involve a melding of individual techniques already in use by various government agencies, such as the White House National Security Council, Joint Chiefs of Staff, Department of Commerce's Office of Program Planning and Evaluation, and National Aeronautics and Space Administration (NASA).

OTA identified several possible actions that could facilitate improved foresight in the executive branch—ranging from bringing foresight into the scope of information resources management, planning, and innovation activities, to designating a governmentwide foresight office, either newly established or as part of an existing agency.

INTRODUCTION

In the early stages of this assessment, OTA reviewed the entire range of known applications of information technology in the Federal Government. OTA identified computer-based modeling and decision support as an applications area about which little concrete information was available. After a thorough literature search and consultation with knowledgeable persons inside and outside of the government, OTA concluded that there was no current, reliable source of information on Federal Government use of computer-based modeling and decision support. In order to develop a sound basis for understanding trends and issues relevant to computer modeling, this topic was included in the OTA Federal Agency Data Request, which was sent to all 13 cabinet departments and 20 independent agencies.

For purposes of this study, computer modeling included the entire range of mathematical models used to support agency activities and programs—from small models run on microcomputers in individual offices to large, complex models run on supercomputers. A model is an abstraction, analog, image, or representation of some aspect of current (or future) reality relevant, in this case, to the missions and programs of Federal agencies. All but the very simplest mathematical models are now routinely programmed as sets of equations and run on computers. Thus, most models are computer-based models, or computer models for short. Computer models can be used for a variety of purposes—from conducting scientific research in aeronautics or climate, to engineering the design of a new highway bridge, to estimating future numbers of school-age children, to analyzing the fiscal impacts of alternative medicare reimbursement policies. Computer models can be and are used to support agency decisions, but have many other purposes as well.

Consideration of computer-based decision support for this study included several types of analytical techniques (along with the necessary computer software, hardware, data sets, graphic displays, and the like) used to support or assist decisionmakers. The categories of computer-assisted analytical techniques used in the OTA Federal Agency Data Request and in this chapter are:

- spreadsheet computer software;
- forecasting techniques (e.g., regression analysis, Delphi survey);
- quantitative decision analytic techniques (e.g., linear programming, queuing analysis, systems analysis, critical path analysis);
- quantitative decision analytic techniques with judgmental input (e.g., decision trees, subjective probability, multi-attribute utility).
- decision conference techniques (e.g., interactive use of computer-assisted analytical techniques by decisionmakers in a group situation);
- electronic voting techniques (e.g., consensor, computer polling);
- computer-conferencing for decision analysis; and
- other (e.g., expert systems).

Most of these techniques also involve the use of models. For example, an analysis of the relationship between rainfall, temperature, and crop yield might use a computer-based multiple regression model to better understand the performance of different varieties of crops (e.g., wheat) under various climatic conditions, or to help an agricultural extension agent or Agency for International Development agricultural employee select specific varieties to recommend for spring planting.

This chapter presents OTA's findings on key trends and issues relevant to computer modeling and decision support. In addition, it discusses the potential for improved government foresight through the use of information technology and decision support techniques. One objective of foresight is to help government decisionmakers better understand and consider longer term trends and implications when making decisions. From that perspective, foresight can be properly viewed as part of decision support.

Realization of the potential to improve government foresight appears to require a synthesis of technical advances, an integration of relevant information, and institutional mechanisms that cut across agency and disciplinary lines. The foresight portion of this chapter extends the earlier discussion of computer modeling and decision support to include:

- remote-sensing satellites for collecting foresight-related data;
- model evaluation procedures for foresight-related computer models;
- systems science for analysis of complex trends and issues relevant to foresight;
- data integration and display techniques, with examples from NASA, the National Security Council, and the Joint Chiefs of Staff;
- advanced decision support techniques that could be applied to foresight; and
- institutional mechanisms, both agency-specific and governmentwide, that could help facilitate improved foresight.

The major foresight sectors can be viewed as spanning the entire range of Federal Government programs and activities, including, for example: energy, environment, water, climate, food, population, transportation, housing, education, the economy, foreign trade, and national security. Not all techniques are equally applicable to all foresight sectors. Thus, for example, remote-sensing satellites are most applicable to the environmental and natural resources (e.g., including food, water, climate, land use) sectors of foresight. Large-scale modeling is most applicable to those sectors, such as energy and climate, where key variables and relationships can be quantified and where substantial input data are available. On the other hand, some decision analytic techniques (e.g., decision conferences, computer-conferencing) are applicable to both quantitative and qualitative, observational and judgmental information, and thus are relevant to many, if not all, foresight sectors.

KEY 'TRENDS

Information Technology Fueling Modeling Revolution

Several key technological developments have profoundly changed the conduct of analytical, forecasting, and research activities that utilize modeling. The first is the microcomputer revolution. This study has documented elsewhere the exponential increase in microcomputers in the Federal Government. From almost no microcomputers 10 years ago to only a few thousand 5 years ago, Federal agencies now have, collectively, more than 100,000. Access to computer power truly has been decentralized, both in terms of actual desktop computer capability and the use of microcomputers as access points to larger mainframe computer resources. This phenome non parallels that found in the research and business communities outside of government.

A second key trend is the large increase in user-friendly computer software, especially software suitable for microcomputers. This includes a wide range of spreadsheet, modeling, and decision analytic software that permits many small-scale, relatively simple decision analytic and modeling applications.

A third key technological trend is at the high end of computer power—the supercomputer. Supercomputers are extending the limits of modeling complexity, whether it be in aerodynamics, high-energy physics, or climate. In the United States, supercomputers have been installed at, for example, the Lawrence Livermore Laboratory (Department of Energy) for magnetic fusion research, and at the Ames Research Center (NASA) for numerical aerodynamics modeling. Both NASA and the Department of Energy (DOE) officials have stated that supercomputers are essential to their modeling activities.[1]

Use of supercomputers is not limited to government agencies. For example, with National Science Foundation (NSF) funding, additional supercomputer centers are being established at several universities-including the University of California at San Diego, Cornell University, Princeton University, and the University of Illinois at Urbana-Champaign-to augment universities such as Purdue and Minnesota that already had supercomputers. At Illinois, illustrative anticipated applications range from high energy physics (e.g., simulation of a particle accelerator to test theories about elementary particles), to chemistry (e.g., simulation of molecular behavior), to civil engineering (e.g., modeling of transportation systems in the Chicago area), to physiology and biophysics (e.g., modeling of electrical activity of nerve and muscle cells).[2]

The earliest computer modeling dates back to the 1950s when first-generation computers were used, for example, to run simple numerical models for weather prediction. Until around 1970, Federal Government modeling was concentrated in the scientific, energy, space, and defense sectors–sectors with the greatest computational needs and the resources to pay for the expensive but necessary computer power. During the decade of the 1970s, however, the widespread availability of relatively cheap computers contributed to the expansion of computer modeling activities to areas such as air pollution, water resources, solid waste man-

'See Frank R. Bailey, "NAS: Supercomputing Master Tool for Aeronautics, " *Aerospace America*, January 1985, PP. 118-121; June Altman, "Cray-2 Called Super in Memory, Performance, " *Management Information Systems Week*, June 12, 1985, p. 12; Don Dagani, "Supercomputers Helping Scientists Crack Massive Problems Faster, " *Chemical and Engineering News*, Aug. 12, 1985, pp. 7-13; and James Connolly, "Cray Doubles Memory On X-MP Line," *Computerworld*, Sept. 23, 1985, p. 4.

[2]Judith Axler Turner, "Supercomputer Raises Expectations Among Researchers at University of Illinois, " *The Chronicle of Higher Education*, Oct. 23, 1985, p. 24. Also see U.S. Congress, Office of Technology Assessment, *Information Technology R&D: Critical Trends and Issues*, OTA-CIT-268 (Washington, DC: U.S. Government Printing Office, February 1985).

agement, urban development, and transportation. The 1980s have been characterized by the expansion of computer modeling, via low-cost microcomputers, literally into the office of the individual scientist, engineer, analyst, or manager, and, simultaneously via supercomputers, to the new limits of modeling complexity demanded in, for example, the energy and climate sectors.[3] The results of OTA's Federal Agency Data Request (presented later) indicate that the span and diversity of computer modeling activities in the Federal Government have, without question, never been greater.

Weather and climate modeling is a good illustration of how computer modeling in general has essentially developed in parallel with advances in computer power. The record shows that the complexity of weather and climate models quickly expands to push the limits of the computational power and capacity of each successive generation of computer technology.[4]

Continuing Heavy Federal Use of Computer Modeling

Federal agency use of computer modeling is substantial-almost 60 percent of 141 agency components responding to the OTA Data Request reported some use of computer modeling to support of agency activities and programs. And this excludes use of decision analytic techniques such as spreadsheet software discussed in the next section. (Note: The OTA Data Request was limited to the Federal executive branch. Other OTA research reviewed use of computer modeling by Congress[5] and State legislatures.' See the discussion inch. 8.)

For agencies that could estimate the total number of modeling applications, the number ranged up to 2,000 per agency component. Among the heaviest reported computer model users are the Economic Research Service (Department of Agriculture), Office of Program Analysis and Evaluation (Department of Defense (DOD)), U.S. Geological Survey (Department of the Interior), Federal Highway Administration (Department of Transportation (DOT)), and the Nuclear Regulatory Commission (NRC).

OTA asked agency components to list the 10 heaviest areas of modeling application. The results demonstrated the wide diversity in the purposes for which computer modeling is used by Federal agencies. Examples from seven selected agencies are shown in table 6-1.

Although the results of the OTA Federal Agency Data Request are not adequate to make a precise estimate of the number of modeling applications, it is clear that the total is far higher than previously thought. A 1982 GAO survey identified 357 models used in the agency policymaking process, based on responses from 12 of the 13 cabinet departments and 18 independent agencies.[7] The GAO survey very likely underreported the total number of policy-relevant models as of that time (1982), and the number has probably increased since then. While a precise estimate is neither possible or necessary, the ballpark *minimum* would appear to be in the thousands for policy models and tens of thousands for all types of computer models used by Federal agencies.

'See Saul I. Gass and Roger L. Sisson, *A Guide to Models in Governmental Planning and Operations*, report by Mathematica, Inc., prepared for U.S. Environmental Protection Agency, August 1974; and OTA, *Information Technology R&D*, op. cit., pp. 57-61.

'The original numerical weather forecast models were run on first-generation mainframe computers (e.g., IBM 701) in the 1950s, and the original atmospheric general circulation models on second-generation computers (e.g., IBM 7094) in the 1960s. The first global coupled atmosphere-ocean model was run in the mid-1970s on the state-of-the-art third-generation computers (e.g., IBM 360-195). (U.S. National Academy of Sciences, National Research Council, U.S. Committee for the Global Atmospheric Research Program, *Understanding Climate Change: A Program for Action*, Washington, DC, 1975, pp. 198-201.)

Today, the most complex climate models are straining the capability of class VI supercomputers (e.g., Cray-1 or Cyber 205) and are providing the impetus for climate modelers to move up to even more powerful supercomputers. (National Center for Atmospheric Research, *Annual Report Fiscal Year 1984*, NCAR/AR-84, Boulder, CO, March 1985, p. 36.)

Stephen E. Frantzich, "Congressional Applications of Information Technology, " OTA contractor report prepared by Congressional Data Associates, February 1985.

'Robert Miewald, Keith Mueller, and Robert Sittig, "State Legislature Use of Information Technology in Oversight, " OTA contractor report prepared by the University of Nebraska-Lincoln, January 1985.

'U.S. General Accounting Office, *Survey to Identify Models Used by Executive Agencies in the Policymaking Process, GAO/PAD-82-46*, Sept. 24, 1982.

Table 6-1 .—Federal Agency Modeling Applications

Economic Research Service (Department of Agriculture)
An estimated 2,250 computer modeling applications, including:
- analysis of farm program alternatives
- analysis of world food supply, capacity, and response
- analysis of conservation alternatives
- trade policy analysis
- forecasting of commodity supply and demand

Forest Service (Department of Agriculture)
An estimated 100 applications, including:
- timber resource allocation model
- integrated pest impact assessment system
- forest growth and yield analysis
- fire management and planning model
- engineering design models for roads, structures, and buildings

***Office of** Secretary of Defense (Office of Program Analysis and Evaluation)*
An estimated 1,250 applications, including:
- impact of defense spending on U.S. economy
- strategic defense initiative effectiveness studies
- military force mobility modeling
- impact of procurement schedule changes on acquisition costs
- impact of second-source/competitive procurement on acquisition costs

Joint Chiefs of Staff (Department of Defense)
A large number of applications, including:
- strategic nuclear war plans analysis
- non-strategic nuclear force mix analysis
- military force posture analysis
- improving crisis war planning processes
- nuclear damage assessment

Bureau of Indian Affairs (Department of the Interior)
An estimated 15 applications, including:
- road and bridge design
- forest and range fire risk analysis
- rangeland usage and conditions analysis
- rangeland market appraisal
- oil and gas lease management and planning

Office of Assistant Secretary for Program Evacuation (Department of Health ***and Human Services)***
A small number of applications, including:
- revenue impact analyses of, for example, including social security and welfare benefits in taxable income, providing additional tax exemptions for children in the first year after birth, and replacing Federal income tax credits for the elderly with higher deductions.
- estimates of participation rates for Aid for Dependent Children (AFDC) recipients in the Food Stamp Program.
- estimates of the Deficit Reduction Act impact on AFDC, Food Stamp, and Supplemental Security Income beneficiaries.

Federal Emergency Management ***Agency***
An estimated 100 applications, including:
- mobilization for nuclear and general war
- earthquake damage and economic impact estimates
- residual capacity of U.S. economy after nuclear war
- strategic stockpile policy development
- flood damage analysis

SOURCE: Office of Technology Assessment Federal Agency Data Request

The numbers could be much higher, especially if spreadsheet-type models are included.

Rapidly Increasing Federal Use of Computer-Based Decision Support and Analysis

Computer-based decision analysis, per se, dates back to the 1960s for its theoretical roots (e.g., as developed by Howard Raiffa of Harvard University),8 and to the 1970s for its practical development and early application—primarily in the military and business sectors. Early Federal Government sponsors of research and development (R&D) on decision analysis included the Defense Advanced Research Projects Agency and the Office of Naval Research. The early decision analytic tools were implemented with paper and pencil, slide rule, and/or calculator.

Since decision analysis techniques may involve many options (e.g., numerical probabilities based on empirical evidence and/or quantified judgments of uncertain future events), the number of calculations per run can be large, and the typical application involves many runs with changing options and values. Thus, decision analysis is a natural match with electronic computer capability. Therefore, almost all decision analytic techniques are significantly if not entirely run on computers, at least for the computational aspects. Many decision analysis software packages are now available off-the-shelf for use on microcomputers, and the software and hardware, together with relevant databases, are frequently known as decision support systems.

The results of the OTA Federal Agency Data Request provided a good profile of agency use of decision analytic techniques-the first complete profile known to exist. The results are likely to understate the full extent of use, given the highly decentralized nature of deci-

‘Howard Raiffa, *Decision* Analysis(Reading, MA: Addision-Wesley, 1968). Also see Rex V. Brown, “A Brief Review of Executive Agency Uses of Personalized Decision Analysis and Support, ” OTA contractor report prepared by Decision Science Consortium, Inc., March 1985.

sion support. Nonetheless, the results are generally consistent with the perceptions of informed observers, especially with respect to the relative differences in levels of use for the various techniques.

The results are summarized in table 6-2. As shown, spreadsheet software is used by almost all (88 percent) of the agency components responding, and half of the remaining agency components (8 out of 16) are planning to use spreadsheet software. Almost half (47 percent) of agency components report the use of quantitative decision analytic techniques, with another 13 agency components planning to use such techniques. About one-fifth (22 percent) of agency components report use of quantitative decision analytic techniques with judgmental input, and about one-fifteenth report use of decision conference techniques. Nine agency components report use of decision conferences, and another seven components indicate that they are planning to do so. About one-twentieth report use of computer-conferencing for decision support, and two agency components indicate use of electronic voting techniques. Also, three components report planned use of expert systems or artificial intelligence for decision support.

Use of spreadsheet software is spread throughout all agencies, and use of quantitative techniques is fairly widespread in, for example, the Departments of Agriculture, Commerce, Defense, Interior, Transportation, Treasury, and about two-thirds (12 of 19) of the independent agencies surveyed. However, DOD is the only agency with more than half of agency components reporting use of quantitative decision analytic techniques with qualitative input (e.g., decision trees, multiattribute utility). Likewise, DOD is the only agency reporting significant use of decision conferences (about one-third of DOD components reporting), although there was very scattered, infrequent use reported in Agriculture, Interior, and Transportation.

With respect to use of quantitative decision analytic techniques, the International Economic Policy (IEP) Group of the International Trade Administration (Department of Commerce) is illustrative. This agency component combines the use of decision analytic techniques, models, and databases "to help improve decisionmaking" and "to enhance IEP's ability to provide policy makers and U.S. business with comprehensive information on trade and investment matters generally. " As one other agency example, the Drug Enforcement Administration (DEA) (Department of Justice) is planning to use quantitative decision techniques to optimize allocation of agency resources (agents, monies for purchase of information and evidence, etc.) in terms of pro-

Table 6-2.—Federal Agency Current and Planned Use of Computer-Assisted Decision Analytic Techniques

	Current use[a]					Planned use[b]
	Yes		No		Total	
Technique	No.	%	No.	%	No.	No.
Spreadsheet software (e.g., Lotus 1-2-3, VisiCalc)	121	88.3	16	11.7	137	8
Quantitative decision analytic techniques (e.g., linear programming, queuing analysis, systems analysis, critical path analysis)	64	47.4	71	52.6	135	9
Forecasting techniques (e.g., Delphi, regression analysis)	33	24.6	101	75.4	134	13
Quantitative decision analytic techniques with judgmental input (e. g., decision trees, subjective probability, multi-attribute utility)	29	22.1	102	77.9	131	10
Decision conference techniques (e.g., interactive use of computer assisted analytical techniques by decision makers in group situation)	9	6.8	124	93.2	133	7
Computer-conferencing for decision analysis	6	4.6	124	95.4	130	4
Electronic voting techniques (e. g., consensor)	2	1.5	132	98.5	134	1
Other: Expert Systems, artificial intelligence				_		3

[a] Agency components reporting current use

[b] Agency components reporting planned use of techniques not currently used

SOURCE: Office of Technology Assessment, based on results of Federal Agency Data Request ductivity as measured, for example, by the number of repeat offender arrests, volume and value of drug interdictions, and reductions in drug availability. Also, DEA plans to use quantitative techniques with judgmental input and artificial intelligence techniques for investigative and intelligence purposes.

Other examples of the use of decision analytic techniques, especially those combining quantitative and qualitative (judgmental) methodologies, include:

- DOD use of multi-attribute utility analysis to aid in the evaluation and acquisition of major military systems such as the Advanced Scout Helicopter, Light Armored Vehicle, Mobile Protective Weapons System, and Single Channel Ground and Airborne Radio System;
- Defense Nuclear Agency use of multi-attribute utility and cost-effectiveness analysis to aid in R&D budgeting;
- Department of the Air Force use of decision analytic techniques to aid in planning and targeting air strikes against enemy air bases, and in developing command, control, and communication countermeasures;
- NRC use of decision analysis to aid in evaluation of proposed new regulatory requirements and safeguard designs;
- DOE use of decision analysis to aid in implementation of the Nuclear Waste Policy Act of 1982 and the siting of repositories for high-level nuclear waste;
- National Security Council use of decision analysis in evaluating alternative strategies for the Middle-Eastern region; and
- President's Council on International Economic Policy use of decision analysis in evaluating alternative export control policies for computer technology.

For further discussion of these and other applications, see the OTA contractor reports prepared by Decision Science Consortium, Inc., listed in appendix C.

KEY OPPORTUNITIES FOR ACTION

Guidelines or Standards for Model Evaluation

Efforts to manage computer modeling and to establish some minimum level of standards have always lagged behind the actual level of applications by many years. In the 1970s, as computer modeling applications proliferated throughout the Federal Government, the National Bureau of Standards, Energy Information Administration, and the General Accounting Office took the lead in attempting to bring some coordination and coherence to civilian modeling activities. The Joint Chiefs of Staff (JCS) did likewise for defense modeling.

GAO issued reports in 1976, 1978, and 1979, and NBS issued reports in 1979 and 1981 (with EIA support).[9] A central theme in all of these reports was the need to develop some kind of common framework for model evaluation or assessment. Many suggestions were made, but none were adopted on a governmentwide basis. A very few individual agencies, such as EIA, eventually adopted some variant of a model evaluation procedure. (For further discussion of EIA model documentation and evaluation, see table 6-3 and related discussion below under the topic of public access to modeling details.)

Given the very extensive use of computer modeling by Federal agencies, the level of formal model documentation, verification, and validation appears to be deficient. Clearly, computer models are judged to be important by many Federal agencies and are used for

[9] U.S. General Accounting Office, *Ways To Improve Management of Federally Funded Computerized Models,* Aug. 23, 1976; *Models and Their Role in GAO,* October 1978; *Guidelines for Model Evaluation,* January 1979; U.S. Department of Commerce, National Bureau of Standards, *Utility and Use of Large-Scale Mathematical Models,* Saul I. Gass (cd.), May 1979; *Validation and Assessment of Energy Models,* Saul I. Gass (cd.), October 1981.

purposes ranging from research to decision support. However, the research on computer modeling makes two things abundantly clear: models can be wrong, and models can be misused.[10] For these reasons alone, minimum modeling guidelines or standards appear to be needed. In addition, such guidelines presumably would make it easier to strengthen the Federal modeling expertise, and, hopefully, achieve a higher return on what must be a substantial Federal investment. (OTA did not develop data on the costs of modeling, and most agencies are unable to readily estimate such costs.)

As noted above, some agencies (e.g., NBS, EIA, JCS) have made a concerted effort to develop and/or apply modeling guidelines. A lead role could be assigned to one of these agencies, perhaps NBS, or to one civilian and one military agency (e.g., NBS and JCS), for developing and promulgating a set of modeling guidelines. Much of the groundwork has already been done, and development of guidelines should be straightforward.[11] The lead agency would presumably involve all major modeling agencies in the guidelines development process. Guidelines for the major, expensive, complex computer models would logically be more complete and extensive than guidelines for small, simple, inexpensive, desktop models. Computer modeling could be brought clearly within the purview of the information resources management concept, through appropriate amendments to the Paperwork Reduction Act if necessary.

Directory of Modeling Applications

Prior studies of computer modeling in the Federal Government have generally concluded that directories of modeling applications would be helpful—at least for the major models. This possibility was reiterated in a 1982 OTA study on water resources models.[12] Given the extremely large number of applications, a comprehensive directory would appear to be costly and difficult to prepare, and many of the applications simply may not warrant the effort. However, there is a stronger argument for a comprehensive directory of selected major models and for an index or pointer system to a larger number of other significant models and modelers, perhaps indexed by subject matter and type of model. These actions would be intended to help reduce possible excessive overlap and duplication, encourage exchange of modeling information among modelers, and facilitate a greater degree of public knowledge of and access to Federal modeling. Some argue that modelers in any given area already know or can learn what they need to know about relevant modeling activities without the help of modeling directories. But given the number and diversity of modeling applications, this could be difficult.

Of 82 agency components that reported use of computer models, 16 or about one-fifth indicated the existence of a modeling directory. Those agencies are:

Department of Agriculture:
—Economic Research Service
—Forest Service
Department of Defense:
–Joint Chiefs of Staff
–Defense Contract Audit Agency

[10] See, for example, Brian Wynne, "The Institutional Context of Science, Models, and Policy: The IIASA Energy Study," *Policy Sciences*, vol. 17, No. 3, November 1984, pp. 277-320; W. Hafele and H.H. Rogner, "A Technical Appraisal of the IIASA Energy Scenarios? A Rebuttal, " *Policy Sciences*, vol. 17, No. 4, December 1984, pp. 341-365; Bill Keepin and Brian Wynne, "Technical Analysis of IIASA Energy Scenarios, " *Nature, vol.* 312, December 1984, pp. 691-695; and David Dickson, "Global Energy Study Under Fire, " *Science,* vol. 227, January 1985, p. 4. For a discussion of errors in forecasting models, see William Ascher, *Forecasting: An Appraisal for Policymakers and Planners* (Baltimore, MD: Johns Hopkins University Press, 1978). For discussion of limitations and risks associated with computer-based planning and forecasting techniques, see Charles Stubbart, "Why We Need a Revolution in Strategic Planning, " *LongRange Plarming*, vol. 18, No. 6, December 1985, pp. 68-76; Henry Petroski, "Superbrain, Superrisk," *Across the Board, vol.* 12, No. 12, December 1985, pp. 48-53; and Kennedy Maize, "How It Didn't Turn Out: The Forecasters Who Failed (And One Other), " *The Energy Daily,* vol. 14, No. 1, Jan. 2,1986.

[11] See, for example, GAO, *Guidelines,* op. cit.; NBS, *Utility,* op. cit.; and GAO, *Validation* op. cit.; Richard Richels, "Building Good Models Is Not Enough, " *Interfaces*, vol. 11, No. 4, August 1981, pp. 48-51; and Saul I. Gass and Lambert S. Joel, "Concepts of Model Confidence, " *Computers and Operations Research,* vol. 8, No. 4, 1981, pp. 341-346.

[12] U.S. Congress, Office of Technology Assessment, Use *of Models for Water Resources Management, Planning, and Policy* (Washington, DC: U.S. Government Printing Office, August 1982).

Department of Energy:
–Energy Information Administration
Department of the Interior:
–Minerals Management Service
–U.S. Geological Survey
–Office of Surface Mining Reclamation and Enforcement
Department of Justice:
–Justice Management Division
Department of Labor:
–Bureau of Labor Statistics
Department of Transportation:
–National Highway Traffic Safety Administration (NHTSA)
—Federal Highway Administration
—Federal Aviation Administration
Nuclear Regulatory Commission
Arms Control and Disarmament Agency
Federal Emergency Management Agency

Most of these directories are reported to be in paper format, although the Forest Service and NHTSA indicate that their directories are in an on-line electronic format. Also, the EIA model directory is in both computerized and printed formats.

In addition, some of these agency components report that they also have a central reference point—usually a designated person —with current information about modeling applications. Several other agency components that do not have a directory do claim to have a contact person. Among the latter agencies are, for example, the Defense Advanced Research Projects Agency, Defense Communications Agency, Department of Energy agencywide (National Energy Software Center—a full clearinghouse operation, not just a person), Employment Standards Administration (Labor), Urban Mass Transit Administration (DOT), and Comptroller of the Current (Treasury).

In total, a little more than one-third (31 out of 82) of the agency components that use computer modeling report having a model directory and/or a designated contact person or, rarely, an actual clearinghouse. This one-third includes many of the agency components that appear to be among those with the heaviest modeling activity. These figures do not include model directories or clearinghouses that include Federal agency models but are maintained by non-Federal entities (e.g., universities, professional associations, and private information companies).

With respect to decision analytic support, only five agencies reported a directory or clearinghouse of such applications. The decentralized and small-scale nature of most decision analytic applications probably makes a directory to these techniques unrealistic.

However, for major modeling applications—such as the major energy, agriculture, water, transportation, and climate models—a directory appears to make sense. Such a directory or family of directories should be useful to all parties concerned–Congress, the public, agency modelers, researchers, and the like. Several prototypes exist. The directories would logically be computerized, to facilitate easy updating, and could be available in on-line electronic format as well as in paper and microform. A common table of contents would be helpful, and would presumably be consistent with whatever modeling guidelines may be developed. The directories could be organized by—at a minimum-agency, subject area, and type of modeling application (e.g., scientific research, decision support, program implementation) to facilitate easy reference.

A lead agency could be designated, perhaps the NBS Center for Operations Research and/or the NBS Institute for Computer Science and Technology, to study the options and develop a feasible directory design. The modeling directories and contact persons reported to OTA by the agencies should provide a good base from which to start.

Clarified Procedures on Public Access to Modeling Details

Only about one-tenth of agency components using computer modeling have formal procedures or policies (beyond the Freedom of Information Act) on the availability of modeling details (e.g., structure, assumptions, input data) to the public and Congress, and there is wide variability among the procedures and policies that do exist.

The overall results indicate that most agencies have not given much attention to questions of public and congressional access to model details. Some agencies cite the Freedom of Information Act as the guiding policy; others state that modeling details would probably be provided if sought by Congress.

The following agencies indicated the existence of procedures or policies on the availability of model details to the public and/or Congress:

- Economic Research Service (ERS) (Agriculture)
- Bureau of the Census (Commerce)
- Joint Chiefs of Staff (Defense)
- Energy Information Administration (Energy)
- U.S. Geological Survey (Interior)
- Bureau of Labor Statistics (BLS) (Labor)
- Urban Mass Transportation Administration (Transportation)
- Federal Aviation Administration (Transportation)
- Nuclear Regulatory Commission

Most of the major Federal statistical agencies are included in the above list (e.g., ERS, Census, EIA, BLS) because they use models in developing statistical trends and forecasts and because there is a highly visible public demand for their information products. Thus, there is a strong felt need to develop explicit access policies.

However, even among the few agencies that have explicit policies, there is considerable variability in the level of public documentation that is routinely made available. This does not appear to necessarily reflect an agency judgment to actively withhold certain kinds of modeling information, but appears to be more a reflection of the particular approach selected for model documentation. Examples from three agencies are presented in table 6-3.

The EIA public documentation of major models is one of the most extensive of all agencies responding to the OTA Data Request. This is partly attributable to the high visibility of energy modeling over the last decade or so, periodic concerns raised about the quality of EIA energy models and projections, and congressional and statutory requirements. For

Table 6.3.—illustrative Agency Formats for Model Documentation

Economic Research Service (Department of Agriculture)[a]
- Model name
- Responsible person(s)
- Model description
- Model applications
- Operating and updating costs

Joint Chiefs of Staff (Department of Defense)[b]
- Model title
- Model type
- Proponent (who maintains model)
- Developer
- Purpose
- General description
- Date implemented
- Input
- output
- Model limitations
- Hardware
- Software
- Time requirements
- Security classification
- Frequency of use
- Users
- Point of contact
- Miscellaneous
- Keyword listing

Energy Information Administration (Department of Energy)[c]
- Model name
- Acronym
- Abstract
- Status
- Part of another model
- Sponsoring agency, office, division, branch
- Model contact
- Documentation
- Archive tape(s) and installation manual(s)
- Reviews conducted (of model)
- Purpose
- Energy system described by model
- Coverage (e.g., geographic, time unit/frequency)
- Special features
- Modeling features
  - —Model structure
  - —Modeling technique
  - —Model interfaces
  - —Input data
  - —Date sources
  - —Output data
- Computing environment
  - —Language used
  - —Core memory requirements
  - —Estimated cost to run
  - —Special features
- Status of evaluation efforts
- Date of last model update

[a]See U.S. Department of Agriculture, Economics and Statistics Service, *Agriculatural and Other Economic Models of the Economics and Statistics Service,* April 1981 According to USDA personnel, this document is still relatively current, and no update has been scheduled

[b]Joint Chiefs of Staff, Joint Analysis Directorate, "Memorandum for Agencies and Organizations Involved in Wargaming and Military Simulation Model ing," re "Catalog of Wargaming and Military Simulation Models," June 1, 1984

[c]U.S. Department of Energy, Energy Information Administration, *Directory of Energy Information Administration Model Abstracts,* Feb. 1, 1985

example, EIA has a statutory mandate to insure "that adequate documentation for all statistical and forecast reports prepared . . . is made available to the public at the time of publication of such reports."[13] Since many such EIA reports are based on computer models, the models themselves are required to be documented. EIA has issued two orders that specify the format and public availability of model documentation.[14] In addition, in part in response to congressional criticism and outside audits and evaluations, it appears EIA has made significant progress in documenting the 33 major computer models currently in use, of which 24 are so-called basic models.[15] EIA has made extensive use of model evaluations conducted by outside groups, as well as internal reviews.

The EIA and JCS model documentation illustrated above provide considerably more information than the ERS format, since the latter is really a pointer system to help interested parties obtain more detailed information if desired. However, ERS also publishes reports on some of the major models. For example, a report on the ERS "World Grain-Oilseeds-Livestock Model" is 64 pages long and includes a narrative description, illustrations of model equations and linkages, and values of key model parameters.[16] This report is backed up by an even longer technical report also prepared by ERS staff. This suggests that, even if modeling information available through directories or other "public access" mechanisms is limited, more detailed information may be available through technical reports prepared by agency (and/or consultant) staff and also via articles in the published literature. Even the EIA's detailed public documentation is only an "abstract" of more extensive information available from knowledgeable EIA personnel.

As noted above, the agencies that use computer models to support major public information products (e.g., statistical reports on forecasts) generally have established means to make modeling information available. However, other agencies have not explicitly dealt with the access question. Some simply recite the Freedom of Information Act. Others suggest that information would be made available if requested. There may not be a real issue here, except to the extent that modeling and decision support information is considered classified (primarily with respect to military applications) or subject to executive privilege. Public access to models developed by government contractors can also be a problem. The public availability of such information appears to need clarification. Also, the current central access mechanisms (e.g., the National Technical Information Service and the National Energy Software Center) could be reviewed for adequacy and possible modification.

Further Research on the Development and Use of Computer Modeling and Decision Support

Judging from the apparent extensive use of computer models and the positive tone of agency comments, computer models and decision support do have a significant impact on agency decisionmaking. For example, the Antitrust Division of the Department of Justice, and in particular the Economic Policy Office, stated that:

> . . . [t]he data manipulation and sophisticated economic and statistical analyses now used in connection with almost all matters could not be performed without computers. While it is impossible to estimate savings in staff time by using computer support, such savings are clearly large.

[13] Public Law 93-275, Section 57(B)(1) as amended by Public Law 94-385.

[14] See Energy Information Administration Order No. E1591O.3A, "Guidelines and Procedures for Model and Analysis Documentation," Oct. 1, 1982, and Order No. E1591O.4A, "Guidelines and Procedures for the Preparation of Model Archival Packages," Feb. 23, 1982.

[15] See Energy Information Administration, *Directory of Energy Information Administration Model Abstracts*, Feb. 1, 1985; and Professional Audit Review Team, *Performance Evaluation of the Energy Information Administration*, report to the President and Congress, June 15, 1984, which noted significant progress on model documentation but with additional work still needed.

[16] Karen Liu and Vernon O. Roninger, *The World Grain-Oilseeds-Livestock (GOL) Model, A Simplified Version,* ERS Staff Report No. AGE5850128, U.S. Department of Agriculture, Economic Research Service, International Economics Division, February 1985.

Nonetheless, the results of the OTA Federal Agency Data Request suggest that the actual use of models for decisionmaking has received little systematic study by Federal agencies. Very few (about 4 percent) of the agencies using computer models report having conducted or sponsored such studies. Likewise, about 7 percent of agencies using decision support report having conducted or sponsored studies.

Of the few agencies that were able to provide concrete examples of studies, only the Federal Emergency Management Agency (FEMA) documented a clearly relevant study program (being carried out both in-house and with NBS assistance). It is likely that some study programs also exist in other agencies, especially in DOD components, but that the details or even the existence of such studies are unknown to headquarters personnel. The responses of the Army, Navy, and Air Force headquarters noted the decentralized nature of agency operations, which makes it difficult, absent a major data collection effort, to be fully knowledgeable about prior or ongoing studies. On the other hand, neither the Joint Chiefs of Staff nor the Program Analysis and Evaluation Office (in the Office of the Secretary of Defense) indicated any such studies even though these two components make heavy use of computer models. It is possible that such studies may be classified, although no indication to this effect was made to OTA by knowledgeable DOD personnel.

JCS staff state that no such studies are conducted because the substantial value of computer modeling is clear and undisputed and, in any event, evaluation studies would be difficult to do, given the multiple factors that affect JCS decisions. Computer model results are just one input among many.

On the other hand, FEMA has made a major commitment to evaluate its computer models, many of which are intended to support planning for, and decisionmaking under, emergency conditions. For example, in 1982, FEMA prepared a 130-page report of the FEMA Modeling Task Force that outlined a comprehensive plan for review and evaluation of FEMA modeling and analytical activities.[17] In 1984, reports were issued on various FEMA models, including the:

- dynamic general equilibrium model designed to simulate economic conditions before and after an emergency, including nuclear attack, general wartime mobilization, and other severe economic disruptions[18]; and
- damage assessment model designed to estimate the effects of a nuclear attack on various critical resources such as livestock, crops, housing, hospitals, and physicians.[19]

These and other models are then to be evaluated within a framework developed by the Center for Applied Mathematics of NBS under contract to FEMA. The evaluation procedure is intended to, among other things, test the extent to which a model meets user requirements. NBS has identified a wide range of analytical techniques for model evaluation, including:[20]

- descriptive analysis (e.g., motivation of model, theoretical underpinnings, model development);
- program verification and analysis (e.g., review of documentation and source code, model implementation);
- data audit (e.g., review of documentation, analysis of computerized files);
- sensitivity analysis (e.g., error analysis, statistical analysis, model stability); and
- program usability (eg., user-model interface, maintenance and update procedures).

This latest NBS effort for FEMA represents a continuation of and builds on earlier work conducted in part for EIA, and could very well serve as a prototype for other agencies.

[17] Bruce J. Campbell, Task Force Chairman, "FEMA Modeling Task Force Study," FEMA, May 1982.

[18] Richard J. Goettle III and Edward A. Hudson, *Final Report on the Dynamic General Equilibrium Model*, prepared for FEMA under contract FPA 76-9, February 1984.

[19] FEMA, Ready II Damage Estimation System *Advanced Analytical Programs, TM-308*, February 1984.

[20] Robert E. Chapman, Robert G. Hendrickson, Saul I. Gass, and James J. Filliben, *Analytical Techniques for Evaluating Emergency Management Models and Data Bases*, prepared by NBS Center for Applied Mathematics under contract to FE MA, May 1985.

Beyond this, there is a considerable body of research and discussion in the published academic and scholarly literature,[21] popular and trade press,[22] and various research reports, for example, those sponsored by NSF on the use of models and decision analysis in risk assessment.[23] Also, variants of computer modeling and decision analysis are being used in the development of computer-based expert systems and artificial intelligence.

In sum, however, while many agencies believe in the utility of computer modeling and decision analytic techniques, few apparently think that studies are worth the time and resources. Nonetheless, it seems highly unlikely that all agencies are making the best and most cost-effective use of such techniques. A coordinated, modest research program could help illuminate what kinds of techniques and applications are working well and which are not. The results of such research would presumably facilitate the exchange of knowledge about computer modeling and decision support, and lead to improved cost-effectiveness. The results would also be helpful to the development of model guidelines (discussed above).

In addition to encouraging and funding research, other mechanisms for sharing knowledge could be encouraged, such as professional forums for model developers and users (as has been tried in, for example, the energy and water resource modeling areas), and additional training opportunities.

The limited research that is available, primarily academic research on model implementation, suggests that models (and, by extension, other decision analytic techniques) can and do have a significant impact on agency decisionmaking. Models may become a significant element in the process of negotiation over assumptions and options that is an integral part of agency (and, in general, political) decisionmaking. However, models can be misused and abused. It may be important to understand the models and their roles in order to understand the ultimate decision.[24]

From this perspective, then, the results of further research may provide some new insights as to what kinds of questions should be asked and information requested in conducting oversight on agency decisions, and what kinds of techniques might be useful in program evaluations and audits conducted by GAO and others.

GAO and agency program evaluation and audit offices are generally very active and looking for ways to improve evaluation and audit methodologies. Indeed, GAO is required, by the Congressional Budget Act of 1974, to monitor and recommend improvements in program and budget information for congressional use. GAO has, for example, identified needed improvements in DOD's planning, programming, and budgeting system, in the Envi-

[21] For further discussion of the history and techniques of decision analysis, see, for example, R.V. Brown, A.S. Kahr, and C. Peterson, *Decision Analysis for the Manager (New* York: Holt, Rinehart& Winston, 1974): S. Barclay, R.V. Brown, C.W. Kelley, C.R. Peterson, L. D. Philips, and J. Selvidge, *Handbook for Decision Analysis* (McLean, VA: Decisions & Designs, Inc., September 1977); and Strategic Decision Group, *The Principles and Applications of Decision Analysis,* Ronald A. Howard and J.E. Matheson (eds.), 1983. Also see Rex V. Brown, "A Brief Review of Executive Agency Uses," op. cit.; and Rex V. Brown and Jacob W. Ulvila, "Selected Applications of Computer-Aided Decision Analysis and Support, " OTA contractor report prepared by Decision Science Consortium. Inc., May 1985,

[22] See, for example, Michael F. Mitrione, "Integration of Decision Support Systems, " *Military Review,* vol. 64, April 1983, pp. 52-59; Philip N. Sussman, "Evaluating Decision Support Software," *Datamation,* vol. 30, Oct. 15, 1984, pp. 171-172; Bernard C. Reimann and Allan D. Waren, "User-Oriented Criteria for the Selection of DSS So ftware, " *Communications of the ACM,* vol. 28, No.2, February 1985, pp.166-179; and Allan F. Ayers, "Decision Support Systems-New Tool for Manufacturing," *Computerworld,* vol. 19, June 19, 1985, pp. 35-38.

[23] See, for example, Judith D. Bentkover, et al., *Benefits Assessment: The State-of-the-Art,* prepared by Arthur D. Little, Inc. for the National Science Foundation, December 1984; and Miley W. Merkhofer, et. al., *Risk Assessment and Risk Assessment Methods: The State-of-the-Art,* prepared by Charles River Associates, Inc. and Applied Decision Analysis, Inc. for the National Science Foundation, December 1984.

[24] See, for example, Kenneth L. Kraemer, "The Politics of Model Implementation, " *Systems, Objectives, Solutions,* vol. 1, 1981, pp. 161-178; John Leslie King, "Successful Implementation of LargeScale Decision Support Systems: Computerized Models in U.S. Economic Policy Making," *Systems, Objectives, Solutions,* vol. 3, 1983, pp. 183-205; John Leslie King, "Ideology and Use of Large-Scale Decision Support Systems in National Policymaking," *Systems, Objectives, and Solutions,* vol. 4, 1984; William H. Dutton and Kenneth L. Kraemer, *Modeling as Negotiating: The Political Dynamics of Computer Models in the Policy Process (Norwood,* NJ: Ablex, 1985); and Lance N. Antrim, "Computer Models as an Aid to Negotiation: The Experience in the Law of the Sea Conference, " November 1984.

ronmental Protection Agency's cost-benefit analyses of environmental regulations, and in DOD's procedures for estimating weapons system costs.[25] In all these areas, decision analytic techniques have a potential role, especially techniques that combine quantitative and qualitative information, identify ranges of uncertainty, and specify the nature and extent of subjective value judgments to the extent present in the analysis. GAO and other audit agencies could experiment with such decision analytic techniques to ascertain their potential to improve program and budget information for congressional use.

Further Testing and Development of the Decision Conference Technique

Despite the widespread and frequently sophisticated use of computer-based decision support by Federal agencies, the results of this effort appear to be used largely by agency staff or, at the most, presented to agency decisionmakers for consideration along with other inputs. There appear to be relatively few situations where the decisionmakers themselves actively participate in the decision analytic process. OTA located only one agency that has a formal program to do this-the decision conference facility of the Office of Program Planning and Evaluation in the Department of Commerce (DOC).

This DOC decision conference facility is used to bring key staff and decisionmakers together for, typically, 1 or 2 days to work through a real decision problem using whatever computer and analytical tools are appropriate. Decision conference staff do advance work prior to the conference and serve as facilitators, analytical experts, and rapporteurs during the conference. But the primary participants are the decisionmaker(s) and his or her staff. The DOC decision conferences use a wide range of computer-assisted analytical techniques—including spreadsheet software, quantitative, and qualitative judgmental–depending on what is most useful. The DOC facility is about 1 year old.[26] A list of illustrative decision conferences is shown in table 6-4.

OTA found that DOD does not appear to have such a facility, despite the very extensive DOD use of computer-based decision analytic techniques. DOD does have numerous de-

[25] See U.S. General Accounting Office, *Progress in Improving Program and Budget Information for Congressional Use, GAO/PAD-82-47,* Sept. 1, 1982; GAO, The DOD *Planning, Programming, and Budgeting System,* GAO/OACG-84-5, September 1983; GAO, *Cost-Benefit Analysis Can Be Useful in Assessing Environmental Regulations, Despite Limitations,* GAO-RCED-84-62, Apr. 6, 1984; GAO, *DOD Needs To Provide More Credible Weapon Systems Cost Estimates to Congress,* GAO/NSIAD-84-70, May 24, 1984.

[26] For more detailed discussion, see Charles Treat, "Commerce Computer Center Attracts Attention," *Commerce People,* vol. 6, No. 4, April 1985, p. 5; Charles F. Treat, "Modeling and Decision Analysis for Management, " a paper prepared for the Government Computer Expo, June 13, 1985; and William A. Maidens, "Better Data Doesn't Always Mean Better Decisions—Decision Analysis Does, *Government Executive,* November/December 1984, pp. 10, 14.

Table 6-4.—illustrative Decision Conferences Conducted by the Office of Program Planning and Evaluation, U.S. Department of Commerce, 1984-85

1, Development of Program and Budget Priorities for the U.S. National Marine Fisheries Service: (a) FY 1986; (b) FY 1967.
2. Promotion of Tourism to the United States—An Assessment of Alternative Marketing Strategies Available to the Department of Commerce in Six Regional Foreign Markets.
3. Review of Alternative Programs and Service Delivery Strategies for the Minority Business Development Agency.
4. Allocation of Saltonstall/Kennedy Fisheries Development Grant Program Funds— Priority Setting for Grant Applications.
5. Assessment of Alternative Foreign Trade Strategies for Promoting the Export of Auto Parts to Japan.
6. Development and Evaluation of Alternative Staffing Standards for Selected, Governmentwide Administrative Functions (President's Council on Management improvements): (a) Personnel; (b) Procurement; (c) Warehousing.
7. Assessment of Alternative Long-Term Goals, Strategies and Implementation Mechanisms for the Telecommunications, Computer, and Information Programs of the Department of Commerce.
8. Assessment of Alternative Long-Term Strategies for Promoting Technological Innovation and the Transfer of Technology from Federal Laboratories to the Private Sector (Preliminary).
9. Assessment of Alternative Operating Objectives and Resource Allocations for Selected Administrative Activities of the Department of Commerce: a) Personnel and Civil Rights Functions; b) Management and Information Systems Development; c) Financial Assistant Oversight Activities; and d) Regional Administrative Support Operations.
10. Alternative Programmatic Allocation of Field Personnel Resources, Center for Food Safety and Applied Nutrition of the U.S. Food and Drug Administration.

SOURCE Office of Program Planning and Evaluation/Department of Commerce cision analytic support centers throughout the various service branches and commands, but they are at the staff and research levels. For example, the JCS staff conducts extensive studies (inhouse and by contract) using modeling and decision analytic techniques. But the Joint Chiefs themselves do not normally participate, except to the extent of approving the major studies. The results of selected decision analytic studies are presented to the Joint Chiefs when relevant to a decision problem at hand.

The decision conference appears to have substantial potential, but the general consensus among practitioners is that further development and testing are needed prior to widespread application. Moreover, at present few decisionmakers are even aware of the technique, and even fewer have tried it.

One of the keys to a successful decision conference is the direct and full participation of the decisionmakers. In order to have greater use of the technique, decisionmakers need both greater awareness and greater understanding of the technique. Conducting pilot tests in selected programmatic areas, holding a workshop or conference, and commissioning a special report on the subject are actions that could help improve awareness and understanding.

One of the areas thought to be most suited for the decision conference approach is R&D decisionmaking. The National Marine Fisheries Service (NMFS) (DOC) has already used a decision conference for decisions on the R&D budget for fiscal years 1986 and 1987. However, it should be noted that NMFS had been exploring decision analysis for several years, and thus appears to have been favorably predisposed.[27] Decision analytic studies also have been used as significant input to R&D decisions at DOD, although not in the decision conference format adopted at DOC.[28] At DOC, decision conferences have also been conducted on budget, programmatic, and strategic decisions.

The real power of the decision conference technique (or concept) is its potential to bring the full range of computer tools, models, analytical techniques, and the like into focus for the decisionmaker within a framework that is relevant to the decisionmaker. This is a concept that has been visualized and partially developed over the last 20 years or so by numerous researchers and innovators.[29] Table 6-5 places the decision conference in the context of other computer-supported conference room concepts. However, note that different decision conference configurations are possible. For example, DOC, in effect, uses software from the electronic boardroom and information center concepts in addition *to* the software listed under decision conference, and uses the orgware (i.e., organizational data and procedures) from the electronic boardroom and information center *instead* of the orgware listed under decision conference.

Overall, the decision conference concept is quite flexible, and many of the elements of the various concepts shown in table 6-5 are interchangeable. Thus it is perfectly feasible for a computer- or videeconferencing capability, for example, to be added to the decision conference. Indeed, OTA's Federal Agency Data Request revealed that some agencies are already using computer-conferencing, although not as part of decision conferences per se. For example, the U.S. Geological Survey (USGS) makes extensive use of computer-conferencing on such diverse topics as cartography, geoscience, computer hardware and software problems, USGS news releases, and Mount Saint Helens' volcanic activity bulletins.

[27] See Bruce Norman, "What Policy Analysis Can Do For You–A Survey, " NMFS memo to Winfred H. Meibohm, Oct. 13, 1978; and Hoyt A. Wheeland, "NMFS Decision Analysis," NMFS memo to William H. Stevenson, June 16, 1982.

[28] For an illustration of R&D budgeting at the Defense Nuclear Agency, see J.W. Ulvila and J.O. Chinnis, Jr., "Analysis for R&D Resource Management, " *Management of R&D and Engineering,* D.F. Kocaoglu (cd.) (North-Holland: 1985).

[29] Among the many researchers, the following are illustrative (in alphabetical order): Rex Brown, Dennis Buede, William Dutton, Kenneth Kraemer, John King, Starr Roxanne Hiltz, Lee Merkhofer, Thomas Sheridan, and Murray Turoff. For a good review and extensive references, see Kenneth L. Kraemer and John L. King, "Computer Supported Conference Rooms: Final Report of a State of the Art Study, " December 1983, presented as a paper under the title "Computer-Based Systems for Group Decision Support" at the Academy of Management Annual Conference, Aug. 15, 1984.

Table 6-5.—Comparison of Computer-Supported Conference Room Concepts

Electronic boardroom: Computer and audiovisuals

Teleconferencing facility: Computer and communications

information center: Computer, databases, and software tools

Decision conference: Computer and models

Element	Electronic boardroom	Teleconference facility	Information center	Decision conference
Hardware. . . .	Conference room; audiovisuals; graphic displays; computer	Conference room; audiovisuals; audio, computer, or video telecommunication controller	Conference room; large-screen video projector; computer; display terminals	Conference room; large-screen video projector; display terminals; voting terminals
Software	Interactive graphics	Communications	Database management software; statistical packages; retrieval, graphics, and text processing software	Decision analysis software; modeling software; voting tally and display software
Orgware. . .	Audiovisuals; corporate reports; standard meeting protocols	Audiovisuals; teleconference protocols	Corporate and other databases; standard meeting protocols; standard meetings (e.g., annual report, market forecast)	Democratic decisionmaking protocols (e.g., one person one vote; all major interests represented; majority opinion rules)
People .	Participants; audiovisual technician	Participants (in two or more locations); teleconference facilitator	Participants; computer specialists; modeling specialists	Participants; decision analysts; group process facilitators
Examples .	Not available, Custom-tailored for each site although some "modular" audiovisual rooms exist	Picturephone Meeting Service; Participate	HOBO System; SYSTEM W; EIS, Express, XSIM	Group Decision Aid; Decision Conferences of DDI and SUNY, Albany

SOURCE Kenneth L. Kraemer and John L King, "Computer-Supported Conference Rooms Final Report of a State of the Art Study, " December 1983, pp 8, 10

Another variation on the decision conference concept is known as "interactive management, " and is intended to deal with three principal functions of managers: 1) intelligence (finding and clarifying problems), z) design (generating or conceptualizing new or improved alternative solutions), and 3) choice (selecting the preferred solution) .30 Like other decision conference concepts, the interactive management approach utilizes a "situation room" with appropriate audiovisual and computer support. What distinguishes interactive management is the explicit focus on intelligence, design, and choice, and the use of a specific set of methodologies to structure ideas, design alternatives, and analyze trade-offs.[31] Several Federal agencies have utilized the interactive management decision approach, including the Forest Service and Agricultural Research Service (Department of Agriculture); National Marine Fisheries Service (DOC); and Food and Drug Administration (Department of Health and Human Services) .32

In sum, Kraemer and King's 1983 prognosis that computer-supported conference techniques are "likely to grow at a slow pace over the next 2 years, and pickup a bit thereafter"[33] may be coming true. It is now over 2 years later, and the decision conference technique (sometimes also known under the rubric of group decision support systems [GDSS] or strategic planning decision support systems [SPDSS]) is now considered to be at the cutting edge of computer-based decision analysis.[34]

' Alexander N, Christakis and David B. Keever, "An Overview of Interactive Management, Center for Interactive Management, George Mason University, Fairfax, VA, 1984.

II Ibid.

[32] See *CIM News*, fall 1985; and Alexander N. Christakis, "The National Forum on Nonindustrial Private Forest Lands, " *Systems Research*, vol. 2, No. 3, pp. 189-199.

[33] Kraemer and King, "Conference Rooms,"' op. cit., p. 7.

[34] At the November 1985 meeting of ORSA/TIM, experts such as Warren Walker, Rand Corp.; Paul Gray, Clarement Graduate School; George Huber, University of Texas at Austin: and Shao-ju Lee, California State University at Northridge agreed on the need to develop and implement a GDSS or SPDSS concept as the state-of-the-art in DSS. Also see Bernard C. Reimann, "Decision Support Systems: Strategic Management Tools for the Eighties, " *Business Horizons*, September-October 1985, pp. 71-77. Also see Fred B. Wood, "Prospects for General Systems Decision Support Centers in the Federal Governmerit, " paper prepared for the Annual Meeting of the Society for General Systems Research, Philadelphia, PA, May 1986.

DECISION SUPPORT AND GOVERNMENT FORESIGHT

Foresight can be properly viewed as part of decision support. In the context of the Federal Government, foresight typically refers to the ability of individual Federal agencies and the government collectively to monitor, anticipate, and analyze key longer term trends and their implications for public policy and programs. One objective of foresight is to help government decisionmakers better understand and consider longer term trends and implications when making decisions.

The major foresight sectors can be viewed as spanning the entire range of Federal Government programs and activities, including, for example: energy, environment, water, climate, food, population, transportation, housing, education, the economy, foreign trade, and national security. Not all techniques are equally applicable to all foresight sectors. Thus, for example, remote-sensing satellites are most applicable to the environmental and natural resources (e.g., including food, water, climate, land use) sectors of foresight. Large-scale modeling is most applicable to those sectors, such as energy and climate, where key variables and relationships can be quantified and where substantial input data are available. On the other hand, some decision analytic techniques (e.g., the decision conferences discussed earlier) are applicable to both quantitative and qualitative, observational and judgmental information, and thus are relevant to many, if not all, foresight sectors.

Information technology-including data collection, archiving, and transfer, as well as modeling and analytic techniques-now makes improved foresight possible. This potential is being facilitated by advances in:

- technical monitoring capability (e.g., through remote-sensing satellites, advanced data communication networks, and computerized data centers);
- computational and analytical capability (e.g., through the entire range of computer tools, from microcomputers to supercomputers, related software, and the procedures necessary for documenting and validating models); and
- the scientific and technical knowledge base in the wide range of disciplines that bear on foresight.

Realization of the potential for improved foresight appears to require: 1) a synthesis of technical advances that are here now or close at hand, 2) an integration of relevant information, and 3) institutional mechanisms that work across agency and disciplinary lines. Each of these is considered below.

Technical Advances

Relevant technical advances include microcomputers, supercomputers, remote-sensing systems, computerized databases, a wide range of software, and model evaluation procedures. Remote-sensing satellites and model evaluation are discussed here. Various applications of microcomputers, supercomputers, and related software were discussed under decision support. Techniques used to integrate information are discussed in a later section.

Remote Sensing

The advent of remote-sensing satellites has revolutionized the collection of data on many variables relevant especially to the natural resources and environmental aspects of foresight. Satellites provide far more extensive Earth coverage than could possibly be achieved through other means, especially for oceans and remote land areas. In addition, these satellites can receive, process, and retransmit data from radiosondes, ships, ocean buoys, and remote land-based automatic stations.

There are two basic types of environmental satellites: polar orbiting (or sun-synchronous) and geostationary (or geosynchronous). The polar orbiting satellites provide coverage of the entire Earth several times per day. The geostationary satellites cover only a portion of the Earth's surface, but coverage is continuous since the geostationary satellites maintain a constant orbital position relative to the Earth's surface. Illustrative kinds of data currently collected by remote-sensing satellites include:[35]

- cloud and snow mapping;
- volcanic eruptions and forest fires;
- urban sprawl;
- specific types of land cover (e.g., trees, crops, grassland);
- geologic fault lines;
- ice mapping (i.e., sea ice, mountain glaciers, ice sheets, ice shelves);
- changes in margins of glaciers (e.g., retreats and advances);
- surface temperature and weather (land and sea);
- cataclysmic weather events (e.g., hurricanes, severe storms);
- atmospheric and oceanic circulation patterns; and
- atmospheric temperature profiles and water content.

More advanced satellites are planned for the future, satellites that will observe all major aspects of the Earth system even more completely. As an illustration, NASA has developed the concept of the Earth-observing system, a future generation satellite that would build on learning from the current generation of operational satellites. Table 6-6 lists the types of parameters on which data would be collected and the types of applications. This list also represents the data needed for a unified approach to earth science, based, in NASA's words, "upon the view that the physical, chemical, and biological processes at work on Earth comprise a coupled global system. "[36] Many of these parameters are relevant to foresight.

The volume of remote-sensing data relevant to foresight is truly staggering, especially when viewed on a global scale; and yet, the volume of data increases substantially every year, reflecting the high level of observational activity. The only answer to this data challenge is heavy use of computerized data centers and sophisticated data management, with data stored and disseminated in electronic form wherever possible. This is, indeed, the strategy followed over the last 10 years, to the point where the data archiving system now could not survive without information technology.[37]

Model Evaluation

Another example of a key technical advance important to foresight is model evaluation. Knowledge about how to improve computer modeling—through appropriate documentation, verification, and validation-could be systematically applied to at least the major models relevant to foresight.

Models are, by definition, abstractions of reality. For very complex systems, it is unlikely that a perfect model can or should be developed. A certain range of uncertainty is usually acceptable. However, to the extent decisionmakers use the results of models, they need to have confidence in the models. Confidence does not mean that the results are always 100 percent accurate. Confidence means that the decisionmaker (or other user) knows the strengths and limitations of the model, the applicability of the model for a particular decision, the sensitivity of the model to changes in key assumptions and in the model structure, and the range of uncertainty of model results .38

For large, complex models, such as many of those used in modeling relevant to foresight

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service, IVESDIS Programs: *NOAA Satellite Operations,* March 1985, pp. 16, 70; also see section on Landsat, pp. 206-237.

[36] U.S. National Aeronautics and Space Administration, Goddard Space Flight Center, *Earth Observing System: Science and Mission Requirements Working Group Report,* vol. 2, August 1984, pp. 1, 9.

[37] For example, NOAA maintains three major computerized data centers that archive remote sensing (and many other kinds of) data: the National Climate Data Center in Asheville, NC; National Oceanographic Data Center in Washington, DC; and National Geophysical Data Center in Boulder, CO. All provide data variously in paper, microfiche, microfilm, photographic, computer tape, computer printout, and digital data form.

[38] Saul I. Gass and Lambert S. Joel, "Concepts of Model Con fidence, " *Computer and Operations Research,* vol. 8, No. 4, 1981, pp. 341-346.

Table 6-6.—Earth-Observing Data Parameters and Applications

Parameter	Application
Soil features:	
• Moisture	Hydrologic and geochemical cycles
—Surface	
—Root Zone	
• Types-areal extent (peat, wetlands)	Geochemical cycles
• Texture-color	Agricultural and forestry
• Erosion	Agriculture and forestry
• Elemental storage	Geochemical cycles
—Carbon	Geochemical cycles
—Nitrogen	
• Permafrost	Geochemical
Surface temperature:	
• Land	Primary production, soil moisture and respiration
• Inland waters	Mass/energy flux
• Ocean	Mass/energy flux
. Ice	Mass/energy flux
Vegetation:	
• Identification	Hydrologic cycle, biomass distributions and change, primary production, plant productivity, respiration, nutrient cycling, trace gas, source sinks, vegetation-climate interaction, microclimate
• Areal extent	
• Condition (stress, morphology, phytomass)	
• Leaf area index canopy structure and density	
Clouds:	
• Cover	Radiation balance, weather forecasting, hydrologic cycle, climatologic processes, tropospheric chemistry
• Top height	
• Emission temperature	
• Albedo	
• Water content	
Water vapor	Weather forecasting, hydrologic cycle, climatologic processes
Snow:	
• A real extent	Hydrologic cycle
• Thickness	Water equivalent
Radiation:	
• Shortwave	Surface energy budget
• Longwave	Surface energy budget
• Short and long wave	Hydrologic cycle
Precipitation	Hydrologic cycle Climatologic cycle
Evapotranspiration	Hydrologic cycle
Runoff	Hydrologic cycle
Wetland areal extent	Hydrologic cycle Biogeochemical cycle
Phytoplankton:	Biogeochemical cycles
• Chlorophyll	
Open ocean/coastal	
Ocean/inland waters	
• Fluorescence	
Open ocean/coastal	
Ocean/inland waters	
. Pigment groups	
Open ocean/coastal	
Ocean/inland waters	
Turbidity:	Biogeochemical cycles erosion assessment
• Inland water/coastal ocean	
Bioluminescence	Ecological processes
Surface elevation:	
• Land	Continental tectonics and surface processes Interpretation and modeling of gravity and magnetic field data
• Ocean	Circulation
• Inland ice	Hydrologic cycle
Wave:	
. Height	Air-sea interactions
• Spectrum	
Inland ice:	
• Thickness	Ice dynamics
• Velocity field	Ice dynamics
. Mass balance temperature	Ice dynamics, hydrologic cycle, climate
Sea Ice:	
• Areal extent	Hydrologic cycle
• Concentrate ion	Oceanic processes
• Sea ice dynamics	Climatological processes
Atmospheric constituents: (Ozone and compounds of carbon, nitrogen, hydrogen, chlorine, sulfur, etc.)	Tropospheric chemistry Middle atmosphere Upper atmosphere
Aerosols	Tropospheric chemistry Stratospheric chemistry
Temperature	Troposphere Middle atmosphere Upper atmosphere
Winds	Troposphere Middle atmosphere Upper atmosphere Surface
Lightning: (number of flashes, cloud to cloud, cloud to ground)	Tropospheric chemistry Atmospheric electricity
Emission features	Upper atmosphere
Electric fields	Global electric circuit
Rock unit mineralogy	Continental rock types Continental soil and rock types and distribution
Surface structure	Tectonic history
Gravity field	Mantle convection, oceanic lithosphere, continental lithosphere, sedimentary basins, passive margins, etc.
Surface stress	Weather forecasting, climate processes, oceanography
Oceanic geoid	Mantle convection, oceanic lithosphere
Magnetic field	Crust and upper mantle, composition and structure, lithospheric thermal structure, secular variation of main field (core problem), upper mantle conductivity
Plate motion	Plate tectonic theory, fault motion

SOURCE: NASA, Earth Observing System, August 1964, pp. 16-19 (e.g., in energy, agriculture, climate, population, and transportation), developing a high degree of confidence is difficult. Frequently, the models are too complex to depend on guesswork or back-of-the-envelope evaluations. But a formal evaluation or assessment program costs time and money, and may be seen as a drain on resources needed for the modeling activity itself.

Nonetheless, there is now at least 10 years of work and research suggesting that a well-developed model evaluation program can help not only to increase decisionmaker (or user) confidence in the model, but also to actually facilitate the development of better models and better communication among modelers.[39] Such a program also could help overcome some of the problems that confronted the *Global 2000* study–inconsistent assumptions about key variables, omission of key variables, lack of clear model documentation, weak or inconsistent model validation, lack of analyses of model sensitivity to exogenous variables, omission of key feedback loops, and inconsistent input data.[40]

Because foresight by definition deals with the future, and because controlled global or hemispheric, or even national, experiments are rarely feasible, modeling is a critical tool of foresight. But even though the computer technologies and databases for modeling have improved substantially in recent years, most opportunities to improve the model evaluation process have not as yet been realized.

Prior research has reviewed many of the model evaluation frameworks proposed over the years. The results of a review conducted by Oak Ridge National Laboratory (ORNL) (DOE) found that evaluation elements could be grouped under the categories of model documentation, verification, validation, and usability. In reaching this finding, ORNL reviewed the work of the Massachusetts Institute of Technology (MIT) Energy Modeling Laboratory, Texas Energy Advisory Council, GAO, Professional Audit Review Team (mandated by Congress to review DOE's energy data collection and analysis, including models), Dr. Saul I. Gass (frequent consultant to NBS), and ORNL's own evaluation technology.[41]

Model evaluation is an activity that can be carried out by the modelers themselves, by model users, by model analysts or auditors, and/or by some combination. From the modeler's perspective, model evaluation is a natural component of the modeling process and may involve spontaneous peer review or more organized modeling groups, meetings, and workshops. On a more formal basis, model evaluation may involve modeling standards or guidelines, formal user reviews or consultant studies, modeling laboratories, and outside audits.[42] An MIT approach to evaluation of energy models is shown in figure 6-1, and could have general applicability to foresight-related models.[43]

Aspects of the evaluation process for DOE energy models were discussed previously (see table 6-3 and related text). DOE has also funded an evaluation of the major climate models (primarily large-scale general circulation models run on supercomputers) used to

[39] See U.S. General Accounting Office, *Ways To Improve Management of Federally Funded Computerized Models,* Aug. 23, 1976; *Models and Their Role in GAO,* October 1978: *Guidelines for Model Evaluation,* January 1979; U.S. Department of Commerce, National Bureau of Standards, *Utility and Use of Large-Scale Mathematical) Models,* Saul I. Gass (cd.), May 1979; *Validation and Assessment of Energy Models,* Saul I. Gass (cd.), October 1981: Also see U.S. Congress, Office of Technology Assessment, *Use of Models for Water Resources Management, Planning, and Policy, OTA-O-159* (Washington, DC: U.S. Government Printing Office, August 1982). Also see U.S. Council on Environmental Quality and U.S. Department of State, *The Global 2000 Report to the President: The Technical Report—Volume Two* (Washington, DC: U.S. Government Printing Office, 1980): U.S. Congress, Office of Technology Assessment, *Global Models, World Futures, and Public Policy* (Washington, DC: U.S. Government Printing Office, April 1982); and Donella Meadows, John Richardson, and Gerhart Bruckman, *Groping in the Dark: The First Decade of Global Modeling (New* York: John Wiley & Sons, 1982).

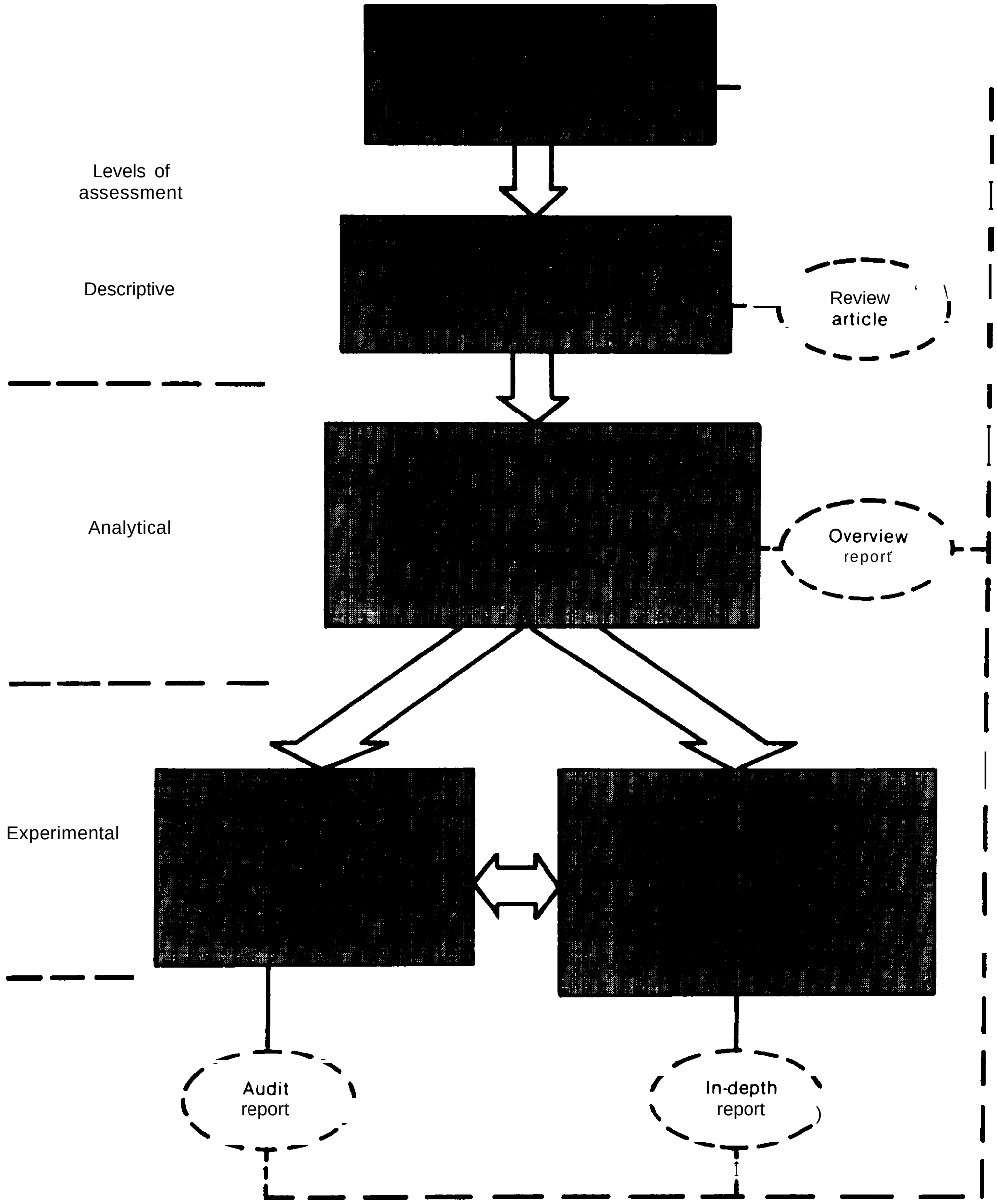
[40] *Global 2000,* ibid., esp. ch.14, pp. 453-499.

[41] C. R. Weisbein, R.W. Peele, and A.S. Loebl, ''An Approach To Evaluating Energy-Economy Models, " *Energy, vol.* 6, No. 10, 1981, pp. 999-1027.

[42] Martin Greenberger and Richard Richels, ''Assessing Energy Policy Models: Current State and Future Direction s," *Annual Review of Energy,* vol. 4, 1979, pp. 467-500.

[43] See D.T. Kresge, "An Approach to Independent Model Assessment, " *Validation and Assessment Issues of Energy Models Workshop,* National Bureau of Standards, NBS SP 569, 1980.

Figure 6-1.—An Approach to Evaluating Energy (and Other) Models



SOURCE D T. Kresge, reprinted in C R Weisbein, R.W. Peele, and A S Loebl, "An Approach To Evaluating Energy-Economy Models," ***Energy, vol.*** 6, No 10, 1981 simulate the effects of increasing atmospheric carbon dioxide.

The results of this evaluation illustrate several general points that appear to be applicable to most or all foresight-related models:

- there are many ways in which model results can be interpreted or misinterpreted;
- even the large, relatively well funded and heavily researched models are Likely to have significant limitations in model variables, structure, and data;
- direct comparison of model variables, structure, and input data can help improve understanding of similarities and differences, strengths and weaknesses of model results;
- a model evaluation process can facilitate communication among researchers, especially where the models involve several different disciplines (which is typically the case with foresight-related models); and
- model evaluation techniques are sufficiently mature for application to even the most complex models.

Thus, by way of illustration, Professor Michael E. Schlesinger of Oregon State University, who conducted the recently completed DOE evaluation, found that:

> . . . the [climate] models might agree extensively in their simulated CO_2-induced climatic changes and yet be all wrong, and the models might simulate the present climate perfectly and yet be wrong in their simulated CO_2-induced climatic change."

Dr. Schlesinger concluded that, although the latest general circulation model results show considerable agreement with respect to simulated global mean surface temperature change, there are substantial disagreements as to the geographical distribution of these changes. The differences in model results and the known model weaknesses (including use of questionable assumptions about key variables) mean that "not all of these simulations can be correct, but all could be wrong. "[45]

Comparison of the structures and assumptions of the various climate models has shown some significant differences. While the major climate modeling centers continually work to improve their models, a formal program of model intercomparison and sensitivity studies is only just beginning. In 1984, an intercomparison was conducted of the ways in which radiative processes are incorporated into general circulation models.[46] The participants reportedly found this to be a very useful activity, which could be extended to other key areas of uncertainty, such as clouds, ocean coupling, sea ice, surface albedos (including snow, ice, land, vegetation), transient (as opposed to steady state) response, and atmospheric turbidity (e.g., from volcanic eruptions and air pollution) .47

This approach appears to have potential for all foresight-related models, regardless of the focus of modeling, whether it be energy, environment, food, population, climate, or international trade. A key evaluation question is whether there are plausible changes in model processes and variables and/or the addition of new processes and variables that could substantially affect the model results, and also whether the range of uncertainty is small enough such that significant effects are highly probable under any plausible scenario.

Relevant Information

In addition to the technologies illustrated above (remote sensing and model evaluation) and those discussed previously, improved foresight requires relevant information presented in an integrated format. Information needs to be relevant and integrated in order to focus

[44] Michael E. Schlesinger, Oregon State University, letter to Fred B. Wood of OTA, Aug. 28, 1985.

[45] See Michael E. Schlesinger and John F.B. Mitchell, "Model Projections of Equilibrium Climatic Response to Increase CO_2 Concentration, " U.S. Department of Energy state-of-the-art paper, in press; also see Michael E. Schlesinger, "Atmospheric General Circulation Model Simulations of the Modern Antarctic Climate, *Environment of West Antarctica: Potential CO_2-Induced Change,* Polar Research Board, National Research Council (Washington, DC: National Academy Press, 1984), pp. 155-196.

[46] See F.M. Luther, *The Intercomparison of Radiation Codes in Climatic Models (lCRCCM): Longwave Clear-Sky Calculations, WCP-93,* World Climate Programme, 1984; also see U.S. Department of Energy, Carbon Dioxide Information Center, "Radiation Codes in Climate Models-A Comparative Study, " *CDIC Communications,* spring 1985, p. 1.

[47] R.E. Dickinson, "How Will Climate Change: The Climate System and Modelling of Future Climate, " ch. 5, B. Bolin (cd.) (Chichester, West Sussex: John Wiley& Sons, Ltd., in press).

on those trends and relationships that are critical to the major foresight sectors (e.g., food, water, energy, climate, housing, population, environment, employment, economic development, and transportation) and the important relationships between sectors.

In the Federal Government, sources of relevant information include all cabinet departments and many independent agencies. For example, the *Global 2000* study was based largely on data and analyses from the U.S. Departments of Agriculture; Commerce (Bureau of the Census, National Oceanic and Atmospheric Administration); Energy (E IA, Brookhaven National Laboratory); Interior (including USGS, Bureau of Mines); and State (including the Agency for International Development), the Environmental Protection Agency, and some outside groups (e.g., the World Bank for world gross national product projections)." The *Global 2000* study would not have been possible without the already existing activities relevant to government foresight of key trends. Likewise, the Joint Chiefs of Staff global "Forecast" model (discussed later) is dependent on a wide range of national and international data sources.

The results of the OTA Federal Agency Data Request used in this study indicate that all cabinet level agencies and many independent agencies use some computer models and maintain some databases that appear, at least on paper, to be relevant to foresight, although such activities are rarely, if ever, explicitly labeled "foresight."" In addition, many agencies are quite active in the international arena with numerous bilateral agreements and treaties that frequently provide for the exchange of information—information that is likely to be relevant to government foresight. The subject areas of such agreements and treaties span the spectrum from agriculture, earth sciences, and oceanography to forestry, water, climatology, and environment.[50] There are also numerous nongovernmental sources" of foresight information.

A major foresight challenge is sorting out the information most important to monitoring and analyzing key trends and their implications. Three relatively recent developments have made this somewhat easier:

1. the maturation of systems science for analysis of complex trends and issues relevant to foresight;
2. the availability of data integration and graphics display equipment that can present and manipulate multiple databases quickly and concisely; and
3. the maturation of analytical and decision support techniques that can help synthesize both quantitative and qualitative information—including ranges of uncertainty-into a format that is usable by decisionmakers.

Systems Science

Numerous systems researchers-such as Ludwig von Bertallanfy, Karl Deutsch, Stafford Beer, Ervin Laszlo, Geoffrey Vickers, and Richard Ericson–have articulated the potential of systems and cybernetics (communications and control) concepts to improve the decisionmaking processes and "steering" mechanisms of government.[51] A common goal has been to design a system (or systems) that brings key information to the attention of decisionmakers, and helps structure and analyze

[48] *Global 2000, Volume Two,* op. cit., pp. 484-499.

[49] See illustrations of computer modeling and decision support presented earlier in this chapter; also see ch. 7 discussion and illustrations of agency databases.

[50] U.S. Department of State, "U.S. Government Participation in International Treaties, Agreements, Organizations, and Programs in the Fields of Environment, Natural Resources, and Population, " an inventory prepared at the request of the Federal Interagency Global Issues Work Group, January 1984, pp. B-1 to B-12 and pp. E-2 to E-6.

[51] See, for example, Ludwig von Bertallanfy, *General Systems Theory: Foundations, Development, Applications* (New York: Braziller, 1968); Karl W. Deutsch, *The Nerves of Government: Models of Political Communication and Control* (New York: MacMillan/Free Press, 1963); Stafford Beer, *Decision and Control: The Meaning of Operational Research and Management Cybernetics* (New York: Wiley, 1966); Ervin Laszlo, *A Strategy for the Future* (New York: Braziller); Geoffrey Vickers, *Making Institutions Work* (New York: Wiley, 1973); and Richard F. Ericson, "Thinking and Management Values in the Microchip Era: An Action Agenda for Institutional Transformation," *Systems Research 2* (vol. 1), 1985, pp. 29-32.

that information so as to facilitate better understanding of the complexities and interrelationships among significant variables.

Systems science is applicable to all foresight sectors, and especially those that are characterized by complex feedbacks and interactions among variables or components. For example, in 1982, James G. Miller wrote that:

> Subsystems of the Earth system consist of sets of interacting components, each such set concerned with particular processes. Because of interactions, including feedbacks among subsystems, changes in one part of the system may have effects throughout the whole system.[52]

Indeed, research results from specific disciplines (e.g., in such fields as geology, oceanography, glaciology, atmospheric sciences, and paleoclimatology) are being published at a rapid rate and are shedding new light on various aspects of the Earth system. These research directions appear to be converging on the need to better monitor and understand the Earth as an interactive system involving the atmosphere, oceans, glacial and volcanic cycles, land mass, and biota (plants, forests, animals, etc.).53 The Earth systems approach can serve as an important foresight methodology.

The significance of this convergence of technology (e.g., remote sensing and computers) with the scientific research enterprise is now well recognized, and cited as one of the rationales for such new initiatives as the Global Habitability Program and International Geosphere-Biosphere Program.[54] In the words of NASA's Dr. Burton I. Edelson, in a *Science* editorial:[55]

> Modern technology has given us the tools of measurement and of computation to study the earth as a system. We can now gain comprehensive knowledge, not only of the state of the earth system and of global processes, but also of changes in state and processes. We have become uncomfortably aware that changes are indeed taking place, and we know that our own species is responsible for some of the changes.

Data Integration and Display

Fortunately, computer graphics and data management equipment that can integrate and display large amounts of data are now available. There are many products under development or on the market. As one example, NASA has developed a comprehensive data management and analysis system, known as the Pilot Climate Data System (a related version is called the Pilot Ocean Data System), that has broad applicability to a wide range of variables relevant to foresight and could serve as a key component of a state-of-the-art "global foresight data display. "[56] While the pilot system includes primarily atmospheric and oceanographic databases, the system concept could be easily extended to cover other foresight-related databases.

The system is run on a mainframe computer with user-friendly, menu-driven software. The system has an on-line catalog of all available data, an on-line inventory of data sets available, a data manipulation subsystem (including the capability for statistical evaluation and merging, averaging, etc., of data sets), and a state-of-the-art graphics subsystem (including two- and three-dimensional color).

Another example is the Decision Information Display System (also developed with NASA support) that was designed to integrate and display selected domestic and international data, statistics, and trends in a geographic format. This system has been used on occasion by some staff of both the Carter and Reagan White Houses.[57] This *system also*

[52] James Grier Miller and Jessie L. Miller, "The Earth as a System, " Behavioral Science, October 1982, p. 310. Also see J.E. Lovelock, *GAIA: A New Look at Life on Earth* (Oxford: Oxford University Press, 1979).

See, for example, Norman Myers, *GAIA: An Atlas of Planet Management,* (Garden City, NY: Anchor Books, 1984); Owen B. Toon and Steve Olson, "The Warm Earth, " *Science 85,* October 1985, pp. 50-57.

[54] M. Mitchell Waldrop, "An Inquiry Into the State of the Earth: Technology Is Making It Possible To Study the Earth as an Integrated System; Problems Like Ozone and Acid Rain are Making It Imperative, " *Science,* Oct. *5, 1984,* pp. 33-35.

[55] Burton I. Edelson, "Mission to Planet Earth" (editorial), *Science,* Jan. 25, 1985.

'National Aeronautics and Space Administration, *Pilot Ch"-mate Data System*, undated brochure, pp. 1-8.

[57] Ronald H. Hinckley, "Information Systems for Elite Decision-making: The White House, " paper presented at the 1985

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could be extended to include a broad range of foresight-related data, statistics, and trends.

A further illustration is the Crisis Management Center (CMC) operated by the White House National Security Council. CMC includes a conference room with state-of-the-art audio-visual and graphics technology, multidimensional charts, and the capability to quickly convert textual material into statistical tables and graphics.[58] Robert C. McFarlane, former National Security Advisor to the President, described CMC as providing staff support for crisis decisionmaking:

> The center conducts pre-crisis collection and analysis of information about likely areas in an effort to anticipate events and to provide extensive background to decisionmakers as a crisis preventive. The center also provides analytical capabilities that can be drawn upon during a crisis. ..59

A final example is the "Forecasts" global model developed for the Joint Chiefs of Staff in DOD. "Forecasts" is basically an outgrowth of previous global modeling efforts, especially the World Integrated Model and Global Macro-Dynamic Model, and was recently updated at a cost of about $1.2 million. The model integrates trend data in key areas, such as agriculture (e.g., yield, land under cultivation, exports, imports for various crops), soils (arable, non-arable), water resources (surface, ground), energy sources (e.g., fossil fuel, hydro, wood), population, transportation, and the domestic economy. The model includes the following major sectors and categories:[60]

- geographic characteristics (e.g., land area, access to sea, and infrastructure such as roads, rail lines, airports, and waterways);
- natural resources (e.g., strategic non-fuel, fuel minerals, other energy sources, soils, and water resources);
- human resources (e.g., population by sex and urban v. rural birth, death, and growth rates, literacy, and median income);
- human resources (e.g., population by sex and urban v. rural, birth, death, and growth rates, literacy, and median income);
- human services (e.g., health, medical care, nutrition, housing, education, and social programs);
- industrial (e.g., agriculture, including grains, non-grains, industrial crops, livestock, and fish; manufacturing, including durable and non-durable goods, electric power, communication, and construction);
- economic variables (e.g., gross national product, balance of payments, and allocation of government expenditures);
- political attributes (e.g., type of government, philosophy, stability, and political parties); and

The data are aggregated by country and region, and the model is capable of monitoring key trends and forecasting these trends based on trend extrapolation and relatively simple relationships between variables. The model does not include all important variables and does not incorporate many important dynamics. For example, the model excludes most climatic trends (the exceptions being mean annual temperature and precipitation) and climate dynamics.[61] Thus, the model is quite limited in its ability to relate climatic changes and trends to, for example, trends in energy consumption, arable land acreage, global food markets, and the incidence of famine. Nonetheless, "Forecasts" is one of the most complete (and probably among the most heavily funded) approaches to integrating foresight information in the Federal Government.

All of these approaches could have a useful role in government foresight across the board, not just in NASA research laboratories, the

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Annual Meeting of the American Political Science Association, New Orleans, pp. 7, 9; also see Edward K. Zimmerman, "The Evolution of the Domestic Information Display System: Toward a Government Public Information Network, " *Review of Public Data Use*, June 1980, pp. 69-81; and Richard S. Beal, "The Transformation to Informatics, " a plenary address presented at the May 1981 National Computer Conference, Chicago.

58 Hinckley, "Information Systems, " op. cit., p. 12.

59 Ibid., pp. 11-12; also see Robert C. McFarlane, Richard Saunders, and Thomas C. Shun, "The National Security Council: Organization for Policy Making, " *The Presidency and National Security Policy*, Gordon R. Hoxie (ed.)(New York: Center for the Study of the Presidency, 1984), pp. 261-273.

60 See U.S. Department of Defense, Joint Chiefs of Staff, "Forecasts Overview, " undated; and Patricia G. Strauch, "The FORECASTS System–U.S. Global Model, " *Futures*, October 1984, pp. 564-566.

61 Joint Chiefs of Staff, "Forecasts,'" op. cit.

White House, or Joint Chiefs of Staff. However, these approaches still fall short of the fully integrative capability needed in foresight and, more generally, high-level decisionmaking, of which foresight is a key component.

Advanced Decision Support Techniques

Electronic databases, computer models, and the like are helpful and necessary, but not sufficient by themselves for high-level decision support and foresight. The central functions of foresight (and decision support generally) are to:

1. help decisionmakers integrate information relevant to decisions at hand;
2. broaden the perspective and improve the understanding of decisionmakers vis-a-vis the direct and indirect factors that may affect or be affected by a decision; and
3. alert decisionmakers to the strengths, weaknesses, risks, and uncertainties in the information and analyses relevant to a particular problem or decision area.[62]

This is obviously a difficult challenge, and one that, in the opinion of many who have served or conducted research in top-level government policy offices, has not received adequate attention, For example, Dr. Ronald Hinckley, a political scientist who has served on the National Security Council Staff, has concluded that:[63]

> The decisionmaking process in the White House is driven by an incomplete information support system. There is an abundance of information transfer (communications) technology, a heavy emphasis on information management (office automation) technology, but insufficient information integration (synthesis and conceptualization) technology. . . The dilemma is that while the President simply cannot have enough information, he and his top advisors often get too much of it because of lack of integration.

Another White House staffer has described the information integration problem in these terms:[64]

> We spend billions and billions of dollars to collect information to get it from the field to an analyst in the bowels of the bureaucracy. , . But having spent a lot of money to sustain an information collection, dissemination, and analysis process, we spend virtually nothing on direct support to a senior-level policy maker. . . We have very few analytic tools for the very high-level people.

In the view of Dr. Hinckley:

> . . . [t]he answer is probably not significantly more computing power; we basically have enough to bring our knowledge base up to par with the technological base.[65]

Part of the answer to improving foresight and decisionmaking may be the decision conference concept. Of all the decision analytic techniques reviewed earlier in this chapter, the decision conference concept stands out because of its potential to integrate data, information, and analyses relevant to a specific decision or problem in a context that is relevant to the decisionmaker(s) and with the full participation of both the decisionmaker(s) and staff (experts, analysts, etc.). In contrast, most decision analytic techniques and computer models are used by individual or groups of analysts, researchers, and scientists, and usually only the results, if anything, ever reach the decisionmaker. Even then, results typically must permeate several institutional layers. The decisionmakers are not actively engaged in the use of decision analytic tools and models.

The decision conference technique is intended to help the decisionmaker make better, more informed decisions and to make those decisions with better foresight. As discussed previously, DOC is the only Federal agency known to have a decision conference facility. The director of that facility reports favorable results from the relatively few decision conferences conducted to date, but no formal evaluations

[62] See, for example, Lindsey Grant, *Thinking Ahead: Foresight in the Political Process* (Washington, DC: The Environmental Fund, 1983); and Joseph F. Coates, "Foresight in Federal Government Policymaking, *Futures Research Quarterly*, summer 1985, pp. 29-53.

[63] Hinckley, " Information Systems, " op. cit., p. 7.

[64] Richard S. Beal, National Security Council official, quoted in Hinckley, ibid., p. 6.

[65] Ibid., p. 15.

have been conducted. The basic idea is to help the decisionmaker and his or her staff work through a decision problem in a reasonably structured way so that options and implications can be clearly identified and evaluated using the best available information. The information can be drawn from a wide variety of sources—prior studies, results of computer modeling, expert opinion, decisionmaker opinion, key trends, and the like. Decision analytic and presentational tools (e.g., computer software and graphics) can be applied on the spot, for example, to help structure and evaluate options.[66] A few Federal agencies have also tried the decision conference approach known as "interactive management. " The director of the Center for Interactive Management at George Mason University also reports favorable resuits.[67]

Possible limitations on the decision conference techniques include the usual requirement that the decisionmakers participate in the entire decision conference–frequently lasting up to 2 days or more, a major time commitment for most decisionmakers. But perhaps the major limitations are lack of: 1) understanding of the technique; 2) recognition and acceptance of a need for the technique (or perhaps any so-called decision aids); and 3) desire to make decisions in a relatively visible, participative way. Some of these limitations can probably be overcome through education and training and the cumulative results of successful decision conferences.

In any event, the technique seems worthy of experimentation and relevant to foresight —given the inherently complex, multivariate, and uncertain trends and issues that foresight must address. An important point is that policymakers usually do not need, nor do they expect, perfect information. Waiting for perfect information very often means waiting until it is too late to make a decision, or too late to do anything about the problem even if a decision is made. For example, in the case of climate, some researchers believe that ocean thermal lag is masking the effects of increasing atmospheric carbon dioxide so that by the time a clear signal is detected, further and possibly substantial climatic change will be inevitable. Of course, other researchers believe that scientific uncertainty over the climatic effects of rising carbon dioxide levels is such that no clear conclusions can yet be drawn.[68]

One or several decision conferences could be held on a pilot basis—with the participation of scientists, policy analysts, and interested decisionmakers-to test the technique in selected foresight sectors, such as energy, agriculture, and climate. The pilot tests could focus on, for example, whether uncertainties and sensitivities in key trends and forecasts are low enough to warrant serious consideration of specific policy options; what the range and magnitude of effects of the options might be; and whether, and in what areas, additional research needs to be conducted. The decision conference(s) could explicitly test the sensitivities of policy options and effects to a wide range of trends and forecasts, including not only those generated by major modeling and research centers, but also those from smaller

[66] See Charles Treat, "Commerce Computer Center Attracts Attention, " *Commerce People,* vol. *6, No. 4,* April 1985, p. 5; Charles F. Treat, "Modeling and Decision Analysis for Management, a paper prepared for the Government Computer Expo, June 13, 1985.

[67] The current director of the Center for Interactive Management at George Mason University is Alexander N. Christakis.

[68] For discussion of ocean thermal lag, see James E. Hansen, et. al., "Climate Sensitivity: Analysis of Feedback Mechanisms, " *Climate Processes and Climate Sensitivity,* J.E. Hansen and T. Takahashi (eds.) (Washington, DC: American Geophysical Union, 1984), pp. 130-163, esp. p. 33; and Michael E. Schlesinger, W. Lawrence Gates, and Young-June Han, *The Role of the Ocean in CO_2-Induced Climate Change: Preliminary Results From the OSU Coupled Atmosphere-Ocean General Circulation Model,* report No. 60, Climatic Research Institute, Oregon State University, January 1985, pp. 31-34 published in J.C.J. Nihoul (cd.), *Coupled Ocean-Atmosphere Models* (Amsterdam: Elsevier, 1985). For discussion of other scientific views and uncertainties, see, for example, Richard C.J. Somerville and Lorraine A. Reimer, "Cloud Optical Thickness Feedbacks in the CO_2 Climate Problem, " *Journal of Geophysical Research,* vol. 89, No. D6, Oct. 20, 1984, pp. 9668-9672; J. Oerlmans, "Response of the Antarctic Ice Sheet to a Climatic Warning: A Model Study," *Journal of Climatology,* vol. 2, 1982, pp. 1-11; Hugh W. Ellsaesser, "The Climatic Effect of CO,: A Different View, " *Atmospheric Environment,* vol. 18, No. 2, 1984, pp. 431-434; and Sherwood B. Idso, "Do Increases in Atmospheric CO_2 Have a Cooling Effect on Surface Air Temperature, " *Climatological Bulletin,* October 1983, pp. 22-25.

research centers, independent researchers, and international researchers.[69]

Institutional Mechanisms

The third ingredient needed to improve the government's foresight capability, in addition to the technical, informational, and analytical advances discussed above, is a supportive institutional framework. This is a difficult challenge because foresight, by definition, cuts across agency and disciplinary lines. The primary foresight sectors collectively involve virtually every cabinet-level department of the U.S. Government and many of the independent agencies. Several of the foresight sectors singly involve multiple departments and agencies. For example, energy foresight, taken alone without considering impacts on and relationships with other foresight sectors, involves departments such as Energy, Interior, and Agriculture. Water foresight involves the Interior, Agriculture, and Commerce Departments, among others. And climate foresight involves the Commerce, Energy, and Defense Departments, along with NASA and NSF among others.

Based on the results of the OTA Federal Agency Data Request, OTA workshops on related topics, and interviews with numerous Federal agency officials, it seems clear that decision support and foresight functions operate with minimum to no coordination and integration at the agency level and governmentwide. Computer modeling, decision support, and foresight generally are not viewed as part of information technology management within the agencies or at OMB and GSA. Likewise, decision analytic and foresight information usually is not easily accessible from agencies or governmentwide.

Thus, an improved government foresight capability appears to require more effective institutional mechanisms at both the agency-specific and governmentwide levels with respect to coordination of foresight activities and exchange of and access to foresight information.

Agency-Specific

One alternative is to define foresight as being within the formal definition of the information resources management (IRM) concept and the responsibility of each agency's IRM officer. Right now, IRM does not include foresight, even though foresight is clearly an information function and heavily dependent on the use of information technology. The Paperwork Reduction Act is silent on foresight per se, although the act could be interpreted to extend to all Federal agency information activities and all agency use of information technology.

The Office of Management and Budget (OMB) could require that consideration of foresight capabilities and activities be included in each agency's IRM plan and in the governmentwide 5-year IRM plan, which is updated annually. The General Services Administration could provide guidance to agencies on how to incorporate foresight capability as part of the triennial IRM review process. (See chs. 2 and 3 for further discussion of the IRM planning and review process.) These changes could also be encouraged or directed by Congress through legislative amendments (e.g., to the Paperwork Reduction Act) and/or reports, accompanying the appropriate authorizing and appropriations acts for specific agencies and/or OMB.

[69] For climate and energy foresight analyses, one illustrative approach might be to start with a broad range of policy options such as those in Thomas C. Schelling, "Climatic Change: Implications for Welfare and Policy, " in National Academy of Sciences, *Changing Climate,* op. cit., pp. *449-482,* or, for energy options, see David J. Rose, Marvin M. Miller, and Carson Agnew, "Reducing the Problem of Global Warming," *Technology Review,* May/June 1984, pp. 49-58. The sensitivity of the options to widely varying trends and forecasts could then be examined, ranging from the results of the major U.S. climate models (see, for example, Schlesinger and Mitchell, "Model Projections, " op. cit.), to simple extrapolations of current trends, to alternative hypotheses such as those developed by John Hamaker, *Survival of Civilization,* (Lansing, MI: Hamaker-Weaver Publishers, 1982) and Kenneth E.F. Watt "An Alternative Explanation of Widespread Tree Mortality in Europe and North America, " April 1985, in preparation, to the results, if available, of U.S.S.R. research and modeling efforts (see, for example, A. Ryabchikov, *The Changing Face of the Earth: The Structure and* Dynamics *of the Geosphere, Its Natural Development and the Changes Caused by Man* (Moscow: *progress* Publishers, 1975), and N.N. Moiseev, V.V. Aleksandrov, et.al., "Global Models, the Biosphere Approach (Theory of the Noosphere)," International Institute for Applied Systems Analysis, Laxenburg, Austria, July 1983)).

Another alternative is to include foresight formally as part of decision support, and encourage or direct agencies to establish a decision support center, if they do not already have one. These centers could be responsible for each agency's role in implementing any governmentwide foresight initiatives. The key point is to establish a focus of responsibility for foresight within each agency, such as the agency IRM officer or the agency decision support center or office.

A final alternative that complements the above is to include foresight and decision support in any enhanced information technology innovation program that may be established. Should one or more innovation centers be created, the center could provide information and assistance to individual agencies on implementing their own decision support and foresight centers.

Governmentwide

For at least the last 35 years, proposals have been made to setup some kind of governmentwide foresight office or the equivalent. For example, many of the study commissions established over the years, from the 1951 Materials Policy Commission to the 1976 National Commission on Supplies and Shortages, have recommended:

> . . . the establishment of a permanent body somewhere high in the executive branch for performing continuous futures research and analysis .70

In addition, the 1980 *Global 2000* study concluded that establishment of an ongoing institutional mechanism in the executive branch was essential to improve the government's long-term global analytic capabilities. *Global 2000* identified numerous problems with the computer models that formed the basis for the analysis, as discussed earlier. *Global 2000* envisioned an ongoing institutional entity with a major role in addressing these problems and, in general, improving the understanding of models and the quality and consistency of the analytic structures and databases on which the models depend.[71]

[70] *Global 2000, Volume Two,* op. cit., p. 710.
[71] Ibid., pp. 460-484.

At present, while there is no governmentwide foresight office, the Council on Environmental Quality in the Executive Office of the President (EOP) coordinates an interagency Global Issues Working Group. The group meets infrequently, with a very limited staff and agenda. Nonetheless, it has sponsored the preparation of several useful documents prepared by agency staff and/or consultants."

In the legislative branch, several key milestones establishing the congressional role in government foresight include:[73]

- enactment of the Technology Assessment Act of 1972, which created the Office of Technology Assessment;
- amendment of House Rule X, Section 101(b)(1) in 1974 to require each standing committee of the House of Representatives, except Appropriations and Budget, to include in their oversight duties "futures research and forecasting on matters within the jurisdiction of that committee'
- authorization of the Congressional Research Service (CRS) to create a Futures Research Group;
- creation of the Congressional Clearinghouse on the Future in 1975; and
- amendment of Rule 29 of the Standing Rules of the Senate in 1977 to require each Senate Committee, except Appropriations, to prepare a report on the future regulatory impact of proposed legislation.

Implementation of these actions has been mixed. For example, the CRS Futures Research Group has been disbanded as a separate entity, but its functions have been dispersed to other CRS divisions-principally the Government Division and the Science Policy Research Division. Relatively few House committees have conducted foresight hearings

[72] See testimony of A. Alan Hill, Chairman, Council on Environmental Quality, Executive Office of the President, before the Apr. 30, 1985, joint hearing on "Global Forecasting Capability of the Federal Government, " conducted by the Subcommittee on Government Efficiency of the Committee on Governmental Affairs and the Committee on Environment and Public Works, U.S. Senate.
[73] U.S. Congress, House of Representatives, Committee on Energy and Commerce, *Congressional Foresight: History, Recent Experiences, and Implementation Strategies,* a report prepared by the Congressional Research Service, 97th Cong., 2d sess., December 1982, pp. 3-4.

under House Rule X, but those few have compiled quite a substantial body of useful information. Two of the most active House committees with respect to foresight—the Committee on Energy and Commerce and the Committee on Science and Technology-issued at least six reports on foresight topics between May 1976 and April 1983.[74] Finally, although OTA does not generally issue foresight reports per se, foresight on advances in science and technology and their implications are incorporated into many OTA studies and reports.

The current debate focuses in part on what kind of new or revised executive branch mechanisms are needed to facilitate government foresight, on the assumption that most foresight activities occur in the agencies and that coordination of these activities must come primarily from the executive branch of government.

The basic alternatives, other than doing nothing, involve strengthening the foresight functions of an existing office (or offices) or establishing a new office. While a governmentwide foresight office could, in theory, be located in any department or agency, most proposals suggest a location in the EOP, on the grounds that cabinet departments are much more likely to cooperate with an EOP entity. Several existing EOP offices are potential candidates for stronger foresight responsibilities –the Council on Environmental Quality, OMB, the Office of Science and Technology Policy, and possibly the Council of Economic Advisors.

Legislation to establish a more formalized governmentwide foresight function has been proposed on several occasions. Most recently, in April 1985, the "Critical Trends Assessment Act" (S. 1031) was introduced to establish an Office of Critical Trends Analysis in the EOP, along with an Advisory Commission on Critical Trends Analysis. The office would identify and analyze critical trends and alternative futures based largely on information obtained from Federal departments and agencies, as well as on outside sources of information. The office would advise the President and issue various reports on the key trends and their relationship to present and future problem areas, opportunities, and policy options. The act also would require the Joint Economic Committee of Congress to prepare a legislative branch report on critical trends and alternatives futures.[75]

S. 1031 was introduced by Senator Albert Gore at a joint hearing of the Senate Governmental Subcommittee on Governmental Efficiency, chaired by Senator Charles McC. Mathias, and the Senate Committee on Environment and Public Works, chaired by Senator Robert Stafford. The April 30th hearing highlighted some of the major arguments for and against government foresight and a governmentwide foresight office. Basically, none of the witnesses argued that there should be no government foresight. All agreed that government policymaking should take into account the best available information and analyses concerning the future. All agreed that computer modeling has a legitimate role in foresight and policymaking, although views differed on the importance of this role.

DOE Deputy Secretary Danny Boggs highlighted the limitations of models due to inferior or incomplete input data, mathematical and conceptual errors in building the model,

'I bid.; U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, *Long Range Planning,* a report prepared by CRS, 94th Cong., 2d sess., May 1976; U. S. Congress, House of Representatives, Committee on Energy and Commerce, *The Strategic Future: Anticipating Tomorrow Crises,* a report prepared by CRS, 97th Cong., 1st sess., August 1981; U.S. Congress, House Committee on Energy and Commerce, *Strategic Issues: Historical Experience, Institutional Structures and Conceptual Framework,* a report prepared by CRS, 97th Cong., 2d sess., July 1982; U.S. Congress, House, Committee on Energy and Commerce, Subcommittee on Oversight and Investigations and Subcommittee on Oversight and Investigations and Subcommittee on Energy Conservation and Power, *Public Issue Early Warning Systems: Legislative and Institutional Alternatives,* hearings and workshop, 97th Cong., 2d sess., October 1982; U.S. Congress, House, Committee on Science and Technology, *Subjects and Policy Areas for the Consideration of the House Committee on Science and Technology,* a report prepared by CRS, 98th Cong., 1st sess., April 1983.

" S. 1031, the Critical Trends Assessment Act, Apr. 30, 1985, 99th Cong. 1st sess. For discussion of prior legislative initiatives, see, for example, Lindsey Grant, *Thinking Ahead,* op. cit.; and Joseph F. Coates, "Foresight," op. cit.

and inadequate theoretical understanding of the processes being modeled. He believes that advances in computing power have outstripped advances in the theoretical underpinning of computer modeling. Mr. Boggs also expressed concern about the apparent bias in computer models, and especially global computer models, toward a negative future, and cited several previous energy supply, demand, and price forecasts (both governmental and private sector) that have proven to be far too pessimistic. Mr. Boggs cited the efforts of the EIA to improve the quality of computer-based models and forecasts.[76]

Senator Gore emphasized that a Critical Trends Office would not be a central planning agency trying to impose a uniform view of the world, but would help the government make more effective use of the already substantial level of data collection and modeling activity. Mr. Lindsey Grant, a former Deputy Assistant Secretary of State, testified that such an office could help improve understanding of what databases and models already exist and how these resources could be used for more informed government policymaking. Senator Mathias outlined what he views as the high payoff of improved global foresight in areas such as long-term export and import needs of U.S. trading partners; long-term supply and demand for energy and food; and preparing for and responding to natural disasters such as crop-freezes, earthquakes, floods, and droughts.[77]

OTA did not analyze the various institutional options. However, three things seem clear. First, many of the applications of information technology considered throughout this chapter (as well as, to some extent, throughout ch. 7 on electronic databases and dissemination of government information) are likely to make the job of any potential governmentwide foresight office more feasible than in the past. Second, many of the options for improved decision support (e.g., guidelines on model evaluation, clearinghouse or index to major models and databases, testing and development of decision conference techniques) considered earlier are also likely to facilitate improved foresight–both agency-specific and governmentwide. Three, in order to realize the potential for improved foresight, some strengthened central coordinating mechanism appears to be necessary in order to ensure high-level support, adequate agency cooperation, and effective implementation of whatever specific measures are agreed to by Congress and the President.

[76] See testimony of Danny J. Boggs, Deputy Secretary, U.S. Department of Energy, before the Apr. 30, 1985, joint hearing on "Global Forecasting Capability of the Federal Government," conducted by the Subcommittee on Government Efficiency of the Committee on Governmental Affairs, and the Committee on Environment and Public Works, U.S. Senate.

[77] See statements of Senator Albert Gore, senato, Charles McC. Mathias, and Mr. Lindsey Grant before the joint hearing, ibid.