POLICY FORUM: SCIENCE AND GOVERNMENT

Improving Science and Technology Advice for Congress

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America's founding fathers created a Congress of citizen-legislators that uses a decision-making model derived from the adversarial traditions of the law. Members of Congress listen to the arguments and pleadings of interested parties on all sides of an issue, and from the resulting synthesis and balancing of interests, they collectively discern and act upon the national interest. Alien as this approach may be to many scientists and engineers, it has worked remarkably well for more than two centuries.

However, there is an important and growing class of problems for which this traditional model needs to be augmented with systematic analysis by experts if Congress is to make wise, well-informed decisions. Many of these problems involve complex issues of science and technology. For example, what is the best way to manage the transition of telephone service from highly regulated conventional switched-line systems to the essentially unregulated packet-switched Internet? How should the benefits and risks of biotechnology (genetically modified organisms, therapies that employ stem cells, bioterrorism) best be managed to enhance human welfare and ensure the prosperity of U.S. industry? What is the best way to evolve a reliable and effective air-traffic control system?

In a 10 May editorial, *Nature* (*1*) argued that "the U.S. legislature is bereft of objective guidance on issues that underpin much of its work." We agree. But Congress is unlikely to act on its own to create the needed analytical capability. Congress is a representative body that responds to its constituents. If Congress is going to create better ways of getting the balanced technical advice that it should have for informed decision-making, pressure needs to come from the outside.

The problem is not a lack of information. Congress is deluged with facts and opinions, and with the partisan pleadings of thousands of interested parties. But information is not knowledge. For more complex issues, especially those involving science and technology, Congress and its committees need more than bare facts and brief interactions with technical experts—they need balanced analysis and synthesis that sorts, integrates, and analyzes information to frame the issues and extract knowledge and insight. This process requires much more time and expertise than are available to most members of Congress, or their staffs.

On 14 June, under the auspices of 18 leading professional societies, universities, and think tanks, a group of more than 100 congressional staffers, policy analysts, and academic and industry leaders met at a workshop to explore a range of alternative institutional arrangements that might respond to this need (*2*). A broad consensus emerged that, although a variety of organizations today address portions of the need, a major gap remains that can best be filled by an organization that is located inside the legislative branch and works exclusively for Congress. The cost of such an analytical capability would be extremely modest when compared with the total budget of the legislative branch, or with costs associated with the decisions it would support.

From 1972 to 1995, Congress had its own technical analysis organization called the Office of Technology Assessment (OTA). It was closed as part of a congressional economy drive. The predominant reasons for this action involved political considerations of that unique historical moment. Although OTA's sole official function was to do analysis for committees, it actually played a more complex role. Its reports were widely used not only by congressional members and staff but also by interest groups, academics, and the general public. By laying out problems and a range of possible solutions, it helped to raise the overall level of political debate. Often the most important impacts of OTA studies did not come from direct inputs provided to committees and members of Congress. They came through feedback from constituents who used OTA reports to frame and support their arguments on all sides of an issue. Because OTA was staffed with a wide range of technical experts, they also played an important, although quiet and informal, role in providing regular consultations with individual senators and representatives and their staffs, committee staff, researchers in the Congressional Research Service (CRS), and others.

The existing legal framework for the former Office of Technology Assessment, including control by a bipartisan, bicameral committee, could be used as the framework to establish a new organization (*3*). However, if this approach were used, it would be wise to consider some improvements in its design and operation. Among these are strategies to perform studies more rapidly, to ensure that the needs of the minority are well served, and to supply technical advice and more explicitly to support to other congressional support organizations. There might also be an advantage in a change of name to, for example, the Office of Science and Technology Analysis.

Lessons from past experience should not be confined to the United States. Fifteen European parliaments have created technology analysis units (*4*). These units were largely inspired by, and in varying degrees modeled after, the now defunct OTA. In reviewing the European experience, N. J. Vig, a political scientist at Carleton College in Northfield, MN, reported to the workshop that the leaders of these organizations "were dumbfounded when Congress voted to abolish OTA in 1995." They found it "incomprehensible" that the leading democratic legislature in the world should no longer have its own source of scientific and technical analysis.

When the OTA closed its doors, a portion of the work it once did moved to the National Academy of Sciences. Work by the academy could be further expanded and strengthened. However, their studies do not serve all the needs of the Congress. They are expensive and proceed slowly. Because academy studies are conducted by committees of independent outside experts, the reports sometimes do not respond to congressional concerns. They often make specific recommendations, sometimes with implicit value judgments, rather than laying out a range of alternative policy options for congressional consideration. Congress does not need to be told what to do by experts—it needs to have experts frame and explain the choices it faces so that it can exercise its decision-making authority with a full understanding of the trade-offs faced, and the likely direct and indirect implications of its actions.

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The program of Congressional Science and Technology Fellows, coordinated by the AAAS and supported by most of the major science and engineering societies, came in for considerable praise during the workshop's deliberations. Science and Engineering Fellows have been an extremely valuable source of technical advice and assistance for Congress as well as the executive agencies. The program should be expanded and strengthened. In addition, a system that provides technical and analytical support to the Fellows would be a very valuable addition.

While the Congressional Research Service serves a different set of congressional needs, its analytical capabilities should be strengthened so that it can better support simple analytical requests from members and committees, which frequently involve substantial science and engineering content. Given their very different institutional cultures, it is not clear how successfully one of the existing legislative support agencies could house a new unit to perform scientific and technical policy analysis on large-scale questions that require foresight, analysis, and synthesis. However, a proposal to fund such an experiment in the General Accounting Office (GAO) only recently passed the Senate (*5*).

In today's high-tech world, legislators need balanced, nonpartisan advice and assistance if they are going to effectively serve the national interest. To make that happen, scientists and engineers, their professional societies, the business community, and individual citizens need to send a clear message to Congress. Two separate pieces of legislation that take different approaches to creating the needed analytical capability are now in progress (*3*, *5*). Others may follow. It is important that the science and technology community become actively engaged in supporting such efforts.

References and Notes

1. "Time for a bipartisan OTA," *Nature* **411**, 117 (2001).
2. The workshop, "Creating an Institutional Structure to Provide Science and Technology Advice to the U.S. Congress," was held in Washington, DC, on 14 June 2001. A summary, including agenda, list of co-convening organizations, and major insights, is available at www.epp.cmu.edu/other/STadvice_toC.html. A book based on the background papers prepared for the workshop will be published by Resources for the Future Press, Washington, DC.
3. Along with more than 30 cosponsors from both parties, Congressman Rush Holt (D–NJ) has recently introduced a simple bill, H.R. 2148, that would fund, and thus recreate, the old OTA at a level of $20 million per year for the next 6 years.
4. N. J. Vig, H. Paschen, Eds., *Parliaments and Technology: Development of Technology Assessment in Europe* (State University of New York, Albany, NY, 2000).
5. Senator Jeff Bingaman (D–NM) has successfully introduced an amendment to the Legislative Branch Appropriations Bill (S. 1172) to provide $1 million to fund a technology assessment pilot project in the GAO.

POLICY FORUM: GEOPHYSICS

The Future of Permanent Seismic Networks

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Seismologists record and analyze elastic waves produced by an earthquake to remotely determine its location and size and the orientation of the rupture plane, and to unravel the physical processes at its source. They also apply imaging techniques to infer the three-dimensional structure of Earth's interior from propagating elastic waves. These observations are done at a variety of spatial scales, from local to global, depending on the magnitude of the earthquake or the purpose of the study. Seismic data collection is also important for monitoring nuclear explosions in the framework of the Comprehensive Test-Ban Treaty (CTBT).

Observational seismology is a young science. The first seismographs that accurately recorded ground motion and time were developed 100 years ago. The first standardized global network (World Wide Standard Seismic Network, WWSSN) was deployed in the early 1960s and used analog recording on photographic paper—replaced, starting in the mid-1970s, by digital recording. Seismic practice gradually evolved from local data storage and analysis at the seismographic station to a modern database system where full waveforms are exchanged by modern media (satellite, digital phone links, or the Internet). It is only since the 1970s that the largest, globally recorded earthquakes (magnitude >5.5), have been reliably quantified, and only since the early 1980s were there sufficient recordings to systematically analyze global strain release (*1*) or to initiate global tomographic investigations of Earth's interior structure. The transition to digital seismology was largely driven by scientific rather than surveillance goals and initiated by a small number of global and regional scientific projects. More recently, a number of national programs have taken steps to install high-quality digital instruments and to upgrade the analog short-period networks to improve national earthquake surveillance.

Seismological research benefits from the availability of a broad frequency band—digital, high–dynamic range systems that can record the full "useful" range of ground-motion amplitudes and frequencies while simultaneously resolving background noise. It is no longer the quality of the data, but primarily the spatial resolution, the centralized archiving, and the continuity in time of the archives that will be critical for progress in understanding the dynamics of the solid Earth and the generation of earthquakes.

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Spatial and Temporal Sampling

The imaging resolution of earthquake sources and of the lateral heterogeneity encountered by earthquake waves along their path is directly related to the spacing of the recorders at the surface. In the early 1980s, the first global tomographic investigations used 10 to 20 globally distributed digital stations, and resolved Earth's structure down to scale lengths of 5000 km, while today—at least on land—most 2000-km by 2000-km patches of Earth contain at least one digital station. Unraveling regional variations of structure, as well as earthquake location, for national monitoring requires a spacing of a few tens to a few hundreds of kilometers. Understanding the distribution of strong ground shaking in urban areas requires even denser spacing, at the kilometer level. Japan has taken the lead in the installation of dense urban arrays.

The processes that cause earthquakes have time scales of millions of years, and recurrence times of large earthquakes are typically a few hundred years in areas of plate boundaries, and up to tens of thousands of years in stable continental regions. The long-term, sustained, consistent, high-quality recording at a variety of scales is crucial to quantifying tectonic motions in Earth's crust.

For example, documenting past seismicity is the key to understanding future hazards. In California, historical earthquake catalogs cover barely over a hundred years, yet they are the basis for the computation of future earthquake probabilities and the implementation of long-term mitigation strategies. As in medical imaging, tomographic investigations of Earth's interior depend on good coverage of ray paths and