The Emergence of S&T Priorities in the United States

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Abstract

Although the United States does not have a formal technology foresight process, it has a number of related processes that gather information about future science and technology opportunities. These processes include a large number of workshops that assess the direction of specific fields, technology roadmapping projects, studies by advisory committees and think tanks, and the work of private research firms. This information, however, is not aggregated in a systematic way. The information is used by a large number of individuals and organizations, both inside and outside of government, to advance their interests, which are sometimes competing and sometimes complementary. Science and technology priorities emerge out of this complex process.

Introduction

This paper attempts address some of the common questions related to technology foresight that international government officials and scholars frequently ask when they visit. Some of these questions are:

- What technology foresight-like activities are done in the U.S?
- Why doesn't the U.S. do formal technology foresight?
- How does the U.S. set technology priorities?
- What is the U.S. strategy for S&T and who is in charge?
- Where do new national initiatives (such as the National Nanotechnology
- Initiative) come from?

These questions assume that the United States has a clear process of S&T policy prioritization and that all one has to do is describe it. In reality, however, U.S. science and technology policy is complex, variable, and changing. The roles of different groups in the process change from Congress to Congress, President to President, and issue to issue. This makes some of these questions difficult to answer in a simple way.

U.S. Activities related to technology foresight

Although the United States does not have a formal technology foresight process, there are many activities that attempt to identify emerging technologies and important areas of research. These include a large number of workshops that assess the direction of specific fields, technology roadmapping projects, studies by advisory committees and think tanks, the work of private research firms, and previously, critical technology studies. The following sections describe each of these.

Workshops

There are a vast number of workshops held each year to help the technical community to understand where a field or subfield of science or engineering is going, and to help set priorities among the research. The National Science Foundation supports a very large number of these workshops, but all of the U.S. technical agencies, including the National Institutes of Health, the Department of Energy, and the Department of Defense hold frequent workshops of these kinds. The workshops are usually organized by a non-governmental person in the technical community, and are funded through a grant or contract.

A search of the NSF grants database[1] for projects that have started since the beginning of 2002 found 877 awards that include the term "workshop" in the title or abstract. While not all off these grants are for workshops that resemble technology foresight activities, many of the awards are for workshops that are intended to identify the most promising research priorities. While many of the workshops have a technical focus, some focus on the socioeconomic implications of the field. For example, many recent workshops have focused on the socioeconomic aspects of information technology, nanotechnology, or biotechnology. A large number of non-governmental people are involved in these workshops and, cumulatively, they develop much information on the promising directions in science and technology. While these workshops do not constitute a technological foresight program, they provide much of the raw material needed for technological foresight.

Technology Roadmaps

Another related activity is technology roadmapping.[2] In the technology roadmap process, technologists get together to try to determine the trajectory of a technology and the developments needed to keep it on its trajectory. Most roadmaps have been organized around existing industries or technologies, such as semiconductors, optoelectronics, aluminum, pulp and paper, electronic packaging. Some have included an assessment of future market needs, as well as the technology developments.

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[1] See https://www.fastlane.nsf.gov/a6/A6AwardSearch.htm

[2] See Kostoff, R.N. and Schaller, R.R. (2001), 'Science and Technology Roadmaps', *IEEE Transactions on Engineering Management,* 48 (2), pp. 132-143.

The model for technology roadmapping has been the semiconductor industry – the International Technology Roadmap for Semiconductors has served as an international focus for technology development in the industry. Many roadmaps have been done by and for industry, but the industries have often received government funding to support the roadmapping process. The Defense Advanced Research Projects Agency (DARPA) and the Department of Energy have supported several major roadmapping efforts.

Technology roadmapping is especially important in complex technologies where there is a need to coordinate the development of many components and subsystems. Roadmaps identify the minimum performance needed for future technologies in order to be part of the system. Roadmaps appear to be most useful in established technologies that are evolving incrementally. They usually do not consider the social effects of the technology.

Policy Studies

A third category of foresight-like activities is the plethora of studies produced by think tanks, advisory committees, foundations, and groups like the National Research Council. Many use committees of experts to produce studies (usually more extensive than a single workshop) that address the social effects of technology and many make recommendations for future research needs. These studies are typically supported by private foundations or government. The studies are performed or funded by groups that represent the full political spectrum, from the most liberal to the most conservative.

Private Forecasts

A third category of foresight-like activities is the work of many private firms that produce forecasts of markets and technologies. These include the firms like Gartner, Forrester Research, and SRI International's spinoff, "SRI Consulting Business Intelligence." These try to provide a look of where markets and technologies are going. The limitations of the private forecasts are that that they are private and expensive, and so do not form the basis for broad-based societal decisions. In addition, their methods are usually proprietary, so it's difficult to know whether one agrees or disagrees with their assumptions.

Critical Technologies

A fourth category of technology foresight-like activities has been "critical technology assessments." At the previous technology foresight conference, Bruce Don of the Science and Technology Policy Institute described critical technology assessments as being the U.S. analog to technology foresight.

These started in the mid-1980s, with the Department of Defense critical technology lists, which identified technologies that were critical to defense. This effort was modeled after longstanding "critical materials" list, in which the Department of Defense identified materials that it needed to have in the case of war. Soon afterwards, in the late 1980s, the Department of Commerce produced a list of important "emerging" technologies. The private sector Council on Competitiveness (an industry-university labor group) produced a critical technology study in 1991, which identified the technologies that were most critical for industry. Shortly after this, the Office of Science and Technology Policy came out with the National Critical Technologies list, and this was followed by legislation that established the Critical Technologies Institute under OSTP, which was operated by RAND Corporation.

These studies served the purpose of focusing attention on the U.S. position in generic technologies and on changes needed in technology policy. Previously, U.S. science and technology policy had focused on basic research and technology development for government purposes (defense, energy, space) and there had been little emphasis on developing fundamental technologies that would provide broad benefits to society. While critical technology studies had an important effect, the critical technology lists did not have a particularly strong analytical basis, and they paid little attention to the social implications of the technologies. The critical technology efforts have largely withered away since the mid-1990s.

The wide variety of processes described above that develop information that could contribute to a technology foresight process in the United States, but there is no formal effort to bring this information together in a systematic way at the national level. This raises a number of interesting questions. Why does the U.S. not have a technology foresight process? How does all this information about future technologies get incorporated into S&T priorities? Does the lack of a technology foresight process hurt U.S. policymaking? To address these questions, it is useful to briefly discuss the U.S. science and technology priority setting process.

U.S. S&T Priority Setting Process

While it is may be common to think of the U.S. S&T priority setting in terms of organizational charts and flow diagrams, these imply a much more orderly process than is in fact the case. There are several other metaphors for the policy making process that may be better descriptions of the actual process.
One is that the policy process is a “marketplace of ideas”. The results of all of the studies and workshops mentioned previously go into a large information marketplace. There is a constant competition of ideas. People and organizations in and out of government are constantly trying to develop and sell the strongest arguments for the action that they want. In this competition, the strongest or most compelling arguments tend to be selected.

Another analogy is to a sausage factory. There a often quoted saying in Washington that "Anyone who loves the law or loves sausages should never watch either of them being made." That is to say, the making of laws, including the laws the direct and fund science and technology activities, is a messy process, in which deals are cut for political or personal reasons. The reality of how policies are made does not fit anyone’s image of how the process *should* work.

A third metaphor, believe it or not, is termite mounds. Termite mounds, as well as ant colonies, slime mold colonies, and city neighborhoods are held up as examples of complex adaptive systems with emergent behavior. In these systems there is no architect or central planner – complex structures are created by a large number of individuals following relatively simple rules. This may be a useful way to think about S&T policy setting. There are a very large number of actors who each have relatively simple and clear goals, but the process is somewhat chaotic and constantly changing. The process might appropriately be simulated with multi-agent models.

Some of these actors are:

- Congress, including the House and Senate, and authorizing and appropriating committees;
- The White House, along with the Office of Management and Budget and the Office of Science and Technology Policy, and the National Science and Technology Council;
- The executive branch agencies, especially the National Science Foundation, National Institutes of Health, Departments of Defense, Department of Energy, and NASA;
- Scientists and engineers in each field;
- Companies and industry associations;
- Universities;
- The National Academies and National Research Council;
- Think tanks and professional societies;
- And others.

Each of these actors has different goals. To oversimplify, scientists are seeking funding for promising research fields; the OMB is trying to restrain funding growth and align funding with the President's priorities; agencies are seeking to increase their budgets; the White House is looking for a few things it can emphasize in the budget that will please constituents. All of these are competing with ideas and arguments for funding.

As with termite mounds, once a program is established it usually changes little each year, although it may evolve over time. The formation of a new program is less predictable. They emerge when enough of the right characteristics, or a coalition of the right actors, come together. There is no set process for this, and different organizations seem to play a key role in the process each time.

To illustrate this process, it is useful to consider some examples, such as the Internet and nanotechnology.[3] The Internet is without question one of the outstanding successes of U.S. investment in technology. The Internet had its beginnings with DARPA funding that led first to the ARPANET in 1969, and later to the protocols that allowed networks to interconnect, creating the Internet in 1983. DARPA's original goal was to

[3] For more information on the history of the Internet and nanotechnology initiatives, see Heaton, George R. Heaton, Christopher T. Hill, Patrick Windham, and David W. Cheney. With Tatsujiro Suzuki 2001. *Public Policies and the Emergence of High-Technology Sectors.* A Report to JETRO-New York. Executive summary available online at http://www.technopoli.net/2001execsum.pdf

share scarce computing resources. From 1983 to about 1993, the Internet expanded as agencies, especially the National Science Foundation, invested to connect many scientists up to the Internet, primarily for scientific computing (although email was perhaps the biggest application). It became a multi-agency initiative in the late 1980s, as many agencies saw the benefit of connecting to it. The initiative received support from both the Congress and from the White House. Then in the early 1990s, with the development of the World Wide Web at CERN and the graphical web browser at the University of Illinois, the Internet expanded to become the global resource it is today.

The Internet was the result of sustained investment over many years, not just a single initiative. The factors that lead to success in its development changed substantially over time, and even the lead agencies changed. Policy development was bottom-up, starting with computer scientists in the technical agencies, but it later received important Congressional and White House support.

The history with nanotechnology is quite different. Although the field of nanotechnology arguably began with a December 29, 1959 talk by Caltech physicist Richard Feynman, it was technical advances in the 1980s and early to mid-1990s that made nanotechnology a real possibility. Some of the underlying research was funded by the government, notably through DARPA. In the mid-1990s, mid-level agency experts, notably at NSF, DOC and DARPA became interested in nanotechnology and began talking to colleagues in other agencies and then talked to White House staff, supplying ideas about nanotechnology policy.

Staff-level policy entrepreneurs at the White House were receptive to ideas for new initiatives and were able get Presidential endorsement for the initiative. But to persuade Congress to provide money for the new initiative, they needed to build a coalition that could persuade Congress to provide the funding. Policy entrepreneurs in the agencies and the White House succeeded in developing a broad political coalition of scientific and engineering communities in favor of the initiative. They were able to argue that nanotechnology would be an enabling technology for many areas of science and engineering; that investment in nanotechnology could help correct an imbalance between funding for health research (which had grown rapidly) and physical science and engineering (which had not been growing); and that nanotechnology R&D would be a valuable investment in long-term economic growth and U.S. competitiveness. They were able to get support from the U.S. semiconductor industry, and also benefited from the budget surplus at that time, which made it easier to get budget increases. They also benefited from the lack of organized opponents

Other initiatives take different paths. Current priorities, such as the "FreedomCAR" initiative and science related to homeland security, involve different agencies and actors and different political contexts.

Concluding Questions

Let us return to the questions asked above. Why does the U.S. not have a technology foresight process? This is difficult to answer, but it may because there is not a client for it. There is no organization in the U.S. system that does multi-year planning for the whole science and technology enterprise that has a direct need for national level technology foresight. Some people think that the White House Office of Science and Technology Policy plays that role, but its role is more to coordinate across agencies and to advise the President on particular issues.

The closest thing to a foresight process was probably the now defunct Congressional Office of Technology Assessment. This Office was originally envisioned as performing future-oriented technology assessments, but it evolved toward doing technology and policy analysis related to decisions that Congress would be expected to make in the next few years. It was closed in 1995 by the Republican-controlled Congress, and while there have been attempts by some people to revive it, these attempts do not seem likely to succeed soon.

Other than OSTP and the Congress, none of the other agencies has a sufficiently broad view to require or support a national technology foresight effort. The National Science Foundation perhaps comes closest, but its tradition is to let peer review committees choose the research directions from the bottom up, and it is likely to see little need for direction from a broader foresight process.

Does the lack of a technology foresight process hurt U.S. policy making? This is another difficult question to answer. On the one hand, one can argue that the U.S. science and technology making process has been fairly successful, and it has not been demonstrated that another system works better. The ad hoc, entrepreneurial, diverse, open, and contentious nature of the U.S. system appears to allow it to move effectively into new areas of opportunity, and many social, economic, and ethical issues related to technology are addressed, if not perfectly, reasonably adequately. On the other hand, it is easy to argue that the system would benefit from some more systematic examinations of social needs and the social effects of future technology, at least if there were a customer that would use the results.

A final point to make is that the way the U.S. system operates may be a function of its size. The U.S. is able to support a very broad range of science and technology activities. The system that works reasonably well for the United States may not work well for smaller countries that need to be more targeted in their efforts.