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"Forecasting Science and Technology Impacts: the Good, the Bad, and the Ugly"

Shaping Science and Technology for National Security: Can Policymaking Ride the Tidal Wave of Technological Change?

Potomac Institute for Policy Studies Forum
Arlington, Virginia

April 2, 2004

I am pleased to be here as the Acting Director of the National Science Foundation.

Your purpose today, as I understand it, is to examine the role of government in shaping science and technology *policy* to meet changing national security needs. I'd like to talk about the process of shaping *science and technology*, within the National Science Foundation context. I call this process "the good, the bad, and the ugly" -- it meets basic national needs but it also generates some risk.

I will describe the process and one area in which I believe it can be improved. Then I'll briefly discuss how scientists can help ensure that sound research serves as the basis for sound policy.

Because of the naturally inquisitive nature of humans, the course of science and technology changes frequently, often preceding and shaping national priorities.

NSF priorities have always reflected--and often anticipated--the nation's economic and technological needs. In particular, even before 9/11, many aspects of NSF-supported research already had national security implications.

The building blocks produced by the nation's science, engineering, and technological experts contribute to antiterrorism efforts, environmental strategies, and energy-efficient manufacturing. Rarely does a national priority arise for which there isn't a lot of related research already in the works.

NSF's mission is to identify the frontiers and advance them to the state where emerging knowledge can be transformed into scientific and technological innovations. The risks are high in supporting emerging fields. And sometimes the results disrupt the scientific status quo. But the ultimate rewards of research at the frontiers are borne out in NSF's record of contributions to the human endeavor and to national goals.

The primary tool for forging a path from idea to discovery to innovation is to invest in people with far-reaching insight. By that I mean people who are turning a corner in an established discipline, or creating a new field, at the juncture of two or more disciplines. The best of these people, and sometimes the most disruptive of the status quo, often turn out to be Nobel Laureates.

We have a good record in that regard. NSF-supported researchers have collected 150 Nobel prizes over the years. Two of NIST's own scientists have also earned the honor.

The federal agencies are the scientist's allies in drawing attention to promising avenues of research. Of course, we have to weave the priorities of the science and engineering communities into those identified for the entire nation. But it is working researchers that generally anticipate and help us identify key areas as they first begin to emerge.

As John Marburger, the President's science adviser, has pointed out, there is efficient communication among working scientists. As he aptly describes it, "Leads are identified, publicized, and followed up." [1]

Two decades before nanotechnology was cited in every newspaper as the next big driver of the global economy, dozens of U.S. scientists working at the nanoscale collaborated among themselves, formed partnerships across agencies and institutions, and together made a decision to raise the issue to national attention.

So the bottoms-up process is just as important as the top-down mandate in shaping national priorities.

Independent advisory committees and peer review panels play a role in this process. As representatives of a broad spectrum of the science, engineering, and technology communities, the members usually have their fingers on the pulse of what's new. Through pooled knowledge, a complex matrix of directions can be shaped into a coherent path.

The National Science and Technology Council of OSTP responds to efforts to raise emerging issues to the forefront. The Council's multi-agency panels provide direction and support for government investments, and expand the range of opportunities for funding the S&T portfolio. This Council, along with the scientific societies, serves an advocacy role in securing funding for the fundamental research that will lead to the next wave of innovations.

Innovations come quickly. While at one time moving an idea from funding to basic research and then to development might have taken years, today it can take months or even weeks. The pace has picked up partly because of advances in telecommunications and the ability to process large databases. Some of the rapidity also stems from the need to quickly address threats to homeland security and from intense global competition.

One of the areas that is due for more attention is predicting the impact of our work, and this is the primary subject I was asked to address today. The expanded definition of national security, and the sophisticated nature of the threat, calls for more predictability of both the benefits and risks of science and technology.

Chairman Sherwood [Sherry] Boehlert of the House Science Committee has called on the scientific community to routinely communicate to policymakers the potential benefits to the nation of proposed and ongoing research. [2] The rationale for continued federal support must be clear and compelling.

I call on researchers to go one step further: to demonstrate to policymakers and to the public--the ultimate source of R&D funding--that an examination of future impacts is an integral part of the research process.

Several years ago, the late George Brown--champion of science and former chairman of the House Science Committee--said, "Given that we can completely transform the world with our knowledge, we are morally compelled to answer the question, What is the end that we seek?" [3]

The end is not always clear at the beginning.

Sensors designed to monitor environmental impacts on ecosystems can also aid in detecting and responding to chemical and biological threats. Imaging equipment produced for medical diagnosis can be applied to transportation screening.

Other areas with national security implications include structural engineering, computer security, microbial genetics, and behavioral science.

The growing complexity of science has driven the development of new skills, tools, and organizational expertise. The ability to produce and share information at lightning speed has spawned partnerships across the boundaries of disciplines and institutions, and enhanced those between academia and industry.

The level of complexity lends richness to the results. Each decade of science enlightens mankind with the previously unimaginable, from the reports of life around deep-sea thermal vents to the creation of nano-capsules that deliver drugs to individual cells.

History has shown, however, that the more capability that is created, the more capability becomes available to those who might pose national security risks.

The dangerous uses are not a rationale for ceasing discovery, but rather a reason to anticipate and plan for all possibilities. The more knowledge at our disposal, the more control we have over the path to innovation.

Ultimately, the end we seek is social and economic prosperity and security. These are enabled by a robust S&T enterprise. We have the responsibility and the mission to support new insights and challenging questions because they are the drivers for growth and change.

We also have a responsibility, as a community, to build in examination of potential consequences, both positive and negative.

One area in which NSF has begun to address this need is in nanoscale science and engineering. This program has, from the beginning, had a portion of its funding designated for research on potential impacts.

The science and engineering community is quickly developing nanoscale manufacturing and business expertise. We know that global competition will be fierce, and the United States must be prepared. There is a simultaneous need to examine the societal, ethical, and security aspects of developments that could transform the way we live and work.

NSF has invested in exploratory grants for studying the societal, ethical, and security implications and has held two workshops on this subject, jointly with the National Science and Technology Council.

Future generations may well judge our success--and our wisdom--by how well we exploit the benefits of nanoscience and nanotechnology while effectively managing their downside.

The social, behavioral, and economic sciences can help us understand and manage the impacts of science and technology in a world that is vastly more interconnected. All aspects of our lives are undergoing rapid and complex change--physically, technologically, and economically. We are behind in our understanding of how humans and institutions respond.

NSF has made research in the human and behavioral sciences a priority in its FY 2005 budget request. We have an intellectual responsibility--and a national need--to explore the human dimensions of change, including how we learn, make decisions, assess risk, and adapt.

Predicting the effects on people's lives, the effects of innovations on markets, and the intentions of terrorists are all areas which can be enriched with social, behavioral, and economic research.

Another area receiving special attention at NSF is the advancing pace of information technology and the need for cybersecurity.

The usefulness of information technology to the scientific process gives the S&T community a double incentive to devote time and money to research to this area.

Advances in computational and information technology enable us to detect subtle changes in the night sky, search for subatomic particles, and make genetic comparisons. They allow us to share massive datasets and remotely operate expensive equipment.

Hundreds of proposals have come into NSF and other agencies for IT research in areas related to homeland security, from language processing to biometrics to coordination of emergency responders.

The downside is the difficulty in securing information systems that have become as much a part of everyone's lives as telephones and TV. Several NSF programs fund research to make computer and network systems more dependable, accountable, and secure. They include a new $30-million-dollar program called Cyber Trust.

I just want to mention one more area crying out for attention--perhaps the one that will affect the future of science and technology the most. That is the training of a skilled S&T workforce and the science and technology literacy of the entire workforce.

The future promises a challenging environment of research across disciplines, more sophisticated equipment, and more powerful information technology.

To operate in this environment, and to remain competitive, we must produce a general workforce that is scientifically and technologically literate. And our science and engineering workforce must be world class by all measures.

Without appropriately trained people, any national science and technology policies will be less effective.

Let me turn now to some ways that scientists might influence national policy-- through educating the public and the policymaker, by engaging the public in the scientific process, and by exercising a voice in policy decisions.

These issues are not ancillary to the science, engineering, and technology enterprise. Research is about exploring, taking risks, and embracing new knowledge. But our broader mandate includes informing the public and engaging broad segments of society in decisions on how the new capabilities should be applied and how they can be secured.

Each NSF program or initiative embodies the need to forge a seamless transition from research results to societal change.

We want to anticipate and guide change in order to design the future of our choice, not just one of our making. As we advance the technology, we have an equal responsibility to ready the social and industrial infrastructure and engage the public in managing change.

Though NSF and the other federal agencies can lead the process of discovery and innovation, communicating to those who make national policy decisions requires a larger effort. The audience includes not just the decision makers who hold public office, but the citizen taxpayers who fund the underlying science and ultimately endorse or decry the decisions.

Carl Sagan warned about a society dependent on science and technology in which hardly anyone understands science and technology. [4]

Scientists have a three-part responsibility in educating the entire population of decision makers.

First, they must join the federal agencies in informing the public about the contributions of science and technology to prosperity and growth.

Second, they must engage the public in generating debate about the uses, risks, and possible restrictions associated with new information and applications. It's important for scientists to recognize the potential for grassroots influence in these areas.

Third, scientists should exercise their voices on regulatory matters, including the issue of balancing access to scientific data with homeland security needs. As John Marburger has said, national security includes securing the freedom to engage in open scientific discourse.[5] Every voice is important in helping the nation decide the appropriate level of scrutiny to apply to the flow of information.

It's important to think beyond publication, to the need for transparency in setting scientific priorities, identifying benefits and risks, and preparing for the transition from discovery to innovation to application.

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I hope these thoughts give you some grist for discussion during your sessions today.

In closing, I'll just re-emphasize that federally supported science, engineering, and technology is in good shape, and it is continually contributing to national needs. It will do so as long as White House and Congressional support continues.

Of course, it's a two-way street. Budget decisions affect the course of science and technology, as do other policies--fiscal, national security, homeland security, intellectual property, and tech transfer, to name a few.

NSF shares with the Potomac Institute the goal of ensuring that good science and technology underlies national policy, and that the risks are anticipated and taken into account.

I'm sure that you'll generate many productive ideas on how that process can be improved.

ENDNOTES

[1] Marburger remarks, "National Priorities in Science and Technology Policy," Rensselaer Polytechnic Institute, November 14, 2003.

[2] Boehlert remarks, conference on Synchrotron Light Source, Brookhaven Laboratory, March 15, 2004.

[3] Brown remarks, "Past and Prologue: Why I Am Optimistic About the Future," AAAS Colloquium on Science and Technology Policy, Washington, DC, April 29, 1998.

[4] Sagan article, "Why We Need to Understand Science," *Parade* magazine, 1989, and remarks to the American Astronomical Society, March 2003.

[5] Marburger remarks, workshop on Publishing in the Life Sciences, Washington, DC, January 9, 2003, and remarks, BioSecurity 2003, Washington, DC, October 20, 2003.

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