Notes for a Panel Discussion at the AAAS S&T Forum, May 8, 2008
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0. We've been asked to address four specific questions, and I will organize my remarks around responses to each one, although not in the order in which they appear on your program.

My focus will be on implications for the United States, although much of what I think is important is inherently and essentially international or global.

1. **What are the major forces that the S&T community will have to deal with in the next century?**

I'd like to consider these in three categories: those internal and those external to the S&T community, as well as those arising from the changing natures of scientific and technical activities themselves.

One set of forces on the S&T community arises from within the S&T community itself. All of these forces are linked in one way or another to the globalization of scientific and technical work.

- The number of countries and places that are prepared and able to conduct research and develop new technologies is increasing very rapidly. This is happening for several reasons:
    - General increase in wealth and education around the globe
    - Liberalization of the societies of many additional countries, responding to the opportunities of market-based participation in the world economy, but leading inevitably to more open societies in which inquiry and invention can flourish.

  - Spread of communications and information technologies that enable many more people to access the latest developments in S&E nearly instantly.
  - Investments in basic infrastructure like stable electric power, clean water, and public order that enable R&D.
- A rapidly evolving global division of labor in which scientific and technical work is being performed by networked teams from around the world, with each team member doing what it does best and in which no one place maintains a "leading edge" capability for very long.
  - Networking
  - Outsourcing
  - Contracting out
  - Capacity building
- Growing private investments in R&D and advanced manufacturing and systems design by leading U.S., European and Japanese firms in emerging countries like China, India, Brazil, South Africa, Malaysia, etc.
- Movement toward a world-wide relatively free market for advanced S&T talent, involving both immigration and international partnerships of all kinds.

A second set of forces that is acting on the S&T community arises externally to the S&T community. This second set of forces represents the many demands being placed on the S&T community by the society of which we are a part. These include:

- Demands that the S&T community address a number of new and very important challenges that were of little concern until recently.
  - Climate change

        - Scientific understanding
        - Technologies for mitigation and for adaptation
        - Social science understanding of behavioral responses
    - Improved understanding of and new ways to respond to the challenges of non-state warfare, especially that waged by technological-leveraged terrorist groups
        - Methods to detect threats to and protect critical infrastructures
        - Intelligence gathering methods
        - Defenses appropriate to WMD and lesser threats
        - Social scientific understanding of the resilience and lack thereof in human and natural systems, as well as of the motivations of and rewards to terrorists, disruptors and others who attack elements of our cultures
- Demands that the S&T community address old problems that have either gone unsolved or that have become more salient owing to changing natural and human conditions
    - Energy supply and conservation and renewables
    - Acceptably safe nuclear power and waste storage and disposal
    - Food supply and distribution
    - New and evolving diseases
- Demands that the S&T community continue to be the wellspring of new technologies that can be used to create wealth and to improve the quality of life for everyone.

The third set of forces acting on the S&T community arises from the very nature of contemporary scientific and technical work. For example:

- What many scientists do and how they do it is increasingly inaccessible to other scientists, to the educated layperson, and to the general public, including young people. Our theories are arcane, our concepts seem strange, and much of what is of interest is either very small or very large or discernible only through the use of specialized equipment or abstruse mathematical and statistical manipulations. In other words, it looks like magic. One of the charms of the Harry Potter books, for example, is the author's frequent appeal to events and phenomenon that look like applications of science, but aren't and can't be. Some are clearly labeled as magic; others are presented as if they are simply manifestations of a perfectly feasible set of inventions that have not yet appeared. How is the typical reader to know the difference? Some of us play squash—shouldn't we expect our clubs to build quiddich courts soon?
- By contrast many of the most interesting and economically important technologies of our time are based, not on direct applications of findings from fundamental research, but instead on the clever combination of pre-existing technologies, new components, marketing insights, creative financing schemes, and an occasional dollop of new science. There is a growing gap between what engineers do and the notion of applied science that informed engineering and engineering education from the reforms of the early 1960s until the turn of the present century.

To reiterate, forces inside the S&T community, forces from the outside, and changes in the very nature of scientific and technical work are all affecting the S&T community today.

Thus, it is time to turn to the second question were we asked to address this morning:

2. How will these forces be reflected in public sentiment and public policies?

Let's consider, first, public sentiment:

- The public's ability to discern real science from all manner of pseudo science is severely limited. Pseudo science is not limited to genuinely fraudulent claims by charlatans and fools. It includes the enormous range of entertainment media, from film, to computer games, to magic shows, in which what appears to happen is not possible within the known limits of scientific understanding.
- The public's expectations of what S&T can accomplish are very high. For example, the Bush administration's continued insistence that developing new technology is key to solving the global warming problem contributes to the expectation that scientists and engineers will be able to "solve" this problem without the need for ordinary people to pay more and/or to endure changes in how they live and work.
- At the same time, the public's frustration with the "failures" of S&T to deliver the goods is likely to mount, in the highly likely event that we won't be able to "solve" all the major world's problems. Further, and more parochially, as an increasing proportion of the world's new technologies and new scientific discoveries are made in other countries around the world, the public will be less

likely to remain convinced that public expenditures on S&T are an un-alloyed good thing.

- And, I can't help but mention that the public's trust in elite institutions, from the clergy to financial institutions to major league baseball to the presidency, has and will continue to spill over into distrust of the authority of scientists and engineers.

Now, let's consider public policies:

- Funding for R&D and STEM education will continue to become harder to get. It's not going to get any easier regardless, for example, of the outcome of the November elections. In fact, the pent-up demands from every sector of society that depends on federal funding are so great that I wouldn't be at all surprised to see R&D funding stagnant or even decline over the next several years.
- Federal funding for basic research will come under increasing scrutiny for several reasons:
    - Lack of clear linkages to outcomes the public cares about
    - Increasing limits on the ability of American companies and institutions to capitalize first and profitability on the findings of basic research owing to globalization
    - Observations of increasing capabilities in other countries and of US use of the results of their R&D for gain here.
- Programs of research to address critical national problems will get a new life, as funds are shifted from fundamental research to problem solving research on the grand problems of our time.

- There will be a renewed emphasis on the use of science in policy making in many areas, with some restoration of the integrity of the processes of science advice at the center and in the agencies. However, the processes for advising on science will become more participatory and make greater use of the outreach capabilities of the Internet and Web applications to engage a much wider array of scientists and engineers in the advisory mechanism. "Trust" will arise from the "wisdom of crowds" rather than from the "wisdom of the elders."

The next big question is:

3. How must the S&T community adapt to its various roles?

It seems to me that the forces and the trends I have identified will lead rather directly to certain adapations in the S&T community. These include the following:

- R&D activities will become more applied and more focused on problem solving. This kind of work typically involves interdisciplinary and multi-institutional teams, often of considerable size. Principal investigators and other leaders in universities, government laboratories, and industry will look more like managers and less like outstanding intellectuals. This is a trend already well underway and I see no likelihood of it changing.
- R&D teams will frequently operate as global teams, organized as cooperatives on a single project, as primes and subs on the model of industrial outsourcing, or unwittingly as contributors of ideas, data, and findings to teams working everywhere.
- A hallmark of a good S or E or will be demonstrated capability to work across cultures and with people of diverse backgrounds and interests. For engineers,

especially, study of foreign languages and cultures, study abroad experiences, and the like will become important.

- In giving science advice, scientists and engineers will need to pay greater heed to the political and social implications of their advice if it is to be of value to policymakers. At the same time, they will need to realize that the array of voices speaking from apparent authority on a wide range of S&T topics will be much greater, and they will need to be content with being one voice among many, or one orchestrator of voices among many, rather than the singular trusted advisor for whom the "ear of the President" is the touchstone of value.

The final question is:

4. How central or peripheral will S&T's role be in the key dynamics shaping this century?

Undoubtedly, S&T will continue to play important roles in American society. But, I am convinced, as I have argued elsewhere, that America will become a "Post-Scientific Society" over the next century, and probably long before that.

For the half century after World War II, the United States unabashedly embraced science as the one of the key, if not the key, solution to national problems. The successful experiences in mobilizing scientists and engineers to deliver miracle weapons and other military hardware and methods during the war gave the public and policy makers reason to believe that science could fix everything. Scientists were only too happy to go along with this view. A nation that can put a man on the Moon should be able to etc etc.

Science was also understood to be THE unchallenged best way of learning about the world around us. It ever seemed to many to offer an alternative answer to the mystery of life. Some will remember when in 1962 Time magazine's cover asked in big bold type, "Is God Dead?" The implication was that science had replaced scripture as the explainer of why we are here.

Every smart kid in the country was urged to become a scientist or engineer and to work, wherever possible, at expanding the frontiers of fundamental knowledge. That new knowledge, coupled with very favorable economic and political conditions enabled the emerging dominance of America in nearly every aspect of global affairs—military, political, economic, cultural, and so on.

The new realities of the global S&T community pose a major challenge to American dominance and to the place of science in defining the spirit of our time. New technologies, new businesses, new wealth, and even new problems seem to lie more in the domain of creation, of marketing, of systems integration and of collaborative effort than they do of Mertonian endeavor or Kuhnian normal science, in which each person does his or her individual best to be first to add the next incremental brick to the edifice of science and invention.

Science still matters to a Post-Scientific Society. But, it may not be OUR science resulting from OUR S&T community. Instead, we will advance by integrating new knowledge from around the world to conceptualize, invent, design, market, sell and use new products, processes, services and capabilities that our own people and the rest of the world want.

In such a Society, American may neither want nor be able to pay for the large numbers of working scientists and engineers that we employed in the past. An S&T career no longer looks to a 17-year-old like the slam-dunk pathway to a successful middle class life that it did to most of us in this room. When one combines the inaccessibility of much of contemporary science to the unaided human senses, with the sense that career opportunities in science and engineering are not what they once were, is it any surprise that "kids today" are opting not to sign up for the demanding devotion to study and learning that such a career involves? I think not. The decline in interest in STEM careers is not limited to the United States. The same thing has been going on in Europe and Japan, and, I am told, is even taking hold in parts of China and India.

A Post-Scientific Society needs science, just as a post-industrial society needs manufactured goods and a post-agricultural society still needs to eat. But, like agriculture and manufacturing before it, science and technology will be carried out by fewer and fewer people, with much of its product being imported or produced by a small number of highly capitalized researchers working in certain favored fields.

So long as we are willing to embrace the demands of the new world of globalized S&T, our Post-Scientific Society can remain successful and vibrant. If, however, we continue to insist on returning to a time that looks like 1958 through 1965, our future is in doubt.

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