Nexus

by Shirley Ann Jackson

where Science meets Society

In an age of discovery and innovation, how can benefits be passed along?

Science and scientists play a vital role in society. The degree of influence wielded by scientific opinion, the reputation of scientific bodies for impartially rendered insight, the priority accorded to scientific research and education all have contributed to the success of nations.

The frontiers of science have never looked more promising than they do today. Opportunities abound. From nanotechnology, to bioengineering, to terahertz imaging, to string theory, to space science, we are in an Age of Discovery and Innovation. The challenge is how to mine these opportunities for all they are worth to impact human health and welfare and security, and to have greater public understanding of, and respect and appreciation for, science.

To frame these ideas, I would like to introduce the simple metaphor of what the ancient Greeks would have called the "agora". This represents the place where, historically, interactions occur among societal sectors and the "public at large". The government occupies a quadrant — the decision-makers, the legislators, the bureaucrats, the regulators, the courts, and the body of law, itself. Industry and the private economic sector — from merchants to corporations — hold their share of real estate. The religious sector — church, mosque, synagogue, and temple — has its place in the agora. And, last but not least, academia — the educators and students who shape the future. The agora is the societal nexus.

This agora is where the public selects its "truth" — or, put differently, what society will accept as "fact." This is where leaders make public policy decisions. But what is the role played by science? Where does the scientist stand in this arena? And how does the role of the scientist shape the formation of public policy — the real nexus of science and society?

Multi-disciplinarity

Before we attempt to diagram the agora of our time — the early 21st century — it is important to understand the convergence of a number of key trends. One is embedded in science and engineering research itself – the trend of multi-disciplinarity.

Consider the rise of nanotechnology. If someone asked you to design more effective armor for soldiers, would you begin by studying the manipulation of matter at the molecular level? Probably not. And yet, researchers in nanotechnology — the practice of manipulating matter at the atomic or molecular level — have made great strides toward developing strong protective clothing for soldiers, in the form of "dynamic armor" which can be activated quickly on the battlefield.

In another example, scientists at Johns Hopkins University have developed a self-assembling protein gel which stimulates biological signals to quicken the growth of cells. Using a combination of cells, engineered materials, and biochemical factors, the gel can replace, repair, or regenerate damaged tissues.

So, there exists a nexus inherent in the multi-disciplinarity of much fundamental and applied research.

Globalization and Security

A second key trend is globalization. The ease of global travel and satellite communication, the inter-linkage of financial systems, the constant movement of merchandise, ideas, and technological know-how, and the electronic exchange of information through the Internet — in itself another synergistic innovation — have morphed the agora into a global forum of ideas. Interdependence among nations and cultures is more complex than at any time in history.

This interdependence has both positive and negative aspects. It brings us enhanced awareness and understanding of global needs, and a greater appreciation of our shared objectives, but it also brings security risks, and facilitates the unchecked movement of terrorists and illicit activity. The efforts of the IAEA to uncover the nuclear weapons technology network of A. Q. Khan and his associates illustrate, dramatically, the vulnerabilities which have come with globalization.

One direct consequence of our heightened security awareness is that technological advances, now more than ever, are being evaluated and funded based on their security applicability — what might be referred to as a "need-based exploitation" of discovery and innovation. Examples would include the search for fool-proof biometrics to safeguard against identity theft, or the use of "hyperspectral imaging" or intricate facial feature databases as technologies to track terrorists or other criminals.

As we look to maintain and strengthen our own security, capacity, and sustainability, we must realize their linkages to global security, capacity, and sustainability.

While the US has a small fraction of the world's population (about 5%), it is by far its greatest consumer of natural resources. This situation cannot pertain forever. The US is very rich. The larger world is very poor — still.

Other nations — some emulating the US model, others not — expect to improve their standards of living, as they should. We are globally linked. The scientific community has always been — through scientist-to-scientist contact. But, as a community, we have not always looked, as we should, at the broader, direct role of science and the scientific community in solving global sustainability and human health and welfare issues.

This requires broadening our focus, entering the policy debates as they apply globally, and having our professional institutions focus in this way.

A primary challenge of the developed world is to deal with terrorism and destabilization by dealing with their causes — primarily in the Third World. Fundamental research, and the innovations which derive from it, give us a way to do this directly, with benefits accruing to all, particularly as they relate to food, health, infrastructure, and environment.

Some examples include: Food, especially genetically engineered, insect-resistant crops; health, especially new medicines and new disease treatment modalities; infrastructure and environment, including new engineering solutions for clean water and sustainability, and, of course, energy. No nation can grow and prosper economically without addressing these needs. Science and engineering can be a potent force for security in this positive sense. This is the nexus where science meets society in global terms.

The Workforce and Education

Another subtle aspect of security relates to human capital development and the threat to them. What is the threat? There are four, actually.

First, as with other countries, the US scientific and engineering workforce is aging. Half of US scientists and engineers are at least 40 years old, and the average age is rising. The number of US scientists and engineers reaching retirement age is expected to triple in the next decade.

Second, world events, and resulting adjustments in federal immigration policy, have made the United States less attractive to international students and scientists, long a source of talent which has augmented our own. Since 2001, visa applications from international students and scientists have fallen. Faced with new hurdles, students from other nations are choosing to study elsewhere.

The number of international students on American campuses declined in fiscal year 2003 by 2.4% — the first drop in 32 years. There was a 28% decline in the number of applications from abroad to US graduate schools, overall, between 2003 and 2004, and a 36% decline in the number of applications from abroad to US graduate engineering programs in the same time period. The decline of graduate applications from India was 28% and from China 45%.

Third, immigrants make up nearly 40% of US science and engineering workers with doctoral degrees (30% of master's degrees). However, the primary sources of science and engineering talent for the United States in recent times — China, including Taiwan, India and the Republic of Korea (South Korea) — are making a concerted effort to educate more of their own at home, and to fund more research within their borders. Between 1986 and 1999, the number of science and engineering doctorates granted increased 400% in South Korea, 500% in Taiwan, and 5,400% (that is correct — 5,400%) in China.

Not surprisingly, the number of South Korean and Chinese students receiving doctorates in the United States declined in the late 1990s. During the decade from 1991 to 2001, while US spending on research and development was rising about 60%, spending rose more than 300% in South Korea and about 500% in China, albeit from an initially much smaller base. In addition, improving global economies are offering young scientists from these and other countries more job options at home, or in other nations.

Fourth, fewer young Americans are studying science and engineering. Moreover, the proportional emphasis on science and engineering is greater in other nations. Science and engineering degrees now represent 60% of all bachelor's degrees earned in China, 33% in South Korea, and 41% in Taiwan. By contrast, the percentage of those taking a bachelor's degree in science and engineering in the US remains at roughly 31%. Graduate enrolment in science and engineering reached a peak in 1993, and, despite some recent progress, remains below the level of a decade ago.

Individually, each of these four factors would be problematic. In combination, they could be devastating.

Multiple Views and Voices

The final set of trends I would cite relates to the exponential rise in the volume and availability of information, and how that has influenced the role of the scientist, and the formation of public policy.

In introducing the metaphor of the agora, I restricted my list of its residents to four basic ones: government, industry, religion, and the academy. But, in the past century, other influential factors, and actors, have appeared and are competing for the attention of both citizens and leaders. This includes the media, which convey factual information, but also filter, editorialize, and provide commentary. It also includes professional societies. While these have existed for centuries, the variety and profile of professional societies increased sharply in the last half of the 20th century.

"Think tanks" are another factor in the mix. In the 1970s, when think tanks began to emerge, they focused, generally, on achieving a specific purpose or analyzing a particular social issue — and the results would be presented in a book or at a conference. Today, in Washington DC, the number of think tanks has grown to more than 200, the budgets of the largest organizations run in the tens of millions of dollars, and the hundreds of experts they employ flood the forum with journals, op-ed commentaries, and television and radio appearances on every aspect of public affairs, from crop subsidies to urban renewal to matters of ethical and moral choice.

And finally, we have the Internet — an engine of information and disinformation without equal. Global in its reach, staggering in its power, it is transforming the Age of Information.

What happens when the marketplace is populated with self-proclaimed experts? When we have instantly available authorities to support every view? The result is the devaluing of information, and even the devaluing of science. This trend threatens the concept of the scientist as the dispassionate, objective voice of reason — and, also, the authoritative role of science in helping to shape sound public policy.

Reinforcing Strengths

I have focused, primarily, on factors which affect the capacity for innovation, which has its roots in the strength and vitality of scientific enterprise and which play off each other — the multi-disciplinarity inherent in important scientific questions, in the application of science, globalization, and national security, the availability of science and engineering talent, and the multiple voices speaking for science in the public policy arena.

So what should we do?

First, we must recognize the centrality of science and engineering for national security, economic health and well-being, and for its ability to help alleviate human suffering worldwide.

This means a full-fledged commitment to invest significantly, competitively, and deeply in basic research in science and engineering across a broad disciplinary front, even in the face of competing priorities. It is stunning when people say that science is just another special interest group, because science (and technology) is the root of success. But it is so embedded that it is taken entirely for granted.

Second, we must have a focus and commitment to develop the complete talent pool: to re-ignite the interest in science and mathematics of all of young people, and to identify, nurture, mentor, and support the talent which resides in people of all ethnic backgrounds and both genders. This requires a focus on early education and preparation, especially in mathematics.

lic and our political leaders must be willing to listen. There needs to be greater awareness and greater respect for scientists and the role of science in resolving critical national and international issues.

The nexus of science and society is not always comfortable for scientists or for the public at large. But, since public institutions largely fund basic research, and support the training of students, science and public policy (even politics) are joined.

We need to look not only at the technical dimensions of public policy, but at the policy dimensions of technological change which springs from basic science.

An example of the nexus of science, technology, and public policy is in the use of risk assessment in the nuclear arena.

If we continue to invest in science and engineering research across a range of disciplines, develop human capital, engage on key public policy issues pro-actively and consistently, and engage the public in new, creative and respectful ways, we can heal rifts and address rising expectations worldwide.

But how do we encourage talented students to commit themselves to the sciences as early as middle school? To stay the often difficult course through high school? To find the means to attend the university, and continue through post-graduate work? To transition into the workplace, the laboratory, the design studio?

Some incentives necessarily must be financial. This would require more economic support for students, and support for a broader socio-economic range of students (of all ethnic backgrounds), and at all educational levels, through graduate school. An example, I and others have suggested could be patterned on portable fellowships like those once offered in the US as a result of the National Defense Education Act for graduate study in science and engineering.

Third, the scientific community must engage on key public policy issues in a consistent, pro-active, not reactive way. Public policy is not always — perhaps, not often — an ideal forum for fair debate. It is a roiling marketplace where every voice has its own agenda, and where an issue can become veiled and confused. But, it is a public marketplace for ideas, it is democratic, and it is open. Of course, the pub-

I was chairman of the US Nuclear Regulatory Commission (NRC) from 1995 to 1999. The major responsibility of the NRC is to ensure safety in the design, construction, and operation of nuclear power plants, and, in so doing, to protect the public, the environment, and to preserve national security.

The NRC's historical approach to this had been prescriptive, with fixed rules. The public gained comfort when all the rules were strictly enforced, even if the safety basis of the rules was not clearly understood. This sometimes leads to public overreaction to events in nuclear power plants, because of an inability to distinguish significant versus non-significant events.

Beginning in the 1970s, probabilistic risk assessment was developed as a quantitative way in which to balance the risks in nuclear operations. It was slowly adopted by the NRC and the nuclear industry. But from the mid-1990s forward, that adoption was accelerated. The regulatory framework began moving from prescriptive to risk-informed, meaning a more robust use of probabilistic risk assessment to inform, but not absolutely determine, all regulatory functions and requirements. Science, then, informed but did not determine regulatory policy. But, what remains, even today, is to move from risk-informed regulation to helping the public understand how risks are evaluated and balanced, in the nuclear reactor arena, as well as in the nuclear waste arena.

Science and technology might suggest that one way of disposing of spent nuclear fuel is to reprocess it, extract plutonium, make mixed-oxide fuel, and burn it in nuclear power plants to gain greater efficiency, and to meet non-proliferation ends by burning up excess plutonium. This is routine in some nations. But, the policy of the US government, since the 1970s, has been not to separate plutonium through reprocessing, because of proliferation risk and instead, to opt for geologic disposal with plutonium embedded in a toxic residual fission product matrix. Science can speak to the risks and energy efficiently of one approach or the other, but which way to go is a public policy decision. Science can inform the policy debate, but not totally control its outcomes.

Fast forward to today. Terrorism and national security are top-of-the-mind issues in the US, and of concern world wide. There are various technologies being used to identify and track potential terrorists. The public, especially in the US, has a general feeling of unease, while some worry about the effect of security measures on civil liberties, and others worry about the scientific community itself — on the ease of communication and interaction with scientists worldwide for the advance of science.

What is not clear is how comprehensively current vulnerabilities are assessed. This is where the scientific community can play a much needed role, and can contribute to a more open discussion, not of terrorist targets, or specifically how risk assessment is used, but at least that it is used. We cannot protect against everything. But, we can use risk assessment to deploy resources in an efficacious way, to track the right things, to aggravate people less, and to calm unnecessary public fears.

Fourth, we must engage the public and make science more accessible to all. It is important that the scientific community, in its outreach, helps people, not only to see the fun of science, but also to understand what science is, what a scientific theory is — as opposed to belief, how science is done, that accepted scientific models or theories are based on evidence, the testing of hypotheses by experiment, and that theories change as new evidence emerges.

What this really means is that the scientific community must understand that the nexus of science and public policy, inherently, means its nexus with public values. We must meet people where they live. Scientific perspectives will not prevail in all arenas, at all times, but we must engage, nonetheless.

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If we continue to invest in science and engineering research across a range of disciplines, develop human capital, engage on key public policy issues pro-actively and consistently, and engage the public in new, creative and respectful ways, we can heal rifts and address rising expectations worldwide. We can ensure our security by helping others to feel secure, and usher in a new "golden age of scientific discovery."

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