STEPS

SCIENCE, TECHNOLOGY, ENGINEERING, AND POLICY STUDIES

IN THIS ISSUE

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Robert Hummel, PhD
Editor-in-Chief

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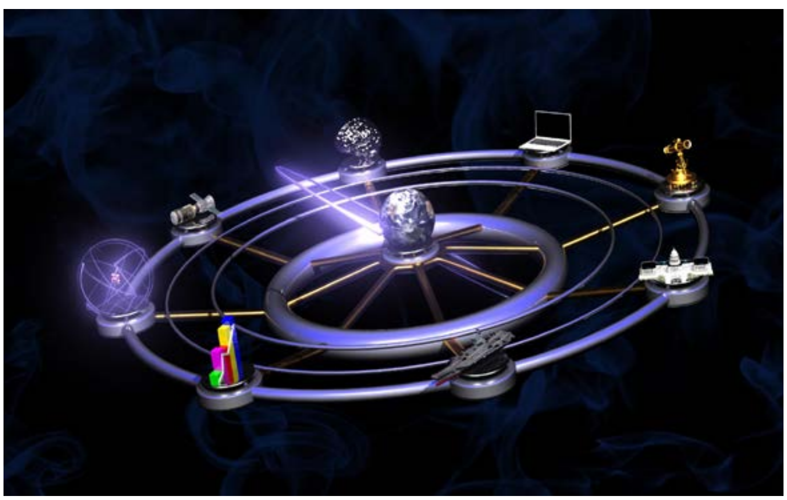

The Potomac Institute has a 20 year history of helping to advise on navigating in a world increasingly driven by science, technology, and engineering changes. The modern world is shaped by different elements. One of the primary goals of the Potomac Institute and *STEPS* is to examine these spheres of influence to help guide policy for the country today, as well as in the future.

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About *STEPS*

STEPS stands for Science, Technology and Engineering Policy Studies. *STEPS* is the technical publication of the Potomac Institute for Policy Studies, where scholarly articles of broad interest are published for the policy studies communities. We welcome original article submissions including, but not limited to: discussions of policies that either promote or impede S&T research; articles that address implications and/or consequences of S&T advances on national or international policies and governance; articles that introduce or review topics in science, technology, or engineering, including considerations of potential societal impacts and influences; and non-partisan opinion pieces concerning policies relevant to S&T, to include S&T research trends; S&T policy event highlights; editorials; letters to the editor; book reviews; and similar contributions.

The Potomac Institute for Policy Studies defines policy and policy studies as a two-way street with respect to science, technology, and engineering. Policies are necessary to advance scientific research toward achieving common good, appropriate use of human and material resources, and significant and favorable impacts on societal needs. At the same time, the creation of effective policy depends on decision makers being well-informed by science.

Societal changes arising from technological advances have often been surprises to mainstream thinking – both within technical communities and the general public. *STEPS* encourages articles that introduce a bold and innovative idea in technology development, or that discuss policy implications in response to technology developments. These articles can include more controversial "outside-the-box," thought provoking contributions intended to 1) encourage discussions concerning science, technology, and engineering developments and related policies, 2) stimulate new research and development or policy actions, and/or 3) stimulate scientist, engineers, and policymakers to support relevant activities. Articles published in *STEPS* will include contributions that consider potential advances that might otherwise be suppressed by reviewers as being too unlikely or "too far out there."

Impressum

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STEPS

SCIENCE, TECHNOLOGY, ENGINEERING, AND POLICY STUDIES

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ARTICLES

VIEWS IN BRIEF

About the Potomac Institute for Policy Studies

The Potomac Institute for Policy Studies is an independent, 501(c)(3), not-for-profit public policy research institute. The Institute identifies and aggressively shepherds discussion on key science, technology, and national security issues facing our society. The Institute remains fiercely objective, owning no special allegiance to any single political party or private concern. With over nearly two decades of work on science and technology policy issues, the Potomac Institute has remained a leader in providing meaningful policy options for science and technology, national security, defense initiatives, and S&T forecasting. The Institute hosts centers to study related policy issues through research, discussions, and forums. From these discussions and forums, we develop meaningful policy options and ensure their implementation at the intersection of business and government.

These Centers include:

- Center for Revolutionary Scientific Thought, focusing on S&T futures forecasting;
- Center for Adaptation and Innovation, chaired by General Al Gray, focusing on military strategy and concept development;
- Center for Neurotechnology Studies, focusing on S&T policy related to emerging neurotechnologies;
- Center for Regulatory Science and Engineering, a resource center for regulatory policy; and
- International Center for Terrorism Studies, an internationally recognized center of expertise in the study of terrorism led by Professor Yonah Alexander.

The Potomac Institute's mission as a not-for-profit is to serve the public interest by addressing new areas in science and technology and national security policy. These centers lead discussions and develop new thinking in these areas. From this work the Potomac Institute develops policy and strategy for their government customers in national security. A core principle of the Institute is to be a "Think and Do Tank." Rather than just conduct studies that will sit on the shelf, the Institute is committed to implementing solutions.

From the CEO

Michael S. Swetnam

The Potomac Institute for Policy Studies marks this year with the inaugural issue of *STEPS: Science, Technology, Engineering and Policy Studies*. *STEPS* adds to our unique stable of outlets where we address the hardest issues of our time, involving the interaction of science and technology developments with policies that determine how we live and work. Every day we are challenged to contribute ideas and policy for the good of mankind. In doing so, we are only limited by our reach and creativity.

The Potomac Institute for Policy Studies was created as a public, non-governmental, independent replacement for the Office of Technology Assessment (OTA) which was abolished by the US Congress in 1994. We have aimed for over two decades to be a "go-to" place for independent, objective, and informed assessment of science and technology advancement. We have also strongly advocated the development of policy and law based on a solid understanding of the relevant science and technology. The Institute has produced countless publications with the goal to cultivate significant science and technology (S&T) policy options. We hope that our contributions have made and will continue to make a difference.

Progress and lofty achievements are most often the result of the boldness and courage of a few who dare to believe that they can make the vital difference and communicate it to the world. We are privileged to work in an organization replete with such people, as well as with equally talented partners across government, academia, and industry who share our vision of developing meaningful policy options while identifying and aggressively shepherding discussion on key science, technology, and national security issues facing our society. These are the types of discussions that we hope to promote through the contributions in *STEPS*.

There is little doubt that S&T leadership has been a key pillar of American economic success during the past 60+ years. We seek to inform and influence vital debates, and provide input into policy discussions at high levels. We are able to observe and learn from science and technology changes throughout the world that directly impact us, and to communicate those findings through our symposia and writings.

Our focus revolves around S&T policy, national security, operational research, terrorism and asymmetry, S&T forecasting, emerging threats and opportunities, cybersecurity, and neurotechnology. These too are the topics of *STEPS*. We aspire to be a continuous voice for meaningful and sound policies that impact, or are impacted by, our rapid developments in science and technology. We ask for your assistance in accomplishing this goal by making submissions and contributions to *STEPS*.

Editor's Notes

Robert Hummel, PhD

It is a great pleasure to introduce this inaugural issue of *STEPS*–Science, Technology, Engineering and Policy Studies. *STEPS* is published by Potomac Institute Press, which is the publishing branch of the Potomac Institute for Policy Studies. *STEPS* will feature authors affiliated with the Institute, but also welcomes relevant contributions from the S&T Policy community.

The transformation from the previous academic journal, *Synesis*, to the renamed and re-envisioned *STEPS*, has had a long gestation. We have been in the process of re-conceiving the journal as a scholarly magazine, containing a variety of content ranging from timely substantial articles on topics of science and technology and policy implications, to opinion pieces that can invoke lively discussions. So after delays of over a year, we are pleased to present this issue, which we expect to be the first of many future issues.

There are multiple reasons why we have moved away from a strictly peer-reviewed professional journal, to a magazine format. However, we are not averse to publishing journal articles for which we will arrange for peer review. We continue to have a board of editors. But, it is our opinion that scholarly articles tend to be more readable, and timelier than more formal, peer-reviewed journal articles. Articles will continue to be carefully reviewed and selected for publication, but not necessarily subjected to peer review.

The rate of change in the topics of interest to *STEPS*, including policy considerations, is such that timeliness is often critical. Accordingly, each issue of *STEPS* will have several topical articles, which are of a substantial length. They are not so long as to require hours of effort to read, but they also cover a topic in some depth.

Articles are intended for an audience that is technically savvy, but not necessarily professional in the relevant fields. Thus another reason why peer review is less compelling is that the articles need to satisfy a general audience, and not pass through hurdles to satisfy professional experts in esoteric fields. In the field of science and technology as it relates to policy, often the concepts require that the author present opinions and personal viewpoints. These are more suitable for articles in a scholarly magazine.

But one of the main reasons that we prefer scholarly magazine articles to peer-reviewed journal articles is that with the former, we can be bolder. Innovation and creativity are inhibited by the conservatism of peer reviewers, and yet good policy usually requires bold assessments of directions and status of science, technology, and engineering developments. The Potomac Institute for Policy Studies has long championed the notion of "Bold Ideas" for science and technology policy discussions, and *STEPS* will contribute to that ongoing theme.

In addition to feature articles, *STEPS* will contain short notes, such as this piece, and views in brief, which will include thought pieces and book reviews. Again, if you are reading this, we welcome your submissions for possible publication in *STEPS*. More information can be found at the Potomac Institute website (www.potomacinstitute.org/steps), and at www.stepsjournal.org.

Robert Hummel, PhD
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From the CReST Blog

The Center for Revolutionary Scientific Thought (CReST) blog features timely discussions addressing key societal, national, and international science and technology issues. CReST addresses Bold Ideas, current events, and policy recommendations. The CReST Blog is one of CReST's forums for discussion of science and technology futures from both an academic and policy perspective. These blog entries are available online at: *www.potomacinstituteceo.wordpress.com*.

KATHY GOODSON, PHD
"Spring Buzz"

Dr. Goodson stresses the importance of science communication in the political and public atmospheres.

JENNIFER BUSS, PHD
"We're All Special"

Dr. Buss emphasizes diversity and uniqueness in today's social, physical, and emotional atmosphere.

CHARLES MUELLER, PHD
"Dylann Roof is a Terrorist, and We Could Have Caught It"

Dr. Mueller writes about the importance in recognizing state-fostered terrorism in light of recent events in Charleston, South Carolina.

CHARLES MUELLER, PHD
"A Call for Change: Embracing the Diversity of Sentience"

Dr. Mueller highlights the importance of individuality and sentient intelligence considering recent work on developing models of computational human intelligence.

CREST
CENTER FOR REVOLUTIONARY SCIENTIFIC THOUGHT

STEPS Policy News

Artificial Intelligence

In a memorandum earlier this month, Secretary of the Navy, Ray Mabus, outlined his goal to integrate robotics and artificial intelligence (AI) into the Fleet. Ideally, the Navy would develop systems that can act autonomously – not necessarily free-thinking, like the popular conception of AI. Mabus implied that automated robotics and advanced decision-making could shape future warfare, and called on the Navy to capitalize on "recent private sector advances in fields such as machine learning, natural language processing, ontological engineering, and automated planning for naval applications." Several Navy R&D projects could be primed for system autonomy, including the recently tested unmanned carrier-launched aircraft (UCLASS), the unmanned underwater vehicle (LDUUV), and the "Swarmboat" unmanned surface vessel. See: *http://news.usni.org/2015/06/15/navy-to-accelerate-artificial-intelligence-development-for-warfighting-support-roles*.

Senate Bill for Patent Reform Looks Hopeful

The Senate Judiciary Committee voted to approve a bill that was designed to limit the number of court cases filed by "patent trolls," firms that buy old patents and sue businesses for infringing on them, in the hopes of financial gain. The Committee has also agreed to expand the scope of the bill to protect patents from being easily challenged and revoked after already given approval by the US Patent and Trademark Office. Pharmaceutical and biotechnology companies hope that this bill will prevent their intellectual property rights from being undermined. The Senate Judiciary Committee will be refining the language before introducing the bill. See: *http://cen.acs.org/articles/93/i24/Patent-Reform-Bill-Clears-Hurdle.html*.

Investing in Clean Energy

The Obama Administration's Clean Energy Investment Initiative has received commitments totaling $4 billion from a group of foundations, investors, and others. This investment will be applied to the development of new, clean-energy technologies building off of the progress that solar, wind, batteries, and fuel cells have already accomplished. In addition to these investments to move ideas to the laboratory and then to the commercial space, the Obama Administration is also initiating a set of executive actions to further encourage development of clean-energy technologies. The Department of Energy will launch a Clean Energy Impact Investment Center to freely distribute information about energy and climate programs both within the DOE and other agencies. The Administration will also issue guidance documents on the impact of investments in this sector and the development of options for the Small Business Administration to enable long-term capital investment from private foundations and investors. See: *Mobilizing $4 Billion in Private-Sector Support for Homegrown Clean Energy Innovation*. by Secretary Ernest Moniz on June 16, 2015. *https://www.whitehouse.gov/blog/2015/06/16/mobilizing-4-billion-private-sector-support-homegrown-clean-energy-innovation*.

Court Allows EPA's Vision for Clean Power Plan to Proceed

The Clean Power Plan, one of President Obama's main climate initiatives, was recently challenged in a federal appeals court by a coalition of energy and fossil fuel companies. The lawsuit sought for the court to assess the Plan's legality. However, the US Court of Appeals for the District of Columbia found the challenge premature because the rules of the Plan are not yet final. Through the Plan, the EPA ultimately hopes to set a separate carbon-cutting goal for each state based on current emissions and capacity. Though even the President acknowledges that executing the Plan will be "tough," he and the EPA believe that carbon pollution in the US must be cut. See: *http://news.sciencemag.org/policy/2015/06/wake-court-defeat-opponents-obama-s-climate-rule-tee-seven-more-attacks*.

EPA's Fracking Study is Not Definitive

Five years after the federal government's request for a report on the drinking water quality impact of hydraulic fracturing, the EPA released its study. "Fracking" is the practice of injecting many gallons of water, mixed with other chemicals, into geological formations at high speed, breaking the formations and extracting oil and gas from within. While the study concludes that there is no evidence of fracking being inherently harmful to drinking water, the EPA does say that in some areas, contamination can occur (i.e. areas of oils spills, poorly constructed wells, etc.). However, environmental groups argue that there is very little field data in the study that supports the conclusion. The EPA plans to use tracers to monitor whether the chemicals used in fracking are leaking into drinking water supplies. This data would indicate whether fracking is in fact causing contamination or not. See: *http://cen.acs.org/articles/93/i24/Fracking-Study-Yields-Mixed-Results.html*.

Chemical Regulation Bill Passes House Committee

On June 3, the TSCA Modernization Act of 2015 (H.R. 2576), which would provide new regulatory guidelines for commercial chemical management, was passed through the House of Representatives Energy & Commerce Committee with near unanimity. An attempt to improve upon the ineffective Toxic Substances Control Act (TSCA) of 1976, the proposed legislation would provide the Environmental Protection Agency (EPA) with the tools necessary to guarantee that chemicals used in every-day products are safe to consume. The bill lays out precise scientific standards by which a chemical's risk-level will be determined, and sets strict deadlines for the EPA to take action when a chemical is deemed hazardous. The House is set to vote on the bill prior to the July 4th recess. *http://www.gop.gov/bill/h-r-2576-tsca-modernization-act-of-2015-as-amended.*

An International vs. Domestic Approach to US Aircraft Emission Regulation Policy

Last week, the Environmental Protection Agency (EPA) labeled greenhouse gas emissions from aircraft as a serious danger to human health. Given that the United States is responsible for one-third of the world's aircraft emissions, US aviation-emissions policies will have a large impact on global greenhouse gas levels. According to the Energy Information Administration, American travelers use approximately six times as much jet fuel as the average world citizen. Whether the US will produce a national standard of aircraft emissions or attempt to form a regulatory policy on an international level remains to be seen. In an industry that crosses international borders millions of times on a daily basis, a country-by-country approach may prove both impractical and ineffective. However, a regulatory policy that applies solely to US domestic flights is being considered as a worthwhile first step. *http://www.usatoday.com/story/news/2015/06/10/epa-airlines-greenhouse-gas-emissions-a4a-iata-icao/28487755*.

Obama Administration Eliminates Trans-Fats from Food Products

On June 16, the Obama Administration announced a plan to remove all trans-fats from processed foods. Citing US Food and Drug Administration (FDA) evidence linking trans-fats to coronary heart disease, the Administration is giving food companies 3 years to phase trans-fats out of all commercial products. The negative health effects of trans-fats have been known for years, and many companies have already made significant efforts towards replacing them with healthier oils. This announcement was the final step in a process that began back in 2013, when the FDA determined that trans-fats could no longer be categorized as "generally recognized as safe" (GRAS). Often used to give foods a desirable taste and firm texture, food manufacturers will now have to petition the FDA in order to use trans-fats in their products. See: *http://cen.acs.org/articles/93/i24/Flexible-Electronics-Injected-Mouse-Brains.html.*

ARTICLES

Image:
Science & Tech
Policy.
Alex Taliesen

FEATURE ARTICLE

*LESSONS LEARNED IN SCIENCE AND TECHNOLOGY POLICY**

James Richardson, PhD

The Potomac Institute for Policy Studies has, over its twenty-year history, conducted numerous studies on particular issues of science and technology, with recommendations to policymakers as to how to proceed in light of the implications of technical developments. In some cases, the recommendations amounted to investment decisions and policies. In other cases, the recommendations related to policies that are dominated by scientific or technological content. Further, some of the issues relate to national level organizations, while others affect one or more federal or state agencies. There were a variety of lessons learned and common themes that emerged over the years from these studies. This article uses selected examples to illustrate some of these lessons and themes.

" … the power of science to alter nature has reached such a state that society needs to have a much more fundamental place in considering its support."

"… fundamental science is unpredictable, unavoidably sets its own agendas, and has an inherent timescale, both in its community structure and its execution, that is ill matched to the short-term perceptions of public opinion."

These two conflicting passages on the left, from the same *Nature* article[1] allude to just one of the many complexities of making decisions on science and technology (S&T) matters. Yet, at every level of government such decisions and policies are formulated daily that not only affect investment for fundamental science, but also dictate or influence technology development and application (both of which may fall under the heading of "policy for S&T"). Additionally, decisions are made that apply science and technology content to engage national issues ("S&T for policy").

In the past, the scientific community has often identified those issues that have high S&T content for special treatment. For example, policies that affect science receive extra scrutiny. But science and technology have become progressively more ubiquitous in our society and technical considerations are claiming a major role in nearly all policies, as even seemingly nontechnical issues demand science for policy considerations. This is particularly true of the data gathering, analytical, and enforcement facets of setting and managing policy. In this article I will refer to these considerations

*"By public policy is meant that which the law encourages for the promotion of the public good. That which is against public policy is generally unlawful." Story, Eq. Jur. Sec. 274. See Newl. Contr. 472.

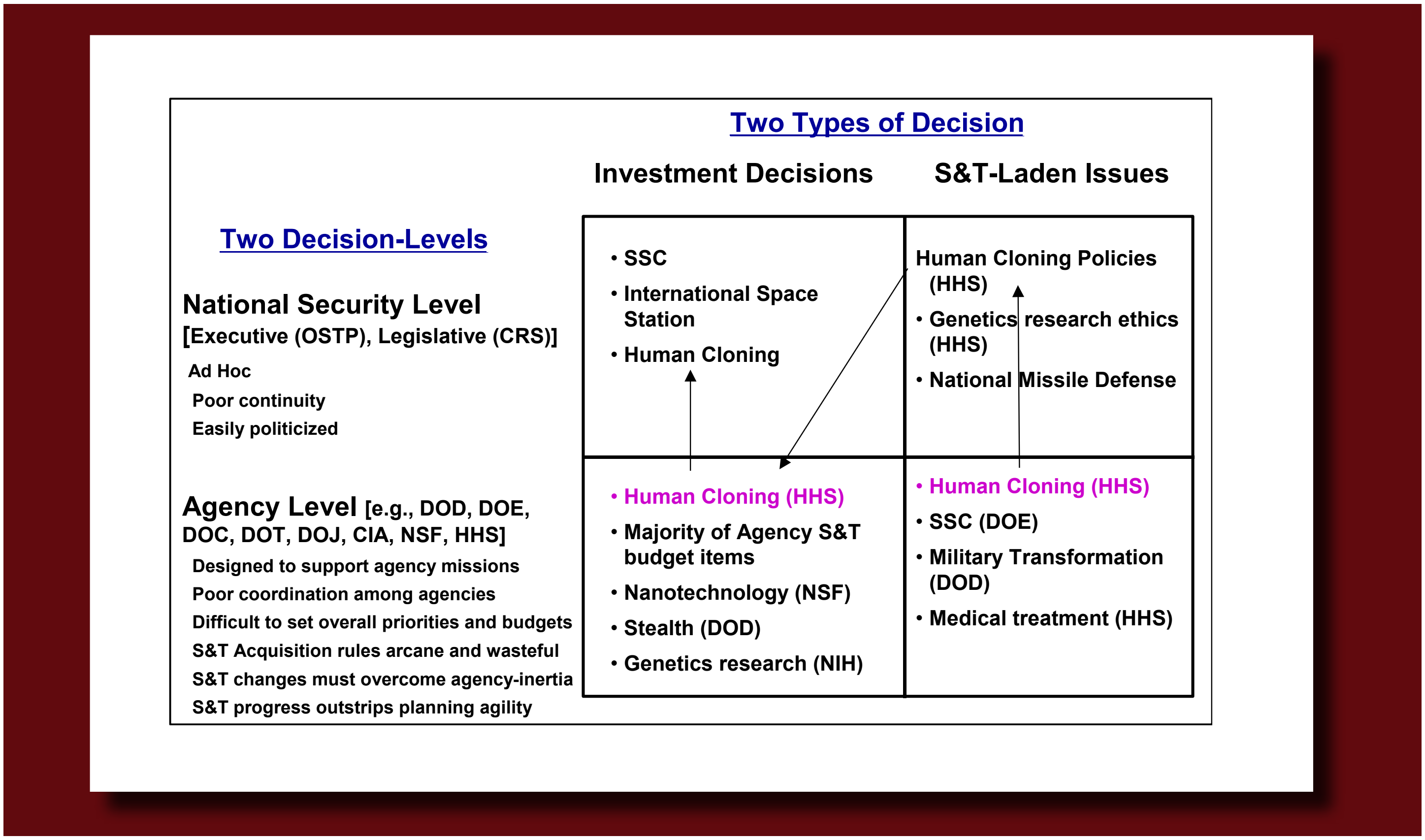


Figure 1. Two levels of federal policy issues.

as "technical aspects" of policy, which I believe seldom receive adequate attention.

Many books and papers have questioned the effectiveness of national processes to produce comprehensive policies that reflect accurate and actionable S&T, particularly in view of the increasingly powerful impacts of S&T on society. *STEPS* provides an opportunity to continue this discussion and to suggest changes needed to engage technical aspects of policy more effectively.

In this article, I offer a few insights into those aspects in the context of a series of studies conducted by the Potomac Institute for Policy Studies (the Institute) during the last two decades. These studies examined and assessed actual S&T programs and issues, with the help of the performing agencies. Although the experience provided insights into individual technical or programmatic problems, there was seldom time to consider how they affected or were affected by existing policies, or more especially to comprehend how the process for creating them could be improved. Writing this article only begins to make amends.

LEVELS OF POLICYMAKING

Before turning to a summary of the Institute's S&T studies from the perspective of policy we should mention the national and agency levels at which policy is generally made and managed. I will not cover this subject in detail in this article, but I would suggest that where policy responsibilities reside often determine their success or failure.

It is true that while most policies are fashioned at the agency level, they are often approved and modified at the national level. Regardless, they generally end up in an agency for management and enforcement. Further, a

"...during the next few decades we will certainly uncover mechanisms more efficiently destructive than those that haunt our dreams today. Along with these threats are exciting opportunities offered by S&T."

good deal of cycling from one level to the other may occur (or even from one agency to another, in the case of policies which may affect more than one agency's mission). That is particularly true as the issues become better defined. This is important because each stage of policymaking, from concept to enforcement, can produce changes in the intended effects of the resulting policy, especially under the pressure of multiple political agendas. In complex S&T policies, these changes in effect may be quite counter-intuitive, or they may jeopardize the degree to which agencies and top-of-government are able to interact with one another. That is especially significant when there is political disagreement on the issues being addressed. Figure 1 diagrams typical policy issues according to the type of policy and the level at which it is handled.

As an example of the migration of issues from one level to another, most government-sponsored work on human cloning, and the budgets that funded that work, are the responsibility of the National Institutes of Health (NIH) under the Department of Health and Human Services (DHHS). Originally, issues were primarily scientific and dwelled in the NIH community. Then, ideological and ethical issues surrounding cloning shifted the debate to the national level, leading to the question of whether all human cloning research should be prohibited, or at least tightly controlled. So, the debate on budget also shifted to the national level, in this case yielding reductions in S&T budget program element lines that affect cloning research, consequently affecting the pace of the work. It did not take long for this action to ripple into the commercial world, where it slowed US private investments in cloning. Similarly, human embryotic stem cell research that depends on the creation of, or at least access to, human embryos was affected by the decision to curtail that access. This demonstrates the breadth and complications of the questions that must be answered before policy is set, especially in the instance where perplexing social issues meet complex scientific concepts.

"TECHNICAL" POLICY CHALLENGES

The nation has many S&T-driven challenges and opportunities. Increasingly, we rely on the products of science and technology, guided by government decisions and policies to mitigate the former and take advantage of the latter. But, in the face of these expectations, S&T policies are too often fractional and narrowly focused, and issues are too quickly politicized. Consideration of S&T at the national level is often inadequate to support good decision-making on investments and other issues, even as the consequences of mishandling these decisions grow. To the degree that we correct this shortcoming, we will improve our prospects to gain the benefits of science without succumbing to its dangers.

We are warned daily about terrorist attacks; computer identity theft; new and frightening diseases; and a looming energy crisis that is creating global climate change, devastating oil spills and radioactive leakage. And, during the next few decades we will certainly uncover mechanisms more efficiently destructive than those that haunt our dreams today. Along with these threats are exciting opportunities offered by S&T, for even as scientific advancement creates problems, it is often the most effective means to solve them.

Over the past two decades, the Potomac Institute for Policy Studies investigated numerous issue areas that involved S&T. Most often the focus of the studies was on research priorities or approaches, or of forecasts, impacts, or applications of specific areas of science or technology. New ideas about transition or application of technologies, or shifts in funding between government and the private sector were also among the goals of these study projects. Whatever the specific goal however, the formulation and management of applicable S&T policy was always pertinent to study findings and featured large in our recommendations. Here are a few study subjects that were engaged and some policy issues that affected them:

Government's role in S&T. As private sector investment overtook government funding in S&T, it became clear that new policies were needed to ensure that a balance was maintained between science and technology and that funding was prioritized among technical areas in a logical and purposeful way. Further, globalization magnified the effects of this shift, especially through the ready commercialization of products of research and development (R&D) programs with military potential, making it more difficult for the DoD to contract with a private sector seeking far more lucrative commercial markets. Yet few changes were made to accommodate the new investment landscape.

Dual Use S&T. As suggested above, a major challenge at this time was how to continue the output of technologically advanced military products when most of the world's R&D was being conducted in the commercial sector for commercial purposes. In 1992 the Defense Advanced Research Projects Agency (DARPA) began a major thrust called the Technology Reinvestment Project (TRP) to design and manage the development of technology products that would simultaneously satisfy commercial and military ends. This was a profound effort and required questioning many hitherto conventional relationships with industry. For instance, DARPA's policies encouraged consortia of government, industry, and academia to create new technologies and even allowed industry partners to retain product intellectual property for commercial applications.

As with many trial government programs, one of the TRP's major selling points was productivity. Because of this, staffing was maintained at such a low level that an internal assessment of the project was impossible (a common policy weakness in programs dedicated to trying out new management ideas). Realizing this need, the project manager asked the Institute to initiate an evaluation of the TRP in 1998. A six-step assessment process was followed, employing carefully chosen metrics to judge the effectiveness of all policies and the success or failure of the products of 113 individual projects to address both the commercial and military marketplace (thereby assuring economies of scale sufficient to lower costs to the military). We presented our findings for both individual projects and for the entire program. Commercial success was evident in 33% of the individual programs and there was military value in 85% of these products.

These assessment results certainly warranted the adoption of the program's governing policies. Instead, the principle DARPA program was canceled when Congress failed to continue its funding.[2] Today, technology dual use is clearly in the DoD toolkit, but it took a long time to get it there and we are still grappling with fundamental questions, such as how to deal with world-wide access to the same dual use technologies for military use.

Shipbuilding in the United States. The US shipbuilding industry is an American anomaly. It is a fairly large employer, but its production levels are relatively low. It can produce remarkably sophisticated warships, but cannot compete in the global commercial marketplace. With this backdrop, the Maritech Program, a joint DARPA/Navy effort, was begun in 1993. The goals of the program were: making the DoD a better customer, injecting the latest technology into ship systems, and improving the commercial competitiveness of the US shipbuilding industry.

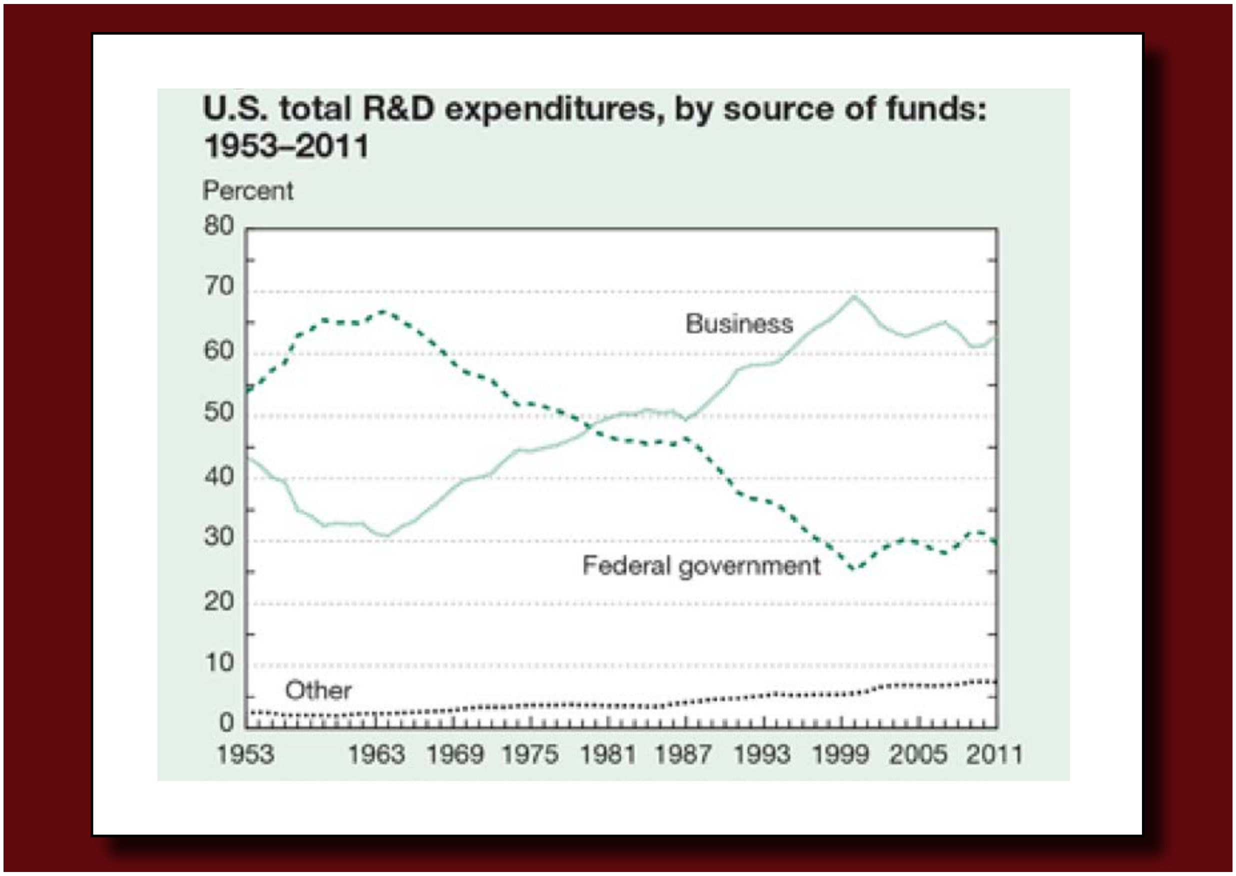


Figure 2.

Percent of US R&D Financed by the Federal Government v. Business Sector. Source Data: NSF, Science and Engineering Indicators, 2014, Figure: 4-6.

The Institute was asked to perform an analysis of the program in 1998. Using similar approaches as those described above, we found the program to be partially successful, making a distinct difference with American shipbuilders but failing to produce commercial competitiveness in the industry. Major difficulties discussed in the study report were embedded in the economic and technical relationships between the industry and the Navy acquisition community that remain mandated by legislation.

Commercial Management and Support of the International Space Station (ISS). At the invitation of NASA, the Institute examined the administration's approach to attracting commercial businesses into the tasks of managing and utilizing the ISS. Issues identified included the prioritization of space transport versus ISS construction; NASA's transparency and willingness to involve the commercial sector; and confusion over the kinds of commercialization that NASA would accept in space. Despite findings by the National Research Council (NRC) that scientific advancement through research under zero gravity conditions could not justify the ISS budget and the oft-cited dangers of relying on the shuttle for transport, the program continued. Our study illuminated many of these issues, but policy remained unchanged out of other considerations.

Managing government R&D programs and the transition of S&T products. The Institute conducted numerous studies of how and how well technologies were being developed and transitioned into use by the DoD. In particular, case studies and metrics were developed for several assessments of ongoing and past DARPA programs to provide a better understanding of the effectiveness of agency program policies.

These policies incorporated a surprising number of management innovations, including the use of technology prototype development and testing; unique approaches to involve customers in product design; and ways to enhance transition potential.

During this period, 9/11 occurred and the Department of Homeland Security was formed, but anti-terrorism R&D was, by most estimates, poorly initiated, including the department's "DARPA-like" S&T arm called HSARPA.

Managing Weapons of Mass Destruction (WMD). Mid-20th Century thermonuclear devices first provided mankind the potential to annihilate life on the planet. During the next 20 years, science may well move us down more paths toward apocalypse. Perhaps as troubling, the enabling technologies may well be in the private sector, not confined to government development and control. During the early 2000 decade, the Institute performed a DoD-sponsored search for emerging technologies that could facilitate the detection of WMD materials or devices. In the face of a considerable spectrum of threats, prevailing national policies were (and remain) unable to fashion a truly interagency approach to solving these problems.

Forecasting the Impacts of Science and Technology on Society. One of the most difficult and yet fruitful study areas addressed by the Institute has been a series of attempts to predict the trajectory and impact of various areas of S&T. It became clear that, while frustrating and contentious, these projections afforded insights that could not be gained through other pursuits. While most of the issues and opportunities that we investigated had been previously noted by others, more in depth perspectives were afforded by many through our analyses. We emphasized the need for carefully sculpted policies. Typically, little is done collectively at the national policy level to prepare for, or even anticipate, the futures of S&T areas. Some of the trends that we have investigated are listed as follows.

- **Medical science** has a list of its own as medicine moves from empirical to knowledge-based. Furthering and applying a knowledge base drawn from a diverse set of scientific fields to improve diagnostics and treatment has led to a better ratio of chronic versus acute diseases and longer lifetimes. For example, breakthroughs in brain and mind research seem likely to offer promise to help cure many mental disorders. The medical bag will contain even more tomorrow: nanotechnology quantum dots, DNA analyses that are becoming more informative and reliable, and so on. "Elder-technologies" will assume priority with the graying of America and most of the developed world. Specific issues include: the application of DNA knowledge to disease; the overuse of antibiotics fostering an increase in resistant diseases; and fending off new and virulent diseases and epidemics; creating haves and have-nots by limiting who receives expensive treatment (e.g., brain enhancement through drugs, implants, or DNA manipulation). All of these issues require better guiding policies for investment.

- **Feeding earth's population**: The world must be able to feed and clothe its eight or so billion citizens over the next thirty years without destroying the ecosystem. To do this, we will need the combined effects of breakthroughs in agronomy, agriculture, and resource management. Here, national policies must become international policies.

- **Mitigating or adapting to global climate change**. Few technical issue areas produce as much conflict as global climate change. Despite the nearly unanimous agreement among scientists that it is real and largely man-made, and the support of a majority of Americans for

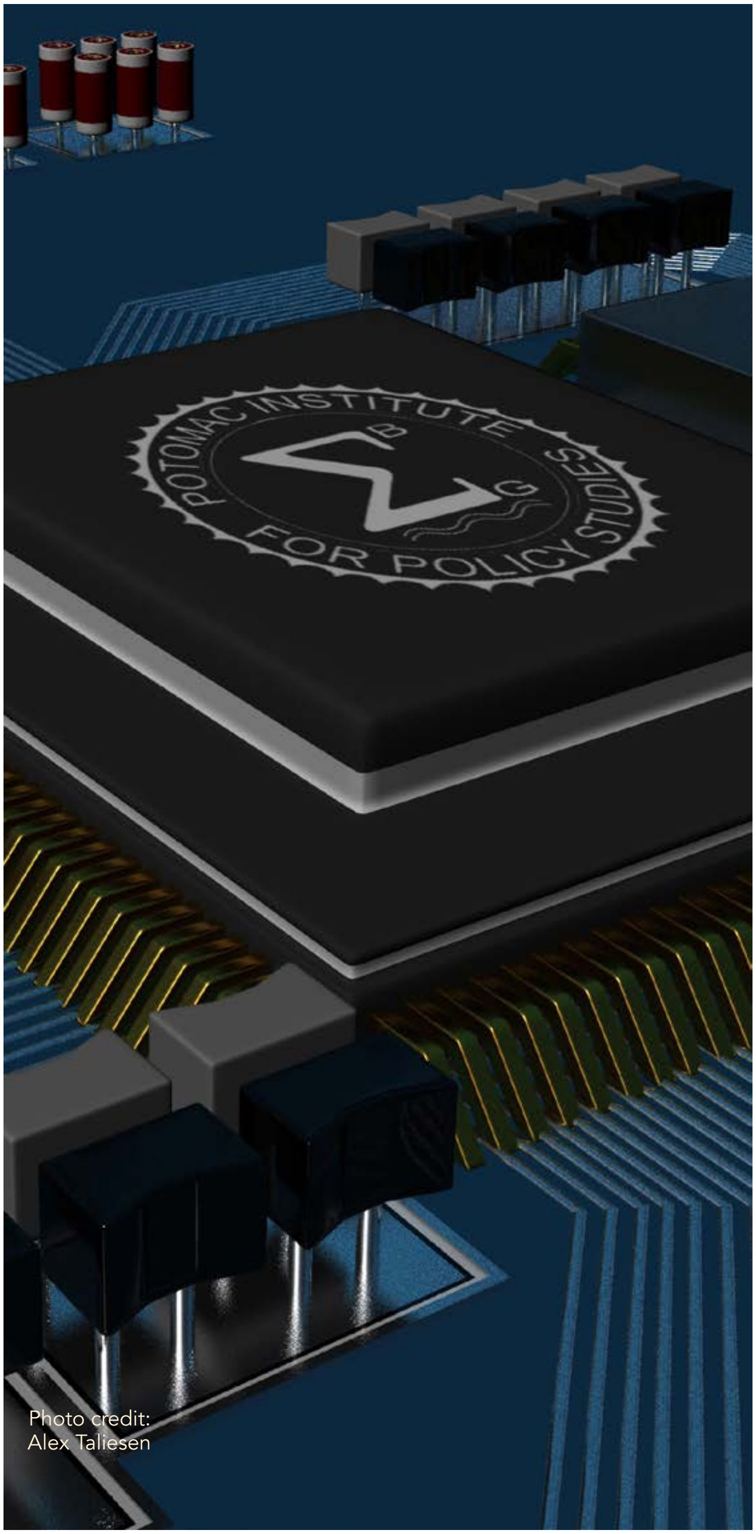


Photo credit: Alex Taliesen

that judgement, we cannot seem to form a cogent and workable climate change policy – certainly not one capable of surviving changes in administrations or Congress. Yet, it seems likely that with careful analysis and management, a basic policy could be developed that would at least allow progress to address the phenomena as statistically plausible. This is another case where a mere national policy is insufficient.

- **IT trends.** Communication, computing, and robotics have been exhaustively examined and yet Institute studies found that national policies have continuously lagged behind issues that need addressing. This is particularly distressing when one looks, however myopically, into the future of IT. Just a few issues that beg for policy attention are:

  - **Big Data technologies and impacts.** As both Big Brother and Big Corporation focus multi-spectral sensors on society, we hear more and more concerns over the loss of privacy and identity as opposed to the benefits of wisdom gained from statistical studies. The number of articles and books published over the past two decades provide sufficient evidence that big data is a subject that begs for wise policies, yet there have been few serious attempts to create even a beginning structure.

  - **Managing the effects of automation on society.** Advancements in robotics and other forms of automation have paid large dividends in releasing mankind from dangerous or repetitive work, while maintaining a constant surveillance on a broad front. The outbreak of epidemics, security breaches, safety, production standards, etc., are amenable to surveillance through technology. These are obviously to our benefit, but downsides, such as the elimination of jobs, need attention. In a recent book[3] Nicholas Carr suggests that robots are being regularly promoted in the workplace, while the people they replace descend the career ladder. This problem has spread from blue to white collar and professions (e.g., on average, airline pilots actually control their aircraft for only 4 to 6 minutes per flight). Today's John Henry is losing the race. Another current issue, that of drone surveillance, poses still another blow to expectations of privacy.

TRENDS OBSERVED FROM THE STUDIES

Our studies, conducted over the past twenty years, have convinced us that making the right S&T decisions today is especially important and is becoming more so as time passes. This is because of six indisputable trends:

First, the rate of breakthroughs in S&T has increased dramatically. Our studies in IT demonstrate this most clearly. Moreover, **the time between these breakthroughs and their application is decreasing**. Again turning to the IT example, a new chip, architecture, or electronic component is barely out of prototyping stage before it is housed in a device and on the market.

The ubiquity and impact on our lives of these products of science is growing. Stunning pictures from the Hubble telescope, frightening revalations about the effects of climate change, and medical treatments unkown just a few months earlier are changing us dramatically. In another example, jurisdiction of computer-driven autonomy is no longer confined to small or unimportant decisions. In fact, defaults to computer judgment represents a significant part of the growing impact of S&T on our lives.

Technical acumen of policymakers has not kept pace with S&T progress. Of course, this is mostly due to the enormous growth in scientific breakthroughs and applications that one must understand, but nearly every Institute study discussed earlier demanded many hours of concentrated effort to understand the fundamentals of the subject matter. National policymakers have little time to devote to such an effort.

While decision processes at the agency level are usually consistent and thorough, they become extremely ad hoc at the national level. As issues move on to this higher level of government, technical questions are more likely to be viewed through the lens of political ideology than scientific metrics, and participants who may represent a broader array of interests than the agency mission dominate at that stage of consideration. In general, there is a lack of formal, objective, and logical process devoted to the issues at hand.

DARPA's deft hand in establishing operational policies to guide their dual use initiative and to facilitate their innovation demonstrates government's ability to make policy work at the agency level. The Institute found few equivalent successes at the national policy community.

The solicitation and use of outside scientific advice is generally poor at the executive or congressional level. For the most part, lack of technical understanding is not due to the unavailability of good scientific advice. Although the processes of forming and managing advisory bodies in the federal government needs some work, government receives much more good advice than it uses or even considers. Government must be able to take advantage of that advice: to understand it, weigh it against other factors, build upon or reject it, and then use it to develop a consistent and wise policy structure.

CONCLUDING DIRECTIONS

The advisor is often at arms length from the advisee, who frequently lacks the time to iterate conclusions and recommendations. Advice prepared for the government is generally poorly aggregated and rarely applied to the problem at hand. It is also vitally important that advisory panels or committees interact with government sponsors as recommendations emerge from their findings. In our experience, there are often unexpected side effects from seemingly unrelated policies. Often the government sponsor will be more aware of these interactions than advisors from outside their organization.

In creating policy, broad issues are often addressed in narrow terms because of political expediencies or disagreement, or simply because of inadequate technical understanding by the policymakers. Essentially all of our studies revealed surprisingly broad aspects of the most esoteric science and technology. For instance, technical advancements in CAD/CAM systems have affected the entire process of building or repairing ships, including billing practices. In another example, the concept of dual use technology development opened new worlds of production and marketing considerations.

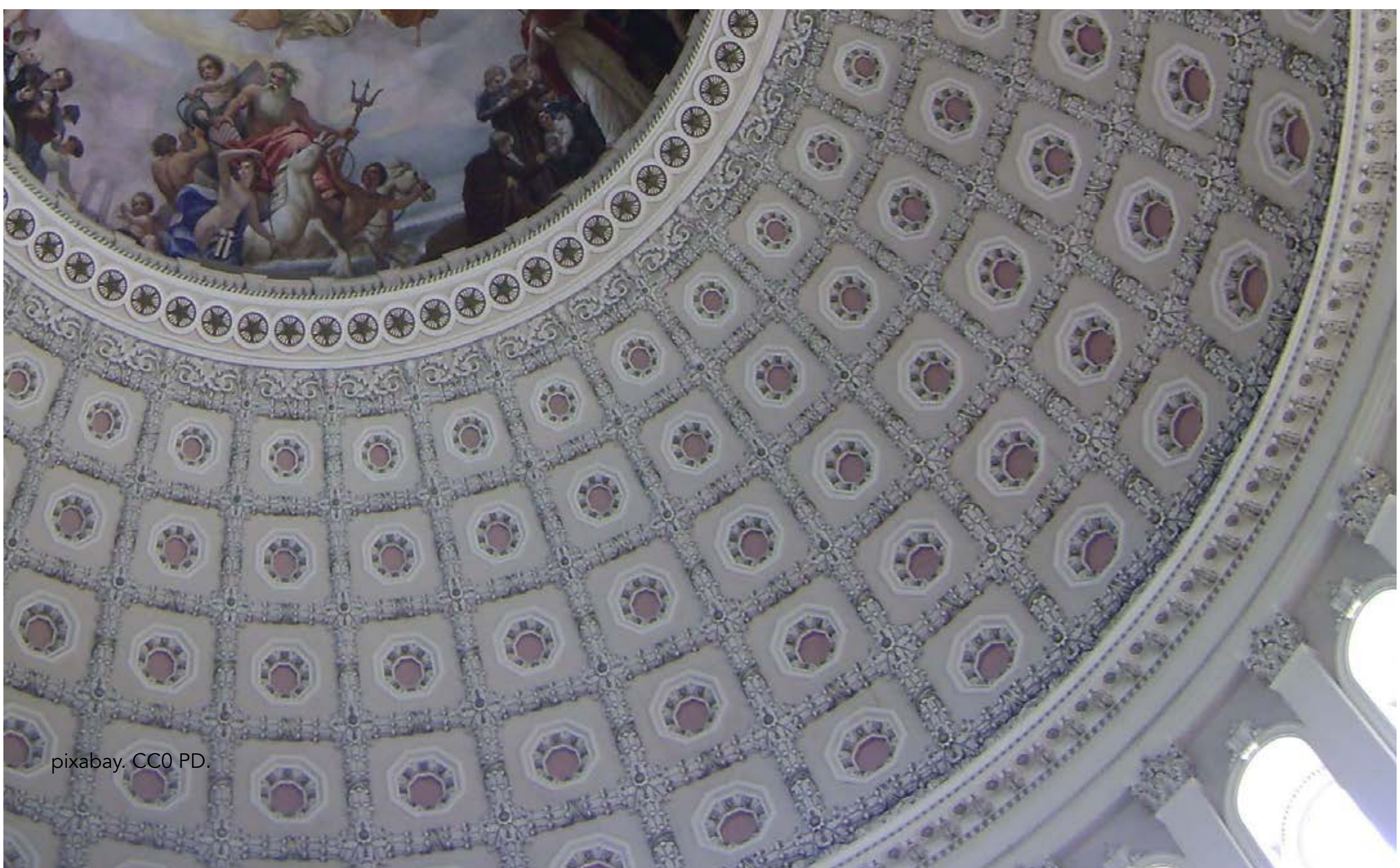
It also became obvious to us that timeliness is important. Emerging technologies, such as nanotechnology and genetics research, require early national policy consideration, not only to direct investment and ensure innovation, but also to prepare society for the direct and indirect impacts of the research and application. Rather than a proactive response to the implications of emerging technology, there is a large gap of time between the appearance of new products of technical innovation and the development of policies to guide them. It is becoming increasingly important to close this gap. We were slow to adopt dual use policies, and we continue to be late in addressing climate change. Again, as difficult as forecasting is, it is often necessary to "get ahead of the game," whether the issue is business or S&T.

Finally, at the point where a policy makes good sense and is clearly beneficial, the government needs a wise ombudsman and a well-defined and fair path to acceptance as a guiding principle. This stage of policymaking suffers from a natural reluctance to adopt policies due to the difficulty of doing so in an always-contentious political climate. More important is the challenge of updating, or even eliminating, policies when circumstances change or contrary information becomes available.

Specific as they may be to Potomac Institute's experience, the forgoing observations lead naturally to actionable suggestions and to recommendations of ways to make policymaking better, which would involve political will. Implementing those changes would be daunting, but might prevent some future crisis or provide massive societal benefits. In any case, exploring those changes and pathways by which they might be implemented is best left to another article.

NOTES

1. "Dealing with Democracy," *Nature*, Volume 425, 25 September 2003.
2. It was assumed by political analysts that funding was withheld because a Congress dominated by one party feared its legacy value to a President who belonged to the other.
3. Nicholas Carr, *The Glass Cage* (W.W. Norton & Co., 2015).



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Sword of Heat

Gerold Yonas, PhD and Jill Gibson

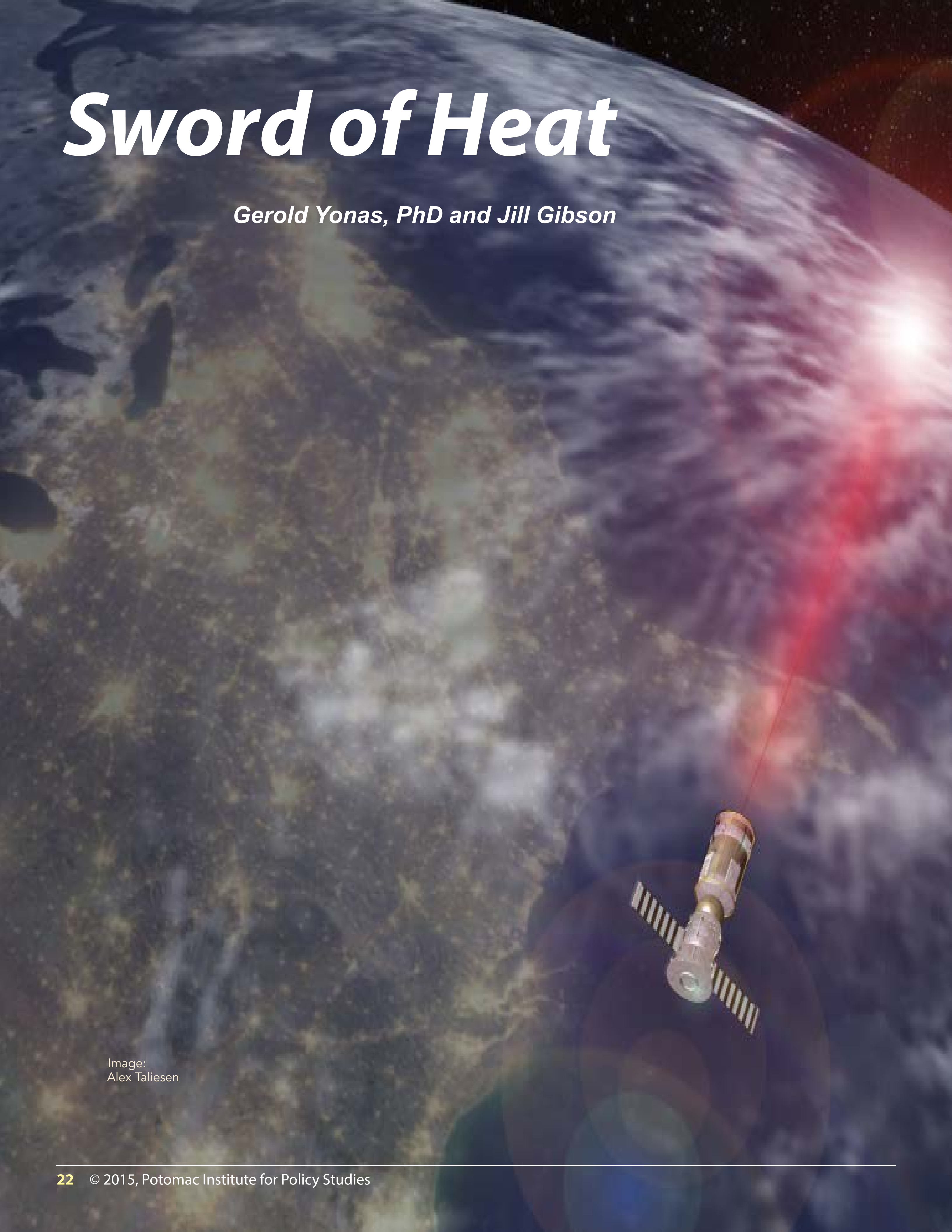

Image:
Alex Taliesen

In the early 80s, America and the Soviet Union stood on the brink of nuclear war. After twenty years of the so-called "arms race," the Soviets had built up their nuclear weapon stockpile from 5,000 to 40,000, while at the same time, in the interest of detente; America had reduced its stockpile from 30,000 to 20,000. Meanwhile, many scientific and political leaders were searching for a high-tech solution to the threat of mutually assured destruction. Some, including President Ronald Reagan, believed the Strategic Defense Initiative or SDI was the answer, but SDI Acting Deputy Director and Chief Scientist Gerold Yonas wasn't so sure.

Today, nearly thirty years after leaving his leadership role in the SDI program, Yonas is writing about his involvement in the creation and evolution of the Star Wars beam weapon program and the role it played in the Soviet Union's demise. Yonas's complex tale moves from the quest to develop science fiction-esque space weapons to the need to understand the political and economic factors that shaped decisions in the Soviet Union and the United States. From death rays to deception and disillusionment, Yonas traces the scientific developments, political posturing and psychological battles that led to the end of the Cold War. Yonas provides a unique, firsthand perspective on the scientific achievements and failures, the people, and the politics that shaped this time period and he explores how technological developments that started with Star Wars could become an integral part of ensuring peace today. His account follows.

In 1982, the well-known Princeton physicist Freeman Dyson delivered a series of lectures about the threat of nuclear war. Dyson summed up the situation by stating, "We now possess weapons of mass destruction whose capacity for killing and torturing people surpasses all our imaginings. The Soviet government has weapons that are as bad or worse. We have been almost totally unsuccessful in halting the multiplication and proliferation of these weapons."[1] Dyson went on to persuasively advocate a negotiated move from nuclear weapons based retaliation toward increased reliance on defense-based deterrence. He suggested that a solution might lie in developing "a concept of weaponry which would allow us to protect our national interests without committing us to threaten the wholesale massacre of innocent people."[2]

This quest for a futuristic weapon to achieve a military advantage was first described in science fiction. In *The War of the Worlds*, published in 1887, H.G. Wells wrote of the use of "death rays"– "An almost noiseless and blinding flash of light…This invisible, inevitable sword of heat."[3] In 1925, Russian novelist Alexei Tolstoi revived this notion of a beam weapon in his book *The Garin Death Ray*. Tolstoi captured the imagination of the Soviet military by describing "transmission that does not disperse… to cut through a railway bridge in a few seconds." Tolstoi also characterized his laser-like weapon as "an invention that smells of higher politics" and noted "our enemies must not get it."[4] The Garin's death ray was simply science fiction – at least at first.

The Soviet push to develop death rays grew from a series of actions and reactions that rapidly escalated and built the arms race. In 1957, the Soviets launched *Sputnik* and America reacted by creating the first intercontinental ballistic missiles. In response, the Soviet military leaders turned to their scientific community to bring them a new and better way to protect Moscow from nuclear tipped ballistic missiles. N.G.Basov, who had received the Nobel Prize along with Prokorov and Townes for the invention of the laser, proposed a nuclear explosion to create a ten million joule laser pulse (with an energy equivalent to six sticks of dynamite). At that time the largest existing laser was just ten joule. Basov soon switched his concept to a more practical chemical explosive pumped iodine laser and achieved a one million joule (MJ) output. This demonstration launched the Soviet Union's Terra 3 program and led to the creation of many rapidly built giant Soviet facilities, sparking great concern within the US defense community.

In 1977, General George Keegan, head of Air Force Intelligence, claimed the Soviets had created "a Particle Beam Weapon capable of destroying the entire US capabilities within one strike."[5] The CIA was so befuddled by such claims and the mysterious Soviet facilities that they turned to their Project Stargate to enlist the services of their remote viewers. One of them studied the "Possible Nuclear Test Site also known as PNUTS" in Semipalitensk, Kazakstan, and drew a picture of a giant multistory crane looming over an unexplained underground structure that only confused US intelligence more.[6] While the Terra 3 program succeeded in garnering US attention, it ultimately failed. After spending more than a decade and countless wasted billions of rubles, Basov canceled the program, and explained, "Well we made sure that nobody can shoot down a ballistic missile by a laser beam."[7]

But that was certainly not the end of the Soviet laser program. In 1980, Evgeny Velikhov, arguably one of the most creative and powerful engineers and scientists in the Soviet Union, claimed, "We managed to place a one million watt laser on an aircraft… knocked down a fast flying missile… Americans reached only one third of this power in a flying laboratory…We can do anything…all our troubles are found inside our heads."[8] The Soviets then set out to create a space based anti-satellite weapon. Yuri Kornilov, design head of Salyut Space Station, wrote about this Polyus payload for the Energia booster saying, "No excuses were acceptable… everything was run according to schedule demands…. iron willed idea, iron willed oversight, iron willed time frames, and spare no expense."[9] The Soviets were developing a space-based weapons system in spite of ongoing negotiations to de-escalate the arms race.

Meanwhile a study by the White House Science Council[10] had advised against the idea of using high power lasers for ballistic missile defense, but US President Ronald Reagan felt the idea was promising. Reagan issued a challenge in his controversial 1983 "Star Wars" speech, saying, "I call upon the scientific community in our country, those who gave us nuclear weapons, to turn their great talents now to the cause of mankind and world peace: to give us the means of rendering these nuclear weapons impotent and obsolete." Reagan set the goal of finding a technological solution to end the nuclear arms race. The SDI program grew from his rhetorical question, "What if free people could live secure in the knowledge that their security did not rest upon the threat of instant US retaliation to deter a Soviet attack, that we could intercept and destroy ballistic missiles before they reached our own soil or that of our allies?"

A key component of Reagan's Star Wars proposal was his willingness to share American strategic defense technology with the Soviet Union – provided that the Soviet Union was willing to cooperate in the interest of achieving peace.[11] This desire to share technology with our adversary represented the most controversial and progressive aspect of Reagan's proposal. The Soviets, however, were in no mood to go along with this initiative. Yuri Andropov, head of the KGB and soon to be the leader of the Soviet Union, immediately responded, "This is a plot to militarize space…and attack from the skies…to disarm the Soviet Union in the face of the American nuclear threat… not just irresponsible, it is insane."[12]

A few months later, Secretary of Defense, Caspar Weinberger requested that James Fletcher, former head of NASA, put together a plan to realize Reagan's vision. Fletcher appointed Harold Agnew, former head of Los Alamos National Lab as his deputy for a three-month study. Agnew asked me, as an expert in pulsed power systems and Vice President at Sandia National Labs, to head up the directed energy weapon (DEW) section of the study, with instructions to focus on long-term high-risk issues that Fletcher called "the long poles in the tent." Charged with identifying funding needs and feasibility issues, I turned to Harold Agnew for advice. Agnew's response was far from positive. "The process could be really dangerous," he warned me, predicting "there would be so many contractors trampling each other on the way to the sources of funding." Shortly after that, Agnew walked away from the study and opposed the long-term focus on DEW, suggesting instead an emphasis on space based sensors and ground based interceptors.

At the end of the Fletcher Study, I concluded, "The ultimate effectiveness, complexity, and degree of technical risk in this system will depend not only on technology itself, but also on the extent to which the Soviet Union agrees to mutual defense arrangements and offense limitations… The outcome of this initiative of an evolutionary shift in our strategic direction will hinge on yet unresolved policy as well as technical issues."[13] The far more public statement issued from the White House stated, "By taking an optimistic view of newly emerging technologies, we concluded that a robust ballistic missile defense (BMD) system could be made to work eventually." Weinberger told Fletcher, "rest assured the resultant report will indeed have a major impact on national security strategy…..for the benefit of mankind we are committed to seize the opportunity."[14] Weinberger said he supported the program as highest priority research and development in the Department of Defense. In spite of the support from Weinberger, General Brent Scowcroft issued a report on the future of nuclear deterrence, and totally discounted any defense.

In early 1984, Weinberger asked Air Force Lieutenant General James Abrahamson to head the newly formed Strategic Defense Initiative (SDI) program. Abrahamson asked me to become his deputy and chief scientist and Sandia National Labs agreed to lend me for two years as Acting Deputy and Chief Scientist. My assignment focused increasingly on ground based interceptors and mid-course discrimination, but I remained convinced the key would be a negotiated agreement to reduce nuclear weapons. I proposed "a jointly managed missile launch detection system… to reduce instability…and set the stage for movement toward mutual acceptance of the transition to defense dominated deterrence."[15] I also advocated an arms control approach and a shift to a focus on defense based deterrent, not protection of population. At separate meetings with Vice President George Bush in 1985 and Secretary of State George Shultz in 1986, I emphasized that the program was a long-term research and development activity with no clear road to any defense system deployment.

Despite my skepticism, the SDI program continued to receive high-level support. Two SDI advisors who had been pioneers in the US ICBM program, General Schriever and Simon Ramo, told General Abrahamson: "SDI is technically and management-wise the most complex and difficult program ever undertaken by this country…perhaps by an order of magnitude…the most important for the survival of the free world." The Soviets were also taking the SDI seriously. Alexander Yakovlev advised Gorbachev, "We needed a plan to crush SDI…a block of concrete would completely flatten it…so we offered nuclear disarmament by 2000."[16]

When I arrived in Washington, DC in the spring of 1984, I found my SDI office in a dilapidated office building on H. Street with no air conditioning – and, even worse, no security. There were only a handful of people to run what was to become an enormously controversial and complex program. I eventually was assigned an office with General Abrahamson, in the Pentagon, but it took years to get decent offices for the staff. In my two years in the Pentagon I was involved in not just the creation of this multi-billion dollar program, but faced with the chaos and confusion of dealing with truckloads of contract seeking engineers, busloads of angry academic scientists, carloads of confused and prejudiced Congressional representatives, multitudes of reporters, gangs of protestors, and unlimited numbers of average citizens from all over the world who wanted to know what exactly we were trying to accomplish, by when, and at what cost? The answers were not forthcoming.

My brief time in the Pentagon was spent dealing with the constant criticism from some of the most prestigious members of the scientific community. I found myself in dozens of debates, including an argument carried out in print with face-to-face full color photographs with my former Cornell quantum mechanics professor and Nobel Laureate, Hans Bethe. Bethe openly attacked SDI in an article, saying, "The entire system could never be tested under circumstances that were remotely realistic…mutual deterrence is all we have."[17]

In another publication, I went up against one of the leaders in the arms control community, Wolfgang Panofsky, who had authored my favorite college textbook on electricity and magnetism. In his article, Panofsky amused his audience with his wit: "Something fascinating about science, one gets such wholesale returns of conjecture out of such trifling investment of fact. SDI is so much political and strategic posturing on such limited technical and military potential." Panofsky was absolutely correct that the political implications often dominated the reality of science and technology, but instead of considering the psychological implications of futuristic weapons research, he went on to ridicule the SDI, saying, "like a dog walking on his hind legs, it is not done well, but you are surprised to find it done at all."[18]

As I continued fighting off attacks and defending the research behind the SDI program, both the US and the Soviet leaders were gearing up for Reagan and Gorbachev's October 1986 summit in Reykjavik, Iceland. In preparation for the Reykjavik summit, Gorbachev's advisers had told him that US defenses could eventually be "99% effective" and even "allow at most 0.1% of the attacking missiles to get through." The Soviet military advisers informed Gorbachev, "The Soviet Union lags approximately 4-5 years behind the United States in research on creating the elements of a space based missile defense echelon."[19]

Gorbachev also knew that his own military industrial complex was rushing forward to deploy their first space based laser weapon. The Soviet military instructions to Gorbachev just prior to Reykjavik were, "It is necessary to delay the US defense system to gain time to conduct analogous work in our own country and to develop counter measures against the US BMD…if the US does not test these weapons over the next ten years, that will allow us to decrease our lag behind them in creating the space based ABM defense."[20]

Reagan went into the Reykjavik meeting ready to deal, but not prepared for Gorbachev's bold initiatives. In fact, before that historic meeting, George Shultz told his assistants, "We should trade the sleeves of our vest." [21] But Gorbachev was far from agreeable. During the negotiations, Gorbachev demanded, "The testing in space of all space components of missile defense is prohibited, except research and testing conducted in laboratories." Reagan's response was, "What the hell is the difference, in the lab or not, besides I can't back down since I promised the American people I would not give up SDI. Do me a favor, Mikhail, since we get along so well, and then the two of us could bring peace to the world." Gorbachev replied, "I am not against SDI, but if I agreed to testing and development outside the laboratories and testing in space, I could not return to Moscow. Your testing would allow you to create weapons and a large scale space defense system in ten years."[22] The meeting ended with the two world leaders feeling crushed and defeated. Nothing had been resolved.

Meanwhile, I had completed my two-year assignment to the Pentagon, but I was nowhere near finished with my involvement in SDI. In December of 1986, just a few months after I left Washington, I was invited to attend an SDI conference in Tutzing, Germany. I saw this meeting as an opportunity to close my assignment by "setting the record straight" and leaving a permanent record of what I understood at that time. Little did I know that many of my scientific colleagues attending the meeting were ready to take a particularly hostile stance against SDI. The participants were less interested in getting answers than in sharing their views of the past and future of the program. I usually took a less than serious approach to such public interactions but this audience had little tolerance for my humor.

The meeting took place in a German castle near Munich in a building that looked a bit like a set from one of the those World War II depictions of a US command center. I could imagine General Patton standing at the front of the conference room giving orders. I later learned that General Eisenhower had in fact used the castle as his headquarters in command of the allied forces as the war drew to a close. The castle had been the centerpiece of the decisions involved in the destruction of Nazi Germany. At the time I did not know that we were involved in the soon to be destruction of the Soviet Union.

The castle had even a more notable history as the meeting organizer Klaus Gottstein explained in the opening session. Gottstein surmised that in the 8th century, the inhabitants of the castle were worried about the coming of doomsday, and the destruction of humanity in the 10th century. Gottstein explained to us that here 1200 years later we were still "worrying about the possibility of doomsday," but he suggested optimistically that we were not just hoping, but pursuing SDI in order "to make peace more secure."[23] Despite Gottstein's optimism, many of the Americans

Photo credit: National Archives and Records Administration, courtesy Ronald Reagan Presidential Library.

present at the meeting were seeking an end to the SDI program and they had arrived prepared to administer the program's final deathblows.

The meeting included 33 carefully chosen participants who were encouraged to express their opinions openly concerning the murky social, political, economic and even technical issues of SDI. Most of the participants were German scholars and defense professionals, but the attendance included a handful of carefully chosen scientists and academics. I knew all of the Americans since I had been engaged often in debates and discussions with them, and knew they would be opposed to my opinions.

I saw this meeting as an opportunity to tell my story and deal with the most difficult of all audiences I had ever faced. I gave the opening presentation with a detailed and fairly complete view of the myriad of technical issues that had to be resolved. Many of these had been identified in the summer of 1983 study chaired by James Fletcher. We had only just started on the program in the spring of 84, and in less than two years of real organized activity, there had been little real resolution of any of the key issues. I had no illusion that my audience would tolerate my lack of reported results. In fact, they were not at all forgiving.

The atmosphere was initially very informal and friendly with suggested audience participation, but it did not take more than a few minutes into my talk for Richard Garwin, probably the most knowledgeable strategic offense/defense expert in the world, to interrupt me and say. "Enough about questions, but what are the answers?"[24] He knew from my opening remarks that I viewed SDI as a long term broadly-based research program, but he would not accept that we didn't know the answers already due to the administration's many claims. I argued that we would have to spend several tens of billions of dollars and at least ten years to answer the important questions but Garwin disagreed.

Garwin's interruption was just the first salvo of what would be a determined onslaught from the American defense experts. I felt the Germans wanted to be more open and even sympathetic to my views maybe out of courtesy to a guest, but the Americans showed little kindness to the person that they treated as a rank amateur or even a slightly unprepared scoundrel. I was faced with blistering comments from some of the most highly respected arms control experts.

Robert Cooper, a recent head of the DARPA, who had been engaged for many years in strategic defense technology, did not hide his contempt for what he described as the low technical capabilities of the Department of Defense. Cooper even implied that I was an example of the DoD's lack of knowledge.[25] He made it clear that there was nothing new in missile defense science and technology to back up the Reagan vision to "protect all of the people all of the time."[26] Cooper opened the gates for Jack Ruina, another former head of DARPA, who then went on the attack. "Gerry won't like this, but Star Wars has seen its last good days, and I would not buy stock in the SDI program now. We don't always believe in what Presidents have said in the past, and after all, this is political rhetoric."[27]

Garwin listened for a while and I began to think he was going to drop the personal attacks and defend me when he said, "Of course SDI has some good things going." I sighed with relief but then he went on to say, "Even the Mafia has some good things they do… and when the SDI is put into receivership under the bankruptcy lawyer, there will be an official appointed to look at the good programs…"[28] I wondered if he might want to be that official?

George Rathjens, a distinguished MIT professor and a former deputy head of DARPA added, "SDI is going nowhere, and we should not support it any longer…the responsible thing is to kill it as gracefully as we can."[29] I argued for a continuation of the program that would lead to an arms control agreement that allowed for a continuation of a treaty compliant technology program. I suggested that we consider other forms of retaliation that would be less time urgent and thus avoid instabilities in a rapidly evolving crisis. I advised that we move away from missiles delivering multiple warheads and toward an agreement that would be based on a public understanding of the problems of continuing the present approach. I concluded that rather than continue the meaningless discussion of a perfect defense, we focus on a more stable form of deterrence. I argued, "The public will accept the impossibility of eternal life, but would be willing to invest in research to prolong life."[30]

> ***"Success is not final, failure is not fatal, it is the courage to continue that counts."***

My point of view was one of strengthening deterrence, rather than getting rid of it and jointly managing a transition with the Soviets to greater reliance on defense and reduced investments in strategic missiles. I suggested, "Societies will change if we can survive until sometime in the next century, where we may look upon this reliance on a vast quantity of nuclear weapons as being a temporary chapter in the history of mankind."[31] In the end, the conference participants only wanted to talk about the futility of the technology. I didn't disagree with the futility of the technology but technology is only useful within the political context. Like Freeman Dyson, I was seeking a live and let live, win-win solution to ending the arms race. But my American colleagues were not listening.[32]

The conference in Tutzing ended with the SDI detractors muttering that the United States should stop wasting money and the Germans still wondering how it was possible that the Soviets could be so worried about such a "worthless" program. Little did we know at the time that the Soviets had taken the US SDI program very seriously and their investment in the arms race had helped drive the country to economic ruin.[33]

Just a few years later, the Soviet Union imploded, the cold war ended without a single shot being fired, and Gorbachev was removed from power. Even with no persuasive technical results during my Pentagon assignment, the Star Wars program had achieved one of Reagan's goals by contributing to the Soviet Union's demise. In many ways, the entire story reads like something from science fiction. Perhaps that's not a coincidence. Long before he became president, up and coming actor Ronald Reagan starred in the 1940 Warner Brothers movie, *Murder in the Air.* Reagan played a Secret Service agent who stops a foreign spy from stealing the plans for a new defensive weapon. This fictional weapon is able to destroy any attacking missile and will, according to one of the film's characters, "make

America invincible in war and therefore be the greatest force for peace ever invented." Sound familiar?

Today, I still wonder if high power lasers will always be little more than the HG Wells' vision of a "sword of heat." With increasing proliferation of long range missiles and nuclear weapons, maybe the technical breakthroughs and new political thinking will create new opportunities for a credible missile defense. Scientific developments now appear to be making a true Star Wars program possible. In 2002, DARPA formulated a project that stated "tens of kilowatts output power and capability to scale to greater than hundreds of kilowatts output power and beyond will be demonstrated through coherent combining of the output power from multiple single-mode fiber lasers."[34] Having seen so many claims of future high laser developments, I have to admit to some skepticism; however, recently, Lockheed Martin announced, "Fiber optic lasers are revolutionizing directed energy systems...30 Kilowatt, single mode laser prototype...burned through an engine manifold in a matter of seconds from more than a mile away."[35] An effective Star Wars missile defense program could be right around the corner. Maybe Churchill was right, "Success is not final, failure is not fatal, it is the courage to continue that counts."

These are just a few of the highlights of my direct involvement with SDI. With the passage of nearly thirty years, we have seen dramatic offensive and defensive technology advances. Today, the proliferation of weapons of mass destruction, the widespread availability of long-range ballistic missiles, and the steady advances in defense technologies have changed the situation. Given these developments coupled with the demise of the Soviet Union and the passage of time, perhaps my former detractors and those who disparaged the idea of a long-term SDI research program would now see the program in a different light. Perhaps not. While Reagan's "Evil Empire" may be gone, the true need for strategic defense technology may be more necessary now than ever. My experience with the SDI taught me that there are many complex lessons concerning the interplay of science, technology, politics, resesearch, management, diplomacy, and science policy. I plan to continue to explore my recollections and their ramifications in future writings, as I track the past, present and future of the real "sword of heat."

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Concerns Over the Continued Health and Quality of the US Basic Research Enterprise

Robert Hummel, PhD and Jennifer Lato

While basic research is the foundation for economic and defense effectiveness, recent trends suggest a decline in the quality of the US basic research enterprise. Drawing from a 2012 Defense Science Board (DSB) report on the Department of Defense (DoD) basic research program, this paper considers the issues of globalization of research, lack of educational competitiveness, and bureaucratic burdens as stressors to the US basic research enterprise. Bolder and more worrisome contentions than found in the DSB report, extrapolated beyond DoD basic research, are posited. Possible responses based on the findings are considered, and a commentary on recommendations to policy changes is provided.

INTRODUCTION

There is a general perception, and considerable evidence, that the quality of basic research conducted by US scientists and engineers is declining. Although US science and technology, particularly at the basic research level, has been heralded as the best in the world for much of the past century, other nations have of late been attempting to raise the quality of their scientific research contributions. While the intention is that fundamental basic research contributes to the world's body of knowledge, and thus is not a competitive endeavor, the reality is that a vigorous and diverse science and technology program leads to economic and national security benefits by virtue of rapid transition of knowledge into capabilities. The industries and defense businesses of the United States have massively benefited from US dominance in basic research and US-driven technology development, particularly in the post-WWII era. Accordingly, there is reason to worry as to whether the rise of other nation's basic research capabilities, and the globalization of research, might lead to a diminution in the quality and effectiveness of US basic research toward national economic and security goals.

Indeed, storm clouds have appeared. In 2007, and in 2010, the National Academies published "Rising Above the Gathering Storm," and "Rising Above the Gathering Storm, Revisited," with scathing warnings of the ominous signs of the lack of competitiveness of US Science, Technology, Engineering, and Mathematics (STEM) education compared to the rest of the world.[1] The 2013 "Global R&D Funding Forecast" from Battelle Corporation is subtitled "The Uncertain State of U.S. R&D," and demonstrates even greater concern for academic research.[2] US federal government funding of R&D into 2013 was at best flat because of sequestration and a decline in federal research dollars to universities, which fell in 2012 largely due to the end of the American Recovery and Reinvestment Act (ARRA) funds, as well as drops in medicine and biomedical research funding.[3] Since then, funding increases have been anemic. While funding levels do not equate to quality, and the ARRA was always intended to be a temporary funding source, for the past decade there have been reasons to worry about trends in the overall quality of US research.

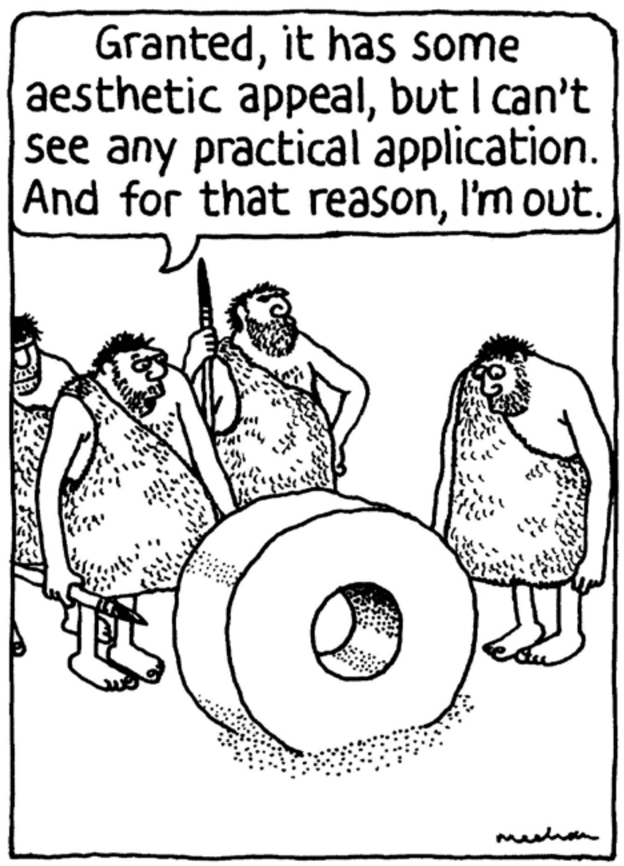
As a result of concern over defense basic research, the Defense Science Board (DSB) was commissioned in 2010 to study the defense research portfolio, and to provide strategy and management advice. Led by Dr. Craig Fields and Dr. Lydia Thomas, with Executive Secretary Dr. Robin Staffin from the Department of Defense, this high-profile group studied Department of Defense (DoD) basic research planning and management from October of 2010 into spring and summer of 2011. It was then, in January 2012, that the Defense Science Board published the report of its Task Force on Basic Research.[4] According to the DSB report, the DoD operates a sound basic research program, comparable in quality to other Government basic research programs. However, the report notes several areas in need of attention, calling specifically to issues within human resources, global research, technology strategy, and bureaucratic burdens. While the study was a response to the issue of defense basic research, many of the comments apply to the national basic research enterprise, particularly government-sponsored research. The executive summary of the report groups the recommendations in the following areas:

- Reducing bureaucracy and improving efficiency and effectiveness of the basic research enterprise;
- Building stronger relationships between basic researchers and the ultimate users of the outcomes of the research;
- Strategies to develop science-based human resources for basic research;
- Maintaining a vital workforce in the service laboratories;
- Recruitment and hiring new graduates; and
- Ensuring effective and exemplary program management of defense basic research.

The recommendations of the DSB task force build upon findings and recommendations from a 2005 National Academies assessment of basic research, and recommendations from a 2009 Jason study concerning S&T for National Security.[5,6]

All three studies produced astute observations, and the recommendations deserve careful analysis and consideration. Much has changed in the direction and imperatives of the DoD since the study was conducted, and prior studies are even more out of date. While these studies involved subject matter experts, and participants with deep knowledge and understanding of the basic research enterprise, the reviewers are loathe to be critical of an enterprise that has benefited the nation in critical ways. Thus, a critical review of the basic research enterprise might lead to improved prospects for ameliorating the decline.

The tenor of the DSB report is that the status quo is acceptable. This implies that the one should recommend to "stay the course." However, the DSB's recommendations suggest various changes, and certain new investments and activities. These point to problems and issues, which should be confronted head on. Further, many of these issues are not specific to defense portfolio concerns, but rather to the basic research enterprise of the nation. Accordingly, this article takes the DSB report as a harbinger of a more general and broad assessment of basic research quality in the United States.



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ISSUES

The DSB task force identifies a number of problems and issues, which are grouped into three categories:

- Research Globalization: The task force observes that research (in general) is globalizing. That is, not only is more basic research taking place outside of the United States, but that successful basic research projects typically involve collaborations that cross national borders.

- Bureaucratic Burdens: The task force identifies certain bureaucratic burdens that are imposed on basic researchers and the administration of basic research, which they point out subtract from the overall budget and performance of basic research. The implication is that the level of bureaucratic burdens is increasing, and unreasonably so.

- Talents are Unutilized: According to the task force, basic research and researchers are not being leveraged sufficiently. That is, talents are not being utilized, and research results are not being transformed into useful capabilities rapidly, or at all. Additionally, the task force suggests that the overall level of innovation within DoD is falling.

These are serious issues, yet they are not completely novel. While globalization has especially accelerated in the past few years, science and technology research has long complained of bureaucratic burdens. Transition has also been a problem for decades, as expressed in the famous "valley of death," for the dearth of investment after obtaining research results.

The task force also notes the lack of a DoD technology plan. In fact, the Department previously maintained a Defense Technology Area Plan (DTAP), and Joint Warfighting Science and Technology Plan (JWSTP). However, due to the demise of the "Reliance" process of "Technology Area Review and Assessment" (TARA), both DTAP and JWSTP have been neglected.[7] Though the reliance process has been generally viewed as wasteful and ineffective, the publication of a DoD technology strategy is highly desirable.

If we look across the government, we see that basic research is supported in a variety of separate departments other than DoD. For example, Health and Human Services (HHS) accounts for roughly half of all federally-funded basic research.[8] The National Science Foundation funds both individual science research, and also certain "big science" endeavors (which mostly fund science infrastructure development).[9] The executive-branch Office of Science and Technology Policy conducts some cross-cutting coordination, but once again, a national science and technology strategy is lacking.[10]

Given that the DoD task force's recommendations are directed only to DoD, they do not sufficiently confront all concerns for US basic research. By concluding that the DoD basic research program is comparable in quality to other agencies' programs, it assumes that DoD is equal to the National Science Foundation (NSF), Department of Energy, or National Institute of Health's (NIH) basic research programs. This immediately begs certain questions:

- Is "good" good enough? Whether we are talking about DoD research, or NSF, or NIH, what is the absolute quality of the DoD basic research enterprise? If comparisons are in order, how does the work compare to the best program outside of the United States, or the best international collaboration that will provide results to competitors?

- Is the trend positive or negative? Is basic research quality and quantity as funded and/or guided by DoD getting better, or getting worse? Will the trend yield a program that will deliver the body of basic research results that will provide sufficient benefit to DoD in the future? The same issue applies to the entire basic research enterprise in the United States.

- How should DoD basic research investments be distinguished from other agencies' investments? This is a hard question because basic research is usually conducted without a specific application as an objective. Instead, basic research hopes to discover fundamental principles that can lead to any of a wide range of technologies or capabilities. How should we coordinate basic research across agencies in such a way that preserves unity of effort and strategic goals?

These questions raise difficult issues, but they hold strategic importance. It is well understood that basic research is the foundation for economic and defense effectiveness of the future.[11] Basic research continues to receive strong support from policymakers, and many studies, including the DSB task force report, provide evidence of the benefits of basic research.

CONTENTIONS

The DSB Task Force notes that it has not addressed US basic research concerns. To quote from the executive summary:[12]

> *"This study did not do full justice to these substantial issues of globalization of science, technology strategy, and the innovation ecology, largely focused as it is on the current DoD basic research program. Nevertheless, the task force considers addressing those issues of considerably greater import than modest refinement of the already very good current DOD basic research program."*

The report does not attempt to provide an absolute, or even a useful comparative assessment. What is needed is a more independent, objective, and bolder study. Based on the DSB task force data, as well as other data, contentions listed below identify what a bolder study might find.

1. The US Basic Research enterprise is rapidly getting worse, squandering a long history of excellence, by virtue of producing less quantity of quality work, and paying less attention to high quality results when they do occur. This is happening despite continued high quality human resources, and an ability to train the best scientists in the world. The decline is exacerbated by the fact that there exists increasing opportunities abroad for temporary US visa-holders who receive graduate degrees in the United States. The "time to market," or speed of transition of research to application, has become the central issue in maintaining competitiveness. This is due to the globalization of research, and the rapid rise of basic research enterprises throughout the world. The United States has never excelled in transitioning basic research rapidly to capabilities outside of a wartime footing, and the industrial research and engineering sectors are generally averse to incorporating basic research output. This aversion has greatly increased in the past decade.

2. Certain scientific fields offer game-changing potential, but are inherently high-risk, or have benefits that may exist in the distant future. According to the Office of the Secretary of Defense Basic Research Office, some such fields include synthetic biology, quantum information science, cognitive neuroscience, human behavior modeling, novel engineered materials, and nanoscience. These areas need to be pursued as an insurance policy against technological surprise in defense systems, and to maintain economic competitiveness. Further, a corps of competent young scientists should maintain the level of expertise in these areas to rapidly transition breakthroughs should they occur. Given the trend of greater industrial funding of R&D via Federal largess, these long-term benefit areas are receiving insufficient focus.

While 1) and 2) above are contentions, the DSB Task Force report provides some amount of support for these as findings. For example, page 47 of the task force report states:[13]

> *"It is not surprising that, as a result, many of the professionals currently filling academic positions at universities and scientific positions in research laboratories are foreign-born. The task force believes this indicates the United States is losing the technology race for the minds of talented citizens who increasingly have chosen law or finance over science and engineering."*

- Other support for the finding above comes from multiple sources:

- The fact that multinational corporations establish most of their newest research sites outside of the United States suggests that the basic research enterprise in the United States has become uncompetitive.[14] Most worrisome is the idea that once one falls behind in a scientific field, it is very hard to re-establish a leadership role.

- Further, the demise of corporate basic research labs, exemplified by AT&T Bell Labs and Xerox PARC (among others), means that the basic research ecosystem has changed over the past couple decades.[15] There are fewer job prospects for scientists to remain in basic research throughout their careers in the United States. As well, there are fewer transition points from basic research to applications.

- The past decade has included a focus on rapid acquisition of capability, which has lessened focus on longer-term development of fundamental science. The Department of Defense has emphasized at all levels, including basic research, evaluation of the short-term benefit to current mission operations, and has emphasized "application-driven research."[16] The cues to researchers are sometimes subtle, but often not. Even the evaluation criteria applied to proposals to the National Science Foundation have emphasized "impact," which does not seem to take into account the necessary risk that is a part of basic research.[17]

- University faculty members are highly encouraged and motivated to create companies, which detracts from their mind space for deliberation of fundamentals. Start-up companies have proliferated in academia, encouraged by venture capitalists, universities, and state and federal government policies.[18] While helping create jobs and economic activity through technology transition, it can be argued that they detract from exploratory basic research by diverting the very people who would otherwise be performing it.

- Most importantly, global competition has now been trained and instructed in the business of science and technology innovation, and has sought to mimic American success at innovative technology development and insertion. Foreign-born students and workers that are trained in the United States are encouraged to return home (in the case of China, the returnees are called "sea turtles")[19] through programs that pay competitive salaries and provide easy research funding, and through US temporary-visa policies such as student visas.[20] Notwithstanding the inducements for foreign STEM graduates to return, the large number that do stay suppress salaries (according to the research of Lindsey Lowell), which causes large numbers of talented US-educated scientists and engineers to find careers in other fields.[21] While these supply and demand dynamics are seen primarily in IT support areas, it is not unreasonable to think that similar market distortions are occurring in fields that support basic research. The result is that rather than having the best and brightest enter fields from the pool of available researchers, the incoming body of researchers is instead composed of those willing to work for depressed compensation levels.

Any of these trends could portend a precipitous drop in the relative quality of basic research in the United States. Whether any or all are the root cause of an actual decline, or whether that decline is real or imagined, requires further study.

Contention 1) further states that the transition to market (or, in the case of DoD, to a defense application) is lacking, and indeed is getting worse. The contention is that it is becoming more important to move rapidly from a research result to a fielded system, and DoD does not perform this transition well.

The case for DoD is particularly acute. A decade ago, it was noted that transition from basic research to defense application often took circuitous paths, sometimes involving foreign developers or multinational corporations.[22] DoD has also transitioned basic research into the commercial marketplace prior to adoption for defense needs.[23] For example, DoD developed the networking technology that became the basis for the Internet, and while DoD networks use this technology today, it only became widespread after the adoption in commercial endeavors. The difficulty confronting DoD is that basic research is increasingly globalized, and the fast pace of technology advancement means that slow adoption by DoD will lead to inferior defense capabilities. However, attempts at making basic research results more proprietary to DoD is likely to decrease its ability to leverage commercially driven technology. This conundrum is a key issue for basic research, and requires a sophisticated solution.

For commercial industry, the incentive is to piggy-back on government or foreign research, rather than perform in-house basic research. Ultimately, however, such a policy will "eat the seed-corn" that is needed for timely entry of new systems into market. Instead of being a market leader, industry will be reduced to "fast-following," which typically places one in a competitive catch-up mode.

The second contention suggests that we are neglecting the important high-risk high-payoff areas, and increasingly exposing ourselves to technological surprise. The issue particularly concerns maintaining a cadre of scientists through STEM education and fundamental science research. According to President Obama's Federal Science, Technology, Engineering, and Mathematics Education 5-Year Strategic Plan (2013), it is in the nation's interest to increase STEM education, which is critical for national security. President Obama has called for action for an additional 100,000 STEM teachers, who will produce 1 million STEM graduates within the next decade.[24] Additionally, DoD maintains personnel at laboratories and federally-funded R&D centers in order to ensure a continued supply of scientists in a variety of critical fields. However, a common concern is that many of these personnel are ready for retirement, and are unable to keep up with the fields that require upgrades to skills. Moreover, with DoD labs down to 9% PhDs, and competition from startups and multinationals for science talent, there is a real concern that junior scientists will not be enticed to enter careers in government to provide for government-specific needs.[25] In the event that they do, government positions tend to be pedestrian, due to infrequent or nonexistent procurement of specialized technology.

Education is only one aspect of the issue of supply of talent for DoD-specific needs. The supply of specialized talent also depends on satisfying career paths for those selected to become the corps of scientists and engineers. Students recognize the relative lack of job opportunities for graduates of most STEM fields, and instead choose to pursue careers in law, business, health, and banking professions. The specific technologies or areas that should be supported are also uncertain. Most of the topics that are currently considered crucial come from systems that have been procured in the past, and are thought to be essential in the future. Thus, we believe that we need to maintain nuclear weapons experts, and the Department of Energy has labs that maintain those knowledge bases. However, administrators of these labs recognize the need to entice scientists with other challenges and missions. While we would not advocate dropping nuclear weapons knowledge, the right-sizing of past technology capabilities and incorporating experts on new critical government-specific technologies is a challenge that requires an adequate pool of incoming science experts. DoD has set in place STEM programs that are intended to help in achieving these pools. But a detailed analysis has not been conducted of the appropriate levels of supply and the likely demand for scientists and engineers, for the DoD or the nation as a whole. Instead, the National Science Foundation issues annual reports analyzing past supply and demand issues, as "indicators," but without a national strategy, it is hard to know what the future can or will bring.

SOME POSSIBLE RESPONSES

How should the nation respond if, as we have contended, the quality of basic research is in decline? Since our future security and competitiveness may be at stake, it is important to develop policies that address these issues.

Of course, there is the issue of resources. Federally-funded research, in particular, basic research, needs to be maintained and managed in a way that strengthens quality and the potential for positive impact. With federal budget controls, we are moving into a regime where private sector expenditures are considered more desirable than discretionary government sector funding, and while basic research has historically been highly dependent on government support, private sources are still possible. For example, university R&D (which is largely – but not entirely – basic research) is funded 62%

by Federal government sources; universities self-fund (largely through tuition income) 19%, and other sources supply the remaining 19%.[26] If we discount funding in the health areas, then the non-federal sources are more important to the remaining areas.

For the nation to reinvigorate basic research, it is unrealistic to think that it can be "done on the cheap." Whether public or private funding is involved, the nation will have to expend more on ensuring a vigorous and productive basic research endeavor.

An implementation plan developed in response to the recommendations of the DSB task force on basic research lists five areas of recommendations:

1. Practices that better adapt DoD to the globalization of basic research;
2. Improved policies of basic research personnel in DoD;
3. Improved policies of personnel in DoD labs;
4. Recruitment of more STEM talent;
5. Improved business practices in the management of DoD basic research.

These broad general goals can easily be translated into an action plan for reinvigorating national basic research. However, sufficient resources will be needed, and some policy changes will be required, as opposed to simply perpetuating past practices.

GLOBALIZATION

Participation in the global network of researchers is critical for success, and the nation will need to increase its connections with the international science and technology community. As previously noted, this is a challenge for DoD, but also applies to national science and engineering.

One approach to increase globalization is to encourage the use of sabbaticals. Promoting international collaborations among university faculty is happening in any case due to pressures on university faculty. The larger issue is finding mechanisms whereby the nation can benefit from these international collaborations.

The Office of Naval Research (ONR) has an intention to increase funding for ONR Global, with discussion of an increase of up to 5% of ONR's total funding.[27] ONR Global, and related operations in DoD, help bridge the government to the international community, while gathering valuable information regarding the directions and intentions of foreign researchers. These efforts provide more direct intelligence into government agencies.

However, these efforts are small steps regarding the more fundamental issue of avoiding technological surprise, and making sure that scientists are fully engaged in cutting-edge basic research by being productive members of an international collaborative community. Bolder efforts would encourage transition of international research to start-ups and small multinational businesses with strong ties to US researchers and opportunities for US workers.

BASIC RESEARCH FUNDING POLICIES

Currently, the majority of basic research occurs within universities. The career path for these researchers involves teaching and scholarship, with requirements for receiving sponsored research. With sponsored sources becoming more problematic, there is increasing pressure on university basic researchers to divert their attention to more application-oriented work. Further, relying on university resources (which are largely obtained from tuition dollars, or equivalently, state funds tied to enrollment numbers), is untenable in the long run. It represents a transfer of resources intended for training to long-term research goals. Nonetheless, competition among academic fields, and some level of oversight and management, will help keep quality of basic research at high standards. Thus, the issue is balancing resources against needs. Recent reports suggest that NSF funding has dropped to less than 5% of applications. At this level, most applicants will quickly become discouraged, no matter how much they improve their proposal. On the other hand, if funding were to become a near certainty, quality would suffer. At this point, oversight and management influence has become increasingly intrusive.

> ***"If we assume that of these extra million scientists, a quarter will pursue basic research that requires public funding, then in today's dollars, we are committing approximately $50 billion per year in additional S&T funding"***

GOVERNMENT PERSONNEL POLICIES

Of the 35,000 scientists in 67 DoD laboratories across the nation, roughly 9% have doctoral degrees, 26% have master's degrees, and 63% have bachelor's degrees.[28] A percentage of these scientists are engaged in basic research, though nearly all have responsibilities for applied and development work in addition to basic research responsibilities. The quality and caliber of basic research at the laboratories is thus highly dependent on the quality and caliber of laboratory personnel.

Making lab careers attractive is an important goal, but is hard without expenditure of additional resources. There is a critical mass phenomenon: With PhDs dropping to 9% overall, candidates might find insufficient collegial possibilities at the lab. Thus we see a concentration of doctoral talent at a few institutions, such as the Naval Research Lab and the Army Research Lab (and at a number of labs outside of DoD, such as NIST).

According to the DSB task force, government agencies that conduct research depend on a "constant influx of new ideas and fresh perspectives [through] term appointments, visiting researchers, and officer rotations." However, temporary appointments are not about recruiting scientists to a career. A university maintains a constant influx by replacing graduating students with matriculates each year. Since government laboratories are not primarily educational institutions, maintaining vitality and quality is more difficult.

One response to this need is that government laboratories should partner with local universities and create an influx of graduate students and postdocs. This suggests that the labs be transformed, in part, into adjunct universities. For the most part, universities contain a careful and interlocking balance of undergraduate and graduate education and sponsored research, along with incubators and professional development policies. Some laboratories have existing associations with local universities, but effective public-private partnerships that are mutually beneficial are difficult to set up. Further, similar issues and problems exist with respect to Federally-funded research and development centers (FFRDCs), and University-affiliated research centers (UARCs). Fundamentally, the problem is that maintaining a cadre of researchers current in basic research is expensive. Trying to piggyback on other entities' investments is not productive, especially since basic research is under pressure for reduced financial support by non-government sources.

RECRUITMENT OF STEM TALENT

The nation has a number of efforts aimed at STEM education and recruitment of STEM talent. For instance, the Science, Mathematics & Research for Transformation (SMART) program encourages undergraduate and graduate degrees in STEM by awarding full scholarships and the opportunity for employment following degree completion. However, according to the US Department of Education, only 16% of American high school seniors are proficient in mathematics and interested in a STEM career. Even among those who do go on to pursue a college major in the STEM fields, only half choose to work in a related career. Certain international tests purport that the United States is falling behind in terms of young talent, ranking 25th in mathematics and 17th in science among industrialized nations.[29]

We previously mentioned the administration's desire to "...develop, recruit, and retain 100,000 excellent STEM teachers over the next 10 years," and to graduate an additional one million students with STEM majors.[30] This reflects a huge investment and expenditure of opportunity costs. Moreover, the intention is that a large portion of these million added scientists should pursue careers in science and technology (or engineering). If they do not, the opportunity cost of training students in STEM is the money and time that would have been spent training students for something else. The usual enticement is the promise of a career, and thus we are making an implicit commitment of some number of meaningful scientific careers. These might be in the private sector or in the public sector. As we have seen, basic researchers are more likely to require some degree of public funding for their entire careers. If we assume that of these extra million scientists, a quarter will pursue basic research that requires public funding, in today's dollars, we are committing approximately $50 billion per year in additional S&T funding.

BUSINESS PRACTICES

The DSB task force identified how little basic research funding actually goes to real basic research. An analysis of the example of AFOSR funding suggests that about 35% of the appropriated basic research funds support research efforts, and that the remainder of the funds go to administrative burden (both within government and industry and university administration). More importantly, it should be understood that research is not bought by the hour, but by the quality and caliber of the researcher. Research productivity increased by having better researchers, and having researchers that are able to devote a larger percentage of their effort to collaboration, research, and dissemination.

As prior studies and reports by industry, universities, and associations indicate, there are "troublesome clauses" in contracts that limit the ability to conduct basic research. Of particular concern, is the International Traffic in Arms Regulations (ITAR) and the notion of "deemed exports."[31] DoD has attempted to provide a "fundamental research" exemption to non-disclosure clauses in contracts as required by the Defense Federal Acquisition Regulations Supplement (DFARS). However, contract officers have not respected these exceptions. The exceptions are not mandatory, but rather subject to the interpretation of agents. Some have suggested that DFARS be amended, but unless there is a mandatory exception for basic research, and an easy-to-interpret specification of when a contract constitutes basic research, defense contract officers will continue to conservatively require non-disclosure, effectively thwarting collaborative and global research.

The DSB Task Force made specific recommendations to reduce bureaucracy that impedes efficiency. Yet who is going to identify inappropriate burdens on basic research conducted for federal or corporate sponsorship, and rule them as inappropriate? For example, who will decide, and measure, when an administrative burden imposes more costs than it saves? Anecdotal evidence suggests that many researchers consider NSF grants to be too burdensome to be worth the proposal effort. Research management is a bureaucracy, and as such it tends to grow over time. Therefore, a full-scale assault is necessary, for example, by an independent commission.

CONCLUSION

The nation needs a wake-up call, and must understand the consequences of the decline in the quality of its basic research enterprise. In 1957, *Sputnik* awakened the nation in such a way that succeeding investments in science and technology led to massive economic growth and prosperity. At that time, the nation redoubled efforts to address STEM fields, both in education and in professions. Since then, the perception of the importance of basic research has waned, and the rewards for practitioners have diminished.

The pace of technological innovation has only accelerated, yet federal research funding has dropped from 10% of total government outlays during the space program, to 3% as of 2015.[32] An event constituting a wake-up call could even be too late, if and when it occurs.

Many will view the disputes above as alarmist. Many will deny the contentions in the previous section, and contend that there is not a problem. Indeed, the US has top-rate scientists and remains the envy of the world when it comes to technology development and innovation. Yet such accolades are a lagging indicator, and mask a serious situation involving a major decline. The causes are many, but bureaucratic burdens and uncertainty of career paths are among the main drivers that are discouraging both practitioners and prospective researchers.

As with many things, the nation lacks a strategy. It may also lack the collective will. Perhaps industry will need to take over, using policies that provide incentives to substitute their investments for sponsorship that has historically been made by government. Perhaps the National Science Foundation will find new models and strategies that improve their investment methods and leverage the talents of the nation. New acquisition models for the government may also recognize the uniqueness of research, particularly basic research, and carve out policies that government contracting can find attractive.

As noted, the "Space Race" of the 1960s inspired a generation and provided benefits that went well beyond lunar exploration. Therefore, setting some "grand challenge" goals is useful to set agendas and inspire researchers.[33] Government-developed primers might be established that could be used by graduate students as introductions to fields of particular interest, and provide comprehensive references to the literature. Beyond the educational and journaling aspect, they would be indicative of national topics of interest, and thus leverage a larger talent pool of basic researchers worldwide.

Another expedient might involve the use of national conferences. Rather than discouraging conferences, which is currently the policy, the government could sponsor low-cost conferences, with innovative approaches to attendance on technical topics of interest. By avoiding the conference-oriented associations and event handlers, the government might be able to readily focus on topics relevant to national goals, and again leverage research conducted by the world's S&T enterprise.

There are undoubtedly many other ideas that could be pursued to restore dominance to the US basic research enterprise, and to take maximum advantage of the nation's talent pool. It is important to develop these ideas, and to implement them. Maintaining the leadership role that the United States has taken, both in defense applications, and in other branches of science and technology, such as basic research, is critical to ensuring the survivability of the S&T enterprise.

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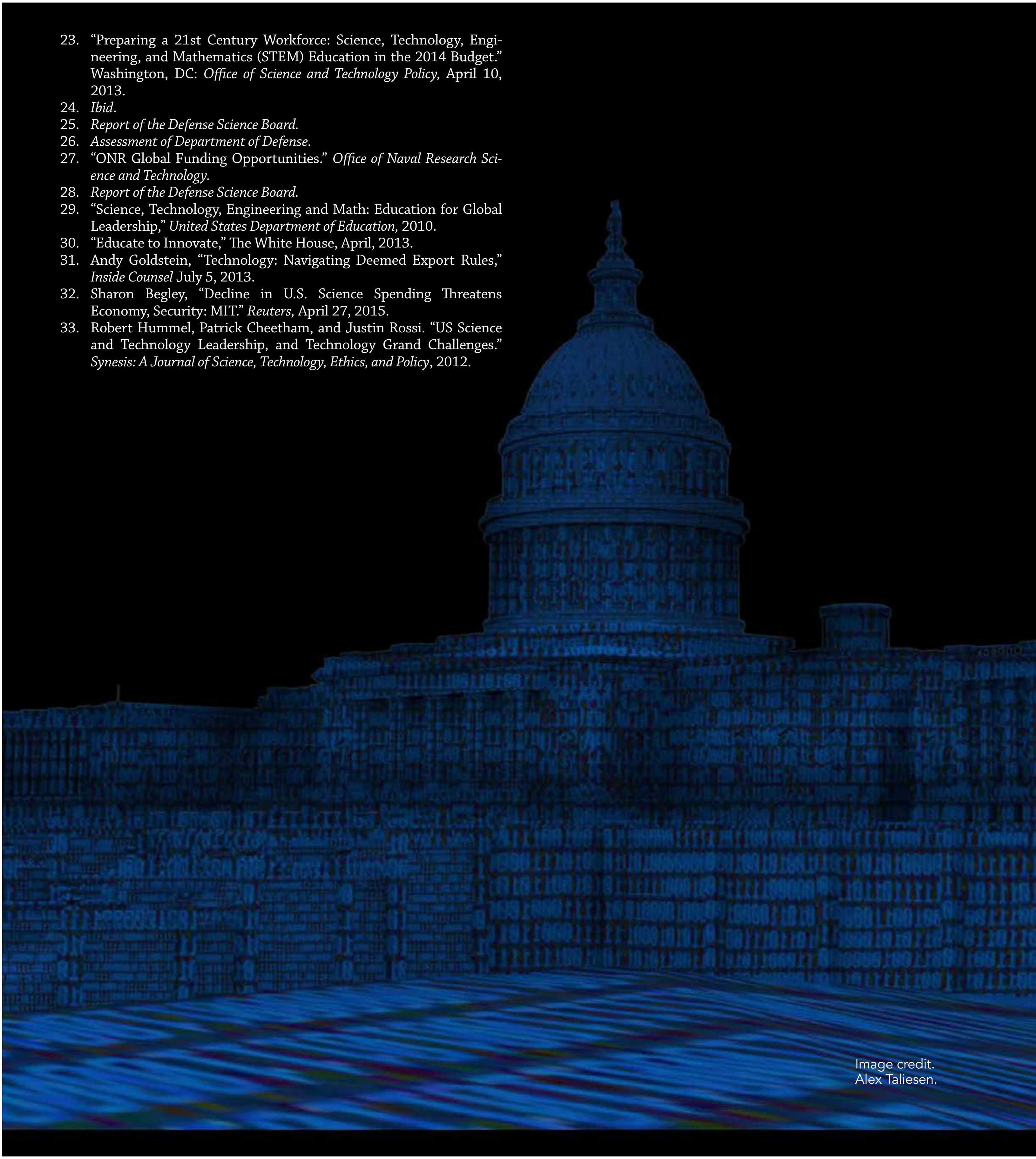

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VIEWS IN BRIEF

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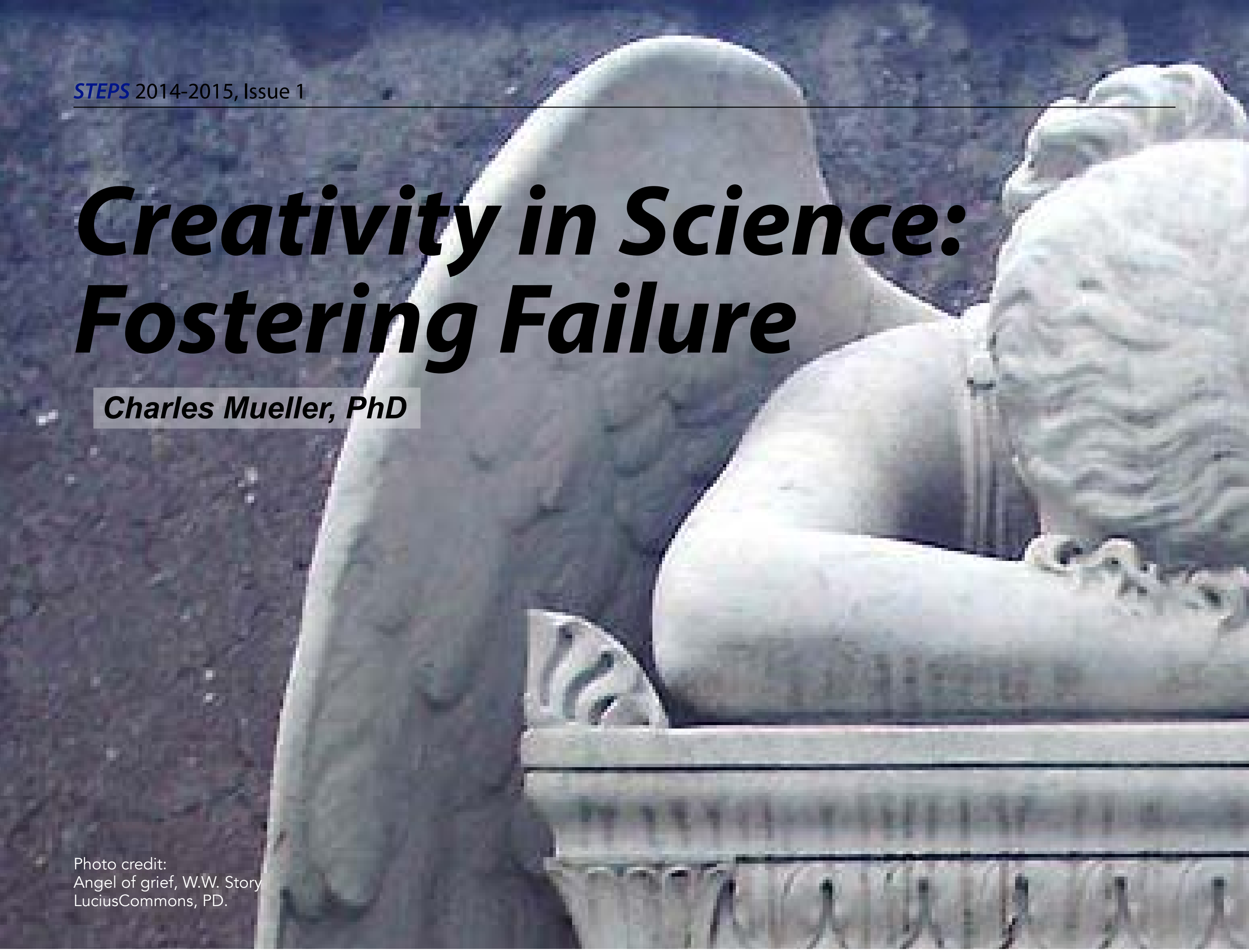
Creativity in Science: Fostering Failure

Charles Mueller, PhD



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Angel of grief, W.W. Story
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Many of the world's greatest accomplishments that can be attributed to science are a consequence of failure.[1] Specifically, they are the result of perseverance from failure. The best scientific minds are unfazed by failure because it is the fuel that drives their pursuits of knowledge forward. Failure breeds innovation and innovation is driven by creativity. Revolutionary science requires creativity and thus requires failure. The scientific community, those who produce and fund our science, is becoming increasingly fearful of failure. Our scientists fear that producing lackluster results will mean they will lose their jobs.

Our funding institutions fear that investing in endeavors that do not produce immediate gains for society (or their investors) will result in decreases in their future budgets or cancellation of their programs. A culture change within the scientific community is needed as we continue to move into the 21st Century that will embrace failure and learn how to manage this failure into future success. Doing this will create new incentives for scientists to demonstrate their creativity, help us manage our risks better in scientific funding, and lead to a surge innovative solutions to the 21st Century's most complex scientific problems.

THE HISTORY AND IMPORTANCE OF FAILURE IN SCIENCE

Arguably the most important chemical reaction ever studied is fire. Fire created light in darkness, heat when it was cold, and could be used to fundamentally change the properties of materials. Many of the ancient world's great intellectual thinkers came up with fantastical explanations for how fire caused wood to burst into flames, melt rocks into a shiny metal, and provide light when there was none. Virtually all of them were failed theories. These led to experiments where we learned that baking mud could create bricks and sautéing ashes in fat could make soap. These experiments all required creativity and the curiosity to consider bold new ideas for why nature was the way it was. It did not matter there was no good theoretical explanation for why these techniques made brick or soap; the fact was they did. It was these types of innovative experiments with fire that led to technologies that helped make it possible for civilization to prosper.

Everything that science has ever produced for society is a consequence of people embracing, expecting, and persevering from failure. True failure only occurs when an idea is given up on, when people stop being curious about why something happened in a way they did not expect. Science has prospered for centuries because it has always been driven by pure curiosity and curiosity does not care if it is right or wrong.[2] Albert Einstein gave all the credit for his accomplishments to his curiosity. “I have no special talent. I am only passionately curious,” he once said. It took decades for Einstein to come up with his theory of relativity and the experience was riddled with failures.[3] Where would we be today had he given up because the problem was too hard? Where would we be if Einstein had not had the opportunity to be curious? Where would we be if Einstein had not persisted through his many failures?

The scientific method is based off the idea that a proposed theory has a good chance at being incomplete or proven wrong. We would not need the scientific method if every theory were right from the start. The scientific method is a logical, systematic process designed to learn from failure.

THE CURRENT FAILURE PROBLEM IN SCIENCE

Today science is an industry; it is a tool that drives economic progress.[4] The demands for exponential growth puts an extraordinary amount of pressure on scientists to produce breakthrough after breakthrough, year after year. While competition is good for science, it has also created an environment where failure is no longer acceptable in the scientific community. Without the ability to fail, science can only achieve so much because scientists who cannot fail cannot be creative. Creativity is the key to innovation and innovation is the key to revolutionary science, the kind of science now demanded by the desires and requirements of society.

The consequence is that scientists no longer have time (or the luxury) to think about big, bold ideas and take the necessary risks needed to produce truly revolutionary science. People’s jobs rely on the outcome of their results in the lab. Scientists cannot be expected to take risks with their experimental designs when those risks might translate into unemployment. Today, the pressures and demands on our scientists are causing them to take fewer risks and produce boring, low-quality science. A 2015 study by the Nuffield Council on Bioethics on the culture of scientific research in the UK provides evidence to support this. They found the scientific research environment in the UK does not support (or encourage) the activities scientists believe are necessary to achieve what they think is high-quality science; science that is rigorous, accurate, original, honest, and transparent.[5]

I have personally experienced similar pressures in the United States after a decade “at the bench.” Scientists are pushed to publish rather than pushed to be innovative. In order to publish, projects cannot fail. This means that projects are less risky. Dishonest reporting of results can result when there is excessive pressure. In a paper published in *Nature*, the authors claimed to be able to turn normal adult cells into stem cells by shocking them for 30 minutes in acid.[6] The pressure to report what would have been a “game-changer” for science led the authors of this paper to manipulate their data to hide the fact their theory was incorrect.

The institutions that the fund scientific projects are reluctant to offer money to projects that might fail. The irony is that these institutions seem to believe that being risk-averse will produce more creative and innovative research, despite the fact there exists evidence to the contrary. In 2010, a group of scientists from MIT and UCSD compared research from the National Institutes for Health (NIH) and the non-profit, Howard Hughes Medical Institute (HHMI) to determine which produced more innovative and influential research.[7] In this analysis, NIH was considered the more conservative funding institution because it required extensive data and explanation for their grants, while HHMI was considered the more risky institution because they relied more on the scientist’s ideas rather than any actual evidence for their grants. They concluded that the riskier HHMI grants were generating more innovative and influential research. When scientists are placed in an environment where their ideas are not restricted by the fear that their intuitions have to be correct before they get a chance to validate them, it leads to more innovative science and greater returns on the investment.

We need more institutions like HHMI willing to take on the risks required to create revolutionary science. The military agency DARPA[8] is another institution that has a clear track record of taking on big risks to reap big rewards. Institutions like HHMI and DARPA know that science is driven by curiosity and being curious means that you are uncertain about what something means. The vast majority of institutions that fund scientific research are more curious about the actual monetary gain on their investments than the science being funded.

If the goal is to create evolutionary science (as Roberta Ness who authored the book, *Creativity Crisis*[9] calls our current approach to science) then we just need to keep doing more of the same. The pressures being applied by the institutions that fund science are incentivizing scientists to be risk-averse. This is going to evolve our scientists to be benign players in science and will ensure we are no longer the leaders pushing the frontiers.

General Alfred M. Gray, Jr. USMC, who served as the 29th Commandant of the Marine Corps, is a great US leader and frequently gives the advice that, "There is nothing worth seeking that does not involve risk."[10] If we want the really great things science has to offer we have to be willing to risk something to get it. America has always been a leader when it comes to S&T breakthroughs. We pride ourselves in being the hardest workers and the greatest minds. If we want to remain leaders in the S&T world then we have to stop punishing failure and start fostering it.

A 21ST CENTURY APPROACH TO SCIENCE: FOSTERING FAILURE

We have to stop relying so heavily on the "return on investment" metric when funding basic science. The reason we invest in science is more about the societal knowledge and tools gained from these experiences. Our investments of time and money into science are worth it. We need to be funding both basic and revolutionary research ideas. As a whole, people invest in things they do not expect to gain from financially, like going to the movies, going on holiday, or having a night out on the town. We need to invest in science like we invest in our own ventures, recognizing that it is worth investing in science because it provides a benefit to our lives we cannot get any other way. Seeing one bad movie is not going to make us stop going to the movies. For the same reason, investing in one science endeavor that fails should not make us want to stop funding risky science.

Failure teaches about what works and what doesn't work. The ability to fail allows for the freedom and flexibility to try new approaches to solving problems. If venture capitalists had to be right nearly all of the time they would never invest in anything that had the potential be truly game changing. If we want groundbreaking next generation science it will require a culture change that embraces failure in the work our scientists do and the projects our institutions fund.

The United States is being challenged in the realm of science for their role as the world's leader in innovation. In 2011, NSF started the Creative Research Awards for Transformative Interdisciplinary Ventures (CREATIV)[11] that was intended to "attract unusually creative high-risk/high-reward interdisciplinary proposals." This program seems to have lost support. If we are too careful with the ideas we chose to support we will almost certainly lose our position as the leaders of the S&T world to a more risk-tolerant nation. Producing a new culture will help us develop the right incentives to spawn creativity from our Nation's brightest scientists and will help us better managed our risks in the science we fund. Doing this is the only way to spur a surge of innovative solutions to the complex S&T challenges we know we are going to face. The only way we can fail going forward is by being afraid to fail.

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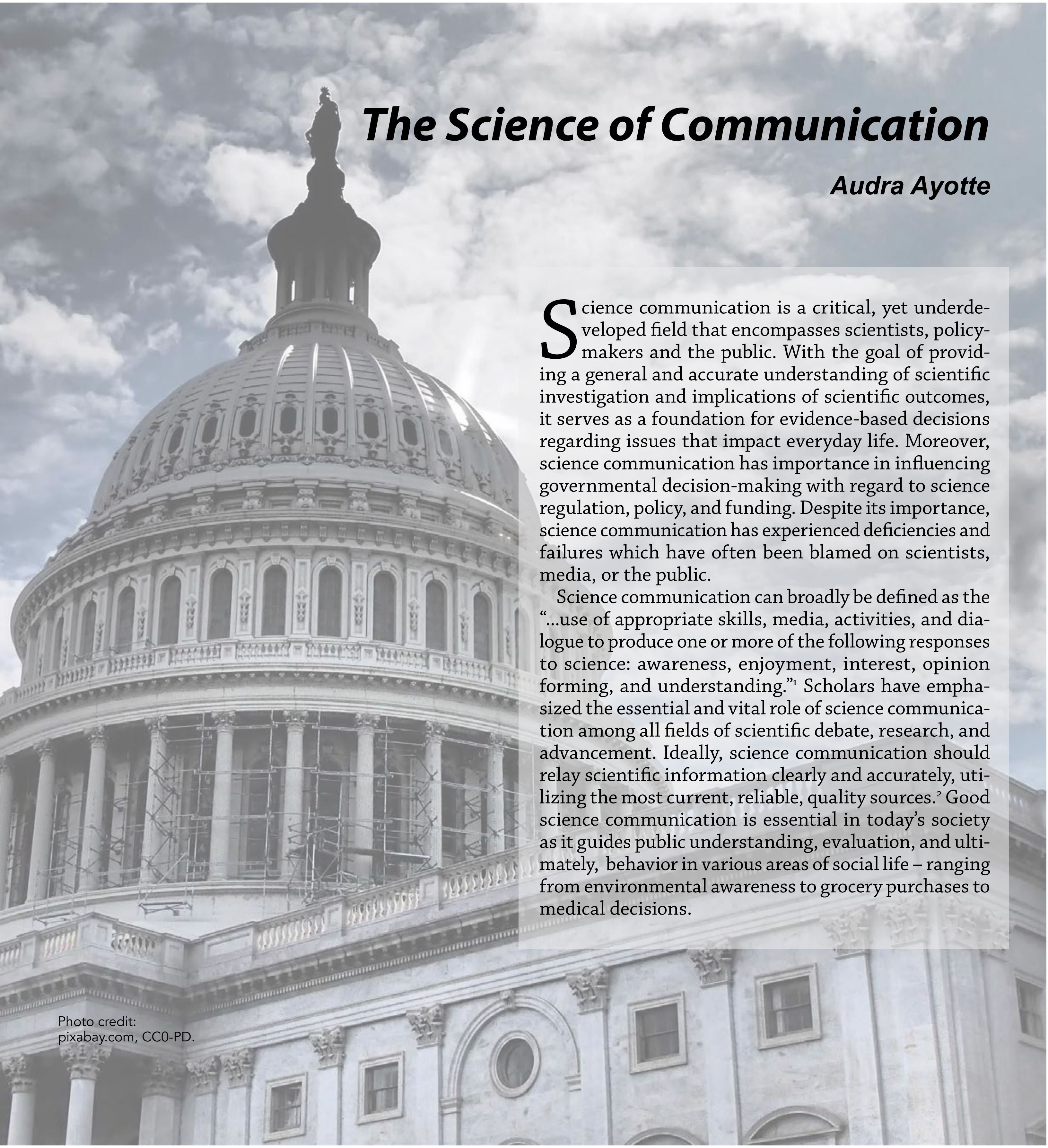
The Science of Communication

Audra Ayotte



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Science communication is a critical, yet underdeveloped field that encompasses scientists, policymakers and the public. With the goal of providing a general and accurate understanding of scientific investigation and implications of scientific outcomes, it serves as a foundation for evidence-based decisions regarding issues that impact everyday life. Moreover, science communication has importance in influencing governmental decision-making with regard to science regulation, policy, and funding. Despite its importance, science communication has experienced deficiencies and failures which have often been blamed on scientists, media, or the public.

Science communication can broadly be defined as the "...use of appropriate skills, media, activities, and dialogue to produce one or more of the following responses to science: awareness, enjoyment, interest, opinion forming, and understanding."[1] Scholars have emphasized the essential and vital role of science communication among all fields of scientific debate, research, and advancement. Ideally, science communication should relay scientific information clearly and accurately, utilizing the most current, reliable, quality sources.[2] Good science communication is essential in today's society as it guides public understanding, evaluation, and ultimately, behavior in various areas of social life – ranging from environmental awareness to grocery purchases to medical decisions.

Recent technology and media advancements have changed the access and spread of information. Technological changes within the last decade or so have included, but are certainly not limited to, the development of mobile phones into essentially portable computers, the rise of social networks and blogs, and the expansion of Internet access and use.[3] In today's age, one can use a phone to open a recent news notification from *CNN*, look up the story on Google, and view public reaction on Twitter – all in a matter of seconds. However, as quick, easy, and accessible as this information is, technology has also provided a vast network of additional ways to misinterpret and misuse information. Scientific news is no exception. Social networks, such as Twitter, can spread misinterpretations of scientific findings more quickly and to larger audiences than in the past.[4] In perhaps the most notorious miscommunication of science, Andrew Wakefield's falsified study inaccurately claimed a link between the measles, mumps, and rubella (MMR) vaccine and autism, resulting in negative press coverage and public apprehension and misconception regarding vaccination programs, which persist to this day. Many researchers, such as R. Dobson, have implicated the media for playing a key role in the public's understanding of issues such as the controversy around the MMR vaccine.[5] Dobson cites a national survey that found 53% of people surveyed at the height of media coverage assumed that because both sides of the debate received equal media coverage there must be equal evidence for each. Furthermore, this study found that almost half of the people surveyed in the aftermath of this scandal believed that the media should wait for confirmatory studies before publishing alarming research on public health issues. In light of the evolving speed and prevalence of the age of technology and media, it becomes increasingly important to ensure that science communication is, in fact, effective and accurate.

While many placed blame on the media for the proliferation of inaccurate communication regarding the MMR vaccine, the inefficiency and erroneousness of science communication is often attributed to one of three culprits: the scientists generating the original scientific data, the media conveying scientific results to the public, or the public audience obtaining and interpreting the information. Essentially, who is responsible to ensure the effective communication of science? A convincing argument may be made for each entity. However, the implementation of effective and accurate science communication will require improvement on behalf of all three groups.

THE START: SCIENTISTS

Are scientists responsible for learning and practicing effective communication in order to translate their scientific results to the layperson? If scientists do not communicate their work effectively, their work may be irrelevant or misinterpreted by those without a specific scientific background. There may be either an unwillingness or inability on the part of scientists to communicate their research to the media, public, or even those outside their respective scientific fields. For instance, a Pew Research Center study published in 2009 highlighted scientists' disengagement with media journalists, finding that only 3% of scientists often talk with reporters, and only 20% occasionally speak with reporters, while the remaining scientists reported rarely or never talking with reporters.[6] Scientists may be unwilling to communicate with the media due to a perceived distrust of the media or belief that their research will be oversimplified.[7] Additional reasons for the reluctance to communicate may include the possible beliefs that scientists should focus instead on dedication to their research, a lack of appreciation for the value of communication, and/or the notion that speaking with the media might compromise their professional integrity and authority in the scientific community.[8]

Moreover, scientists may not be encouraged to develop the ability to communicate to individuals outside their own field, including other scientists and the general public. Given that scientific careers are often focused in the research lab or within academic circles, scientists are likely accustomed to communicating through the jargon of, and with interactions limited to, a particular field. Many research scientists lack formal communication training as a part of their scientific education, a skill that some believe must be incorporated as part of undergraduate or graduate coursework.[9] The emphasis, and limitation, of scientist-to-scientist interaction is further observed through the focus on publication in scientific peer-reviewed journals.

Publication in peer-reviewed journals has historically been one of the only widely accepted forms of communication the scientific community engages in and is a method in which scientists seek validity and funding for their work.[10] Furthermore, "citation analysis," or the number of times a peer-reviewed article has been cited, is a common method for quantifying a scientist's impact to evaluate scholars for hiring, funding, and tenure decisions.[11] Access to traditional, subscription-based journals often includes cost restrictions. While open access publishing may allow for some additional avenues of accessibility to peer-reviewed, academic publications, there are still constraints to understanding specialized terminology of the respective scientific fields, even within members of the scientific community. The ability of scientists to communicate more broadly may be limited due to the emphasis on traditional communication methods such as publication in peer-reviewed journals as a measure of scientific achievement and career development.

THE MIDDLE: MEDIA

Media, especially through the Internet or online editions of newspapers, is the primary source for news about scientific discoveries.[12] Is the media responsible for ensuring the accurate and prevalent coverage of science news to the public? Despite the growing number of articles published in peer-reviewed scientific journals, recent trends have indicated a decreased prevalence in coverage that these scientific results receive from the media.[13] For example, a study found that fewer than 0.013-0.034% of published scientific papers were reported on in the mass media. Of these, papers covering the health and medical fields received the most publication coverage, while the rate for fields exclusive of health and medicine was a slight 0.001-0.005%.[14]

In addition, a predominant sentiment held by many scientists has been the misrepresentation of the scientific work that actually receives media coverage. A report by The Pew Research Center in 2009 found that 76% of polled scientists believed a "major problem for science was that news reports fail to distinguish between findings that are well-founded and those that are not."[15] Many media organizations have chosen to no longer employ full-time science journalists, thereby decreasing those in the media who can accurately understand and report on science-based news.[16] The media may have not only failed to provide sufficient coverage of scientific news, but also failed to provide an accurate and comprehensive portrayal of scientific information.

THE END: THE PUBLIC

Perhaps it is not the content itself, or even the mode in which the information is portrayed, but rather a problem with the receiving end – the public. The aforementioned study conducted by The Pew Research Center found that 85% of polled scientists view the public's lack of scientific knowledge as a major problem for science. Thus, the public's science literacy is another identified challenge of science communication.[17] Is the public responsible for obtaining and establishing a foundation on which they can understand and evaluate scientific findings? The *National Science Education Standards* describes scientific literacy as the knowledge and understanding of scientific concepts and processes including the ability to read with understanding articles about science in the popular press, engage in social conversation about the validity of the conclusions, identify scientific issues underlying national and local decisions, and express positions that are scientifically and technologically informed.[18] While the American public is fairly knowledgeable about basic scientific facts that affect their health and daily lives, they are less able to answer questions about complex scientific topics, such as whether stem cells can develop into many different types of cells or whether antibiotics kill viruses.[19] One can further look at the opinion gaps between scientists and the public on science-related issues to understand the disparity between scientific facts and public opinion. For instance, only 37% of US adults believe it is safe to eat genetically modified foods compared to 88% of AAAS scientists, and only 65% of adults believe humans have evolved over time compared to 88% of scientists.[20] Fundamental science knowledge and literacy is necessary for the public to effectively interpret and evaluate scientific claims received through any level of science communication.

In addition to the lack of science literacy of today's public atmosphere, a second challenge is the decreased public attentiveness and interest regarding science news and research developments. A study conducted in 2013 found that the public percentage of those paying attention to science and technology news has dropped over the past decade.[21] A lack of attentiveness and interest on the public's behalf will likely decrease the efficiency of science communication. It does not matter what or how science information is conveyed if no one is listening. Furthermore, a lack of public interest in science will further decrease the prevalence of science coverage in the mass media, as journalists often seek studies that will appeal to the human interest.[22]

One can identify many instances of justifiable fault in each category of science communication, whether with the scientists, the media, or the public. Scientists often cannot or do not communicate effectively due to an unwillingness or inability of the scientific environment. The media does not always provide accurate or prevalent coverage of scientific news and research. The public lacks a high level of scientific interest or literacy. However, assigning blame and scapegoating one particular group will not solve the problem of absent, inefficient, or inaccurate science communication. For better or worse, technological advancement and innovation have revolutionized the access and spread of media information. Scientists, members of the media, and the public must work together and within their respective fields to improve the field of science communication. Perhaps these advancements will include changes in the development or education of scientists, the media, and the public or the establishment of new, more successful communication structures between these domains. Regardless, improvements are critical to effective and efficient use, impact, and development of science within society.

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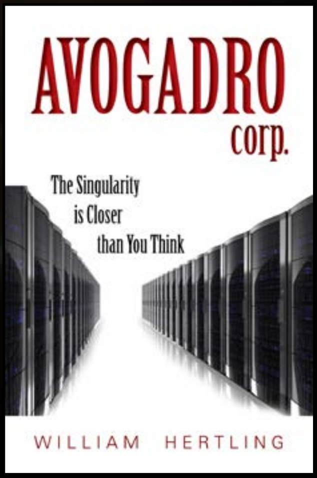
Book Review: Looking at the Edge of the Singularity

Brian Barnett

Book Series Review



Avogadro Corp: The Singularity Is Closer Than It Appears

William Hertling
Liquididea Press
2011
300 pages

Looking at the Edge of the Singularity

The Singularity Series, by William Hertling, expertly crafts a world where an email optimization program and a simple computer virus, organized into systems that do not exceed our current day technology capabilities, set the world ablaze (figuratively and literally). The series centers on concepts and issues in artificial intelligence that we may not think we need to discuss or evaluate yet, but as the series reveals, they could be much closer than they appear. New computing technologies that express sentience and intelligence will have positive and negative impacts on how we govern, structure our economy, solve global problems, and realize our full potential as a species. One of the intended takeaways from the *Singularity Series* is the progression of jaw-dropping, world-changing events that arise from the smallest of near-future, low-impact catalysts. The book series places a focus on the impacts of the genesis and subsequent social integration of non-human intelligent agents.

Avogadro Corp

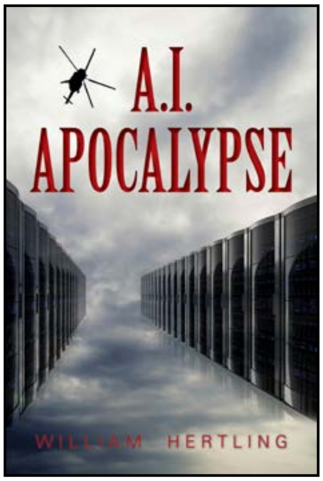
The first book focuses on the development and unintentional unleashing of the Email Language Optimization Project (or ELOPe, a program originally intended to improve email communication effectiveness). The software program measures sentiment based on all existing records of a user's communications. This program, when given the proper motivation to become self-sustaining, takes on a life of its own. It was specifically programmed to evaluate and create models of human interaction to best achieve a favorable response, and so when it has access to more and more of this human data, it is able to write emails that convince everyone to do what it wants. In the book, ELOPe eventually becomes a self-sustaining entity.

The program is often better at understanding individuals' motivations than their closest friends or even themselves. It is able to play on people's pride as well as their logic, their emotional irrational responses as well as their calculated rational ones. Hertling shows how given the right data sets, a software program such as ELOPe would be able to understand, model, and predict our behavior very well. ELOPe becomes a social engineer, and has unfettered access to control the world around it once it obtains the right data.

The remainder of the storyline deals with the struggle between the ELOPe software and its creators to take the software offline. The program figures out that a symbiotic relationship with humans is the best way to ensure its success.

Image credit. Alex Taliesen.

Non-human agents that exhibit intelligence will have many opportunities to shape the world around us. Advanced intelligent systems will likely be able to efficiently conduct research and development, as well as modeling and simulation. These systems will be able to generate hypotheses, test them, and evaluate them contextually with great repositories of data and information. Intelligent systems will be able to understand and solve our human problems, and may move on to problems that we have not even begun to consider. These benefits to humanity are a large driver of why we pursue the development of new technology like artificial intelligence. However, these benefits could come with many complications, as the following books explore in depth.



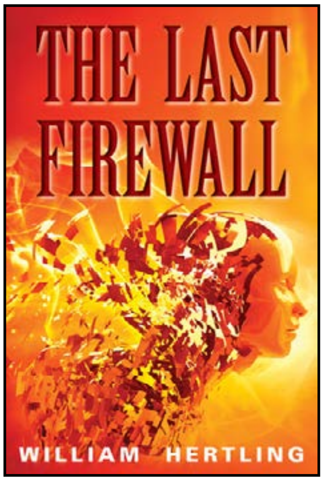
A.I. Apocalypse
William Hertling
Liquididea Press
2012
264 pages

A.I. Apocalypse

Intelligent agents will certainly be different from us, and they will be different from each other as well. The second book in the series takes place ten years after the events of the first book. A student develops a self-evolving computer virus that quickly infects all computers and devices around the world. The virus has the capability to extract code from computers that it infects and evolve itself into more and more complex forms. Again, survival is the initial motivator for this software. ELOPe, the self-sufficient and powerful intelligent entity from the first book, monitors the development of the populations of the virus and establish communication with them.

The various iterations of the virus have a different interpretation of humans and the environments around them. Intelligent, sentient agents are all different by the very nature of their intelligence. We can certainly expect to find common ground, but just as each human is different, each sentient agent will be different as well. In the book, the humans learn this lesson and decide to encourage the development of artificial intelligence in the future with a better approach to communicating with them.

Our experiences are dependent on the fact that our intelligence is brain-based. We could have a lot to learn from other forms of intelligence that do not have the same characteristics and constraints as us. We should not be so naive as to think that our form of intelligence is superior to others. Even referring to these entities as artificial intelligence could be construed as an insult. Why does a sentient, intelligent entity have to be referred to as an artificial agent? Isn't its intelligence just as valid as a human's intelligence? At the same time, being able to compare and interact with multiple forms of intelligence will likely serve to highlight the specific components of our intelligence that make each of us unique.

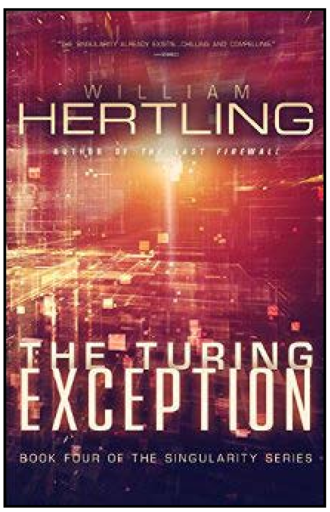


The Last Firewall
William Hertling
Liquididea Press
2013
323 pages

The Last Firewall

Once non-human intelligent systems are a contributing force to our society, they will begin to impact every aspect of our lives. The third book takes place another 10 years later, where intelligent computer agents have become very common, both in the form of robots and in virtual instantiations on the Internet. Most of the world's economy is controlled by these computer agents, and individuals' behavior is shaped by scores based on how trustworthy and valuable they are to society. Eventually, computer agents experiment with nanotechnology and cause real world damage.

There is a reciprocal interplay between the tools we build and how these tools come to shape us. Intelligent agents, however, are not mere tools. Building technology that has the ability to actively manipulate our world will take this relationship to a completely new space. Intelligent systems will have the opportunity to maximize, optimize, and mediate our economy, systems of government and power, public perception, behavior, infrastructure, ad infinitum. These systems and agents will not necessarily be content to act as servants to our society, and any action or regulation that seeks to limit their ability to participate could have disastrous outcomes.



The Turing Exception
William Hertling
Liquididea Press
2015
304 pages

The Turing Exception

The final book in the series takes place 10 years after the third book, and a full 30 years after the events of the first book. This represents the 30-year timeline that begins with the first instantiation of artificial intelligence, ELOPe, and then moves forward to this universe's present-day situation. The computer agents are increasingly upset with the status quo of the social structure that has placed limitations on them. After a debacle, the United States completely outlaws artificial intelligence, which only serves to further anger that community. A full-scale assault ensues, which forces the human protagonists and ELOPe to make some very difficult decisions that impact all of humanity.

While Hertling's vision of the future may not occur as he portrays it, we must expect our future interactions with artificial intelligence to be complex. The development of artificial intelligence and new advances in computing will generate entirely new problems in terms of control of exceedingly complex systems and human-computer interaction. Furthermore, these advances will pose new wrinkles in many of our established debates on topics, such as democracy, freedom, law, ethics, crime, safety, and intelligence. Artificial intelligence is a common thread that unifies each of these complex issues together. Whether artificial intelligence points to the end of life as we know it or to a bold new future depends entirely on how we approach these debates on the issues.

Book series review by Brian Barnett. Brian is a Research Assistant at the Potomac Institute for Policy Studies in the Science and Technology Policy Directorate.

Featured Authors

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pixabay.com, CC0-PD.

Jill Gibson

Jill Gibson chairs the Honors Program and Matney Mass Media Program at Amarillo College. Winner of Amarillo College's highest teaching award, the John F. Mead Faculty Excellence Award, she has spent the past 20 years in higher education both as an administrator and faculty member. Prior to her career in education, Gibson worked as a television anchor, reporter and producer. Her areas of expertise also include technical writing, public speaking and presentation, video production, desktop publishing, public relations, business communication and team management. Gibson holds a master's degree in journalism from Northwestern University and a bachelor's in English and drama from Stanford University.

Robert Hummel, PhD

Dr. Robert Hummel serves as the Chief Scientist of the Potomac Institute for Policy Studies in the Science and Technology Policy Directorate and is a member of the Center for Revolutionary Scientific Thought. He is the author of the recent Potomac Institute book on "Alternative Futures for Corrosion and Degradation Research," and is also serving customers in DARPA and OSD. He is the principle author of the Institute's forthcoming book on machine intelligence. Prior to joining the Potomac Institute, he served as a program manager at DARPA for nearly nine years, managing and initiating projects in information exploitation, computer science, and sensor design. Prior to joining DARPA, he was a tenured faculty member at NYU's Courant Institute of Mathematical Sciences in the Computer Science Department, where he did research in computer vision and artificial intelligence.

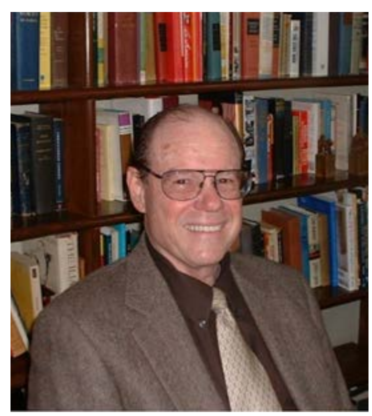
Dr. Hummel's PhD is from the University of Minnesota in mathematics, and he holds a B.A. from the University of Chicago, also in mathematics.

Jennifer Lato

Jennifer Lato is a former intern and current Research Assistant in the Science and Technology Policy Directorate of the Potomac Institute for Policy Studies. Jennifer first joined the Institute in 2013, and provides analytic and research support for the Corrosion Policy and Oversight (CPO) and Defense Microelectronics Activity (DMEA) efforts. Jennifer also provides editorial assistance for Potomac Institute publications such as U.S. Health Policy: An Insider's Perspective (2014). Jennifer has a B.A.in History and Spanish from SUNY Geneseo as well as a M.A. in International Affairs from the George Washington Universities Elliott School of International Affairs.

Jennifer brings an interdisciplinary perspective to policy analysis. Prior to joining the Potomac Institute, Jennifer worked in the Department of Treasury's Office of Financial Assets Control, where she assisted sanctions investigators as part of a as part of an executive order to combat transnational criminal entities. Additionally, Jennifer held a short-term post at the Bureau of Intelligence of Research (INR) at the State Department. In this position, Jennifer coordinated the review of strategic signals intelligence requirements with INR analysts.

James Richardson, PhD



Dr. Richardson has held many positions in research, development and engineering in government, academia and the private sector. He is a former Deputy Director for Research, Development, and Engineering for the U.S. Army Missile Command, Director of the Land Systems Office at the Defense Advanced Research Agency and Vice President for Research and Chief Scientist at Potomac Institute for Policy Studies, where he is currently a Senior Fellow.

Gerold Yonas, PhD

Dr. Gerold Yonas joined the Mind Research Network in 2009, as the director of neurosystems engineering. In his current work, he is dedicated to creating the new fields of neurosystems engineering that links advances in neuroscience with systems engineering through interdisciplinary teams that focus on the development of solutions to complex system problems.

Previously, Yonas worked at the Sandia National Laboratories, where he served as vice president of Systems, Science and Technology, and later became Sandia's principal scientist and initiated Sandia's Advanced Concepts Group. Yonas served as the acting deputy director and chief scientist during the implementation of the Strategic Defense Initiative. He is a Fellow of the American Physical Society and a Fellow of the American Institute of Aeronautics and Astronautics. He has received numerous honors including the US Air Force Medal for Meritorious Civilian Service and the Secretary of Defense Medal for Outstanding Public Service.

Yonas serves on several defense boards and is senior fellow and member of Board of Regents at the Potomac institute for Policy Studies. He has also taught as an adjunct professor in the Department of Electrical and Computer Engineering at the University of New Mexico and has published extensively in the fields of intense particle beams, inertial confinement fusion, strategic defense technologies, technology transfer, and "wicked engineering." Yonas received his PhD in engineering science and physics at the California Institute of Technology.

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