A Vision for 21st Century U.S. Policy to Support Sustainable Advancement of Scientific Discovery and Technological Innovation

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Summary

POLICYMAKERS IN THE UNITED STATES have long recognized the strategic importance of science. The formation of the National Academy of Sciences by President Lincoln in the middle of the Civil War is a powerful testimony to the importance of science for the United States. Now, science plays even a greater role, as President Obama said in 2009: "Science is more essential for our prosperity, our security, our health, our environment, and our quality of life than it has ever been before" (Obama, 2009). The Office of Science and Technology Policy site quotes the current U.S. President stating that "our future depends on reaffirming America's role as the world's engine of scientific discovery and technological innovation" (OSTP, 2010; <http://www.whitehouse.gov/administration/eop/ostp>). Sixty-five years ago Vannevar Bush helped to formulate new Federal policy toward science (Bush, 1945). We argue that now is the best time to do the same. In this article, we express our opinion that the Federal government has to consider a new, 21st century science policy to enable the sustainable advancement of "scientific discovery and technological innovation." We recommend that such a policy includes three steps: (1) *the transformation of the current OSTP into a full-fledged Department of Science and Technology*, (2) *the primary support of basic and applied research*, and (3) *the facilitation of modern approaches to collaboration*. The proposed policy does not require any additional Federal funds, but rather is transformational in nature.

Science in the United States is widely understood to be essential to the country's economic growth, and the technological innovations derived from basic and applied research provide enormous benefits to society (Levin, 2001). The U.S. Federal government dedicates a considerable amount of funding toward science (CBO, 2007; Hather et al., 2010). Many projects were developed with Federal support and have provided tremendous benefits to people's lives, including, for

example, the laser (e.g., Hather et al., 2010) and the PageRank algorithm (Brin and Page, 1998). The laser, which was developed and supported by the government since the 1950s, now has a wide range of applications worldwide (e.g., Hather et al., 2010). Several agencies, including the National Science Foundation and Department of Defense's Defense Advanced Research Projects Agency (DARPA), supported the development of the PageRank algorithm, named after one of its cocreators Larry Page (Brin and Page, 1998). Today, the PageRank is one of cornerstones of the mighty Google, serving billions of people.

Although many countries are developing policies to promote and sustain scientific discovery and technological innovation, the United States is involved in an uneasy discussion about the level of its scientific and technological competitiveness (e.g., CBO, 2007; Hather et al., 2010; Karin and Hill, 2010). Some think that advances in science and technology made by other countries are threatening the United States; we disagree. We welcome such a new reality in which we both compete and collaborate and, as a result, benefiting all the countries involved (Hather et al., 2010; Mankiw, 2008). We recently analyzed the state of scientific research in the United States since the 1960s and made comparisons with two other major population and economic regions, the European Union and China, for the last decade (Hather et al., 2010). Our findings can be summarized as follows:

1. Since the 1960s, the level of U.S. Federal support for basic and applied research has declined from twice that of industrial research funding to roughly equal today.
2. Federal funding of overall research and development (R&D) has had a similar trajectory: whereas in the 1960s it was almost twice that of industry funding, it is now less than half.
3. Federal spending has also shifted in focus: in the 1960s, only 30% of the total U.S. R&D spending was directed

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to basic and applied research versus almost two-thirds today.

4. Although well below the United States and the European Union in overall R&D funding, China has recently shown high and sustained growth of its Federal support versus stagnation in the United States and the European Union.
5. The European Union currently produces more science and engineering doctoral graduates and scientific publications than the United States in absolute terms, but not per capita.

Given the results of our analysis, we must consider "How will the United States continue to foster its scientific and technological strengths?" It also appears the United States is starting to fall behind other parts of world in its ability to develop and retain scientists and engineers. The United States has made up for a deficiency in the domestic output of scientists and engineers through immigration of foreign nationals who have been educated in or come to work in the United States. Let us consider only one country, China, which is rapidly becoming a major scientific and technological player. Universities and companies in the United States will likely have a harder time in the long run attracting and retaining scientists and engineers from China as funding opportunities significantly increase there. Again, this is becoming even more common with the globalization of science and technology, as the United States has to compete and collaborate on an international level more than ever before.

Still, as science and technology are founded on rigor and quality, it will be a mistake to be distracted by sheer quantity. It is crucial that the United States focus ever more diligently on the quality of the science and engineering workforce it produces (Alberts, 2009; Hather et al., 2010). Also, given that a substantial increase in funding is unlikely, the U.S. government will have to find new ways to increase the effectiveness of current funding through new Federal policy. Similar to 65 years ago, when Vannevar Bush (1945) helped to formulate new Federal policy toward science, we argue that now is the best time to do the same.

Therefore, we recommend that the Federal government consider a 21st century transformational policy to ensure sustainable advancement of scientific discovery and technological innovation by a three-step plan: (1) *the creation of a Department of Science and Technology*, (2) *the primary support of basic and applied research*, and (3) *the facilitation of modern approaches to collaboration*. The proposed policy does not require any additional Federal funds, but rather is transformational in nature.

1. Although the current Office of Science and Technology Policy (OSTP) played and continues to play its vital role in the U.S. scientific and technological agenda, the 21st century challenges the U.S. and Federal government to adopt a more powerful and sophisticated approach. We therefore recommend *transformation of the 25-year-old, mature and proficient OSTP into a full-fledged, executive, Cabinet-ranked Department of Science and Technology*. This will ensure a refreshing of the U.S. mission, strategic goals, and objectives in science and technology, as well as revising priorities, capabilities, and responsibilities of the science and technology leadership, community, and policymakers.

2. We found that industry spending on development far exceeds that of the government. Although development will remain the focus on industry, the Federal government should *primarily focus its efforts in funding science R&D on supporting basic and applied research in its early or innovative stages*. As international competition and collaboration intensifies, the United States should continue to carefully review the research playing field and reinforce its commitment to support only high-quality research. This, in turn, will ensure that limited research dollars are well spent. The continuous search for black swans (Taleb, 2007) becomes even more imperative. The realignment of OSTP divisions, appropriate Federal departments, and agencies into agile DARPA-like entities responsible for renewed science and technology priorities will be beneficial.
3. The Federal government should *establish policies that facilitate modern approaches to collaboration of all the world's best minds*. Modern collaborative efforts in 21st century will come in many shapes and forms, ranging from intergovernmental and multiagency projects through government-academia-industry partnerships to multiinstitutional U.S. and worldwide collaborations. Modern means of such effective collaborations through cloud computing, crowdsourcing (Howe, 2009), data-intensive science (Gray, 2009), material, information, and knowledge sharing, public access publications, and social networking (Tapscott and Williams, 2008) should be further explored and, when proven, endorsed.

Successful multiinstitutional collaborative projects include, for example, the infamous DARPA-supported ARPANET network (DARPA, <http://www.darpa.mil/index.html>) and multiagency Human Genome Project (HMP, http://www.ornl.gov/sci/techresources/Human_Genome/project/hgp.shtml), as well as ongoing Department of Energy's *Genomes to Life* (GTL, <http://genomicscience.energy.gov>), National Institutes of Health's *Beta Cell Biology Consortium* (BCBC, www.betacell.org), *Human Microbiome Project* (HMP, http://www.ornl.gov/sci/techresources/Human_Genome/project/hgp.shtml), *Nuclear Receptor Signaling Atlas* (NURSA, www.nursa.org), and National Science Foundation's *Long-Term Ecological Research Centers* (LTERC), *National Nanotechnology Initiative* (NNI, www.nano.gov), *Science and Technology Centers* (STC, 2008, www.nsf.gov/od/oia/programs/stc/). Still, the above success stories are less frequent than they should be.

We think that the proposed three-step policy will significantly enrich the U.S. science and technology community and bring unparalleled advancements and superior scientific and technological outcomes.

Conclusions

The 21st century, even in its first decade, has shown itself to be a time of ever-intensifying globalization and human connectivity. The pursuit of scientific knowledge and technological progress is well served by interactive and collaborative endeavors, and so we should be poised to remake that pursuit in this new century's image. A 21st century Federal policy to enable sustainable advancement of scientific discovery and technological innovation [through (1) *the transformation of the current OSTP into a full-fledged Department of Science and*

Technology, (2) the primary support of basic and applied research, and (3) the facilitation of modern approaches to collaboration will help conquer the challenges of today and tomorrow. In our opinion, more funding is not the answer; we must transform and reinvigorate our thinking and approach to continue the U.S. legacy of scientific and technological leadership. The time is now!

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References

- Alberts, B. (2009). Restoring science to science education. *Issues Sci Technol* 25, Summer.
- Brin, S., and Page, L. (1998). The anatomy of a large-scale hypertextual Web search engine. *Comput Networks ISDN Syst* 30, 107–117.
- Bush, V. (1945). "Science: The Endless Frontier." Report to the President.
- CBO (Congressional Budget Office) (2007). *Federal Support for Research and Development*. Washington, DC: CBO.
- Gray, J. (2009). Jim Gray on eScience: a transformed scientific method. In *The Fourth Paradigm: Data-Intensive Scientific Discovery*. T. Hey, S. Tansley, and K. Tolle, eds. (Microsoft Research, Redmond, WA), pp. xvii–xxxi.
- Hather, G., Haynes, W., Higdon, R., Kolker, N., et al. (2010). The United States of America and Scientific Research. *PLOS ONE*, 5(8): e12203.
- Howe, J. (2009). *Mindset* (Random House, New York).
- Kahin, B., and Hill, C.T. (2010). United States: the need for continuity. *Issues Sci. Technol.* 26.
- Levin, R. (2001). The university as an engine of economic growth. LTERC (Long-Term Ecological Research Centers). Available at: www.lternet.edu
- Mankiw, N.G. (2008). *Principles of Economics* (South-Western College Pub, Florence, KY).
- Obama, B.H. (2009). What science can do. *Issues Sci. Technol.* 25, Summer.
- Taleb, N.N. (2007). *The Black Swan: The Impact of the Highly Improbable* (Random House, New York).
- Tapscott, D., and Williams, A.D. (2008). *Wikinomics* (Penguin Group, New York). STC (Science and Technology Centers). Available at: www.nsf.gov/od/oia/programs/stc/

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