U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION

HEARING CHARTER

Investing in High-Risk, High-Reward Research

Thursday, October 8, 2009
1:00 p.m. – 3:00 p.m.
2318 Rayburn House Office Building

1. Purpose

The purpose of this hearing is to examine mechanisms for funding high-risk, potentially high-reward research, and the appropriate role of the federal government in supporting such research.

2. Witnesses:

- **Dr. James P. Collins**, Assistant Director for Biological Sciences, National Science Foundation.

- **Dr. Neal F. Lane**, Malcolm Gillis University Professor and Senior Fellow, James A. Baker III Institute for Public Policy, Rice University. Dr. Lane was a member of the American Academy of Arts & Sciences committee that published the report, *ARISE: Advancing Research in Science and Engineering*.

- **Dr. Richard D. McCullough**, Professor of Chemistry and Vice President of Research, Carnegie Mellon University.

- **Dr. Gerald M. Rubin**, Vice President and Director, Janelia Farm Research Campus, Howard Hughes Medical Institute.

3. Overarching Questions:

- What is high-risk, high-payoff research? How does it differ from the research traditionally funded by federal science agencies? What metrics should be used to evaluate the success of any approach to funding high-risk research?

- Relative to the total funding for basic science and engineering research from all sources, is the current level of support for high-risk research appropriate? If funding for high-risk research were to be increased as recommended in several recent reports, what should be the responsibility of the federal government in achieving that increase, and how does that responsibility differ from that of private sector research organizations and funding sources as well as research universities?

- How can federal science agencies such as the National Science Foundation (NSF) increase their support for high-risk research? In particular, what are the pros and cons of establishing targeted programs or set-asides for high-risk research versus changing how proposals are reviewed and selected across an agency's research portfolio? What are the biggest challenges or risks associated with each of these approaches?

4. Background

What is high-risk, high-reward research?

The terms 'high-risk, high-reward' (or high-risk, high-payoff') and 'transformative' research are often used interchangeably. The National Science Board has proposed the following definition for transformative research:

> *Transformative research is defined as research driven by ideas that have the potential to radically change our understanding of an important existing scientific or engineering concept or leading to the creation of a new paradigm or field of science or engineering. Such research is also characterized by its challenge to current understanding or its pathway to new frontiers.*

The Board, mindful of NSF's unique role in funding basic research across the disciplines, says nothing in its definition about research leading to new technologies or solutions to societal challenges. Federal mission agencies, on the other hand, use a mission inspired definition for high-risk, high-reward research, or some comparable term. For example, a few years ago NIH created the Pioneer Awards for this purpose.

> *The term "pioneering" is used to describe highly innovative approaches that have the potential to produce an unusually high impact on a broad area of biomedical or behavioral research.*

A handful of philanthropic organizations also invest in high-risk research. One such organization, the Keck Foundation, makes a distinction between "high-risk" and "transformative" as follows:

> *"High-risk" comprises a number of factors, including questions that push the edge of the field, present unconventional approaches to intractable problems, or challenge the prevailing paradigm. "Transformative" may mean creation of a new field of research, development of new instrumentation enabling observations not previously possible, or discovery of knowledge that challenges prevailing perspectives.*

What is common to all definitions of high-risk, high-reward, or transformative (or pioneering) research is a tolerance for failure that departs from the overwhelming tendency, within the federal system at least, to fund research for which there is already a proof of concept or preliminary data, and for which the likelihood of achieving the stated aims is pretty high. In other words, scientists and engineers are not encouraged by the current federal funding system to propose their wildest (but scientifically sound) ideas; rather, they believe their only chance at getting funded is to propose something that they already know will work.[1] The resulting incremental advances in science and engineering are a necessary, but not sufficient element of the science and technology enterprise. In many if not most cases, great breakthroughs and paradigm shifts in S&T were the result of scientists and engineers stumbling upon some unexpected result or suddenly imagining some new application and then having the funding and/or flexibility to alter their research plans accordingly.

The call for a greater federal role in funding high-risk research

In 2006, the National Academies Committee on Prospering in the Global Economy of the 21st Century released the report, *Rising Above the Gathering Storm*, that became both the impetus and intellectual foundation for the 2007 America COMPETES Act. In addition to the many recommendations regarding K-12 STEM education, funding for basic research in the non biomedical sciences, and creation of an ARPA-E that were implemented as part of the COMPETES Act, the Academies Committee recommended that at least 8 percent of the budgets of federal research agencies should be set aside for discretionary funding managed by technical program managers in those agencies to catalyze high-risk, high-payoff research. They provided no further details on how that might be done and chose 8 percent because it was a compromise between committee members who thought 5 percent was sufficient and those who argued for 10 percent.

In 2004, the National Science Board convened a task force on transformative research to make recommendations on how the National Science Foundation (NSF) could encourage more funding of high-risk, potentially high-reward research. In the resulting 2007 report[2], the Board recommended that NSF develop a distinct, Foundation-wide Transformative Research Initiative "distinguishable by its potential impact on prevailing paradigms and by the potential to create new fields of science, to develop new technologies, and to open new frontiers." Beyond defining transformative research and stating that the NSF Director's leadership is essential its success, the Board did not go into any details on how such an initiative should be carried out, nor did it recommend a specific percentage of the NSF budget for investment in transformative research.

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[1] One historically successful federal model for funding high-risk research is DARPA, credited with funding early development of the internet, not to mention countless advanced military technologies. In 2007, the S&T Committee applied the DARPA model to the Department of Energy (DOE) by creating ARPA-E. ARPA-E invests in technologies that will promise true transformations in how we use or produce energy – what DOE describes on their website as high-risk, high-payoff *concepts*. While there may be elements of DARPA and ARPA-E that are broadly applicable to all models for funding high-risk research, the ARPA model is driven by a need for mission-specific technologies, making it inappropriate for replication in basic science agencies.

[2] http://www.nsf.gov/pubs/2007/nsb0732/nsb0732.pdf

Perhaps in recognition of the absence of details in these reports, the American Academy of Arts and Sciences launched a new study in 2007 to develop specific recommendations for how federal agencies, universities and private foundations can encourage more high-risk, high-reward research, even absent significant growth in overall research budgets. The Academy assembled a distinguished committee of Nobel Laureates, (former) agency and National Lab directors, university presidents, private research organization directors and other notables for this purpose. The committee also addressed support for early-career faculty, which shares some challenges in common with support for high-risk research. The resulting report, *Advancing Research in Science and Engineering: Investing in Early-Career Scientists and High-Risk, High-Reward Research* (ARISE)[3], was completed in 2008.

Role of Charitable Organizations and Universities

According to NSF, non-federal, non-business entities provided $23 billion in funding for R&D in the United States in FY 2006, out of a total of $340 billion from all sources. This "other" category is pretty broad, including state and local governments, nonprofit organizations (e.g. charitable foundations), and universities. Funding for academic R&D in FY 2006 totaled $48 billion.[4] Institutional (university) funds accounted for $9.1 billion, or 19 percent of that total. A different category of "other" sources of funds for academic R&D, including nonprofit organizations and gifts from private individuals, accounted for $3.2 billion, or 7 percent of all academic R&D in FY 2006.[5]

There are many charitable foundations of varying size that fund what they consider to be high-risk, high-reward research, sometimes at universities and sometimes in their own, privately run research labs. The Keck Foundation, for example, funds academic research projects across all disciplines that might not be funded otherwise. Keck's evaluation criteria are: 1) is this idea scientifically sound?; 2) if anyone can pull it off, can this particular individual/team?; and 3) does this individual/team have the tools at their disposal to carry out this research? In other words, Keck takes a chance on people with strong track records and access to first class research facilities. The Howard Hughes Medical Institute (HHMI) similarly takes a chance on the reputation of individual scientists, but HHMI investigators become HHMI employees, freeing them from the constant pursuit of federal support, or they join HHMI's own world class research campus, severing ties with their home institutions altogether. Some foundations make lump-sum grants to universities and rely on the leadership within the university to run an internal competition for the best ideas.

Institutions also support their own faculty, in particular by providing start-up funds to newly recruited faculty. In the case of young investigators just starting out, the new faculty need money to build their labs and gather preliminary data before they can apply for federal funding with a reasonable chance of success. But universities may also offer generous packages to well established scientists recruited from other universities. In

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[3] http://www.amacad.org/AriseFolder/

[4] Institutional funds encompass: 1) institutionally financed organized research expenditures, and 2) unreimbursed indirect costs and related sponsored research.

[5] From 2008 Science and Engineering Indicators: http://www.nsf.gov/statistics/seind08/?org=NSF

general, institutional funding may provide more flexibility for faculty wanting to pursue high-risk ideas than do standard federal research grants.

Challenges and Approaches to Investing in High-Risk Research

There is little doubt that flat research budgets and low proposal success rates across agencies such as NSF and NIH have contributed to more conservative funding decisions on the part of peer review panels. When budgets are constrained and success rates low, a single critical review by a peer may be sufficient to scuttle a proposal. Human nature surely plays a role as well. As an expert in the same field as the applicant, the critical reviewer may have his or her own career invested in the paradigm being challenged by the applicant. The peer-review system is, on balance, strong, functional and successful, but it is not perfect.

In general, there are two approaches to funding more high-risk research, described in detail in the ARISE report: creation of targeted programs or grant mechanisms, or systemic reform of the current peer-review process.

In the case of targeted programs or grant mechanisms, the agencies, or Congress, must decide how much of the total research dollars to set aside for this purpose. The National Science Foundation has such a mechanism already, one that they have had in place for a number of years. It was called Small Grants for Exploratory Research (SGER) and just this year (partially to satisfy a requirement in the COMPETES Act) was split into two programs: Exploratory Grants for Early Research (EAGER), and RAPID grants for urgent response research, typically after a natural disaster.

EAGER grants are reviewed only internally at NSF and may be up to $300,000 and for up to two years in duration. Program officers were allowed to use up to 5 percent of their program budget for the former SGER awards. In FY 2008, a total of 389 SGER grants were awarded across all directorates, accounting for only 0.6 percent of NSF research obligations.[6] The directorate that made the most use of SGER grants was Computer and Information Sciences and Engineering (CISE), at 1.9 percent. Similarly, NIH has its Pioneer Awards, but they account for about 0.01 percent of NIH's total budget and have a dismal success rate that discourages many potential applicants.

The ARISE committee also makes a number of recommendations for strengthening the entire system to support more high-risk research, from changing the make-up of review panels to altering the charge to those panels. Finally, the ARISE committee recommends greater investment in agency program officers to strengthen program leadership and facilitate the injection of new ideas into agency and community deliberations.

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[6] For a directorate by directorate breakdown, see Appendix 8 of the NSB's 2008 Merit Review Report: http://www.nsf.gov/nsb/publications/2009/nsb0943_merit_review_2008.pdf

In the FY 2010 budget request, NSF announced a new Foundation-wide transformative research initiative in which each research division will set aside a minimum of $2 million ($92 million Foundation-wide) to explore methodologies that help support transformative research.

Metrics for Success

The ARISE committee also took on the question of how to measure the success of any new policy or program to support high-risk research. They recommended evaluating programs in two phases. The first phase involves determining whether the new program or policy was successful in attracting high-risk research proposals and in funding proposals that would normally be rejected under the traditional peer-review system. The second phase should occur no sooner than 10 years after the initiation, according to the committee, and would involve evaluation of scientific outcomes.

Evaluating the effectiveness or impact of any basic research program is a difficult, perhaps impossible task, thereby making them easy targets during the zero-sum game appropriations battles. Policies or programs for high-risk research, therefore, could face even greater uncertainty in the federal budget process. For that reason, some argue that charitable organizations and universities are better positioned to ensure long-term support for high-risk research.

5. Questions for Witnesses

James Collins, NSF

1. Please describe the National Science Foundation's (NSF) proposed transformative research initiative. What definition is NSF using for 'potentially transformative research?' What guidance has been provided to research divisions regarding implementation of this initiative and how was that guidance developed? To what extent does this initiative entail targeted programs and grant mechanisms versus modifying the standard grant review process across the Foundation? To what extent does it overlap with initiatives to support young investigators? How will NSF evaluate the impact of its transformative research initiative?
2. How in particular is your directorate, Biological Sciences, planning to implement and evaluate the transformative research initiative?
3. What is the role of the program officer in identifying and funding potentially transformative research? What guidance is provided to program officers regarding their role? To what extent does that guidance vary across disciplines/divisions? What has been the impact of flat agency operations budgets on program officers' ability to identify and support potentially transformative research proposals?
4. Is there a unique role for NSF versus the university and the private sector in investing in potentially transformative research? How can NSF's models for support of potentially transformative research complement or facilitate university as well as private sector, including philanthropic support for such research?

Neal Lane, Rice University

1. What were the key findings and recommendations in the 2008 American Academy of Arts and Sciences report, "Advancing Research in Science and Engineering (ARISE): Investing in Early-Career Scientists and High-Risk, High-Reward Research." In particular, what were the key findings and recommendations with respect to support for high-risk, high-reward research, especially in non-biomedical disciplines?
2. What are the pros and cons of establishing targeted programs or set-asides for high-risk research versus changing how proposals are reviewed and selected across a federal science agency? What are the biggest challenges or risks associated with each of these approaches? What metrics should be used to evaluate the success of any approach to funding high-risk research?
3. What are the appropriate roles and responsibilities of the various funders, including the federal science agencies, the private sector and universities themselves, in supporting high-risk research? How can federal investments in high-risk research be used to leverage private sector and university investments, and vice-versa?

Richard McCullough, Carnegie Mellon University

1. What percentage of science and engineering research funding at your institution comes from the federal government? The private sector? The university itself? How do the proposal selection methods and criteria vary across the funding sources?
2. Which of the funding sources described previously provides the most flexibility to your faculty to pursue high-risk, high-reward (or 'transformative') research? Do all of your science and engineering faculty have equal access to those sources (or types of sources) of funding given meritorious proposals?
3. Given the total funding for academic science and engineering research from all sources, is the ratio of funding for high-risk research appropriate? If the ratio were to be increased as recommended in several recent reports, what should be the responsibility of the federal government in achieving that increase, and how does that responsibility differ from that of the university itself and the private sector?
4. Do you have any specific recommendations for how federal science agencies such as the National Science Foundation could increase their support for high-risk research? In particular, what are the pros and cons of establishing targeted programs or set-asides for high-risk research versus changing how proposals are reviewed and selected across a federal science agency? What are the biggest challenges or risks associated with each of these approaches? What metrics should be used to evaluate the success of any approach to funding high-risk research?

Gerald Rubin, Howard Hughes Medical Institute

1. What is Howard Hughes Medical Institute's model for funding high-risk, high-payoff research? What are the benefits of this model? What are the challenges? Is this a model that could or should be duplicated by federal funding agencies or federally funded research and development centers such as the Department of Energy National Labs or the National Institutes of Health?

2. Given the total funding for basic science and engineering research from all sources, is the ratio of funding for high-risk research appropriate? If the ratio were to be increased as recommended in several recent reports, what should be the responsibility of the federal government in achieving that increase, and how does that responsibility differ from that of private sector research organizations and funding sources such as HHMI?

3. Do you have any specific recommendations for how federal science agencies such as the National Science Foundation could increase their support for high-risk research? In particular, what are the pros and cons of establishing targeted programs or set-asides for high-risk research versus changing how proposals are reviewed and selected across a federal science agency? What are the biggest challenges or risks associated with each of these approaches? What metrics should be used to evaluate the success of any approach to funding high-risk research?