On October 8, 2009, the Subcommittee on Research and Science Education of the House Committee on Science and Technology held a hearing on "The Need for and Government's Role in High-Risk, High-Reward Research." The hearing focused on many of the findings and recommendations of the Academy's *ARISE* Report.

ARISE Committee member and co-chair of the Academy's Initiative on Science, Technology, and Engineering Neal Lane (Rice University) testified on behalf of the Academy. His written testimony is below.

To view video of the hearing and to read the testimony of other witnesses, click here.

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Statement to
The House Committee on Science and Technology,
Subcommittee on Research and Science Education

On behalf of
The American Academy of Arts & Sciences
October 8, 2009

Hearing on High-Risk, High-Reward Research

Chairman Lipinski, Ranking Member Ehlers, and members of the committee: I am Neal Lane, the Malcolm Gillis University Professor at Rice University. I also hold appointments as a Senior Fellow of the James A. Baker III Institute for Public Policy, where I am engaged in matters of science and technology policy, and in the Department of Physics and Astronomy. Prior to returning to Rice University, I served in the Federal government during the Clinton Administration as Assistant to the President for Science and Technology and Director of the White House Office of Science and Technology Policy, from August 1998 to January 2001, and as Director of the National Science Foundation (NSF) and member (*ex officio*) of the National Science Board, from October 1993 to August 1998.

I am also proud to be a Fellow of the American Academy of Arts and Sciences and to serve on its Council. I co-chair with Charles Vest the Advisory Committee for the American Academy's Initiative for Science, Engineering, and Technology. Last year, as part of the Initiative, the Academy released a report, *ARISE: Advancing Research In Science and Engineering*. I am pleased to appear today on behalf of the American Academy to discuss the findings of the *ARISE* report as they apply to the issue of federal funding for high-risk, high-reward research.

The American Academy of Arts & Sciences was founded in 1780 by John Adams and other scholar-patriots to encourage dialogue among leaders of science, the arts, business and public affairs. Today, the Academy is an independent policy research institute, engaged in the study of complex problems vital to our nation's future. Through its projects and studies, and publications like the *ARISE* report, the Academy pursues practical policy responses to pressing national and global problems. On behalf of the Academy I wish to thank the Subcommittee for inviting me to summarize briefly this report's timely findings and recommendations. They are, we believe, vital to the future progress and prosperity of the nation.

I would also like to acknowledge the distinguished Fellows of the Academy who served on the committee that developed the *ARISE* report. The group was chaired by Nobel laureate and former Howard Hughes Medical Institute President Thomas Cech. Committee members included some of the nation's preeminent scientists and policy leaders from government, academia, and industry. In particular, I want to mention University of

Maryland President C. D. (Dan) Mote, Jr. Before the hearing date was changed, President Mote rearranged his schedule in order to testify before the subcommittee on behalf of the Academy, an indication of his strong commitment to the issues raised in the *ARISE* report. He was a valuable member of the committee and is a leader on competitiveness and science and technology research issues at his own university and nationally.

Many studies have focused on the need to increase the level of federal funding for science and technology research in order to sustain America's competitive advantage. The Academy committee that generated the *ARISE* report began its deliberations with a different question: Regardless of the levels of overall federal research funding, what are the things that all stakeholders - government, universities and foundations - must do to ensure the most efficient and effective use of those federal research funds?

In considering this question, the committee identified two issues central to the vitality of America's research enterprise: 1) the support of early-career investigators; and 2) the encouragement of high-risk, high-reward research.

Early-Career Faculty

Before turning to the Committee's interest in high-risk, high-reward research, permit me to briefly summarize key points from the *ARISE* report related to new tenure-track faculty, those most talented individuals who will lead our science and technology enterprise into the future. The two issues are, of course, related since many of the most novel ideas come from early-career researchers.

In recent years, many early-career faculty have faced greater obstacles in launching and sustaining their careers than their senior colleagues. Many, probably most, early-career investigators spend excessive amounts of time constantly preparing and submitting multiple grant proposals for awards, and when they succeed, new awards often are inadequate in size and too short in duration. New researchers must sustain an intense pursuit of funding, diverting time from their research and teaching during the formative years of their research and teaching careers.

Data from the National Science Foundation and the National Institutes of Health confirm worrisome trends, shared, we suspect, across all fields of physical sciences and engineering. In general, early-career investigators must compete harder, succeed less often, and start careers later than did older, established investigators, most of whom also confront intense competition for limited resources.

While NSF and NIH have helpful trend data on early-career faculty, most mission agencies lack comparable data and analyses; they do not track demographic data on their applicant and investigator populations. The enterprise as a whole lacks an analytical capability to produce a systemic view across all agencies and fields of research.

Early-career investigators typically have had to wait too long to receive their first grant. The average age of first-time NIH awardees has risen steadily and in 2007 stood at 42.6. In many cases, tenure-track faculty will be facing an up-or-out tenure decision before they have received their first competitive grant and had time to demonstrate their research capability. In such cases, the university loses a promising faculty member and the investment it has made with a start-up package.

Of new investigators who applied for NIH awards in 2007, 20.6% succeed compared with 23.8% of established researchers, according to data reported by the Institutes.

In 1980, about 33 percent of NIH individual investigator awards went to first-time investigators; by 2006 less than 25 percent of awards went to early-career investigators.

One-half of new NSF investigators never again receive NSF funding after their initial awards.

Meanwhile, NSF and NIH data confirm that the investigator population across the sciences and engineering is graying even as non-tenure track ranks continue to grow.

In light of these trends, high frustration levels and low morale felt by many new tenure-track researchers are

being communicated to promising undergraduate and graduate students as they make their own career decisions. Discouraging our brightest students from pursuing research careers is an ineffective strategy for assuring our nation's science and technological leadership in the future.

Despite these worrisome findings, there is some good news. The Obama Administration, and NSF and NIH in particular, recognize the importance of these issues and are taking steps to address them. There is evidence that mission agencies are also becoming aware of the particular challenges facing early-career investigators. But more must be done.

Recognizing that the Subcommittee's jurisdiction does not extend to all of the federal government's science and technology research-funding agencies, the American Academy encourages this Subcommittee and the Congress to support initiatives designed to strengthen incentives and opportunities for early-career investigators. Specifically we ask you to:

1. Monitor closely actions taken to address the needs of early-career researchers across the sciences and engineering disciplines;
2. Encourage all agencies to establish targeted programs for early-career faculty;
3. Encourage all agencies to establish new research programs only if they have sufficient fiscal support to fund a reasonable percentage of applicants. Grant programs that fund a very small percentage of applications are inefficient uses of money, time, and effort;
4. Encourage agencies to give special attention to proposals of early-career investigators during competitive merit review and to adopt career-stage-appropriate expectations for grant funding;
5. Encourage agencies to create seed funding programs for early-career investigators to enable them to explore new ideas for which no results have yet been achieved;
6. Encourage agencies to remove barriers affecting those who serve their families as primary caregivers, for example, by providing grant extensions or other appropriate support mechanisms, and, finally;
7. Encourage agencies to collect and analyze demographic data on applicants and principal investigators government-wide and in a uniform format to establish a comprehensive federal database on how agencies support research. The current nonstandardized tracking among funding agencies hinders efforts to analyze funding trends. Since NSF has an excellent track record of collecting and analyzing data relevant to the future of the nation's science, engineering and technology enterprise, its example could be helpful to other agencies that do not have such a tradition.

High-Risk, High-Reward Research

Turning now to high-risk, high-reward research, the *ARISE* report highlights several important themes that I believe merit consideration by the Subcommittee.

Most research scientists and engineers achieve their goals by persistent, step-by-step work built on the discoveries and advances of others. This is, and must remain, the vital foundation of our research enterprise. Important breakthroughs do result from incremental research.

Science also progresses from bold innovation in methods, instruments, and computer software. Curiosity-based or intuition-based boldness can require even greater leaps into the unpredictable unknown. Most such efforts will fail, but the few pioneers who are successful can profoundly influence the direction of science by challenging accepted paradigms. Such research can generate deep changes in concepts, create new subfields of science or bring together different fields to make discoveries and advances that would otherwise be impossible. This research can also allow the entire community to extend its reach by creating revolutionary technologies, new products, new markets and industries and high quality jobs. Thus, high-risk, high-reward research is

needed to maintain the U.S. position of leadership in science and technology and to ensure the nation's future economic competitiveness. The *ARISE* report cites several examples of such transformative payoffs, including the transistor, quantum mechanics, and angiogenesis. The report recommends that every agency set aside a certain portion of its research budget for high-risk research.

For most of its history, the NSF has received far more proposals that have been judged by the competitive peer-review system to merit funding than the agency has sufficient funds to award. It is up to the program officers to make the final judgments as to which proposals receive awards and the large majority that do not. Other research agencies are in a similar position. When funds are this tight, all components of the system - researchers writing the proposals, experts reviewing the proposals, and program officers making the final decisions - naturally tend to become more risk averse. They tend to give highest priority to projects likely produce incremental success in the near term. Short-term, low-risk and measurable results dominate competitive review and program management systems and decisions. The *ARISE* Committee summed it up in these words:

> "As the resulting constant hunt for dollars fosters conservative thinking, it also impedes the pace of research. The thought, 'Don't put it in your grant proposal unless you know it will work,' too often guides senior and junior faculty alike as they compete in an intense national grant-writing mill."

It is important to emphasize that the system continues to fund excellent research, that it does help prepare the next generation of scientists and engineers, and that virtually all proposed research projects are challenging and are judged to advance scientific and technical understanding. But, some potentially path-breaking research is not being funded because it just looks too risky.

The American Academy and the *ARISE* committee are encouraged by several promising recent developments designed to counter the prevailing incentive system.

In 2007, Congress created the Department of Energy (DOE) ARPA-E program as part of the America COMPETES Act. ARPA-E is modeled after DARPA with the goal of enhancing the economic and energy security of the United States through research into transformative energy technologies. DOE is currently evaluating the first round of applications, and successful proposals will be funded by the American Recovery and Reinvestment Act (ARRA).

Similarly, this year will see the first grants awarded under the NIH Transformative R01 program (TR01), a targeted high-risk, high-reward initiative designed as a result of strategic planning to fund ground-breaking research opportunities. The proposed FY2010 budget expands funding for this program to $70 million, double the 2009 funding level.

The economic stimulus program enacted by Congress will support promising high-risk research at other agencies as well. NSF Director Arden Bement has pledged to give increased priority to new principal investigators and high-risk, high-return research in allocating ARRA funds. Building on the momentum provided by stimulus funding, the proposed NSF FY2010 budget sets aside $92 million specifically to foster transformative research.

The Academy commends the Congress, the National Science Board and NSF for their early recognition of the need to nurture high-risk research and their recent actions to address this need. The Foundation has taken important first steps to expand opportunities for new and established researchers alike to pursue high-risk opportunities. For example, NSF program officers now have the flexibility to award up to two years of funding for potentially transformative research through the EAGER program (EArly-concept Grants for Exploratory Research). This mechanism should be used more frequently across the NSF grant programs and at other funding agencies as well. Clearly, each agency must stand behind the program officers making these difficult decisions, since many of the truly bold, high-risk ideas will not bear fruit. If the agencies' expectations are too high, the entire effort will fail.

President Obama's Innovation Strategy aims to restore American leadership in fundamental research. In outlining this strategy in a September 21st speech in Troy, New York, the President stressed the importance of valuing and promoting "the risk takers who have always been at the center of our success" and pledged "more support for high-risk, high-return research, for multidisciplinary research, and for scientists and engineers at the beginning of their careers."

Looking to the future, the Obama Administration has emphasized the need to build on these commitments to encourage potentially transformative research. In an August 4 memorandum from Office of Science and Technology Policy Director John Holdren and Office of Management and Budget Director Peter Orszag, executive departments and agencies were asked to prioritize high-risk, high-reward research in preparing FY2011 budget requests, stating "Agencies should pursue transformational solutions to the Nation's practical challenges, and budget submissions should therefore explain how agencies will provide support for long-term, visionary thinkers proposing high-risk, high-payoff research." The directive also asked agencies to create metrics to evaluate the success of programs designed to promote high-risk research.

To these ends, the Academy respectfully asks this Subcommittee and the Congress to encourage all of the science and engineering research agencies to:

1. Establish and strengthen policies, programs, and targeted funding mechanisms designed to foster potentially transformative research:

    - Applications should be relatively short and focused on the qualifications of the researcher, an explanation of the potentially transformative nature of the research, and an explanation of why the researcher believes the proposed approach could succeed.
    - The proposal and the review process should place a premium on innovation.
    - Fast-track seed money to evaluate a novel idea should be made available.
    - Agencies should be open to providing longer funding periods for those proposals that require it.
    - A possible model for sustained funding is the NSF Industry/University Cooperative Research Centers program—an initial five-year grant that, if moving forward appropriately, can be renewed for an additional five-year period at a reduced level of funding.

    Because federal research agencies are highly diverse in their missions, needs, and programs, funding mechanisms that support potentially transformative research will and should vary across departments and agencies. Such diversity is a national asset and the foundation of the research enterprise. Therefore a final recommendation is:

    - Convene interagency meetings to share information on how departments and agencies design, organize, implement, and evaluate their investments in potentially transformative research.

2. Nurture high-risk, high-reward research programs that have a critical mass.

3. Establish metrics with which to evaluate the success of targeted research programs:

    - Short-term metrics: Are proposals of higher quality compared to those submitted to standard grant programs? Does the funding rate discourage future applicants?
    - Long-term metrics: Wait ten years to evaluate scientific outcomes – fruits of transformative research are not apparent in the short term.

4. Adopt funding mechanisms and policies that nurture transformative research in all award programs, not just those targeted at high-risk, high-reward research:

- Charge reviewers to identify new ideas, innovation, and creativity. Consider alternative ways to select and mentor reviewers.
- Give program administrators in all agencies the flexibility to provide extra resources or time to research unexpected but promising developments, potentially using the NSF EAGER grants as a model.
- Recognize in grant-reporting requirements the value of fortuitous findings not related to the main objective of the research proposal.
- For grant renewals or new grants on the same topic, restrict the number of submitted publications and require a self-assessment of each cited publication's impact.

5. Strengthen application and review processes. High-risk research proposals face even greater challenges in a stressed peer-review system not equipped to appreciate them:
   - Require recipients of multiple grants from an agency to serve as reviewers.
   - Achieve greater continuity in reviewers.
   - Require applicants to address the following question about their proposed research: "If this works, what long-term scientific difference will it make?" Evaluate proposals based on this criterion.
   - Establish interdisciplinary review panels to consider high-risk research proposals across programs and fields.
   - Evaluate renewals for first awards for high-risk, high-reward research on the basis of project execution and potential scientific impact, not on deliverables. Resist fine-grain assessments of whether a project "worked"; expect some hypotheses to fail.
6. Strengthen investments in the career development of agency program officers who are indispensable to the vitality and productivity of the entire research enterprise. They should be encouraged and expected to engage with the professional communities they fund. This requires an adequate administrative budget, which should not come at the expense of the research budget:
   - Program officers should be leaders not only within their agencies but within their external scientific communities as well.
   - Program officers should be able, indeed encouraged, to attend professional meetings and to visit institutions and laboratories funded by programs for which they are responsible.
   - Many university faculty members serve as temporary program officers at NSF, or "rotators," while on leave from their university. They provide essential service and leadership for NSF's research programs. Consideration should be given to providing this flexibility to other agencies as well.

As a former Director of the National Science Foundation, I wish to affirm and commend the dedication and the quality of its program officers. They are the core of the NSF. The encouragement and support they receive directly determines how well NSF performs its important work. They must be able to travel to professional meetings, make site visits to universities, and in other ways become more active and visible leaders in their fields. Just as the program officers need to stay current on the latest developments in science and engineering research, the research community needs to know and respect these professionals, who have such large responsibilities for the quality of U.S. science and engineering. I urge Congress, through its oversight and appropriations roles, to provide the resources the NSF requests for support of the agency's staff.

The committee will note that the *ARISE* report recommends both the creation of targeted grant programs specifically aimed at high-risk, high-reward research and the promotion of such research within all existing

funding programs. There are several advantages to the creation of targeted grant programs, and a few attendant challenges. High-risk, high-reward research involves unique objectives, time-frames and evaluation metrics, and targeted programs permit these research proposals to be evaluated separately from standard proposals. It may also be faster and easier to implement a new targeted program than to re-tool standard funding processes to accommodate the particular needs of high-risk, high-reward proposals.

Challenges associated with targeted funding programs include the potential for extremely low funding rates that could discourage future applicants. A further challenge is that funding agencies must be prepared to follow unexpected research directions arising from high-risk, high-reward research. Finally, in evaluating the merits of high-risk, high-reward research programs, it must be kept in mind that the fruits of transformative research are often not apparent for at least ten years. Near-term evaluation of these programs must be based on different metrics, for example, whether the quality of proposals differs from those received through standard grant programs.

The *ARISE* committee was also concerned with the role of other institutions, particularly universities, in supporting high-risk research. Institutions of higher education—especially medical schools—have tended to enlarge their faculty in times of expanding federal investment by shifting the salary burden to faculty. For the federal funding agencies, this salary support reduces the number of projects that can be funded. For the faculty member, this requirement fosters conservative, risk-averse thinking as the path to sustained funding. When funding tightens, faculty, especially early-career faculty, after years of training often simply leave the field.

Two final *ARISE* recommendations directly address the role of universities in supporting early-career scientists and high-risk, high-reward research. These recommendations aim to mitigate concerns over the effects that boom and bust funding cycles have on tenure, training, and capital investment on campuses:

1. Universities should accept greater institutional responsibility for the salaries of faculty members.
2. In building new facilities and programs, universities should shoulder a larger share of the financial cost.

Thus, university resources are needed to buffer the scientific enterprise from the ups and downs of federal funding. If funding campaigns for construction were expected to assume some significant portion of the research expenses, it would lead universities to limit excessive building programs based on unrealistic expectations about the expansion of the research enterprise. Some universities are now beginning to recognize the wisdom of setting aside money from building campaigns for research and equipment. Universities could go even further and underwrite the creation and maintenance of centers specifically devoted to potentially transformative research. In times of economic downturn and shrinking endowments, the government and universities should consider ways to provide general support for science and engineering research that protect against disruptive boom and bust funding cycles.

The Academy is initiating a second phase of *ARISE* to study how the distribution of federal funds affects the administration, faculty, students, and the academic mission of the university. The Academy would be grateful to this Subcommittee for its input as we develop this phase of the *ARISE* study.

I look forward to your questions about all aspects of the *ARISE* report. Thank you, once again, for this opportunity.

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Dr. Neal Lane is the Malcolm Gillis University Professor at Rice University in Houston, Texas. He also holds appointments as Senior Fellow of the James A. Baker III Institute for Public Policy, where he is engaged in matters of science and technology policy, and in the Department of Physics and Astronomy.

Prior to returning to Rice University, Dr. Lane served in the Federal government during the Clinton Administration as Assistant to the President for Science and Technology and Director of the White House Office of Science and Technology Policy, from August 1998 to January 2001, and as Director of the National Science Foundation (NSF) and member (ex officio) of the National Science Board, from October 1993 to August 1998.

Before becoming the NSF Director, Dr. Lane was Provost and Professor of Physics at Rice University in Houston, Texas, a position he had held since 1986. He first came to Rice in 1966, when he joined the Department of Physics as an assistant professor. In 1972, he became Professor of Physics and Space Physics and Astronomy. He left Rice from mid-1984 to 1986 to serve as Chancellor of the University of Colorado at Colorado Springs. In addition, from 1979 to 1980, while on leave from Rice, he worked at the NSF as Director of the Division of Physics.

Widely regarded as a distinguished scientist and educator, Dr. Lane's many writings and presentations include topics in theoretical atomic and molecular physics and science and technology policy. Early in his career he received the W. Alton Jones Graduate Fellowship and held an NSF Doctoral Fellowship (University of Oklahoma), an NSF Post-Doctoral Fellowship (while in residence at Queen's University, Belfast, Northern Ireland) and an Alfred P. Sloan Foundation Fellowship (at Rice University and on research leave at Oxford University). He earned Phi Beta Kappa honors in 1960 and was inducted into Sigma Xi National Research Society in 1964, serving as its national president in 1993. He served as Visiting Fellow at the Joint Institute for Laboratory Astrophysics in 1965-66 and 1975-76. While a Professor at Rice, he was two-time recipient of the University's George R. Brown Prize for Superior Teaching.

Through his work with scientific and professional organizations and his participation on review and advisory committees for Federal and state agencies, Dr. Lane has contributed to public service throughout his career. He is a fellow of the American Physical Society, the American Academy of Arts and Sciences (member of its governing council), the American Association for Advancement of Science, the Association for Women in Science and a member of the American Association of Physics Teachers. He serves on several boards and advisory committees.

Dr. Lane has received numerous prizes, awards, including the AAAS Philip Hauge Abelson Award, AAAS William D. Carey Award, American Society of Mechanical Engineers President's Award, American Chemical Society Public Service Award, American Astronomical Society /American Mathematical Society/American Physical Society Public Service Award, NASA Distinguished Service Award, Council of Science Societies Presidents Support of Science Award, Distinguished Alumni Award of the University of Oklahoma, and over a dozen honorary degrees. In 2009, Dr. Lane received the National Academy of Sciences Public Welfare Medal, the American Institute of Physics K.T. Compton Medal for Leadership in Physics, and the Association of Rice Alumni Gold Medal for service to Rice University

Born in Oklahoma City in 1938, Dr. Lane earned his B.S., M.S., and Ph.D. (1964) degrees in physics from the University of Oklahoma. His thesis advisor was Chun C. Lin (currently at the University of Wisconsin – Madison). He is married to Joni Sue (Williams) Lane and has two children, Christy Saydjari and John Lane, and four grandchildren, Allia and Alex Saydjari, and Matthew and Jessica Lane.