U.S. Senate Commerce, Science, and Transportation Committee working group discussion, "Maximizing the Impact of Basic Research."

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My name is Tim Sands, and I am privileged to serve as the 16th President of Virginia Tech. But, before my career in higher education administration, I was a researcher in industry and in a national lab. During my two decades as a professor and principal investigator at UC Berkeley and Purdue, my primary source of research funding was the federal government. Over the course of my time as a researcher, I was principal investigator or co-principal investigator on 26 federal agency grants from NSF, DOE, DARPA, and ONR, as well as several grants from the State of California and too many companies to list here. These grants supported more than 100 graduate students (49 of which were supervised by me), 35 undergraduate researchers mentored by me and by my PhD students, and a dozen U.S. patents, three of which were licensed by industry.

I share this, not in any way to toot my own horn, but rather to say that my story is not unusual at all. My story as a researcher is the story of so many researchers across the country. Thousands upon thousands are working hard every day to make advancements in science and at the same time, prepare the next generation of scientists and engineers. These advancements are making life better not only here in America, but across the globe; advancements that will lead to new jobs and help propel our economy forward.

I am privileged to be here because, I imagine, like you, we all want the same thing: A robust federal research program that is operating efficiently and maximizing impact. Towards that end, I offer the following comments on the Committee's five areas of discussion.

1. ***What functions should the federal government, academia and the private sector be encouraged to perform in driving the U.S. "innovation ecosystem" and how can they strengthen their partnership to ensure the U.S. position as a global innovation leader?***

- Basic research is the feedstock for our innovation ecosystem – We are not close to a point of diminishing returns in the U.S. Greater investment = greater output. In my experience, many outstanding research proposals as judged by expert panels are not funded today simply because there are insufficient funds. Every review panel on which I have served in recent years has struggled with placing highly meritorious proposals below the funding line. Given the relatively modest cost of much of this research, this is a waste of talent and capacity.

- The federal government should drive the system by sustained growth in research agency budgets. Flat or declining budgets drive talent away (especially early career women and potential researchers emerging from lower income families).

- Vacillating program and agency budgets have the same effect on a large scale. My own experience as a researcher in thin-film solar cells in the early 1980s is an example. When the price of oil dropped after the oil embargo, federal support for solar cell research plummeted. I made a personal decision to move into telecommunications research in private industry. I have no regrets with respect to my own career trajectory, but an entire generation of solar cell researchers left the field, never to return. Had steady progress been maintained, we would be in a much better situation now with respect to the technology and its economic viability.

- Research universities are taking on a greater role in both basic research and commercialization. I spent the first nine years of my career at Bell Communications Research in New Jersey. We were driving applied science in our domain. That lab does not exist anymore as private industry has stopped funding basic research. Industry is relying instead on universities. An advantage in this shift

is that universities are also preparing the next generation of scientifically and technically competent citizens, and our undergraduate students are more engaged in research than ever before.

- Opportunities to improve partnerships across sectors would include supporting the development of innovation districts by modifying rules that inhibit collaboration, and creating incentives for co-location. For example, current regulations make it difficult for private companies to partner with universities in facilities built with tax-exempt bond financing.

- The Industry/University Cooperative Research Center (I/UCRC) program at NSF has worked extremely well for over 40 years. Every Federal dollar is leveraged with eight dollars from industry; there are now approximately 70 active centers with 10-30 research partners each. Virginia Tech is a member of eight active I/UCRCs. I was active in I/UCRCs as a faculty member at Purdue and at Berkeley. We need to build on this time-tested model.

- Agencies need to work together. Challenges of this century span health, security, sustainability and resilience. NSF must coordinate with NIH, DoD with NSF, and partnering globally is important as well.

2. ***How can the federal government best structure, coordinate, and/or prioritize its R&D investment portfolio to provide predictability for research initiatives, facilitate the discovery of new knowledge, drive lasting economic growth, and address critical emerging challenges?***

- First of all, the system we have now, despite its chaotic and uncoordinated elements, is working quite well. Each agency has a different culture, a different way of communicating results, and different processes for funding and managing research. Although there is more room for streamlining, coordinating and partnering, just investing more in our current system would be a win for the country.

- In my experience, the sweet spot for innovation is between curiosity-driven research by opportunistic researchers, and needs-driven research by curious researchers. My personal story as a scientist and engineer is highlighted by a discovery a student, a colleague and I made back in the late 1990's: A laser process that became a critical step in the process to manufacture high-brightness LEDs – the technology that is the basis of automotive headlights, solid-state lighting, and the back-lighting for almost every TV and monitor manufactured today. That accomplishment would not have been possible without federal support for our basic research along with directed research sponsored by industry and catalyzed by the State of California. That breakthrough was a discovery rooted in a fundamental study of the interaction of lasers with materials, but the fact that we were working with industry gave us the perspective to recognize the commercial value of an experiment that yielded a puzzling and unexpected result.

- Working across agencies and sectors to identify broad priority areas, and then making commitments to fund steadily over a decade or more will make for a greater ROI. I am encouraged by the emphasis in recent years in cross-sector partnerships. Last week, Flirtey (a commercial drone start-up based in Australia and Nevada), Health Wagon, RAM Clinics, the FAA, NASA, and the Mid-Atlantic Aviation Partnership (an FAA Unmanned Aerial Systems test site led by Virginia Tech with partners in Maryland and New Jersey) all came together to demonstrate the first FAA-approved package delivery by drone. Delivering prescription medicines to a remote mobile health clinic in the Appalachian mountains demonstrated the life-saving potential of this technology. That all of these partners came together without direct federal funding is significant. With a federal investment, this technology could catch up and pass the government-backed efforts in Europe and Australia. That U.S. is already playing catch-up in this nascent technology space should be alarming.

3. ***What steps can the federal government take to maximize the research obtained for each dollar of federal investment?***

- The biggest challenge is unnecessary regulation, exacerbated by low funding levels that force researchers to win a large number of projects from different sponsors, each with its own requirements. When I was an active researcher, I had six to 15 PhD students at any given time, working on five to ten separate grants and contracts. My colleagues and I feel like we are running small, tightly regulated and highly unpredictable businesses. Because funding rates are low (7% - 15% is not unusual for single-investigator core projects and multi-investigator centers), we also have to be proposal machines. If awards were larger and reporting requirements were more consistent, more of our talent could be applied to the research itself. Our graduate and undergraduate research students see this rat race, and they decide it is not for them. And the successful researchers are those that can manage a complex business rather than those who have the best ideas and perform the highest quality research. I strongly recommend that we follow precepts in the 2014 NSB report: *Reducing Investigators' Administrative Workload for Federally Funded Research.*

- At Virginia Tech, more than 50 full-time positions are dedicated to research regulatory compliance, including 14 FTE in animal, human, and biosafety; nine in export controls; and more than 30 FTE in post-award financial controls. No doubt, some of these compliance activities are critical, but there are opportunities to save resources. A National Academies study underway should illuminate these opportunities. That said, the cost of personnel dedicated to compliance is dwarfed by the effort wasted in unnecessary administration by principal investigators.

- The aforementioned NSF I/UCRC program is an example of smart sharing of burdens across sectors.

- Not-so-smart cost sharing is asking a research university to cost share. We are not profit centers. In fact, we do not recover all or even a majority of the Facilities and Administration costs that support research. At Virginia Tech in FY14, we had just over $100M in unrecovered Facilities and Administration expenditures on about $500M in total research expenditures. We invest institutional funds because it is our mission. Asking us to share the costs means we have to find the money somewhere, for example, in nonresident undergraduate tuition or philanthropy.

- Asking for large matches of state resources on big projects may make sense from a financial and commitment perspective, but it also may exclude the best technical teams if they happen to be based in a state that does not invest in research.

4. ***What principles should guide federal agencies in ensuring adequate transparency, oversight, and rigor in the process of funding, conducting, reviewing, and reproducing research?***

- Peer review is expensive, cumbersome, and does not always pick the winners correctly, but it is vastly superior to any other process. It is by far the most rigorous, especially when it comes to basic research. When you move into needs-driven research, you should have those who understand the need at the table as well.

- We should increase use of post-award peer review, and we should make sure that program managers, sponsors and government scientists can participate in technical meetings.

5. ***How can the results and value of Federally-funded research be better communicated across the research community and to the private sector and general population?***

- We owe it to the public to effectively communicate our results, and to make sure these results can be understood by the lay public.

- In the long run, it may be more effective to raise the public's level of competency in science & technology by investing in early education. As it is now, we lose about half of our talent pool before they start kindergarten.

- The great opportunities for garnering public support come from the big ideas that cut across sectors and disciplines.

    - For example, advances in functional brain imaging are forever changing our thinking about human decision-making. Everything from diagnosing autism (the Virginia Tech Carilion Research Institute has developed a 2-minute test to determine a patient's position on the spectrum of autism disorders), to understanding and treating addictive behaviors. In the near future, neuroscience will form the foundation for every field that involves human decision-making, from political science to economics to marketing. And the physical sciences are allowing for smaller and more portable brain imaging instrumentation.

    - The convergence of science, engineering, art and design is at the foundation on much of our emerging technology-based economy. At Virginia Tech, our Institute for Creativity, Arts and Technology (ICAT) is introducing the next generation of K-12 student to science and technology through the intersection with art and design.

    - The rapid advances in cancer treatments made possible by genomics, proteomics, enhanced understanding of cell differentiation, high-speed cell sorting, targeted drug delivery, big data and nanotechnology are leading to a revolution in personalized medicine (Big Data). This work cannot be catalyzed by NIH alone. Every agency has a role, as does every major sector. A collaborative and coordinated approach is required.

    - The comprehensive understanding of urban resilience (security, transportation, financial, health, climate) is the modern land-grant challenge.

- All of these great opportunities cut across the broadest range of inquiry, from computer science, to behavioral science to the arts. This breadth is not just a feature of impactful research teams, it is also permeating undergraduate education. For example, just last year, Virginia Tech launched a major in *Water: Resources, Policy and Management*. Five of our eight colleges are partnering. The students not only learn the complex science of water, they are exposed to public policy and the practices of managing these precious resources.

- In 2050, the vibrancy of our economy and the security of our nation will depend on the degree to which we invest now in science, technology and education. We are not in danger of over-investing! We need to broaden participation; we need to be more efficient, but forget about picking winners 100% of the time; We need to build on programs that work and systems that self-adjust; we must focus on freeing up investigator effort to address the creative process, away from administration and compliance; we should work across agencies and sectors; and we need to be bold and take risks.

- Finally, we need to rescue our public and land-grant research universities (see the June 2015 publication of the American Academy of Arts & Sciences and Lincoln Project, *Public Research Universities: Why They Matter*). They were founded 1) to prepare students from all classes to participate productively in our democracy and 2) to advance regional and national economies. These missions have never been more relevant. Our public research universities operate at scale, and with ever-increasing impact in teaching and learning, discovery and commercialization, and engagement. Co-operative extension is a model that has worked effectively for over 100 years to translate new knowledge and disseminate solutions directly to people and businesses in every corner of the country. We need to adapt lessons learned from the co-operative extension model to this century and the challenge of bringing the fruits of science to every

citizen. I personally think that higher education can also learn from the 119-year-old motto of Virginia Tech: *Ut Prosim – That I May Serve*. This generation is service oriented. They are naturally inclined to see their time at the university as an opportunity to harness their passions and develop skills that will prepare them for a meaningful life of service. If this generation is exposed to authentic scientific inquiry in the context of solving our biggest challenges, I do believe that we will see an economic and social renaissance in this country.