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Seidel Testimony for Senate Committee

Chairman Manchin, Ranking Member Barrasso, and members of the Committee on Energy and Natural Resources, thank you for the opportunity to testify on the role and programs of the Department of Energy's Office of Science.

My role. I am honored to testify today as perhaps the University of Wyoming's first representative to this committee. I will do my best to represent the broadest scientific interests of the nation and our universities across the country, including those in rural areas who have much to contribute to the national science, technology, and innovation ecosystem. As a practicing astrophysicist, I have had the honor to serve in roles at high levels in the national scientific enterprise. For example serving as National Science Foundation (NSF) Assistant Director for Mathematical and Physical Sciences, where in partnership with the Office of Science we brought the LSST Telescope to life, or as Director of the National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign where I oversaw the largest computing facility on a university campus, or as a member of Argonne National Laboratory's Board of Governors where I helped steward one the Office of Science's 10 national labs (out of 17 DOE labs in total), which are truly crown jewels in the nation's scientific enterprise. And I have been VP for Economic Development and Innovation at the University of Illinois, so I think every day about how our universities and the national science establishment can better drive innovation for the US economy.

A year ago I was given the honor to serve as the 28th President of the University of Wyoming which was founded in 1886 when Wyoming was still a territory and retains a frontier spirit. I have taken on this role with energy and enthusiasm. In this new role I can have a different kind of impact in a rural state which, like many such regions, has an enormous amount to contribute; collectively rural America offers many new opportunities for partnerships with the Department of Energy (DOE) in research, in workforce development, and in national innovation and economic development.

It is with both these national and regional perspectives that I testify today.

Strength of American science ecosystem and needed enhancements. I would like to start by stressing the importance of the vibrant and complementary scientific and innovation ecosystem provided by not only the DOE and its many parts, including the Office of Science, but very importantly, organizations such as the NSF, NASA, the National Institute of Standards and Technology (NIST), the Defense Advanced Research Projects Agency, the National Oceanic and Atmospheric Administration (NOAA), the Institute of Education Sciences (IES), the National Institutes of Health (NIH), the US Department of Agriculture (USDA), the Department of Commerce (DOC) and other agencies that support scientific research, education, and innovation across the country. These different agencies, each with a different orientation, complimentary approach, and distinct mission, come together to support the strongest scientific capacity in the world. It is essential to the health and competitiveness of our nation that these agencies continue to be strengthened, and coordinated as they are by the Office of Science and Technology Policy (OSTP), the Networking and Information Technology Research and Development Program (NITRD), and other organizations.

However, we cannot take US scientific leadership for granted. Indeed, we are on the verge of not only losing our lead in science, but very importantly, in related technology, economic development, and national defense areas. Other nations, notably China, but also others in Asia and Europe, are investing heavily in science and technology, including related education and workforce efforts, and importantly, the scientific infrastructure needed to support it. In many cases, competing national science and technology programs are strongly linked, and deeply coupled to efforts to commercialize for economic might (and surely for defense as well).

US science efforts must similarly receive new investments in research, education, and infrastructure, and be more strongly linked to efforts in technology and innovation. The continuum of effort from discovery to technological and economic innovation must be tightly connected, with basic science ready to drive technology at any point in its development. This must be the result of purposeful planning and programming, not serendipity. The DOE, particularly with its national labs, is well poised to do exactly this, but needs additional support to do so.

To these ends, I strongly support recent efforts in Congress to grow this science and technology ecosystem, and to couple it more closely to innovation, creating in effect what is a *national innovation infrastructure*. The recent US Innovation and Competition Act (USICA), passed by the Senate this summer, and the parallel efforts in the House (NSF for the Future and DOE Science for the Future Acts), propose a tectonic shift in science, technology and innovation funding that aims precisely to support and further develop this entire ecosystem from discovery-based basic science through technology and innovation to drive American competitiveness. The many parts of USICA further support the diverse federal ecosystem of science and technology agencies, aiming to greatly strengthen key areas of science that drive technology, and further, create much more support for innovation that will lead directly to economic development. Among other provisions, these acts increase foundational basic science at agencies such as NSF and DOE, which is needed to drive technology development; they better couple science to technology and innovation (e.g., adding a technology directorate to NSF or creating a targeted effort to enhance critical industries, such as microelectronics, important to the global technology leadership). Further, they provide funding for technology-based innovation hubs for continued innovation in the future (e.g., through the Department of Commerce in USICA). *It is essential that the Senate and House reach agreement on legislation on science and technology; other nations are not waiting while the USA considers different approaches*.

It is also essential, as I discuss below, that rural areas are not excluded in these activities; indeed, they should be embraced as they have assets that contribute unique strengths to advance research and innovation in ways that other regions cannot. *USICA specifically has provisions for rural states to be able to compete effectively for such funds; I urge that such provisions be kept in the final bill that emerges*.

Not only are various federal agencies and national labs poised to move quickly to roll out programs with such funding, but universities across the nation are also hungry, ready, and further positioning themselves for such funding and to become stronger engines of innovation for their regions and for the nation. Driven by similar motivations as USICA, my own University of Wyoming has proposed a major restructuring of its academic programs, including creating new cross-campus structures powering all-in-university approaches to research, education and innovation, including a new School of Computing and a new Center for Entrepreneurship and Innovation. Under this proposal, all students, regardless of major, will be able to gain skills in digital literacy and innovation and entrepreneurship to grow a new, 21st century economy;

faculty from the arts and social sciences to engineering and life sciences, will be able to work in new organizational structures, and with companies, to attack grand challenges such as those supported by the DOE. We have also come together with our seven community colleges to form a new Wyoming Innovation Partnership to align all higher education across the state, as well as schools and corporate partners, to drive the state's future economy. *And our entire EPSCoR (Established Program to Stimulate Competitive Research) region[1], including the Dakotas, Montana, Idaho, and Wyoming, is forming a Rural Mountain West Innovation Consortium, bringing our considerable regional assets to bear on our workforce and economy, to create a science and technology based distributed, regional innovation hub that will contribute significantly to our states' and the nation's economic vitality.*

Similar efforts are underway across the nation, including my former backyard of Illinois, that has created a statewide Illinois Innovation Network of all public higher education, led by the University of Illinois, along with the University of Chicago, Northwestern University, Argonne National Laboratory, and an array of corporate partners that will all have a common home in the Discovery Partners Institute in Chicago.

In all the combined national academic and corporate enterprise is ready to work with national labs and other parts of the science and technology enterprise to innovate and drive our economy forward as we compete with formidable forces in China and elsewhere around the world.

Enhancing strengths of the DOE Office of Science. Within this framework, the Office of Science underpins a large and very important fraction of the national scientific enterprise, playing an incredible role in making the US scientific establishment the strongest in the world. This, in turn, has added significantly to the national defense and has helped provide the foundation for innovation that has made our economy the strongest in the world. While my colleagues will surely testify on the many specific strengths of the Office of Science, including centrally its national labs and their user facilities, I would nonetheless like to highlight examples of what I see as cornerstones to anchor the scientific, technology, and innovation enterprise for the future.

Unique among these strengths, and a top priority among needs for continued increases in funding, are DOE's unparalleled advanced computing programs. Support for advanced computing in all its forms (exascale computing hardware and associated software and science teams that will utilize it; the growth of novel Artificial Intelligence (AI) and big data approaches that are revolutionizing science and impacting society alike; computational mathematics; quantum computing; and more) is essential for advances in all areas of science. Without significant investment in these technologies, all areas of science suffer; likewise, significant investment in a broad computing agenda is a necessary investment in all of science. Computing is and must continue to be a centerpiece in DOE's strategy for current science efforts, as is support for the next generation of computing technologies to come, including importantly quantum computing. Planning and investment for future generations of computing technologies and their applications must continue, just as current exascale, AI, big data, novel quantum computing approaches are deployed now to support current generation science applications.

For example, the LSST telescope, a deep interagency collaboration between the NSF and the Office of Science, is "more silicon than steel". The telescope itself is essentially a peripheral to the massive computing environment needed to support the science. Among DOE Labs it is a collaboration between Stanford National Accelerator Laboratory (SLAC), FermiLab, Lawrence Berkeley, Brookhaven, and Argonne

[1] I note that 15 of 20 members of this committee represent EPSCoR jurisdictions.

National Labs. Perched atop a mountain in Chile, when operational its DOE-built 3 Gigapixel camera will make unprecedented images of the sky, that are sent over optical networks to the US where they are digitally processed within seconds and served to thousands of collaborators. But even more exciting, every few minutes it will take an image, move to its next position, create another image, and then on to the next, robotically scanning the entire southern half of the universe every three days. Then, it starts over again. Every night, as many as a million new events will be discovered as stars explode and black holes collide; over a decade it will produce a movie of the universe, hundreds of petabytes in size, driving a new scientific revolution. Specific purpose-built computing environments are required to analyze the data in real time using advanced AI techniques to instantly alert astronomers, physicists---and the public---who have other instruments, for example gravitational wave detectors, to observe the same events through other means, anchoring the new and revolutionary field of "multi-messenger astronomy" that has been decades in the making.

Likewise, the planned upgrade to Argonne's Advanced Photon Source will shine a light of unprecedented intensity with hard x-rays, providing new insights into the structure of materials and biological processes that cannot be obtained any other way. Its detectors will provide data at rates that, again, require advances in the highest end computing and networking to handle the data streams never seen in such a laboratory. Beamlines for different science domains and industry alike will serve communities across the nation and the world for revolutionary advances in materials and biological sciences, while also advancing innovation and economic development.

In another example, of hundreds I could provide, Argonne's Joint Center for Energy Storage Research (JCESR) is a leading international center for advances in energy storage systems that will power next generation electric vehicles and store energy as national power grids are diversified from coal and hydro power to include solar, wind and other sources of power. Here too, advances in computing accelerate the development of new materials, for example using the highest end petascale and soon exascale machines to simulate every atom in a material or using advanced AI techniques to predict behavior of materials that can be tested by a lab to improve efficiency of new batteries needed to power the nation.

I have barely scratched the surface of how the Office of Science is essential to advancing the nation. Its programs in areas ranging from materials to environmental science impact virtually every area of research and innovation needed to address the nation's energy needs, and to steward its precious natural resources from water to rare earth minerals, at a time of fierce international competition. It is one of the most important assets in the US to keep America competitive in an uncertain and profoundly changing world.

However, this is not a time to rest on our laurels. Challenges to US leadership are extraordinary, unlike any time in our recent history. Stronger efforts are required, not only via an "all-in-government" approach across DOE and other agencies, but in deep partnerships with academia and industry with enhanced attention and funding to support more comprehensive public-private partnerships. Recommendations for such activities abound; the recent Council on Competitiveness report on "Competing in the New Economy" recommends specifically expanding formal DOE Lab missions to encompass economic competitiveness. Labs are already working in these directions. Oak Ridge National Lab's quantum technology hub and Chicago's Quantum Exchange, with Argonne National Lab, FermiLab, and a consortium of leading universities and companies, are two examples of what is already happening. But

these examples are just a start of enhanced economic competitiveness efforts that need to be further cultivated and supported.

Opportunities for rural America and science itself. Many of the best-known examples of science and innovation efforts come from urban areas. What opportunities then do states like Wyoming, and other rural parts of the nation, bring to the Office of Science, and more broadly, to the entire federal science, technology, and innovation ecosystem? After my first year in Wyoming, I have learned much that I would like to share with the committee. First and foremost, great talent resides everywhere, in every corner of Wyoming, and in every state in the nation (and in other nations, where it is being very well supported!). Robert Rathburn Wilson, a physicist, a sculptor and architect, a key member of the Manhattan project, the founding Director of FermiLab and prominent leader of the 20th century scientific enterprise, grew up on cattle ranches near Frontier, Wyoming (and he brought the frontier spirit to FermiLab, introducing a herd of American Bison in the restored prairie within the accelerator ring, inspiring me as a grad student there in 1981). This same talent and spirit is found in Wyoming today. A few months ago I had the opportunity to visit a high school in the town of Ten Sleep, a school small enough that senior officials from the University of Wyoming almost outnumbered the graduating seniors. I was introduced as an astrophysicist, and was greeted by an enthusiastic female student who excitedly raised her hand exclaiming "I want to be an astrophysicist—one who studies black holes just like you!" In Wyoming, such talent is combined with our proud cowboy culture filled with grit, determination and resilience in the face of hardships. Such combinations of talent and culture are just what the nation needs to compete! We are also a proud home for Native American tribes and a rapidly growing Hispanic population, further providing a diversity of cultures that drives innovation.

Our natural and environmental assets are virtually unmatched. We have some of the largest deposits of precious minerals and rare earths, and high abundances of uranium, lithium, and helium. Animal migration paths of ungulates such as mule deer are extraordinary examples of learned animal behavior to survive in a harsh world. Grand Teton and Yellowstone National Parks are unique-in-the-world ecosystems, tremendous laboratories for understanding our natural environment. Our national forests absorb significant carbon dioxide, but wildfires, relentlessly increasing with drought as our world warms, cause releases of carbon dioxide and pollute the air, leading to health hazards that can spread literally thousands of miles. Water from Wyoming is essential for the west; snowmelt from the Tetons support agriculture in Idaho and beyond. Even more, a significant fraction of the western water supply comes from Wyoming. Spring snowmelt in Wyoming flows into the Colorado River, equaling roughly half the annual allocation from the river to the 18 million people in the Metropolitan Water District of Southern California (including LA). In June alone, Wyoming provides nearly three times as much water as Phoenix receives annually. Future climate scenarios would reduce our snowpack, and therefore June flows, by 66-83% by the end of the century, depending upon the degree of carbon mitigation. The change in June alone is enough to require each of the 18 million people in LA area to go for 3-4 days without any water or to require the entire City of Phoenix (and others) to be permanently disconnected from the Colorado River system.

Clearly there is much overlap with DOE's Office of Science mission, and clearly deeper partnerships between our university---and others in rural and EPSCoR regions---and national labs would be mutually beneficial. EPSCoR regions have vital research programs and unique assets and strengths to bring to the table. Indeed, our faculty are now having regular scientific discussions with Argonne National Lab, Pacific Northwest National Lab, and other labs on these topics to prepare for our future collaborations. Lengthy

lists of research topics that excite the lab staff and faculty are being developed. *To help support such activities, I recommend specifically that more representation from EPSCoR state university faculty be added to DOE Office of Science Advisory Committees.*

But just as environmental issues do not respect political or state boundaries, the science problems they drive are not contained in any single agency. Such problems require cooperation between federal agencies with different approaches and assets that all contribute uniquely to solutions needed by all. For example, Cheyenne, Wyoming is home to the supercomputing facilities of NSF's National Center for Atmospheric Science (NCAR). The "NCAR Wyoming Supercomputing Center" (NWSC) is a state-of-the-art facility that serves primarily atmospheric science research. But NWSC has ample unused capacity, and could be a home for a multi-agency approach to environmental science that could serve DOE, NSF, USGS, and other related agencies. Massive, shared datasets could be co-located with advanced computing facilities that leverage DOE's exascale program for a unique and coordinated attack from multiple agencies on such environmental problems critical to the nation's future.

Just as importantly, such an enhanced computing environment could be a regional facility to serve as a hub for economic development, corporate partnerships, and education and workforce development, across Wyoming, and across the rural mountain west. It could be an important anchor for the entire region's new innovation economy that USICA and its companion bills in the House aim to support. *I strongly urge the committee to examine such possibilities as part of the national innovation infrastructure foreseen by USICA and advocated for by organizations such as the Council on Competitiveness.*

While I have focused on Wyoming in this discussion, it is representative of rural parts of the nation and world. The problems we face are like those in many rural parts of the nation; solutions found here may be replicated elsewhere. Of all the problems faced, the development of the workforce and the pivot of the economy are central to rural America's, and to the nation's future. The EPSCoR program of DOE and NSF is a major tool to build the education and research capacity of states like Wyoming. But I would urge creation of new mechanisms for even deeper partnerships with the DOE Office of Science, particularly its national labs, around research, education, and innovation programs to grow our tech-savvy workforce and our economies. While we provide unique assets of importance to DOE and the nation, so that better solutions to our national problems may be found, we also have special needs. The digital divide is growing as our economies fall further behind other parts of the country; nearly 70% of University of Wyoming graduates leave the state. Similar problems are faced across our region. Our rural areas must not only modernize their educational opportunities but also grow their economies. Stronger partnerships with the DOE and its labs, for example along the directions outlined in USICA, with the creation of distributed technology-based innovation hubs, will have tremendous impact in rural regions like ours, helping to grow our economies and retain and attract more talent. Just as importantly, such investments will pay extraordinary scientific, educational, and economic dividends back to the DOE Office of Science, and to the entire nation.

Summary. In summary, the Office of Science is an extraordinary national asset with extraordinary impact on the nation. But this impact can, and needs to be, enhanced. Its efforts in advanced computing and its applications must be continued and strengthened as a key element of the ongoing modernization of our national scientific and innovation infrastructure. Large scale public private partnerships can be further developed and strengthened, particularly in the fields that will determine global economic leadership and national security. This national effort, needed to compete in the global economy, must encompass the

assets from universities, national labs, and industry. Such efforts require contributions not only from the Office of Science, but from the entire federal, academic and private sector components, each with different approaches and strengths. *This must include rural regions of America, with their unique assets, culture, and talent base, in order for our national efforts to succeed in this global competition.*

I want to thank you for your time, and for inviting me to testify.