Testimony of

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Chairman Lummis, Ranking Member Swalwell and distinguished Members of the Subcommittee, thank you for inviting me to participate in this important hearing. The nation's capacity to innovate, grow its economy and advance societal solutions depends on our ability to conduct basic research today. You and your colleagues' review and consideration of the Report of the Particle Physics Project Prioritization Panel will help to ensure that today's scarce resources are targeted strategically to ensure the best return on the federal investment and maintain a vital and world class physics research program in the United States. Thank you for undertaking this important hearing.

My name is Natalie Roe and I am the Director of the Physics Division at Lawrence Berkeley National Laboratory. Berkeley Lab is part of the U.S. Department of Energy's Office of Science national laboratory system. It is managed by the University of California (UC) and is charged with conducting unclassified research across a wide range of scientific disciplines. Home to 13 Nobel Prizes, the Lab was founded in 1931 by Ernest Orlando Lawrence, a UC Berkeley physicist who won the 1939 Nobel Prize in physics for his invention of the cyclotron, a circular particle accelerator that opened the door to high-energy physics and to the many other scientific, industrial and medical applications of accelerators today. It was Lawrence's belief that scientific research is best done through teams of individuals with different fields of expertise, working together. His teamwork concept is a Berkeley Lab legacy that continues today.

It is an honor to be here today and to play a small role in your consideration of the P5 report. My testimony will focus on the P5 recommendation that small and medium sized projects continue to play an important and robust scientific role in the nation's high energy physics portfolio of experiments. Doing so will help keep us in the forefront of scientific advancement, provide important training and education opportunities, and ensure a steady flow of world-leading scientific results on a broad front.

I completed my graduate studies in particle physics twenty-five years ago at SLAC. Since then the field has changed dramatically – it has become a much more international endeavor and the scale of its flagship experiments has grown tremendously. My thesis experiment had roughly a dozen scientists and cost less than $1M to build. It was built, commissioned, took data and published its main results all during my time as a grad student.

Today, the Large Hadron Collider is a multi-billion dollar machine, financed primarily by Europe. The design of the four experiments at the LHC began over 20 years ago, and each of them has several thousand physicists. Two years ago the ATLAS and CMS experiments announced the discovery of the Higgs boson, a long-sought cornerstone in particle physics. With suitable upgrades, the LHC will likely continue for another 20 years. This increase in scale – in size, in dollars, in time, and in human capital - is necessary to extend our reach to higher and higher energies, or in the case of the Long Baseline Neutrino Facility, to higher intensities in pursuit of new particles, new types of interactions and a better understanding of our Universe.

Although the field has changed dramatically, as P5 recognized, small and intermediate scale projects, such as those in which I participated at Stanford, still play an important role in particle physics and have tremendous potential to make ground-breaking discoveries. P5 stressed the value of a balanced program that includes experiments at a variety of scales. Below, I will provide a few key examples of small and medium sized projects with big potential.

As evidenced by my personal experience, these smaller projects provide excellent training for students and postdocs, who can take on major roles and responsibilities and see their work through to fruition much sooner. Smaller experiments can also go after "blue-sky" ideas, they can be nimble and take risks with the potential to shake up the field. A healthy portfolio of experiments should include a good mixture of these smaller projects, and P5 has been wise enough to call this out as a priority.

Many of these small to medium size experiments are in the so-called Cosmic Frontier, the study of dark energy, dark matter and the early Universe. The US is already a leader in this area, and a strong particle physics program would ensure that we stay there.

A prime example of what can come out of a small experiment is a project started in the early 1990s to measure the rate at which the expansion of the universe is decelerating due to the attractive force of gravity. The Supernova Cosmology Project, as it was called, involved a small team of scientists and graduate students, led by a young physicist named Saul Perlmutter. Saul's plan was to use supernovae, or exploding stars, because their light is so bright it reaches earth over billions of years of cosmic time. He developed a method to detect these rare events in a predictable way and a technique to calibrate them as standard candles.

In what is now a famous result, Saul and his team had measured enough supernovae by 1998 to conclude that the universe was not decelerating at all, but was in fact accelerating – the expansion was going faster and faster. In other words, some force counter-acting gravity was at work in the Universe. This result was completely unexpected and a dramatic event for the physics community. It would probably not have been believed - except that a competing team arrived at a similar result. This work, this "small" project, ultimately led to a Nobel Prize for Saul and for the leaders of the other team.

Saul's discovery has attracted the attention of scientists all over the world and inspired a new generation of students to study physics. It has unleashed a wave of scientific creativity that has generated thousands of new theories, technical concepts, experimental ideas and computational methods. Out of this small experiment a whole new field of research has been created and our concept of the

Universe has been fundamentally changed forever. Obviously, the return on the federal government's investment was huge.

Although we call this accelerating expansion "dark energy", this is really just scientific jargon to say we have no idea what it is. Is it a failure of general relativity on very large distance scales? Could it be Einstein's cosmological constant? Or could it be something very strange, a new energy field in the Universe? Is it related in some way to the Big Bang or the initial period of rapid expansion known as inflation? We still do not know, and dark energy remains one of the biggest unanswered questions in fundamental physics today. Much more precise data is needed to figure out which theory is correct.

The Dark Energy Spectroscopic Instrument, or DESI, is one of the small-scale projects recommended by P5 that would tackle this problem. DESI re-uses an existing telescope at Kitt Peak, Arizona that was scheduled by the NSF to be retired from service. By installing a new instrument on this telescope and dedicating it to a wide area survey of the Universe, DESI will bring a new level of precision to the study of dark energy by mapping the locations of millions of galaxies and quasars, constructing a map going back over billions of years of cosmic time. This exciting project has attracted dozens of institutions and is now an international collaboration of almost 200 scientists. It could be built for about $40M over four years. Although DESI does not fit in the most stringent budget scenario P5 was charged to evaluate, it could become a reality with a modest increase in funding. This would enable the US to remain a leader in dark energy research into the next decade, when the Large Synoptic Survey Telescope (LSST), will begin taking data from a mountaintop in Chile. DESI and LSST employ complementary techniques that together will reveal whether new laws of space and time are responsible for cosmic acceleration.

Another example of a medium sized experiment that P5 recommended is the next generation of experiments that are studying the faint glow from the early Universe, the so-called cosmic microwave background (CMB) radiation. A next generation Stage 4 CMB experiment would give us a more detailed snapshot of the infant Universe, shedding light on the conditions that existed more than 13 billion years ago.

P5 also recommended that the US should remain a leader in the search for dark matter. We call it dark matter because it doesn't shine, like stars and galaxies, but we know it is there through its gravitational effects. Dark matter outweighs normal matter by about 6 to 1 and without it the stars in our galaxy would fly off into space. Dark matter is omnipresent but very weakly interacting, so to have a chance of detecting it we have to build very quiet, low background detectors deep underground that are sensitive to very low signals produced when dark matter occasionally collides with normal matter. P5's recommendation supports another class of small to medium scale experiments to address dark matter that will advance the frontiers of our knowledge of the dark universe.

A deep underground site to carry out this type of dark matter search already exists in the US in South Dakota. It is called the Sanford Underground Research Facility (SURF). SURF has been built with funds from the state of South Dakota, generous private donations, and federal funding, creating a modern state of the art underground laboratory on the site of the former Homestake gold mine. In addition to hosting LUX, currently the world's most sensitive dark matter experiment, SURF could provide a home for one of the next generation dark matter experiments (G2 DM) that P5 recommended.

SURF is also where the neutrino detectors for the Long Baseline Neutrino Facility will be located. As Nigel Lockyer has already described, these detectors will detect a neutrino beam generated at Fermilab after it has traveled almost 800 miles through the earth's crust, from Illinois to South Dakota. During this long journey, the neutrinos produced at Fermilab have time to morph into different states before they are detected at SURF. By comparing the behavior of neutrino and anti-neutrino beams, LBNF may reveal clues that could explain how our matter-dominated Universe came into being.

Particle physics has come very far in the past century, discovering the quarks and leptons, the gluons, the W and Z bosons, and finally, the long-sought Higgs boson - only to realize that we do not understand what makes up 95% of the Universe, the mysteries we call dark energy and dark matter. P5 has recommended a carefully selected set of interlocking experiments, including a number of small to medium sized projects. This program is optimized to address the five science Drivers efficiently within tight budget constraints, to achieve the most cost effective approach in our quest to further understand the nature of matter, energy, space and time.

Thank you very much for your attention. I am very happy to answer any questions that you may have.