On the cover:

A stylized illustration of a quantum bridge showing an array of holes etched in diamond with two silicon atoms placed between the holes. (Courtesy, Sandia National Laboratories.)

Sandia researchers have demonstrated for the first time on a single chip all the components needed to create a quantum bridge to link quantum computers together. This work demonstrates an integrated platform for scalable quantum nanophotonics based on efficient interfaces between photons and emitters as the basis for quantum networks. Distributing quantum information on a bridge, or network, could also enable novel forms of quantum sensing, since quantum correlations allow all the atoms in the network to behave as though they were one single atom.

In the work, the researchers used ion-implantation to replace one carbon atom of the diamond with the larger silicon atom, which causes the two carbon atoms on either side of the silicon atom to feel crowded enough to flee. That leaves the silicon atom a kind of large landowner, buffered against stray electrical currents by the neighboring non-conducting vacancies. Though the silicon atoms are embedded in a solid, they behave as though floating in a gas, and therefore their electrons' response to quantum stimuli are not clouded by unwanted interactions with other matter.

Once the silicon atoms are settled in the diamond substrate, laser-generated photons bump silicon electrons into their next higher atomic energy state; when the electrons return to the lower energy state, because all things seek the lowest possible energy level, they emit quantized photons that carry information through their frequency, intensity, and the polarization.

The work was supported by Sandia’s Laboratory Directed Research and Development program. Some work was performed at the Center for Integrated Nanotechnologies (CINT), a Department of Energy Office of Science User Facility operated by Los Alamos and Sandia national laboratories.

Prologue

On behalf of the Office of Science, we welcome you to this year’s National Science Bowl® Science Day. The National Science Bowl® is one of the most prestigious annual academic competitions, and we congratulate the 116 teams of middle and high school students who have earned a spot in this year’s national finals by finishing in the top four percent of the teams that competed regionally. You are now one of the more than 275,000 students that have participated in the National Science Bowl throughout its 27-year history, making it one of the nation’s largest science competitions. The Department of Energy (DOE) created the National Science Bowl in 1991 to nurture students’ interest in pursuing careers in science and technology fields, and help our nation remain prosperous and competitive in the world. The DOE’s research activities rely significantly on 17 DOE laboratories, which employ more than 30,000 workers with science, technical, engineering, and mathematics (STEM) backgrounds. Home to some of the world’s most powerful lasers, fastest supercomputers, and talented researchers, the Department of Energy’s National Laboratories are a powerhouse of science and technology. This system of 17 labs pushes the frontiers of scientific knowledge, keeps our nation secure, and fuels our clean energy economy, providing scientists access to large-scale research infrastructure unavailable in universities or industry to serve our nation in unique ways. Today you will have an opportunity to hear directly from researchers working at our labs, as well as from our plenary speaker, Dr. Charles Bennett, an IBM Fellow at the IBM Thomas J. Watson Research Center, and a world-renowned quantum information theory pioneer.

The prior two Science Days also focused on aspects of computational and information sciences covering some of the latest developments from the fast-paced fields of high-performance computing, including simulation, modeling, visualization, data mining, and the technological roadmap to exascale computing, as well as diverse topics in “big data”, involving cognitive solutions, ultrafast networks, and scientific user facilities. This year’s Science Day program celebrates the NSB’s 27th annual competition with Quantum Information Science (QIS) as its theme addressing aspects of computational systems and solutions based on quantum information, which is a new frontier capable of harnessing quantum phenomena as a means to process information in novel and promising ways.

Classical computers encode information using bits with each bit having a value of either 1 or 0 representing an on or off state as the basis for its functions. On the other hand, quantum computers are based on qubits (short for quantum bits) operating according to two key principles of quantum mechanics - superposition and entanglement. Superposition means that each qubit can represent either 0 or 1, but also a mixed state with a value of 1 and 0 at the same time. Entanglement means that qubits can be correlated with each other causing the state of one to depend on the state of another, even if separated by large distances. It is these two quantum properties that enable qubits to be much more sophisticated logic switches. For example, two bits in a classical computer can be in four possible states (00, 01, 10, or 11), but in only one of these states at any given time, limiting it to processing one input at a time. In a quantum computer, two qubits also represent the exact same four states (00, 01, 10, or 11), but due to superposition, qubits represent all four states at the same time, which is equivalent to four classical computers running side-by-side. With each additional qubit added to the system, the processing power doubles, causing a quantum computer’s processing power to grow exponentially, so 64 qubits yields $2^{64}$ or 18,446,744,073,709,600,000 simultaneous possibilities. In contrast, while 64 classical bits also represents $2^{64}$ states, a classical computer can only represent one state at a time, so it must cycle through all combinations of states, which would take some 400 years at a typical microprocessor speed of 2GHz. Hence N qubits can process $2^N$ states simultaneously making a quantum computer exponentially faster than a classical device and able to solve certain problems otherwise impossible using today’s (and likely tomorrow’s) most powerful computers. Examples where quantum computers could represent a transformative alternative is in areas such as factoring large numbers for code breaking, recognizing patterns in data useful for machine learning, simulation of quantum mechanical systems in biology and chemistry, or applications not yet realized.
However, practical realization of a quantum computer remains in the hands of researchers, with its technology roadmap not yet precisely determined, since the complexities of generating, preserving, manipulating, and scaling qubits are significant, as is the development of new quantum physics based algorithms required to exploit their special properties. Despite these challenges, quantum information based systems will be part of your future. For example, in 2015, the European Telecommunications Standards Institute (ESTI) confirmed the need to switch to Quantum-Safe Cryptography standards for sensitive data archived for more than ten years, since the threat posed by future quantum computers being able to calculate the prime factors of large integers to break sensitive data on the internet is now thought to be on that time horizon.

We also know that currently used microprocessor technology is rapidly approaching its spatial and power scaling limits, harkening an end to Moore’s law, which states that the number of transistors on a microprocessor chip would double every two years or so. New types of structures, architectures, and materials will be required to extend the technological advancement of classical computers into the foreseeable future (beyond Moore’s law). Moreover, for many applications, a quantum computer would be little better than a classical one, so this research is increasingly important for continued future development of superfast computers (exascale and beyond).

Some 25-30 years ago, Dr. Bennett and his colleagues discovered the concept of quantum cryptography based on the uncertainty principle instead of usual computational assumptions such as the difficulty of factoring. They then developed a practical system to apply it allowing secure communication between parties who share no secret information initially. Quantum teleportation plays a significant role in current methods for quantum error correction and universal quantum computation, and Dr. Bennett’s work and breakthroughs have shaped our understanding of the relationship between physics and information processing, and has contributed many of the basic building blocks that guide experimental work to build a universal quantum computer - one capable of carrying out any quantum algorithm much more quickly than the best classical computer. In honor of his many contributions, the American Physical Society named an award in quantum computing after Drs. Charles Bennett and Rolf Landauer (former IBM researcher, and information theory pioneer). Today’s speakers presenting their research at DOE laboratories will amplify some of these ideas, covering topics in QIS that span quantum computer concepts and applications to discovery and innovation in quantum devices and materials.
About the Sessions

All participants will enjoy the Plenary Session in the Aiton Auditorium. For Seminar Sessions I and II, students can choose to attend the session that interests them the most. Make sure to get to the sessions on time as the seats fill up fast! All of the speakers are presenting during both sessions, so once all of the seats are filled in a room, participants will be asked to attend a different presentation for that seminar block.

Sessions by Times and Locations

PLENARY SESSION: 8:20 – 9:45 a.m.

<table>
<thead>
<tr>
<th>Room</th>
<th>Title / Speaker</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aiton Auditorium</td>
<td>Quantum Computing - To Boldly Go Where Einstein Feared to Tread - Dr. Charles Bennett</td>
<td>4</td>
</tr>
</tbody>
</table>

SEMINAR SESSION I: 10:00 – 11:15 a.m.

<table>
<thead>
<tr>
<th>Room</th>
<th>Title / Speaker</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missouri Room</td>
<td>Controlling and Observing a Material at the Atomic Scale Using Ultrashort Laser Pulses - Dr. Pam Bowlan</td>
<td>6</td>
</tr>
<tr>
<td>Clover Room</td>
<td>Diamonds Aren't forever: How Atomic Imperfections Could Be the Key to Quantum Engineering - Dr. Ryan Camacho</td>
<td>7</td>
</tr>
<tr>
<td>Ohio Room</td>
<td>What Do You Do with a Quantum Computer? - Dr. Travis Humble</td>
<td>8</td>
</tr>
<tr>
<td>America Room</td>
<td>The Second Quantum Revolution - Dr. Irfan Siddiqi</td>
<td>9</td>
</tr>
<tr>
<td>Iowa Room</td>
<td>High Magnetic Fields - Dr. Vivien Zapf</td>
<td>10</td>
</tr>
</tbody>
</table>

SEMINAR SESSION II: 1:00 – 2:15 p.m.

<table>
<thead>
<tr>
<th>Room</th>
<th>Title / Speaker</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missouri Room</td>
<td>Controlling and Observing a Material at the Atomic Scale Using Ultrashort Laser Pulses - Dr. Pam Bowlan</td>
<td>6</td>
</tr>
<tr>
<td>Clover Room</td>
<td>Diamonds Aren't forever: How Atomic Imperfections Could Be the Key to Quantum Engineering - Dr. Ryan Camacho</td>
<td>7</td>
</tr>
<tr>
<td>Ohio Room</td>
<td>What Do You Do with a Quantum Computer? - Dr. Travis Humble</td>
<td>8</td>
</tr>
<tr>
<td>America Room</td>
<td>The Second Quantum Revolution - Dr. Irfan Siddiqi</td>
<td>9</td>
</tr>
<tr>
<td>Iowa Room</td>
<td>High Magnetic Fields - Dr. Vivien Zapf</td>
<td>10</td>
</tr>
</tbody>
</table>
Quantum Computing - To Boldly Go Where Einstein Feared to Tread

To build a quantum computer — and to understand what it’s good for — scientists will have to stretch their minds farther than Einstein could stretch his. During the 1920s and ’30s, two of the century’s greatest physicists, Albert Einstein and Niels Bohr, locked brains in a series of debates. Bohr argued that physicists must learn to accept the weird behavior of subatomic particles — their essential unpredictability even under completely controlled conditions, and a still stranger effect called entanglement, in which two particles, no matter how far apart, behave in ways that while individually random, are too strongly correlated for the particles to be acting independently. Quantum randomness and entanglement are real, confirmed by innumerable experiments, and explained in meticulous detail by the theory Einstein rejected, so it’s pretty clear that the greatest scientific mind of the 20th century, flexible enough to bend space and time, wasn’t flexible enough. Moreover, quantum theory has played an essential role in technologies such as the laser and the transistor, which could not have been developed on the pre-quantum physics of Newton, Maxwell, and Einstein.

Toward the end of the 20th century, scientists gradually realized that quantum weirdness was not just a philosophical conundrum or a communications problem between scientists and laypeople, but implied the existence of powerful and previously unsuspected kinds of information processing, feats that could not be predicted or understood using pre-quantum notions.

Now, in the 21st century, this realization is propelling a race to design and build a “quantum computer,” that is to say a device within which quantum effects are directly harnessed for information processing, and by functioning the way nature does, quantum computers offer the hope of simulating (and therefore improving upon) natural processes in ways no classical computer could. To properly explore this new field, scientists and technologists will need to understand quantum laws in a deeper and more intuitive way than most of them have until now.

When told of any scientific innovation, practical-minded people always want to know what it’s good for — or, in modern parlance, whether it has a “killer app.” The honest answer is that we don’t know, but it must be explored to find out. Quantum information science has brought the biggest change in our understanding of the nature of information and computation since these concepts were crystallized (alas, classically) in the mid-20th century, but only time will tell what it will eventually be used for.
About the Speaker:
Dr. Charles Bennett is a physicist, an information theorist, and one of the founders of quantum information theory. He graduated from Brandeis University, majoring in chemistry, in 1964. He received his PhD from Harvard in 1971 for molecular dynamics studies (computer simulation of molecular motion). For the next two years, he continued this research at Argonne National Laboratory. He began working at IBM Research in 1972, and has worked on various aspects of the relation between physics and information. In 1973, he showed that general-purpose computation can be performed by a logically and thermodynamically reversible apparatus, which can operate with arbitrarily little energy dissipation per step because it avoids throwing away information about past logical states; and in 1982, he proposed a reinterpretation of Maxwell's demon, attributing its inability to break the second law to the thermodynamic cost of destroying, rather than acquiring, information.

In collaboration with the Professor Gilles Brassard of the University of Montreal, he developed a practical system of quantum cryptography, allowing secure communication between parties who share no secret information initially, based on the uncertainty principle instead of usual computational assumptions such as the difficulty of factoring. Other research interests include algorithmic information theory, in which the concepts of information and randomness are developed in terms of the input/output relation of universal computers, and the analogous use of universal computers to define the intrinsic complexity or “logical depth” of a physical state as the time required by a universal computer to simulate the evolution of the state from a random initial state.

In 1993, Bennett and collaborators from the US, Canada, Britain, and Israel discovered “quantum teleportation,” an effect in which the complete information in an unknown quantum state is decomposed into purely classical information and purely non-classical Einstein-Podolsky-Rosen (EPR) correlations, sent through two separate channels, and later reassembled in a new location to produce an exact replica of the original quantum state that was destroyed in the sending process. Working with collaborators from 1995 to 1997, he helped found the quantitative theory of entanglement and introduced several techniques for faithful transmission of classical and quantum information through noisy channels, part of the larger and recently very active field of quantum information and computation theory. Recently he has worked on the capacities for quantum channels and interactions to simulate one another and the tradeoffs among communications resources, and quantum questions in cosmology. He is an IBM Fellow, a Fellow of the American Physical Society, and a member of the National Academy of Sciences. His main hobbies are photography and music.
Controlling and Observing a Material at the Atomic Scale Using Ultrashort Laser Pulses

Most electronic devices, like hard drives in computers, electronic shutters or camera flashes, operate by switching magnetic or electric fields as quickly as possible. Because of fundamental limitations of electronics (i.e. how fast a current can be switched off and on), this cannot be much faster than $10^{-9}$ seconds, or a nanosecond. While that might sound fast, compared to the time scales of motion in atoms, where an electron orbits its nucleus in $150 \times 10^{-18}$ seconds, or 150 attoseconds, this is 7 orders of magnitude, or 10 million times too slow to keep up with the electron. Fortunately there exists a faster tool for controlling and studying matter that can keep up. These are special lasers, known as ultrashort lasers, which emit a train, or sequence of extremely short bursts of light lasting from 100's of femtoseconds ($10^{-15}$ seconds) down to even attoseconds. These pulses of light serve as a “camera flash” for freezing motion to make movies of electrons, spins (atomic scale magnetic order) or a crystal lattice, to learn how different types of materials function on the spatial and temporal scales of atoms. Secondly, ultrashort laser pulses can also be used to control, or switch material properties, and 7 orders of magnitude faster than electrons, which could lead to ultrafast devices in the real world, such hard drives or cameras.

In this talk, Dr. Bowlan will explain how such extremely short laser pulses are generated and how they can be measured these using slow electronic detectors like standard cameras. Then examples will be shown of how ultrashort laser pulses are used to understand the quantum mechanical origin of material properties like magnetism, reflectivity or resistance. Finally, ultrashort laser pulses can also be used as a way to “press buttons” in femtoseconds, turning on and off very specific functions of materials, such as magnetism, ferroelectricity, or superconductivity, something known as coherent control of which several recent examples will also be shown.

About the Speaker:
Pamela Bowlan has been a staff scientist at Los Alamos National Lab in the Chemistry Division since October 2016, working mostly on ultrafast and x-ray spectroscopy of energetic materials. Prior to this, she was a Director’s postdoctoral fellow at Los Alamos, and before that a postdoctoral fellow at the Max Born Institute in Berlin, Germany. Her postdoctoral research focused on using ultrafast lasers to control and understand properties of materials, such as semiconductors, Dirac and magnetic materials. Before staring her postdoctoral fellowships, she spent one year working at a small startup company, Swamp Optics, to develop simple devices for measuring ultrashort laser pulses. Pamela earned her Ph.D. in physics from Georgia Tech in 2009 for developing new methods of measuring ultrashort laser pulses both in space and time, with nanometer and femtosecond resolutions. She also has a B.S. in Physics and Chemistry from Georgia Tech.
Just like people, diamond has quirks that sometimes are its most interesting features. While most diamond buyers look for perfect gems, quantum scientists have discovered that non-conformist atomic-sized defects are where the really exciting stuff happens. A single nitrogen atom embedded diamond’s carbon lattice, for example, can absorb a single photon, store it in a neighboring carbon atom for more than a second (a near-eternity!), and then read it back out, all while preserving its fragile quantum state. In this talk, we’ll take a look at some recent work suggesting that these atomic defects can be linked together to form quantum networks. Such quantum networks may have profound implications on both the nano- and Mega-scale. At the nano-scale, custom designer materials might be synthesized to allow for complete quantum control of every atom in the “quantum meta-material” network. This might allow future ultra-low power information storage and processing, as well as the construction of micrometer-scale NMR machines. Can you imagine swallowing an NMR pill that would take images from the inside? On the macro-scale, networking the quantum state of atoms might allow for enhanced remote quantum sensing and communications. By harnessing what Einstein called “spooky action at a distance,” quantum engineers are starting to design devices that use quantum entanglement to make exquisite measurements. All based on quirky, imperfect diamonds!

About the Speaker:
Ryan Camacho is a quantum scientist at the Center for Integrated Nanotechnology at Sandia National Labs, where he has worked since 2010. Most recently, he was the lead scientist on the SECANT program: the Department of Energy’s largest investment ever in quantum communications science and technology. In the SECANT project, his team successfully integrated an entire table-top of quantum photonic elements on a single micro-chip. In addition to his work on quantum communication, he leads teams investigating diamond as a next generation quantum material and radiation pressure forces as a possible light-to-sound quantum transduction mechanism. He is the author of numerous journal publications and patents, with some of his most recent work appearing Nature, Science, and several popular media outlets. Before joining the staff at Sandia, Ryan was a postdoctoral fellow at Caltech from 2008-2010. He earned a Ph.D. in physics from the University of Rochester in 2008, and a B.S. degree in physics from Brigham Young University in 2003.
What Do You Do with a Quantum Computer?

Quantum computing uses the principles of quantum physics to generate, store, and process information. State-of-the-art examples use the spin states of individually controlled atoms, the quantized currents in cryogenically cooled superconductors, and the microscopic defects in nanodiamonds to manipulate bits of quantum information. There is a world-wide effort to realize these ideas and, after several decades of research, quantum computing devices are now coming online. But what do we do with quantum computers once they become available? And how do we use them?

In this talk, we will review the basics of how quantum computers work, how they can be used for scientific computing and the types of problems they can solve. The Department of Energy is currently evaluating how quantum computing can influence future computing systems dedicated to scientific discovery. This includes understanding the origin of superconducting in materials, discovering the design of energy efficient biocatalysts, unravelling the dynamics behind protein folding, and many other scientific applications that have direct impact on DOE’s scientific mission. Of course, there are applications outside of energy too, like searching for anomalous signals from space, testing control systems in fighter jets, and even mining Bitcoin! We will conclude by talking about the needs for future scientific software to run this exotic new hardware, the types of architectures available for large-scale quantum computing systems, and the research challenges that lay ahead.

About the Speaker:
Travis Humble is the director of the Quantum Computing Institute at Oak Ridge National Laboratory. He oversees research and development of quantum computing technologies and their use in solving problems for scientific discovery and energy security. Working at the intersection of computing, physics, and information, he focuses on the design and development of new computing platforms. This includes developing mathematical algorithms based on quantum information, translating algorithms into software that can run on quantum computing hardware, and discovering how quantum computing can support scientific applications. He was recently awarded the prestigious Department of Energy Early Career Award to research how quantum computing can be used to support high-performance computing applications. Travis received his doctorate in theoretical chemistry from the University of Oregon in 2005. He then joined Oak Ridge National Laboratory as an intelligence community postdoctoral research fellow before becoming a member of the research staff. Travis also holds a joint faculty appointment with the University of Tennessee Bredesen Center for Interdisciplinary Research and Graduate Education.
The Second Quantum Revolution

Quantum mechanics continues to stretch the limits of human thought by asserting that objects can exist simultaneously in multiple states until they are projected into a familiar classical outcome by a measurement—hence a cat in a sealed box can be dead and alive until the lid is opened. Moreover, two objects can be entangled such that a probe of one automatically yields information about the other, even if they are at opposite ends of the universe. Already observed in the spin properties of atoms and the polarization of photons of light, generating entanglement in bulk at the macroscopic scale is the engine behind the second quantum revolution, promising ultra-secure communications systems and unparalleled computing power. At a yet larger cosmic scale, this same entanglement which once troubled the architect of the theory of general relativity, Einstein, is now postulated to be the thread that stitches the fabric of the universe, producing Hawking radiation from evaporating black holes and wormhole singularities. In this talk, I will illustrate the essential features of quantum measurement and entanglement and how their combination is at the heart of exemplar cutting-edge quantum technologies, along with their potential practical and philosophical impact.

About the Speaker:
Irfan Siddiqi is Professor in the Department of Physics at the University of California at Berkley, where he currently serves as Vice Chair. He is also a Faculty Scientist at the Lawrence Berkeley National Laboratory. Siddiqi and his research group, the Quantum Nanoelectronics Laboratory, focus on the development of advanced superconducting circuits for quantum information processing, including computation and metrology. Siddiqi is also the founding director of the interdisciplinary Center for Quantum Coherent Science at Berkeley.

Irfan received his A.B. in chemistry & physics from Harvard University. He then went on to receive a Ph.D. in applied physics from Yale University, where he also completed his postdoctoral research. Irfan joined the Berkeley physics faculty in 2005.

Irfan is known for groundbreaking contributions to quantum measurement science, including real time observations of wavefunction collapse, tests of the Heisenberg uncertainty principle, quantum feedback, and the development of a range of microwave frequency, quantum noise limited analog amplifiers. Irfan is a fellow of the American Physical Society, and in 2006 was awarded the George E. Valley Jr. prize for the development of the Josephson bifurcation amplifier. Siddiqi is a recipient of Young Investigator Awards given by the Navy, Airforce, and DARPA, the Hellman Family Faculty Fund, and the UC Berkeley Chancellor’s Partnership Faculty Fund. Siddiqi is among five faculty members who received the “2016 Distinguished Teaching Award,” UC Berkeley’s most prestigious honor for teaching.
MRI machines use magnetic fields to peer inside the body. It turns out that high magnetic fields can serve as powerful microscopes for a wide range of materials - not just biological systems but also metals, magnets, superconductors, semiconductors, and complex fluids. All the components of atoms - neutrons, protons and electrons - are bar magnets and can be influenced and sensed by magnetic fields. Furthermore the trajectory of charged particles that conduct electricity are controlled by magnetic fields. High magnetic fields can induce and destroy states of matter like superconductivity, and can map out the energy scales and quantum states of materials. I will discuss how world-record high magnetic fields at the USA's National High Magnetic Field Laboratory are critical to advance scientific understanding in a range of fields.

About the Speaker:
Dr. Vivien Zapf is a physicist at the National High Magnetic Field Laboratory at Los Alamos National Lab, https://www.lanl.gov/orgs/mpa/nhmfl/index.shtml. She uses record high magnetic fields to study magnetism and its interaction with ferroelectricity. Her research focuses on understanding the fundamentals of novel magnetic orders, and their interaction with the crystalline lattice and its electric properties. Her work has applications to sensing, energy storage and harvesting, new data devices and high-frequency circuitry.

She has >100 peer-reviewed publications, >2000 citations, and regularly speaks at international conferences and gives colloquia and seminars around the world. She serves as P.I. and co-P.I. on internal and external funded research proposals, and serves as the chair for physics of the National High Magnetic Field Laboratory science council.

Vivien received her Bachelor’s degree from Harvey Mudd College and her Ph.D. from the University of Califórnia at San Diego, both in physics. Vivien was a Millikan Postdoctoral Fellow at Caltech before joining LANL.
About the Office of Science

The Office of Science’s (SC) mission is to deliver scientific discoveries and major scientific tools to transform our understanding of nature and advance the energy, economic, and national security of the United States. SC is the Nation’s largest Federal sponsor of basic research in the physical sciences and the lead Federal agency supporting fundamental scientific research for our Nation’s energy future.

SC accomplishes its mission and advances national goals by supporting:

- The frontiers of science discovering nature’s mysteries from the study of fundamental subatomic particles, atoms, and molecules that are the building blocks of the materials of our universe and everything in it. Each of the programs in the SC supports research probing the most fundamental disciplinary questions.

- The 21st Century tools of science providing the Nation’s researchers with 27 state-of-the-art national scientific user facilities, the most advanced tools of modern science propelling the U.S. to the forefront of science, technology development and deployment through innovation.

- Science for energy and the environment through fundamental research on energy production, conversion, storage, transmission, and use.

Over the decades, SC investments and accomplishments in basic research have provided the foundations for new technologies, businesses, and industries, making significant contributions to our Nation’s economy and quality of life.
Acknowledgements

The U.S. Department of Energy Office of Science thanks the speakers for participating in the 2017 National Science Bowl® finals competition event.