Understanding and controlling quantum phenomena permeates the research done throughout JQI. Researchers at the institute both explore fundamental physics and develop its practical applications. For example, quantum mechanics promises to revolutionize computing, cryptography, and communication in the coming decades. Federal and academic researchers at JQI are working side by side to bring about this revolution.

“JQI is a joint government and academic effort,” said Jake Taylor, a theorist at NIST and also a JQI Fellow. “What that means practically is you get all the benefit of all the long-term thought and freedom of research from the academic side with all the resources of the government side.”

Can the U.S. Work Well with International Partners?

By Michael Lucibella

The consensus among policy-makers at the 2015 APS April Meeting in Baltimore is that large international collaborations are the future of “Big Science” research projects. However, arriving at the best role the United States can play is complicated.

Right now the Department of Energy (DOE) is putting together the Deep Underground Neutrino Experiment, the first major international physics collaboration hosted on U.S. soil. Those in charge have been looking to other collaborations as a guide for how to manage current and future international projects in the United States.

“The trend now is to do these big science projects internationally,” said Nigel Lockyer, the director of Fermilab. “The trick for us here in the U.S. is we need to start to understand how we will host an international science facility on U.S. soil.”

The trend in particle physics carries over into astrophysics as well. “Most major projects in practice are multinational,” said Roger Blandford of the Kavli Institute for Particle Astrophysics and Cosmology. “We’re not going to be able to afford to be the major player in everything. It’s just unrealistic.”

2014 APS “District Advocate of the Year” Awards

Each year, APS recognizes its members who made extra effort to reach out to U.S. and state senators and representatives to argue for support of science.

Eric Beier is an undergraduate student at Washington State University. Eric wrote an op-ed and also spearheaded a student letter to Senators Murray (D-WA) and Cantwell (D-WA) on the importance of federal science funding. After personally delivering the letter, Eric was called by Senator Murray’s office to discuss funding priorities.

Matt Bishop is a graduate student at the University of Alabama-Birmingham (UAB) and the CEO of AskAScientist. Matt

Scientists Criticize Curbs on Travel

By Michael Lucibella

In a recent letter to legislators, APS and 125 other scientific organizations sharply criticized restrictions imposed on government researchers’ travel to conferences. The letter, addressed to the chairs of the Senate Appropriations Committee, expressed “deep concern over the negative impacts that burdensome paperwork, expensive oversight, and long approval time were having on research.”

“Current policies are reducing government scientists’ and engineers’ participation in scientific and technical conferences while the administrative cost of overseeing these activities has increased significantly,” the letter reads.

Three years ago, at the behest of the Office of Management and Budget, the Department of Energy (DOE) and the Department of Defense (DOD) instituted strict approval requirements for scientists wanting to attend conferences. At DOE, for example, the deputy secretary must approve total agency conference travel above $100,000 while the secretary needs to sign off if the total exceeds $500,000. The DOD instituted even more stringent oversight requirements.

This followed a presidential executive order in November 2013 requiring agencies to more carefully scrutinize how they pay for conferences. This resulted in an official OMB memorandum in May 2012 requiring that agencies spend 30 percent less on travel the following year for three years. The catalyst was a series of instances of excessive spending by the General Services Administration and Department of Justice in 2010.

This introspection was prompted by the 2013 Particle Physics Project Prioritization Panel report, which called for the Deep Underground Neutrino Experiment (DUNE, formerly known as the Long Baseline Neutrino Experiment) to be converted from a primarily U.S. project to one that brings together a number of international partners. [This is] “partly because the costs are so big and partly because it makes sense to bring together the science community of the world,” said Lynn Orr, the head of research at DOE. “The [DUNE] group has been able to assemble faster than I ever thought possible.”

This is in stark contrast to the administration’s push to spend 30 percent less on travel. Each agency is required to consider approving conferences if the total exceeds $500,000. If a conference costs between $40,000 and $500,000, the agency’s deputy secretary must review the request. If it costs above $500,000, then the secretary must sign off.

The Department of Energy has also been particularly restrictive. DOE’s travel processes are complicated.

By Michael Lucibella

Founded in 2006, the Joint Quantum Institute (JQI) at the University of Maryland (UM) is a superposition of research approaches. The collaboration between UM and the National Institute of Standards and Technology (NIST) brings together the freedom of academia with the resources of a federal agency.

Among other projects, the researchers there are laying the groundwork for future quantum computers.

“JQI is a joint government and academic effort,” said Jake Taylor, a theorist at NIST and also a JQI Fellow. “What that means practically is you get all the benefit of all the long-term thought and freedom of research from the academic side with all the resources of the government side.”
This Month in Physics History

June 1849: James Prescott Joule and the Mechanical Equivalent of Heat

By Richard Williams

During the mid-1800s, many scientists accepted the caloric theory of heat, which considered heat to be a fluid that could neither be created nor destroyed and which flowed between warm bodies to cold ones. But an obscure home-school brewer’s son in the north of England, James Prescott Joule, was impressed by the celebrated cannon-boring experiments of Count Rumford, which showed that heat could be created continuously by the mechanical work of boring a cannon. He recognized that Rumford’s discovery needed to be justified by an experimental determination of the mechanical equivalent of heat. Thus, this unlikely physicist, who had never had adult instruction or a single course in physics, began his careful experiments that would change the physics of energy. These experiments became the foundation of the First Law of Thermodynamics, the principle of conservation of energy, and the support of much of the energy technology of modern life.

Joule was born in 1818 in Salford, England, near where his family operated a brewery in Manchester. Working there was what considered the scientific hinterland during much of his career, Joule was learned by the scientific establishment. He did not have formal schooling, but received some tutoring from scientist John Dalton, who showed Joule the theory of atomic weights and the composition of molecules. As an adult Joule became the manager of the family business; he worked a full day making beer and then pursued his scientific investigation at the end of the day, as an avocation. [1]

He investigated the heat generated by many mechanical actions, including the stirring of water by a paddle, expansion of a gas into a vacuum, and the generation of heat by current flow in electrically conducting materials. The experiment that showed most directly the connection between mechanical action and heat involved the stirring of water by a paddle. He gave an extensive summary of this work in a report [2] to the Royal Society of London in June, 1849. In one design, the paddles, immersed in water, were mounted on a vertical shaft, rotated by a cord propelled by falling weights. The temperature increase of the water was of order one degree centigrade. The experiment required very careful control of the ambient conditions and corrections for extraneous heat flow. Some scientists were skeptical whether the experiments could be accurate enough, but, in the end, Joule’s work stood the test of time and was confirmed by others.

Combined with the results of other researchers, Joule’s determination of the mechanical equivalent of heat led to the First Law of Thermodynamics. The law, based on the idea of the conservation of energy, states that for a process in a defined system, the change in internal energy is equal to the amount of heat absorbed minus the work done. Joule recognized that, in a container that cannot exchange heat with the surroundings, if a gas is compressed, and then allowed to expand, the expanding gas does no work. Therefore, according to the First Law, the energy of an ideal gas would not change, nor would its temperature. His experiments showed this to be the case. However, small temperature changes do occur that were too small to be detected in his experiments.

This work came to the attention of Lord Kelv-in, who joined Joule in more sensitive experimental involving expansion of the gas through a porous plug. This experiment showed significant temperature changes that depended on the initial temperature and pressure. Later, these changes were understood to be due to the force between molecules. This was the Joule-Thom-son experiment. When it was fully understood, it enabled the liquefaction of what were known as “permanent gases.” Liquefaction of gases is the basis today of the multibillion-dollar industries of conditioning and cryogenics.

By measuring current flow versus resistance in various materials, Joule established the P = FR relationship between resistance, current flow, and the rate of heat generated. This was not as easy as it looks today. Owing to the work of Georg Ohm, the concept of electrical resistance was just emerging, and electrical current was still a controversial idea. But, again, Joule was right about the physics before the consensus emerged. Down to our own time, electrical heating by current flow in a resistor has been both a bane and a bounty. Resistive heating improves daily life in our stoves, furnaces, etc.
think anyone had thought would happen.”

Lockyer, however, sounded a note of caution about the future of solar energy. “Although it is clear to any of us that our present system is set up in order for us to be a reliable host for other countries to invest in,” Lockyer said. “For us to take on the role of a friendly, reliable host is something we’re not used to... We must figure out how to host an international facility.”

Speakers highlighted two European facilities operating under different models as some examples of role models and cautionary examples of how to run a collaboration. “CERN has been one of the most successful to get all the players together, the whole community for their project. The Large Hadron Collider (LHC), it’s clearly been super-successful,” Lockyer said. “That is the type of thing that we want to do with neutrino physics in the U.S.”

Orr echoed Lockyer’s sentiment, adding that much of LHC’s success comes from the powerful central organization. CERN effectively sets the rules and directs all of the construction and operations, while participating European nations supply the funding. “You need a very strong central organization in charge,” Orr said. But it’s a success that is difficult to replicate.

Lockyer added, “There are bad examples out there where that’s not been followed, where project management has been shown to be lacking. ...you can look at the ITER project as an example.”

ITER, the international collaboration to build a giant Tokomak in the south of France, has been in development since the 1980s, but its full operation has been delayed until the mid 2020s. In his own talk, Robert Iotti, present chair of the ITER Council, candidly highlighted many of its shortcomings, and its root causes. “Whether the ITER model is a success or ultimately a failure has yet to be determined,” Iotti said.

He traced many of its problems to a weak central organization that wields little power to manage the contributions from the various international partners. All major decisions that would affect the cost of the project needed unanimous agreement from all seven partners, effectively giving every participating country veto power over any critical decision.

“Reaching a unanimous agreement was so important that it seemed far more important than to reach an agreement that would make the project successful,” Iotti said.

He added there had been much criticism lobbed at ITER’s “in-kind” development, where each nation contributes discrete pieces of equipment to the central organization. Redesigns and late or missing contributions have been the primary time-sink in the project’s delay. For part of the problem, he said, is that the responsibilities were divided up among the countries based on how much money each contributed, rather than which could build a given piece.

“Contribution in kind works if you set it up correctly,” he said.

“The way that it’s been applied gives you an impression it’s the wrong model, but it can be made to work.”

It’s a similar model to what’s been successful with the International Space Station. The United States has been the leader in hosting, directing and supplying most of the project with significant hardware contributions from Russia, Canada, Japan and Europe.

International collaborations in astronomy and astrophysics are transcending the U.S. taking both leadership and support roles. Projects like the National Air and Space Administration (NASA) James Webb Space Telescope are run by NASA with international contributions, while the European Space Agency’s upcoming Jupiter Moons Explorer is getting support from NASA.

“Virtually all of our NASA science missions … are international collaborations,” said John Grunsfeld, NASA Associate Administrator for the Science Mission Directorate. “It would really be the exception to see some large difficult science project that isn’t an international collaboration.”

However, the United States had had an uneven history leading large international particle physics projects. Fermilab’s two big detectors at the Tevatron were run as successful international projects, but such wasn’t the case for the never-built American particle accelerator that would have eclipsed the LHC.

Discussing this sad episode, physicist and historian Michael Riordan of the University of California Santa Cruz highlighted some of the shortcomings in the United States’ 1990s-era Superconducting Super Collider project. Among the many problems, the United States was never able to bring in the international investment built into the project’s planned budget.

“There was a fundamental flaw,” said Riordan. “We were expecting that we could get something on the order of 20 percent in foreign contributions for a project that was intended to reestablish American leadership.”

He added the lessons he drew from the experience is that for large projects, international partners need to be treated like real partners with real input into the project. It’s a lesson that Lockyer said he and U.S. Secretary of Energy Ernest Moniz had also drawn and hoped to apply to DUNE and future projects.

“You start from the beginning by creating an oversight organization that brings [international partners] in from the beginning, from the top, and allows them to participate in that process,” Lockyer said.

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**Physicists Look at Chemicals in the Environment**

*By Michael Lucibella*

Researchers are looking more closely at protection mechanisms in commercial chemicals that lead to potentially damaging effects on the human body and the environment.

"We are the first to highlight that 100% of the American population are exposed to artificial sweeteners. Come 2015, 30% of the American population will be overweight. Why is this?" said Monica of Wesleyan University.

Indeed, the long-term health effects of artificial sweeteners are now being examined, and the results are not promising.

"There is a long history of building individual partnerships with each other. In 2003, the two institutions signed an agreement to formally increase their collaborative efforts, yielding the UM-NIST Center for Nano Manufacturing and Metrology in 2005. In 2005, NIST and the university established JQI, modeled on JILA, to capitalize on Maryland’s history of building quantum and atomic research programs.

JQI has grown considerably since then. Though originally envisioned as a research center for quantum information, it’s interacting strongly with bio-

"The National Science Foundation (NSF) and the Department of Energy (DOE) have added 135 fellows since 2005. One year later, NIST and the University of Colorado Boulder, in which four-year colleges was often a close second, the majority of those jobs were temporary positions, such as lecturerships and postdoctoral positions. Even at the bachelor’s and master’s degree levels, those graduates who go straight into the workforce after receiving their degrees, over half will be in the public sector [3, 4].

Of course, it should come as no surprise that physicists have an important role to play in the wide variety of careers available outside of academia. The far-reaching expertise that physics students develop while receiving their degrees, through exposure to a broad set of techniques and equipment and skills, makes them exceptional problem-solvers. Moreover, the ability to approach problems from general principles often means that physicists can apply their knowledge to novel contexts, and often produce innovative advances in technological development.

However, many of these graduates find these eventual careers in spite of, rather than because of, the career mentorship of a typical physicist.

"I am pleased to take this opportunity to introduce APS members to the APS Online Professional Guidebook," said waitress. "It has been my privilege to work with these excellent people for the new world of open access publishing."

"The journals are the jewels of the APS, a result of the hard work and dedication of all of the editors and the Ridge staff," said Sprouse. "It has been my privilege to work with these people and the staff during my tenure, including many outstanding young people who are the future of the APS journals. The journals are healthy and strong, and it must be the top priority of APS to keep them that way.”

2015 APS President Samuel Aronzon added that “Gene leaves the APS family of journals stronger than they have ever been, and my many accomplishments have greatly benefited the Society. We will miss his commitment and expertise as we move forward, and we wish him the best in future endeavors.”

Until a new Editor in Chief is appointed, APS Editorial Director Daniel Kalp will assume the responsibilities of the position.

**SUCCESS continued on page 6**

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**International News**

**Fostering U.S.-Korean Physics Collaboration**

By Jaehoon Yu

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POLICY UPDATE

Budget and Appropriations Bills on the Horizon

The House of Representatives has begun work on Fiscal Year 2016 (FY16) appropriations bills and, constrained by strict funding levels set by the Budget Control Act, the early drafts reflect an essentially flat funding scenario. The House passed the FY16 appropriations bill that funds the Department of Energy (DOE), providing an increase of $524M for the Office of Science but $414M less for the President’s Budget Request (PBR). The bill dramatically reduces spending on climate science and energy efficiency programs. As this issue went to press, the House will soon be introducing funding bills into committees for the National Aeronautics and Space Administration (NASA), the National Institute of Standards and Technology (NIST), the National Oceanic and Atmospheric Administration (NOAA), and the National Science Foundation (NSF). Funding for NASA Science is $7M below the FY15 enacted level; funding for NIST is $9M below; funding for NOAA is $274M below; but funding for the NSF is $505M above FY15.

The Administration has already issued veto threats to several House budget and appropriations bills over policy provisions and concerns on funding priorities.

America COMPETES

The America COMPETES Act, at press time, is expected to be introduced on the House floor the week of May 25. Passing COMPETES out of committee proved to be a contentious and partisan affair, with almost every amendment and the bill itself passing or failing along party lines.

The divisive factors in the bill include a number of policy provisions that APS strongly opposes, such as (1) restricting the use of scientific research funded by DOE for policy making and (2) creating unnecessary inefficiencies in NSF’s management of large scale facilities. APS sent a letter to the House science committee that Ranking Member Johnson (D-TX) cited in her opening remarks. The letter can be read at http://bit.ly/1EVj5d3.

The Elementary and Secondary Education Act

The Elementary and Secondary Education Act (ESEA), set to replace No Child Left Behind (NCLB), passed the Senate Education committee with a vote of 22 for, 0 opposed. And true to the bipartisan nature of ESEA, multiple amendments passed overwhelmingly. Missing from earlier drafts but now restored by the STEM-Ed Amendment are the Math Science Partnerships. Also of importance is that “evidence-based” has now been defined in the legislation, something that was sorely lacking from NCLB.

Looking forward, ESEA is expected to be introduced on the floor before the August recess. Additionally, now that ESEA has moved out of committee, the Senate education committee will be taking up the Higher Education Act shortly.

WASHINGTON OFFICE ACTIVITIES

Media Update

Austin Hinkel, a physics student at the University of Kentucky, wrote an op-ed in the Lexington Herald-Leader (KY), calling for robust support of science funding and an end to sequestration. Read the piece: http://bit.ly/1E1V6j3.

APS Director of Public Affairs Michael S. Lubell opined about changing the nation’s tax policy as an incentive to get companies to invest in long-term scientific research in his latest column. Read the op-ed: http://bit.ly/1E1HeIt.

APS Panel on Public Affairs

The member comment period for the proposed Statement on Earth’s Changing Climate concluded on May 6th. A review committee is assessing membership feedback and will report its recommendations to the APS Panel on Public Affairs (POPA) in the coming weeks.

The POPA Physics & the Public Subcommittee continues its work on a survey focused on overcoming the obstacles of recruiting teachers in the physical sciences. It plans to carry out a survey this summer, with results expected by year’s end. Two proposed APS Statements, one a revision of the APS Statement on Civic Engagement and the second on the Status of Women in Physics, will be made available for APS membership comment this summer.

The POPA National Security Subcommittee will introduce a revised proposal at the Panel’s mid-year meeting for a study on non-weapons scientific research conducted at the nation’s national security laboratories.

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2015 APS Fellows Reception, Berkeley CA

To the South Pole and Beyond!

Michael Lucibella, intrepid staff writer at APS News since the March 2009 issue, has left for the South Pole. Or rather, to join the U.S. Antarctic Programs office as editor/writer for the Antarc-Sar newspaper. When not stationed at the Denver office, he will head south and report on work going on at the research stations. During his time atAPS, he wrote many articles for APS News and contributed blog posts and podcasts to PhysicsCentral. We will miss his energy and good humor, and wish him every success in his new job.

In an economic and scientific funding universe that seems about to collapse on itself, there are some wormholes that might lead to novel sources for research capital. Over the last two years, the Science Philanthropy Alliance (SPA), a partnership of six of the world’s leading scientific foundations, has emerged as a potential supernova with a distinct mission: It seeks to increase philanthropic annual giving for science by $1 billion within 5 years.

At the helm of this endeavor is physicist Marc Kastner, who served as physics department head and dean of science at the Massachusetts Institute of Technology (MIT). Kastner is well qualified to take on the challenge of expanding fundamental research funding, having spent years building up the MIT research programs and portfolios. He was nominated by President Barack Obama to serve as Director of the Office of Science at the Department of Energy, but he was not confirmed. In early 2015, the heads of the six foundations came calling with an offer he knew he couldn’t refuse: a chance to lead the fledgling SPA organization and make a unique global impact on research funding.

SPA comprises the Howard Hughes Medical Institute, The Kavli Foundation, the Gordon and Betty Moore Foundation, the Research Corporation for Science Advancement, the Alfred P. Sloan Foundation, and the Simons Foundation. It was initiated in 2013, as “The groups asked what they could do as a unit that they couldn’t do as individual organizations, especially given the sad state of support from the federal government,” says Kastner.

The resulting discussions led to the creation of SPA and a new dawn for philanthropy, as the Alliance hopes to leverage its assets, strengths, and brands to raise even more money for research. Its strategy is almost unassuming: “We aim to educate high-net-worth individuals and other existing foundations about the value and importance of basic science and the role foundations have in making a difference,” he explains. With federal government support for basic science lower than it’s been since the 1960s, he adds, philanthropy alone can’t fill that gap. Furthermore, individual donors want to know that their support makes a difference and is not used for administrative costs. To achieve this aim, SPA partners with major universities to encourage and enable them to launch endowments for basic science. Then the Alliance brokers deals between donors and the universities to help them grow those endowments, and this money stays on campus; but the money is steered to the campus in the first place by the power of the Alliance and the reputation of its foundations. “We can tell donors there is a place to go to send their money,” says Kastner. “This creates quick targets for philanthropists to

Philanthropy Led by a Physicist

By Alaina G. Levine

Marc Kastner

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APS NEWS

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Photos by Darlene Logan
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which were widely reported in the press in April 2012.

In March 2015, the Government Accountability Office issued a critical report on the impact of these requirements. They found that the number of applications had reduced the number of government scientists attending conferences and decreased their ability to travel, thereby increasing the time and the cost of oversight.

“DOD and DOE officials and professional society representatives provided examples of changes in conference participation — particularly reduced attendance — since implementing the departments’ policies.”

The length of the review and approval processes under the DOD and DOE conference policies has increased, resulting in scientists and engineers not always receiving timely decisions about conference requests to attend. For instance, they may have to take on active conference roles or take advantage of lower-cost travel arrangements,” the report found.

The report also discusses the effect on defense research, but the Department of Energy’s travel restrictions aren’t as stringent.

The report did not look at how the restrictions were affecting scientists in other government organizations and agencies such as the National Aeronautics and Space Administration or the National Science Foundation.

The additional scrutiny has decreased conference participation by government scientists. Though data is incomplete, labs reported a 17% decrease in scientist participation at conferences almost across the board. Some conferences saw decreases in federal participation by much as 80%.

Wait times for approvals have dramatically increased. Across the DOD, the average approval time was well over 100 days and upward.

One of Kastner’s major goals is to share success stories about funded research and build a catalog of scientific areas that need support, where donors can make a difference. “We all have to work at doing this,” he says. “I think the best way to reciprocate is to share success stories about major accomplishments.”

To this end, the report found. Current, the average starting age of MIT assistant professors is in the mid-30s, and the average age of a professor of 50 years of experience is 67 years old, he notes. Today, “... it’s much harder to do basic science.”

As it happened, Kastner almost wasn’t a scientist himself. “My father was a physicist, so I decided at an early age physics was something I would never do, because my dad said that I would be a laughing stock. And that’s exactly what he recounted with a laugh. “So I decided to become a lawyer.”

Kastner studied chemistry as an undergraduate at the University of Chicago and by the time he took E & M, he was smitten with physics. In fact, he applied only to graduate schools and any physics program he was accepted by the University of Chicago.

He positively gushes when discussing his chosen field. “I love physics. It’s beautiful. You can describe nature with mathematics and understand it in a quantitative way.”

And studying the subject has enabled him to be a successful manager, he stresses. “When you are an experimental physicist, especially as soon as you become a faculty member, you are running a small business and you are a public explorer. People tend to keep track of every dollar and spent. Those skills are the most important in taking on that challenge, to be a successful physicist, you have to keep your eye on the ball and readjust your strategy depending on which way nature tells you, and those experiences help in administration as well.”

Kastner counts his service to early career faculty and postdocs as some of his most proud accomplishments thus far. “Most faculty avoid [administration] like the plague,” he says. “I got satisfaction out of it because I could see how I could help faculty, especially young faculty.”

He is also very concerned about the plight of postdocs and the dearth of academic jobs available to talented early career scientists.

But as the wheel of fate turns, Kastner is in a new position to potentially help many more early- and mid-career physicists than he ever could have imagined. “I can see good news for the physics community, he says, because it will create more opportunities for both financial support and publicity for fundamental investigations in discovery-driven experimental and theoretical physics.”

“I believe that by telling the stories of how basic research done in the past has made our lives better, and by telling stories about the exciting opportunities for research right now, physicists and other scientists can convince philanthropists to invest in basic research and seed the next generation of great science, which is critical to our future.”

Alaina G. Levine is president and chief executive officer of the APS science career and professional development consulting enterprise. She can be contacted through email: alainalevine.com, or followed on twitter @AlainaLevine.

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ics department. Generally speaking, there are few faculty members present in physics departments with prior experience in the food industry (a stark contrast with other STEM disciplines like engineer ing, which frequently employs faculty with strong business acumen in the workforce). Furthermore, while many well-meaning physics professors want to advise their students on how to pursue careers outside of academia, few have industrial colleagues in their professional network to whom they can turn for advice, or whom they could ask to be industrial mentors for their students.

Fortunately, APS can help. In the last several years APS has been working hard to develop and disseminate resources and information on careers outside of academia through our website, through new programs such as the Distinguished Lectureship in the Applications of Physics, and through workshops and panels at APS division and section meetings. One of these resources is the online APS Professional Guidebook, available through the APS Careers site at go.ap.org/physics/guidebook.

The Guidebook contains eight chapters that describe the essential elements of a successful transition into the industrial workforce. Chapter titles include Career Planning and Navigation, Conducting Informational Interviews, Networking, Writing an Effective Application, Interviewing, Negotiating, and Self-Assessment. The site contains a downloadable slideshow which is a customizable tool. Visit www.ap.org/careers/insight to customize.

Responsible mentorship of students and early career physicists means providing them with information about the full breadth of career options available to those with a physics degree. It also means giving them access to information which will help them prepare adequately for those future careers.

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In both sucralose research and in the studies of ionic liquids, researchers hope that the knowledge gained might lead to chemical variants that are safer, as well as a better handle on how chemicals affect health.
U.S.-KOREAN continued from page 4
to 240 (a 78% increase). Among these, the number of lifetime members has grown from 27 to 40, and 151 AKPA members are also jointly registered in the KSEA.

To bring physics closer to the community, the AKPA initiated a National Student Physics Congress (NSPC) in 2013, and the Fermi National Accelerator Laboratory (FNAL) continued on page 4

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Building the H-Bomb: The Big Idea

By Kenneth W. Ford

On March 9, 1951, Edward Teller and Stan Ulam issued a report, LAMS-1225, at the Los Alamos Scientific Lab, where they both worked at the time. It bore the ponderous, hardly illuminating title “On Heterocatalytic Detonation I. Hydrodynamic Lenses and Radiation Mirrors,” and it changed everything. Since it dealt with thermonuclear weapons (H bombs), it was, of course, classified secret. For some reason, it remains secret to this day. The highly reduced version of it that can be found on the Web is mostly white space. Nevertheless, most of what was in it is well known.

Their big idea, which we refer to now as radiation implosion, was that the electromagnetic radiation (largely X rays) emitted by a fission bomb, if appropriately channeled, could compress and heat a container of thermonuclear fuel sufficiently that that fuel would be ignited and the nuclear flame would propagate, not fizzle. The expected result: megaton of energy, not kilotons. History validated the Teller-Ulam idea. On exactly who contributed what to that big idea, history is a little fuzzier.

Ulam and Teller

Stanislaw Ulam (always known as Stan) and Edward Teller (always Edward, never Ed) had some things in common. They were both émigrés from Eastern Europe—Stan from Poland, Edward from Hungary. They were both brilliant. The both had great curiosity about the physical world. And they were both a bit lary. But like oil and water, they differed notably. Stan, a mathematician with a gift for the practical as well as the abstract, was—to use current slang—laid-back. He had a droll sense of humor and a world-weariness. He longed for the Polish coffee houses of his youth and the conversations and exchanges of ideas that took place in them. Edward was driven—driven by fervent anti-Communism, by a desire to excel and be recognized—driven, it occurred to me, by internal demons. Edward was too intense to show much sense of humor. Stan had an abundance of humor. Stan and Edward did not care very much for each other (which may help one to understand why a “Heterocatalytic Detonation II” report never appeared).

I was a twenty-four-year old junior physicist on the H-bomb design team at Los Alamos when the Teller-Ulam report was issued. I saw Stan and Edward every day. I liked them both, and continued to like them, and to interact with them now and then, for the rest of their lives. Stan and I later wrote a paper together, on using planets to help accelerate spacecraft (the so-called “slingshot effect”). Edward and I later worked together as consultants to aerospace companies in California.

Looking back, the odd thing to me now is that the Teller-Ulam idea landed in the midst of numerous ideas, some of varying complexity and varying chance of success. These included “boosting” (having a small container of thermonuclear fuel at the center of a fission bomb to “boost” the fission bomb’s yield); “Swiss cheese” (having numerous pockets of thermonuclear fuel scattered throughout fissile fuel); the “alarm clock” (a name Edward Teller and Robert Richmyer had coined in 1946 for alternative layers of fission and fusion fuel, and which Andre Sakharov in the Soviet Union, as we later learned, had separately envisioned once—without immediately abandoning other ideas. As it turned out, the more we calculated, the more promising the new idea looked. Within three months, it had become the idea and was endorsed by the General Advisory Committee of the Atomic Energy Commission as the route to follow. Up until February 1951, when Ulam approached Teller with the idea of imploding thermonuclear fuel and Teller realized (or, as he later claimed, recalled) that radiation was the best thing to do the implooding, everyone working on H-bomb design in the United States assumed that the Super would have to be a “runaway” Super, a device in which the temperature of the material would have to be “run away” to over 10 million degrees to ignite the thermonuclear fuel and keep that temperature of the radiation. Otherwise, it seemed, the radiation would soak up too much of the energy and there wouldn’t be enough left to ignite the thermonuclear fuel and keep that temperature. We would have to change this blakcg prompt, Ulam and Teller realized, would be great compression of the material. It was this February meeting and its insight that led to the Teller-Ulam report of March 9, 1951, and to the new direction of the idea.

Put briefly, thermal equilibrium—that is, having the matter and the radiation at the same temperature—could be tolerated if there was enough compression. Occupying less volume, the radiation would soak up less of the total energy. More energy would be left to heat the matter and stimulate its ignition and burning. Up until then, those of us working on the Super accepted the idea that thermal equilibrium would be intolerable because of the excessive “loss” of energy to radiation. And we accepted an argument Teller had made that compression would not help. Teller had pointed out that although compressing the thermonuclear fuel increases its reaction rate, it also increases, and by the same factor, the rate at which the matter radiates away energy. So there was no net gain, he had argued, from compression. But that argument posits a runaway Super, which was our mindset at the time. Once equilibrium is established, matter is not “losing” energy to radiation, it is capturing energy with radiation, gaining as much as it is losing.

Teller, in the now-famous conversation with Ulam, apparently did realize very quickly, despite his earlier arguments to the contrary, that compression could be a key to success. In his memoirs, written many years later, he says that Ulam’s idea was “far from original” and that, for the first time he [Teller] didn’t object to it. He doesn’t tell us why he didn’t object to cold omission given his previous rejection of the idea. In the same paragraph, in a further put-down, Teller says that Ulam did not actually understand why compression was a good idea.

Our understanding of this meeting is murky indeed despite the clarity of the conclusion that flowed from it. Did Ulam come in with a full understanding of why compression might be the key to success in designing an H bomb? We don’t know. Had Teller ever seriously entertained the idea of compression before? We don’t know. (In later writings, Teller claims to have had the idea before Christmas 1950 and also about February 1, 1951. These claims are dubious, especially in light of his own account of the meeting with Ulam and in light of his own role in developing the idea—through idea occurred before late February 1951.) What we do know is that out of the meeting came the successful idea of the “equilibrium Super,” in which compression is so great that the huge energy given off is soaked up by radiation in equilibrium with matter is tolerable.

Calculating in New Domains

Inevitably, calculations on the “equilibrium Super” reached into domains of temperatures and pressures and densities light years removed from anything that can be tested in the laboratory. Edward Teller and Stan Ulam were among those theorists whose ingenuity allowed them to visualize and calculate what would go on at these extreme conditions. What makes this possible? The physicists’ knowledge that the laws of electromagnetism and of mechanics, both classical and quantum, extend to domains far beyond direct observation and even imagination. Furthermore, given what the conditions, one is dealing with the same electrons and nuclei and photons as in the “ordinary” world around us.

This is an edited excerpt from Chapter 1 of the book Building the H Bomb: A Personal History by Kenneth W. Ford, copyright © 2015 World Scientific Publishing. Footnotes and citations that appear in the original are here omitted. For more information visit www.worldscientific.com/worldscibooks/11448982

Kenneth Ford has conducted research in nuclear physics and taught at several universities, including UC Irvine, where he was the first physics chair. His writing includes textbooks and books on quantum physics. In 2006, he was recognized by the American Association of Physics Teachers with that organization’s Ostered Medal for contributions to teaching.