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Careers Report
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Kavli Session Speakers Tackle the Universe

The Kavli Foundation sponsored a plenary session on the theme "Our Changing Universe" at the 2015 APS April Meeting in Baltimore. From left: Nobel laureate John Mather reviewed the history of research on the cosmic microwave background, Clifford Will discussed high-precision experiments that test general relativity, and Stuart Shapiro described computer simulations of mergers of black holes and neutron stars.

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 2011 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,

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Maryland-NIST Joint Quantum Institute Reaches Critical Mass

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 the first generation of 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."

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.

"You started with two separate institutions, which both had a critical mass of quantum researchers," said Taylor. "If you suddenly get them all in the same room on a regular basis, tremendous things can happen."

It's not the first institution to blend federal resources and an

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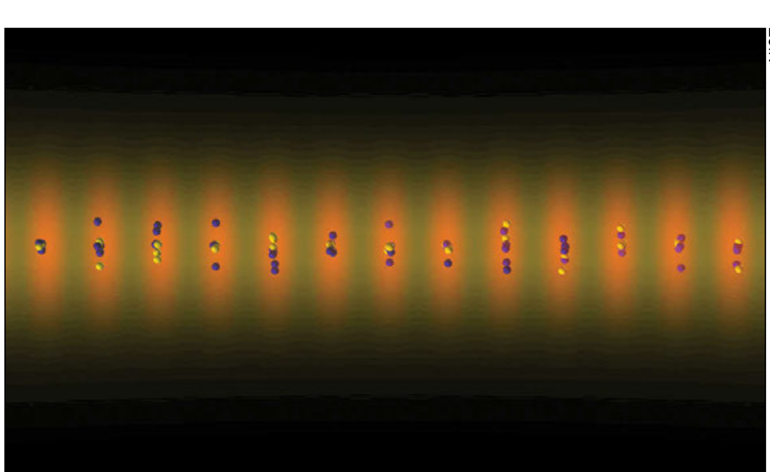

NIST

Among other things, the Joint Institute for Quantum Information studies how trapped atoms (shown here in an artist's depiction) interact with each other and the outside world. The results are key to atomic clocks and quantum computers.

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."

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

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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

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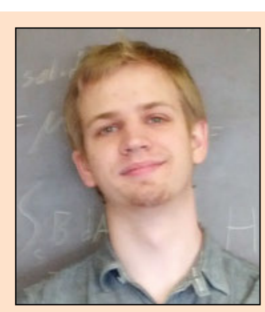
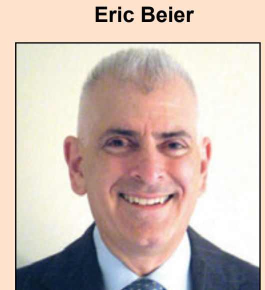


Eric Beier

Matt Bishop



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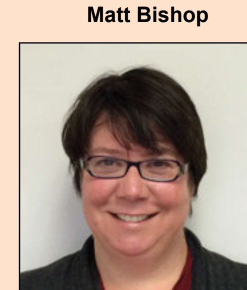

Rachel Scherr

Members in the Media

"It is impossible to write a readable book about real mathematics for nonmathematical readers. The best anybody can do is to write about a real mathematician."

***Freeman Dyson**, Institute of Advanced Study, discussing his favorite books, including a biography of Srinivasa Ramanujan by Robert Kanigel,* The New York Times*, April 19, 2015.*

"You might have seen the difference between a Lego fire engine and a real fire engine. … The Lego fire engine has little doors that open and some features of it that make it somewhat realistic for describing a fire engine, but it doesn't have all the features of a true fire engine, it's just a model fire engine. I'd like you to think of string theory as like my Lego set."

***Amanda Peet**, Perimeter Institute, Ontario, Canada, on explaining string theory to nonexperts,* The National Post*, May 6, 2015.*

"Factors include practical matters like a lack of reliable parental leave and affordable childcare, cultural issues like pervasive implicit bias that reduces women's chances of being hired or promoted in a field seen as 'masculine,' and cultural conditioning that makes it harder for professional women to advocate or negotiate for the resources they need to succeed."

***Elizabeth Simmons**, Michigan State University, on underrepresentation of women in physics,* dailypress.com*, May 8, 2015.*

"The electron isn't a little speck of dirt that orbits the nucleus, that's the whole point. It's a wave function, very close to its ground state, without a well-defined position or momentum. And what is the distance over which that wave function spreads? The size of the atom! … Atoms aren't 'mostly empty space,' they are 'mostly the wave function of the electron'."

***Sean Carroll**, California Institute of Technology, on why you don't fall through the chair when you sit down,* www.wamc.org*, May 19, 2015.*

"These findings might be a step towards creating our ultimate goal of steady-state fusion, which would last not just for milliseconds, but indefinitely."

***Tom Osborne**, General Atomics, on heating a tokamak plasma by injecting grains of lithium,* phys.org*, May 20, 2015.*

"Until we have the EIC, there are huge areas of nuclear physics that we are not going to make progress in."

***Donald Geesaman**, Argonne National Laboratory and chair of the U.S. Department of Energy's Nuclear Science Advisory Committee, which is studying a proposed electron-ion collider (EIC),* nature.com*, May 19, 2015.*

"It's sort of like a divided highway for the electrons, so they don't bounce into things," Kane said. "They just keep going straight in their lane."

***Charles Kane**, University of Pennsylvania, on topological insulators,* The Philadelphia Inquirer*, April 24, 2015.*

"When you put all that together, what you realize is you can do a lot of cool neutrino physics."

***Manoj Kaplinhat**, University of California, Irvine, on understanding neutrino mass by studying the polarization of the cosmic microwave background,* symmetrymagazine.org*, May 19, 2015.*

"The idealized view of science is misleading and mythological and … I think that's destructive."

***Leonard Mlodinow**, California Institute of Technology, on the view that science progresses only when brilliant people have sudden "aha moments,"* LA Weekly*, April 16, 2015.*

"Paul, Weiss has asked me not to comment and to refer questions to the N.F.L."

***Daniel Marlow**, Princeton University, on his participation in a report written by the law firm of Paul, Weiss, Rifkind, Wharton & Garrison, commissioned by the National Football League on whether the New England Patriots football team cheated with underinflated balls, which included the statement "The measurements recorded for the Patriots' game balls at halftime cannot be entirely explained by the Ideal Gas Law,"* The New York Times*, May 6, 2015.*

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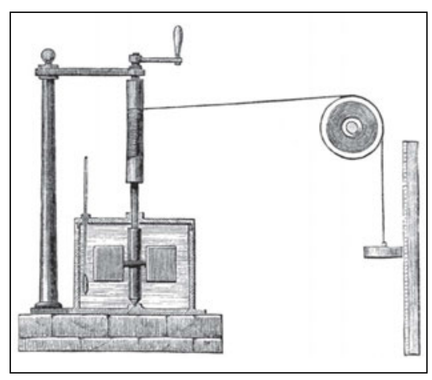
This Month in Physics History

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 from warm bodies to cold ones. But an obscure home-schooled 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 quantified 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.



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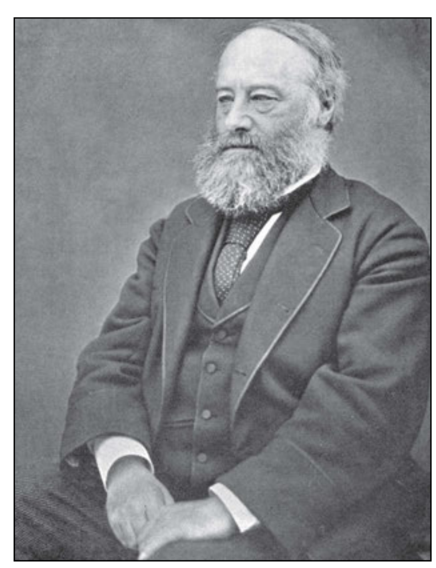
Engraving of Joule's apparatus for measuring the mechanical equivalent of heat, in which the energy from the falling weight on the right is converted into heat at the left, through stirring of water.



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James Prescott Joule

Joule was born in 1818 in Salford, England, near where his family operated a brewery in Manchester. Working there in what was considered the scientific hinterland during much of his career, Joule was long ignored by the scientific establishment. He did not have formal schooling, but received some tutoring from scientist John Dalton, pioneer of 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 investigations 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 into a vacuum, 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 Kelvin, who joined Joule in a more sensitive experiment 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-Thomson experiment. When it was fully understood, it enabled the liquefaction of what were known as "permanent gases." Liquefaction of gases is the basis of today's multibillion-dollar industries of air conditioning and cryogenics.

By measuring current flow versus resistance in various materials, Joule established the $P = I^2R$ relation 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 a 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,

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Education Corner

APS educational programs and publications

2016 PhysTEC Conference

Save the date! The 2016 PhysTEC Conference, the nation's largest conference on physics teacher preparation, will be held March 11-13 at the Royal Sonesta Harbor Court, in Baltimore, MD. The conference will precede the APS March Meeting. See www.phystec.org/

Sign up for Wavefront Newsletter

Educators, stay informed! APS *Wavefront* is a free electronic newsletter for physics educators. Sign up to stay informed about APS programs, upcoming meetings, recent APS actions, and activities within the physics community. Go to www.aps.org/programs/education/wavefront.cfm

Research Mentor Training Seminar Guide

This Guide provides suggestions and materials for preparing and presenting an educational seminar for physics faculty, postdocs, and graduate students in mentorship roles. It is ideal for Research Experiences for Undergraduates (REU) programs, and can be run as a weekly seminar during the summer. The guide is available in pdf format on www.aps.org; enter "mentor training" in the search bar and select the first option in the search results.

Free Graphs and Raw Data

APS generates statistical reports on issues in undergraduate physics. These reports are freely available for your use. You may use the graphs in reports and presentations or you may use the raw data to create new graphs and charts. Access the reports here: www.aps.org/programs/education/statistics/index.cfm

Physics Education Research Speakers

The APS Speakers Lists contain names, contact information, and talk titles of physicists who are willing to give talks on physics education research. At www.aps.org/programs/speakers/, select "Education" in advanced search and then click on "Physics Education Research."

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irons, and other household conveniences, and underlies a multitude of industrial operations. At the same time, it steals power on the way from generating stations to users, and damages electronic circuits and electric motors. We can deal better with both bane and bounty because Joule quantified the physics.

After years of being ignored in his early life, he was finally honored by the scientific community in England and named to the presidency of the Literary and Philosophical Society. His honors spread to Europe and far beyond. "A crater on the moon has been named after him and a French submarine was named *Joule*; sadly, she was lost with her crew in the Dardanelles in 1915" [3]. More than one hundred fifty years after the work was done, his name lives on in the physics community around the world. His initial, J, is the symbol for the unit of energy in the SI system. The $P = I^2R$ relation is known as Joule's Law.

Joule passed away in 1889 at his home not far from his birthplace. An epitaph for another gentleman-scientist, Benjamin Franklin, said "He seized the lightning from the sky and the scepter from tyrants." When James Prescott Joule bypassed the caloric theory and determined the mechanical equivalent of heat, it could be said that "He seized the heat from darkness and the work from isolation."

References

1. D.S.L. Cardwell, *James Joule, A Biography*, Manchester University Press, 1989.
2. J.P. Joule, On the Mechanical Equivalent of Heat, *Philosophical Transactions of the Royal Society of London* 140 (1850): 61-82.
3. D.S.L. Cardwell, *op. cit.*

The author is a regular contributor to This Month in Physics History.

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"Although the scientific details are not presented, I suspect the conclusion reasonably follows from the data and simulations. … Moreover, Dan Marlow is a good physicist and I would place great weight on his scientific opinion."

Alan Nathan*, University of Illinois at Urbana-Champaign, on the NFL report,* The New York Times, *May 6, 2015.*

"It sounds like they've got a guilty party."

Timothy Gay*, University of Nebraska-Lincoln, on NFL report,* The New York Times, *May 6, 2015.*

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think anyone had thought would happen."

Lockyer, however, sounded a note of caution about the future of such collaborations. "It's not 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 management styles as role models and cautionary examples of how to run a collaboration. "CERN has done a great job of pulling together the world 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 the LHC's success comes from the powerful central organization. CERN as an organization directs all of the construction and operations, while participating European nations supply the funding. "You need to have someone who is 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 at least the mid 2020s. In his own talk, Robert Iotti, present chair of the ITER Council, candidly highlighted many of its shortcomings, and their 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 delays. A major 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 best build a given piece.

"Contribution in kind can work 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 common, with 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 Icy 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."

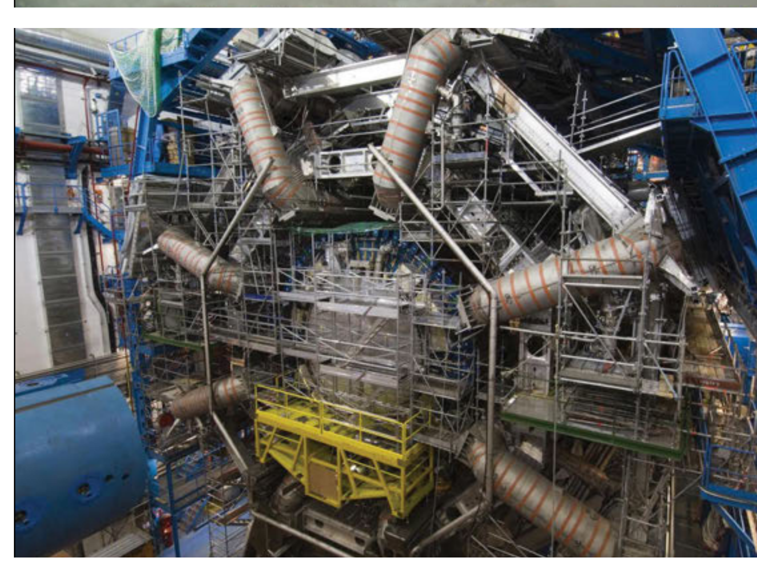
However, the United States has had an uneven history leading large international particle physics projects. Fermilab's two big detectors at the Tevatron were run as successful international projects, but such wasn't the case for the never-built American particle accelerator that would have eclipsed the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



Top to bottom: PhysicsCentral (APS); CERN; iter.org

Models of collaboration (top to bottom): past (SSC), present (CERN), and future (ITER).

APS Editor in Chief Steps Down

Gene Sprouse, Editor in Chief of the APS research journals since March 2007, stepped down from the position as of April 28, 2015. Given the importance of the journals to the Society, APS Chief Executive Officer Kate Kirby said that she will work with the APS Board of Directors to quickly fill the position.

"During the five years we worked together, it became clear to me that Gene's dedication to the APS journals was exceptional," Kirby said. "He raised the quality of the journals, launched vital new publications, and was instrumental in helping us anticipate and prepare 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 excellent people for the last eight years, and it has been most rewarding to see them grow professionally during this time. I am proud of the people that we have added to 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 Aronson added that "Gene leaves the APS family of journals stronger than they have ever been, and his 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 Kulp will assume the responsibilities of the position.

Gene Sprouse

Physicists Look at Chemicals in the Environment

By Michael Lucibella

Researchers are looking more closely at molecular mechanisms in commercial chemicals that lead to potentially damaging effects on the human body and the environment. Two of these investigations — one on the artificial sweetener sucralose, the other on a class of fluids called ionic liquids — were highlighted at the 2015 APS March Meeting in San Antonio, Texas.

Sucralose, an artificially modified sucrose molecule, is a common sugar substitute used in products like Splenda. The molecule is a calorie-free sweetener because the body can't metabolize it. Early research has raised the possibility of serious implications for the complex and poorly understood ecosystem of intestinal bacteria.

Though the research is thin and results have been inconsistent, a few preliminary health studies hint at some negative health impacts of high-artificial sweetener diets. "What we're finding is that sucralose is not an inert molecule, and it's interacting strongly with biomolecular structures," said Cristina Othon of Wesleyan University.

She and her team used optical absorption spectroscopy to study how the presence of this modified sugar can affect a protein molecule's ability to fold. They found

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Careers Report

Your Gateway to Success in the Physics Workforce: The APS Online *Professional Guidebook*

By Crystal Bailey, APS Careers Program Manager

Contrary to what most young physicists (and many of their faculty mentors) believe, most physics graduates, whether bachelor's, master's, or Ph.D.s, will find permanent careers in the private sector rather than in academia. According to the American Institute of Physics Statistical Research Center, 64% of the potentially permanent initial hires of Ph.D.s are in the private sector [1]. The National Science Foundation Survey of Doctoral Recipients has put the percentage of Ph.D.s working in the private sector at between 40% and 55% over the past three decades [2]. While employment in four-year colleges was often a close second, the majority of those jobs were temporary positions, such as lectureships and postdoctoral positions. Even at the bachelor's and master's degree levels, of those graduates who go straight into the workforce after receiving their degrees, over half will be in the private 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 phys-

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International News

...from the APS Office of International Affairs

Fostering U.S.-Korean Physics Collaboration

By Jaehoon Yu

I am pleased to take this opportunity to introduce APS members to an organization that has been working for almost four decades to foster U.S.-Korean physics collaboration, and to excite young Koreans and Korean-Americans in the United States about studying physics. The Association of Korean Physicists in America (AKPA) was founded in 1979 in Washington, DC, with Dongyoung Lee as the first president of the organization. It was established to promote collaboration and academic exchange as well as networking among members. In 2014, AKPA celebrated its 35th anniversary in a symposium at the University of Chicago, in which close to 100 physicists from Korea and from the U.S. participated. This event was jointly supported by the Korean Institute for Basic Science (IBS), the Korean Consulate General of Chicago, the Korean-American Scientists and Engineers Association (KSEA), the Korea-U.S. Science Cooperation Center (KUSCO), the Korean Physical Society (KPS), and APS.

A group photo taken after the 2015 OYRA award ceremony during the FIP reception at the 2015 APS March meeting.

Building on its previous successes, AKPA has accomplished a tremendous amount since Eun-suk Seo wrote about the association in the *Spring 2013 Newsletter* of the APS Forum on International Physics (FIP). First of all, the membership of AKPA has grown substantially. The number of registered members on the overall email list is now close to 500. The total number of active members, including the associate members (who are not physics majors but are either in related areas or family members of an AKPA member), grew from 135

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academic setting. JILA, the collaboration between NIST and the University of Colorado Boulder, served as the model for JQI.

JILA was originally founded in the 1960s as an astrophysics lab, but has since expanded its purview to include research in atomic, molecular, quantum and optical physics, as well as biophysics. In 2001, researchers at JILA shared the Nobel Prize in Physics for creating the first Bose-Einstein condensate in an alkali gas.

Thus far, researchers at JQI have kept their attention in the quantum realm. "It's an institute that is focused on a second revolution in quantum mechanics and its application to society and technology," said Chris Monroe, a physicist at UM and a fellow at JQI. "We're based on a university model, so we do curiosity[-driven] research. But it has a mission."

This focus has made JQI a research powerhouse. In the ten years since its founding, it has become one of the top places in the country for quantum science, attracting some of the best physicists in the field. NIST's Nobel laureate William Phillips helped set it up. In 2015, JQI Fellow Gretchen Campbell won the APS Maria Goeppert Mayer Award. Chris Monroe an Ian Spielman each received a recent APS prize or award. "We're competing with the big leagues," Monroe said.

UM and NIST have had 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. One year later, NIST and the university established JQI, modeled on JILA, to capitalize on Maryland's existing strong quantum and atomic research programs.

JQI has grown considerably since then. Though originally envisioned to host about twenty scientists, today there are 33 fellows and more than 140 faculty and graduate students working at JQI, split about evenly between NIST and the university.

"From the NIST side it provides a great source of young and eager scientists," said Steve Rolston, JQI co-director. "From the Maryland side, it's almost like having another 15 faculty members."

Bringing together the two institutions lets their different approaches complement each other.

"There are different cultures between national labs and universities," Rolston said. "In this case it's not very extreme. NIST has a mission. When they do research it's relevant to their mission. When the university does research, it's because they find it interesting."

NIST isn't the only federal agency with an interest in quantum computing and a hand in JQI. The promise of quantum encryption and unbreakable codes has long attracted the interest of the National Security Agency (NSA).

"You usually think of the NSA as sort of spooky, but my experience with them is far from that," Monroe said. "They have open research in certain fields and this is one of them, quantum information."

Working through the long-established Laboratory for Physical Sciences (LPS) adjacent to campus, NSA's research done through JQI is all open and unclassified. One of JQI's 33 fellows is from the LPS and ten of the 100 labs associated with the JQI are run through the LPS. The labs primarily, but not exclusively, focus on the applications side of quantum information.

"It's the NSA's little physical science connection to the outside world," Rolston said.

Bringing together agencies and academia has led to collaborative work. For instance, last year JQI linked up with Lockheed Martin and established a division to develop workable quantum computers.

On its own, Monroe's group proposed a modular, scalable computer architecture with ions entangled in separate traps. But Monroe is quick to point out that while researchers at JQI are broadly working towards a quantum-computing goal, JQI is at its core focused on exploring fundamental science. "We're not a quantum computing center," Monroe said. "We are a quantum physics center."

Washington Dispatch
Updates from the APS Office of Public Affairs

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 $32M for the Office of Science but $240M less than 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 committee 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 $50M 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://1.usa.gov/1HhSBRG

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/1EVj5d3.

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 *Roll Call* column. Read the op-ed: http://bit.ly/1EH1elt

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 science conducted at the nation's national security laboratories.

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2015 APS Fellows Reception, Berkeley CA

Photos by Darlene Logan

APS President Sam Aronson hosted his first reception for current and new APS Fellows at the Berkeley City Club on April 22, 2015. Upper left: Eli Yablonovitch, Sam Aronson, Xin-Nian Wang, Lower left: Lucille Poskanzer, Arthur Pozkanzer, George Trilling, Maya Trilling, Right: Dan Stamper-Kurn, Robert Cahn, APS Chief Executive Officer Kate Kirby, and Alfred Schlachter. More than 100 Fellows and guests attended.

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 *Antarctic Sun* 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 at APS, 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.

Michael Lucibella

Profiles In Versatility

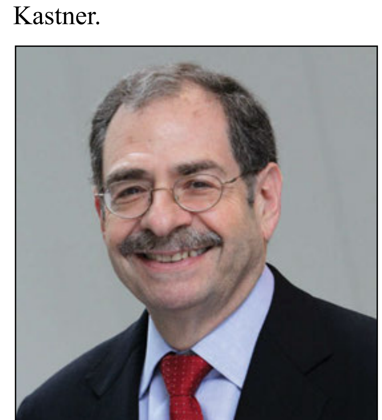
Philanthropy Led by a Physicist

By Alaina G. Levine

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.



Marc 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

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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 regulations significantly reduced the number of government scientists attending conferences and dramatically increased approval times 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. In addition, 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 determine whether they could take on active conference roles or take advantage of lower-cost travel arrangements," the report found.

The GAO focused strictly on defense research, but the Department of Energy's travel restrictions apply to civilian research as well. The report did not look at how the restrictions were affecting scientists in other government institutions or agencies, such as the National Air 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 decrease in scientist participation at conferences almost across the board. Some conferences saw decreases in federal participation by as much as 95 percent.

Wait times for approvals have dramatically increased. Across the five DOD research divisions examined by GAO, average wait times for approval ballooned from seven days to more than four months. The report went on to find that due to these long delays, many scientists are not presenting research at conferences, and those that do are missing out on cheaper airfare rates and lower registration and hotel costs.

There is evidence that the additional oversight eats into a portion of the remaining travel budget. For example, at Los Alamos National Laboratory, oversight costs for conference travel ballooned from $0.2 million a year in fiscal years prior to May 2012, to $1.6 million in 2013.

The agencies have been taking steps to streamline the process. The report did find some evidence that more scientists were able to attend meetings in 2014 than 2013 or 2012, as researchers have become more accustomed to the regulations.

The GAO report also recommends that the agencies set clear timeframes to make decisions and establish a plan to evaluate how the regulations are applied.

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invest their money in universities," which in itself is highly significant, given that "The process is very slow to raise money for basic research," and given the challenges of courting donors for projects that might not even exist yet.

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 this," he implores his physicist colleagues. "Given the state of politics, the hope of getting [federal] funding levels back up is not great. So we need to educate philanthropists …" about the essential nature of fundamental research in discovery-driven or seemingly blue-sky subjects.

Knowing Kastner's own philosophy about research, it's not hard to imagine why he would take on this challenge. "Support of basic science is something I've been passionate about my whole career," he says. Shortly after he graduated in 1972 with his Ph.D. in physics, he had a job lined up at MIT. By June of 1973, he received his first NSF award. "I was not even 28 years old, and was an assistant professor with a grant," he recalls. "I was enormously lucky to start my job when there was federal funding." Currently, the average starting age of MIT assistant professors is in the mid-30s, and the average age of a first-time NIH grantee is 42, he notes. Today, "… it's so 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 he was so much smarter than me," he recounts with a laugh. "So I decided to become a lawyer." But his dad suggested that he at least major in science so "if I can't get into law school, at least I would get a job." 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 programs in physics and 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're an experimental physicist, especially as soon as you become a faculty member, you are running a small business," he notes. From hiring people to keeping track of every dollar gained and spent, "Those skills are the most important in taking on administrative responsibilities. To be a successful physicist, you have to keep your eye on the ball and readjust your strategy depending on what 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, "but 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 at the wheel of SPA, Kastner is in a new position to potentially help many more early- and mid-career physicists than he ever could have at MIT. The Alliance is 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 help support our basic research enterprise, which is critical to our future."

Alaina G. Levine is president of Quantum Success Solutions, a science career and professional development consulting enterprise. She can be contacted through www.alainalevine.com, or followed on twitter @AlainaGLevine.

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that in a solution of concentrated sucralose, the protein began to fold at much lower temperatures.

"What we think is happening is sucralose [changes] the electronic properties of the molecule," Othon said. "[The protein and the sweetener are] going to interact with each other and create a torque."

The team tested the effects on two common lab proteins, bovine serum albumin and streptococcal nuclease, chosen because of their very different structures. But the effects did not depend on protein's arrangement of amino acids. "This is a generalized mechanism; it's not sequence-specific whatsoever," Othon said.

In addition they found that the sweetener seems to interact with cell membranes. In a different set of tests, the researchers found that the lipids that make up cell membranes thinned out and weakened when exposed to high levels of sucralose. Othon added that the sucralose concentrations they were studying were far in excess of those used in food.

It is not yet clear exactly how these effects of sucralose might impact the overall health of someone who consumes it. Othon said that it would probably have minimal direct effects on a person's body, because little would be absorbed into the bloodstream, but that it might affect the micro-biome of a person's gut bacteria.

"There's not a lot of physical data on its interactions," Othon added. "If you were to look for an effect, you would look for it somewhere in the intestinal tract. … Hopefully we can get some insight into how these gut bacteria might be affected by it."

In another example where damage starts at the molecular level, researchers at Notre Dame discovered the source of the toxicity for a class of substances that is starting to find applications in industry.

Ionic liquids are salts whose molecules form long, poorly coordinated chains, keeping them liquid at room temperatures. Although the subject of much academic interest in recent years, they haven't yet been widely adopted by industry. However, because they resist evaporation at relatively high temperatures, they show much potential as industrial solvents.

Previous studies of their impact on living things have shown that these liquids can be a potential threat to the environment. Even low concentrations of different ionic liquids in water have been shown to kill microorganisms at high rates.

"We have to be very careful about how we treat these new chemicals," said Brian Yoo, a graduate student at the University of Notre Dame. "If we compare ionic liquids with conventional organic solvents, we can see that ionic liquids are much more toxic."

Yoo and his team used computer simulations to discover how ionic liquids kill an organism's cells. "Essentially what happens is ionic liquids insert [themselves] into a cell membrane," Yoo said. The molecules of the liquid penetrate through the outer layers of a cell's membrane, causing it to deform and buckle, destroying its integrity.

"Using our computer simulations we've essentially identified the precursor to toxicity," Yoo explained. "With our experiments we've also seen complete disruption."

His team found also that the molecular structure of different liquids played a role in how toxic they are. Ionic liquids with longer molecular chains seemed to be particularly damaging to the cell membrane.

"The concentrations at which the bilayer gets disrupted are in the millimolar concentrations," Yoo said, referring to the small amounts that can get into the environment. He added that for some liquids with the longest molecular chains, his team saw the effect in even micromolar concentrations.

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.

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ics department. Generally speaking, there are few faculty members present in physics departments with prior experience working in industry (a stark contrast with other STEM disciplines like engineering, which frequently employs faculty with private-sector experience). Furthermore, while many well-meaning physics faculty want to advise their students on how to pursue careers outside of academia, few have industrial colleagues in their professional network to whom they could 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.aps.org/physicspdguide.

The *Guidebook* contains eight chapters that address the essential elements of a successful transition into the industrial workforce. Chapter titles include Career Planning and Self-Assessment, Conducting Informational Interviews, Networking, Writing an Effective Resume, Interviewing and Negotiation, and more. Each chapter not only contains important advice and information, but also links to other resources on the website — such as five-minute "webinette" clips from our top webinars on career preparation, online tutorials, links to employment and salary-statistics information, and more. It really is a "one-stop-shop" for all the resources available on the APS Careers Website for physicists preparing to eventually transition into the industrial workforce.

In addition to the *Professional Guidebook*, the APS Careers website also offers an extensive library of archived webinars on everything from choosing a graduate school, to finding a six-figure salary job in the private sector, to commercializing academic research. We also offer a free product called Physics InSight, which is a downloadable slideshow featuring physicists from a diversity of degree and career paths, and which is suitable for display on LCD screens in common areas around physics departments. You can even add your own slides for a customized show: Visit www.aps.org/careers/insight to download.

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 adequately prepare for those future careers.

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ANNOUNCEMENTS

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 High School Physics Contest (NHSPC) jointly with KSEA in 2012 as a pilot program in the North Texas and North Carolina chapters. NHSPC has reached a milestone, having a total of 108 participants showcasing their physics skills across the nation. Many of them are of non-Korean ethnic origin. Of the 109 participants, 23 (21%) were female students. This total number is a marked increase compared to NHSPC2013, with 52 participating students in 9 locations.

While the NHSPC seems to have taken hold, it still is in the toddler stage, and there is plenty of room for growth. A notable change this year is that 2 of the 14 sites had physicists of non-ethnic Korean origin helping with the organization by proctoring and grading the contest, along with an increased number of non-ethnic Korean participants (22). The physicists were very excited about this contest and are willing to help next year. I truly believe this is an excellent sign that NHSPC can become not just an ethnic Korean event but can evolve into a nationwide event that would allow us to be a leader in this endeavor, working closely with APS.

In 2014, AKPA became an officially registered 501(c)(3) nonprofit organization. This allowed us to raise funds in a much more substantive manner. To leverage this status, a Fundraising and Special event Committee (FSC) was established. FSC took action immediately and established the Kiuck Lee High School Physics Scholarship endowment in 2015, thanks to the generosity of the late professor Lee and his family. This scholarship will be awarded to the top three winners of NHSPC, starting in 2016. FSC also established the AKPA Named Scholarship Policy, which the Executive Committee has subsequently ratified, for future donations.

AKPA and KPS have been working closely together as in the past. This tight cooperation has been exemplified in granting two Outstanding Young Researcher Awards (OYRA) jointly for five years in a row. We were able to invite both OYRA winners this year — Donghui Jeong of Pennsylvania State University and Donghun Lee from the University of California, Santa Barbara — and we presented the award at the FIP reception at the 2015 APS April Meeting. AKPA works closely with FIP and is one of the major contributors to the forum. The two OYRA winners showcased their research at the Korean Physicists Symposium during the 2015 APS March Meeting.

AKPA continues to work very closely with KSEA. Not only did many AKPA members play significant roles in U.S.-Korea Conferences and lead them splendidly, but they also played various roles in many KSEA events. A good example is the KSEA's Professional Development Workshop Event (ProDeW) in 2014 in Chicago. Since many AKPA members play leading roles in the field of physics in the U.S., they can naturally become role models to younger generations.

While there is still a long way to go, AKPA's finances are healthy and becoming more stable. We, the members, have all worked together to bring us this far. Last but not least, I am in tremendous debt to the executive committee and the members of all the committees. They, and indeed all members, have contributed their time and effort to raise AKPA to this level. This shows the underlying strengths of AKPA on which future progress will be built.

AKPA has a new administration as of May 1, 2015, under the leadership of Seunghun Lee of the University of Virginia, the 31st president of AKPA, who will take the organization to the next level with the enthusiastic participation of all AKPA members.

Jaehoon Yu is the 30th president of AKPA and is professor of physics at the University of Texas at Arlington. Yu is a particle physics experimentalist involved in Higgs searches and precision measurements of its properties at the ATLAS experiment at the LHC. He is also working on low mass dark matter search and neutrino experiments at the high intensity proton beams at Fermi National Accelerator Laboratory.

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worked with other students to create a video about research at UAB, the impact on Alabama, and how the research was funded. After posting the video, Matt contacted every state representative along with Congressional representatives and senators to promote the video, which was viewed by over 10,000 people.

Matthew Bobrowsky is the director of special programs at Delaware State University and the author of "Phenomenon-Based Learning: Using Physical Science Gadgets and Gizmos." Matt wrote an op-ed about federal funding of scientific research. He also helped to organize and participate in a visit to Congress to talk about the issues raised in his op-ed.

Rachel Scherr is a senior research scientist at Seattle Pacific University. She crafted an op-ed about women in STEM and promoted the op-ed to media outlets in the Seattle area. Also she took part in penning a faculty letter to Senators Murray and Cantwell on the importance of federal science funding.

Corrections

The article "The Art and Science of Black Holes" (*APS News*, May 2015) misstated the contributions of one of the researchers involved in the simulations of gamma rays generated by mergers of black holes and neutron stars. The text should have read:

> But Shapiro's colleague, Princeton physicist Vasileios Paschalidis, found a way. "All the simulations have assumed that the magnetic field was confined to the interior," says Shapiro. So Paschalidis allowed the magnetic field to extend to the exterior of the doomed star.
>
> In his computer rendition, which he ran with the help of Milton Ruiz of the University of Illinois...

In the same issue, the article "Environmental Physics at the April Meeting" incorrectly quoted Howard Branz. The quotation about solar cell research at Caltech should have read "about 35 percent to nearly 50 percent." And regarding advanced optics research at ARPA-E, "dry cleaning" should have read "dry cooling of power plants."

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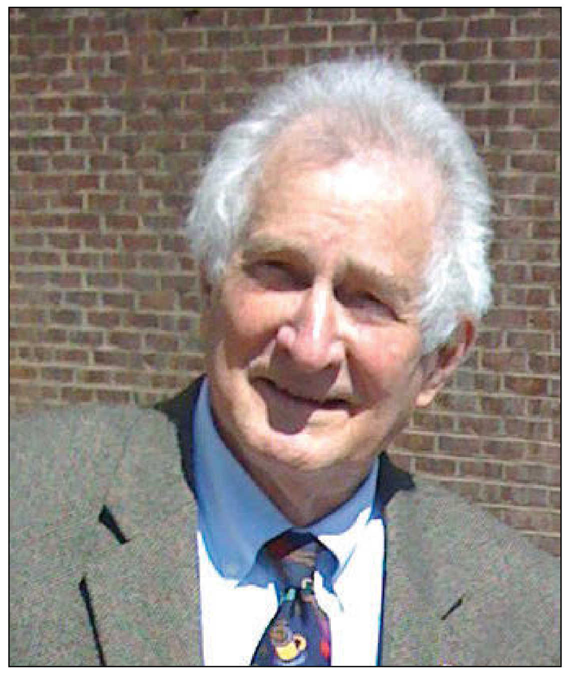
The POPA Energy & Environment Subcommittee is pursuing partnerships with other scientific organizations to study the long-term challenges of helium supply and pricing. A workshop is anticipated in the early fall.

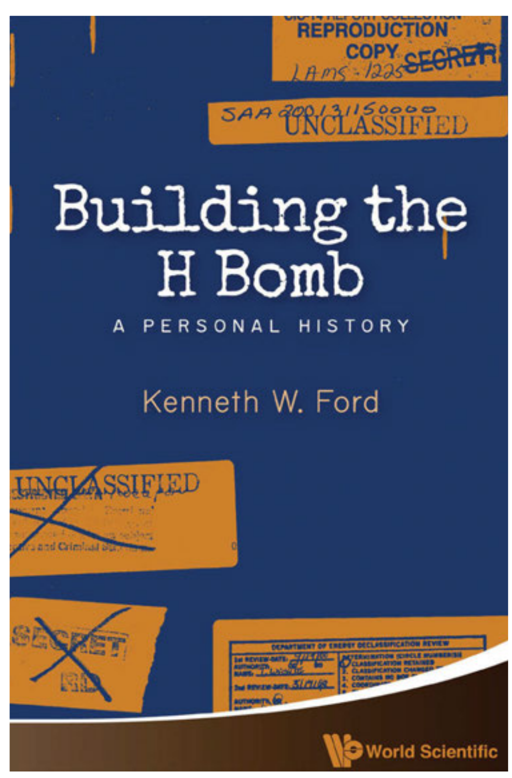
A template for study proposals can be found online, along with a suggestion box for future POPA studies: www.aps.org/policy/reports/popa-reports/suggestions/index.cfm.

The Back Page

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 redacted 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: megatons 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. They both had great curiosity about the physical world. And they were both a bit lazy. 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-weary demeanor. 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 often seemed, 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 to explain 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, at the time it was advanced, didn't shake the Earth under our feet. There were vibrations, but no earthquake. There was a new sense of cheer, but no parties or toasts or flag waving. We didn't take the trouble to analyze, as so many have since, who exactly had what part of the idea and who deserves the greater credit. Years later, Edward said to me (I paraphrase), "Stan had a dozen ideas a day. They were almost all crazy. He himself had no idea which ones were valuable. It took me to pick out of the jumble the one good idea and exploit it." Also years later, Stan said to me (again, I paraphrase), "Edward just couldn't bring himself to admit, after his years of effort, that the idea on how to make the H bomb work was mine. He just had to take it and call it his own."

Alarm Clocks, Layer Cakes, and Supers

The Teller-Ulam idea landed in the midst of numerous other ideas, of varying complexity and varying chance of succeeding. 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 fission fuel); the "alarm clock" (a name Edward Teller and Robert Richtmyer had coined in 1946 for alternating layers of fission and fusion fuel, and which Andrei Sakharov in the Soviet Union, as we later learned, had separately envisioned and separately christened a "layer cake" in 1948); and the "Yule log" (John Wheeler's macabre name for a cylinder of thermonuclear fuel with no limit on its length or on its explosive power). Behind these lay the basic idea that had been around for nearly a decade and on which we were working assiduously at the time. That idea, known as the "Super" (and later as the "classical Super") was simple in concept but maddeningly difficult to model mathematically, so that there was no sure sense of its potential. At the time of the Teller-Ulam idea, however, there were more reasons for pessimism than optimism about the prospects of the classical Super. Calculations kept suggesting that igniting the fuel, even with a powerful fission bomb, and even with a good deal of highly "combustible" tritium mixed in, would not be easy, and that even if it were ignited, it would probably fizzle rather than propagate. A homeowner trying to get a fire started in a fireplace with wet logs and inadequate kindling can relate to the difficulty.

So the Teller-Ulam idea landed in our midst not as "just" another idea—it was special—but also not as a lone idea where there were none already. It was like a new sapling introduced into a nursery, not like a palm tree miraculously delivered into the desert. We thought, "Now there is an idea with merit," and we started exploring its consequences at 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 imploding, 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 "run away from" the 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 it burning. What could change this bleak prospect, 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 1951 and to the new direction in H-bomb design.

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 just exchanging 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, an odd 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 my own recollection that no breakthrough 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 amount of energy 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 to 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 their understanding that ultimately, no matter 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/10.1142/9269*

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 Oersted Medal for contributions to teaching.