the SPS Observer

Volume XLIX, Issue 4

WINTER 2015-16

Navigating FAILURE

AS LONG AS YOU LEARN, YOU CAN'T FAIL

Space is Hard

WHAT TODAY'S SPACEFARERS CAN LEARN FROM NASA'S MISTAKES

Epic Physics Fails

SPS MEMBERS SHARE THEIR MOST EPIC PHYSICS FAILS

the SPS Observer

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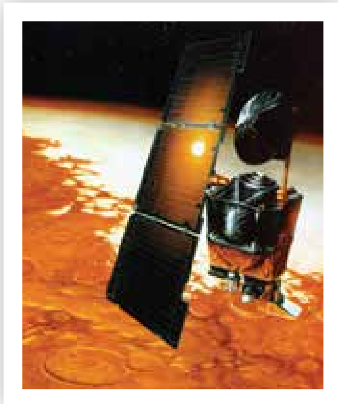

ON THE COVER
The Mars Climate Orbiter disintegrated in the Martian atmosphere because a subcontractor programmed its thrusters in imperial units instead of the metric units NASA was using. See "Space is Hard" on page 19. Image credit: NASA.

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My **Successful Null** Result

AS LONG AS YOU LEARN, YOU CAN'T FAIL

by Sean Bentley
Director, Society of Physics Students and Sigma Pi Sigma

SEAN BENTLEY. Photo by Liz Dart Caron.

Cogito ergo sum. **You may recognize this phrase as "I think, therefore I am." While I won't play philosopher here and examine Descartes' words, I will discuss the importance of doubt and critical thinking in this letter.**

Attacking a problem can be daunting. Whether in a classroom, a laboratory, or the "real world," you often won't find the solution on your first try. That's okay. The more times you don't get the "right" answer, the better your thinking can become. To paraphrase Descartes: "I learn, therefore I succeed."

You have to question what went wrong, analyze the evidence, and draw a conclusion. This process develops critical thinking skills. Additionally, the experience can lead you to new results that are often more interesting than what you were originally trying to find.

I know because I had a seven-year version of such an experience, namely, my entire PhD.

In graduate school I wanted a thesis project involving quantum mechanics and high-power lasers. When I heard a talk about how quantum fluctuations might cause laser beams to break apart, I was hooked. The talk was on the theory—no one had observed the effect experimentally. I went to the professor who led that group and told him I wanted to be the one to do it.

> THE MORE TIMES **you don't get the "right" answer,** THE BETTER YOUR THINKING CAN BECOME.

For the next seven years, I tried. Along the way, I found many interesting results, published several papers, and ultimately wrote my thesis. However, I never observed the effect.

After I defended my thesis, my advisor told me he had never really expected the experiment to work, but he let me do it because he knew it would lead me down many new paths as I tried to overcome the challenges of the project. To him the outcome was as expected. It was not a failure, and I earned my PhD.

I learned much from that experience, most importantly that science isn't the papers, it's the process. Education should not be about simply learning facts, but rather about learning to think. Virtually any known fact can be found via your smartphone in a matter of seconds. Our goal (as humans and physicists) should be to look at the world around us, the problems we face, and be able to think critically and creatively to make things better.

So keep questioning, keep thinking, and don't be discouraged when things don't go as planned. As long as you learn from all that you do, you will never truly fail. //

Accessing My Creativity App

Image by Bea.miau.

A THEORIST'S JOURNEY THROUGH SUPERSYMMETRY

by Sylvester J. Gates, Jr.
Sigma Pi Sigma Honorary Member, John S. Toll Professor of Physics,
University of Maryland in College Park

One hundred years ago, Einstein completed his theory of general relativity. It was a feat of imagination, and, as Einstein himself said, "Imagination is more important than knowledge."

In honor of this anniversary, it is my very great pleasure and honor to share with the SPS family my own thoughts about how imagination can be a source of creativity in physics. As I am only a "simple country theoretical physicist," not a neuropsychologist or psychologist, I can share only my own experiences.

Physics is the only piece of magic I have ever seen in the real world. Its incantations are written in mathematics. People often share with me their creative ideas about issues at the frontiers of theoretical physics, ideas that often challenge Einstein's. The problem with most of those proposals is that their authors do not recognize the importance of having an appropriate mathematical perspective. Even Einstein first obtained a PhD before he dazzled the world with his deep insights about nature.

As a mathematical physicist, I spent my younger years building that foundation. It allowed me to use what I call my "creativity app," the capacity for creativity that lies within all of our minds. I have focused mine on the subject of supersymmetry. It has long been my hope to discover a piece of magical mathematics in this area.

BOOTING UP THE APP

One early indication of my creativity occurred when I was four years old and living on a US military facility, named Pepperrell, near St. John's, Newfoundland in Canada. My family went to see a science fiction film, "Spaceways." That evening, according to family lore, I attempted to explain how rockets worked to my dad! As a child I loved to draw rockets, ships, and airplanes, of my own imaginative designs. These sketches included cut-away views showing what their interiors were like.

On March 27, 1962, my mother died. This was, of course, an enormous, almost overwhelming tragedy for a child to face. Driven by this to a large extent, I retreated throughout my teenage years into the world of my imagination, of science fiction and comic books. My favorite superheroes included scientists such as Reed Richards of the Fantastic Four. These figures inspired me.

In the fall of 1967, I took my first physics class. For years I had been using my imagination to build worlds within my head. In this class I saw how mathematics allowed people to build tiny portions of the real world within their heads. That astounded me.

In my first year at MIT, I learned calculus. I had always been good at math, but it was calculus that made me pointedly aware of my creativity app. My experience showed me a portion of my subconscious capable of interacting with my conscious rational mind to produce solutions to mathematical problems. This may sound mystical, but I am sure it is what is meant by the idea of a "muse" in other areas of human creativity.

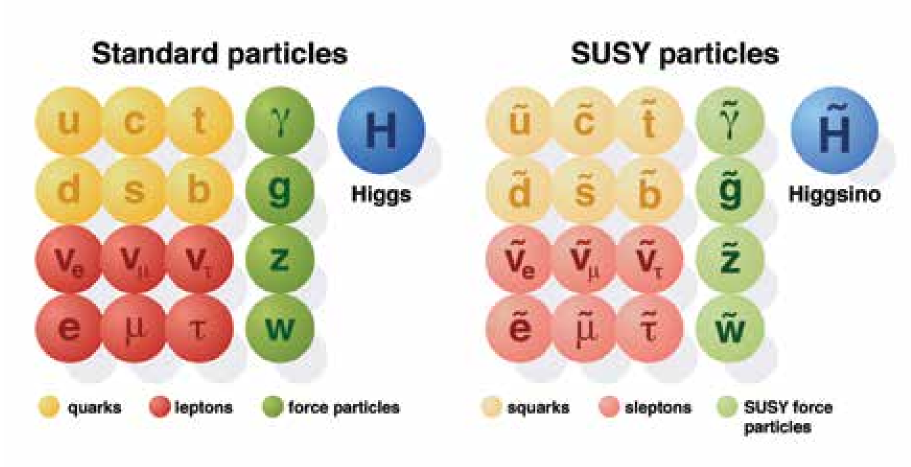
LISTENING FOR CAT PAW'S FOOTFALLS IN THE MIST

Once one has experienced one's creativity app, being able to notice subtle discord becomes important. This was clearly

Einstein's great ability. Anyone who had studied Newton's classical physics and Maxwell's equations could have spotted the tiny incompatibility between the two with regard to their implications about the behavior of space and time. It took the genius of Einstein to fully realize the significance of this incompatibility. It also took his commitment to transcend what he likely would have said was "traditional thinking" and today we call "conventional wisdom." One must make an absolute commitment to avoid being swept along by the crowd and be willing to take the chance to tread mathematical pathways others avoid.

As I mentioned before, I have long hoped to discover a piece of magical mathematics related to supersymmetry (SUSY). I hoped it would accurately describe something buried deep in nature. SUSY is not a single model any more than Newton's second law is a rule that applies solely to falling apples. Instead, SUSY is a framework for many models breaking the rule that all matter particles are fermions and all carriers are bosons. It relates each standard model particle to a new form of matter and energy called a "superpartner."

With many different sets of equations that incorporate supersymmetry, how do we pick the right ones? In the last decade of my work, it seems possible I may well have found a way forward. A group of my colleagues and I have been studying "adinkras," a term we borrowed from West Africa that originally referred to visual symbols used to represent concepts. For us, an adinkra is a graphical representation reminiscent of genomic structures that precisely encode the mathematical relations between the members of supersymmetry families. It could help us to ensure that the SUSY property is made manifest at every stage of calculations involving the quantum behavior of these equations.



PARTICLES KNOWN TO THE STANDARD MODEL OF PARTICLE PHYSICS (left) and predicted by supersymmetry (right). Image by CERN / CMS Collaboration.

While a composer's work is judged by the nature of the audience, a theoretical physicist must be judged by the audience of nature. As revealed by experiments and observations, nature is the final arbiter.

Particle colliders have found no evidence yet in favor of SUSY. But such searches can strive only to observe the predictions of models. Even under many reasonable assumptions, numerous such models remain possible. Ruling out one or a few does not exclude a far greater multitude of others.

Even at the age of 65, I do not know if I have succeeded in my personal quest to understand the subject of supersymmetry at its deepest levels. But such strange possibilities, arising from my apparently still functioning creativity app, excite me. They make the experience of being a theoretical physicist a great joy for me. //

SYLVESTER J. GATES, JR. is a University of Maryland physics professor who was awarded a National Science Foundation medal for his work in string theory. He's also a member of the Maryland State Board of Education. He is pictured outside the physics building at The University of Maryland in College Park. Photo by Sarah L. Voisin / *The Washington Post* via Getty Images.

Spring Award Deadlines

SPS Award for Outstanding Undergraduate Research

Given to one or more SPS members annually, awards $500 honorarium for winner and $500 for the SPS chapter. Pays expenses for winner to attend and present a paper at the annual International Association of Physics Students (IAPS), which is usually held in Europe. Formerly known as the Outstanding Student Award for Undergraduate Research.

Applications due March 15

SPS Outstanding Chapter Advisor Award

The Outstanding SPS Chapter Advisor Award is the most prestigious SPS award. It recognizes annually an outstanding SPS chapter advisor. A truly successful SPS chapter requires leadership, organization, a broad spectrum of activities, and enthusiastic student participation. An outstanding chapter advisor provides the stimulus for such success.

Applications due April 15

Blake Lilly Prize

The Blake Lilly Prize, named after the late Blake Lilly and given in his honor, recognizes SPS chapters and individuals who make a genuine effort to positively influence the attitudes of school children and the general public about physics. For example, many chapters perform something like a "Physics Circus," conduct classroom demonstrations, offer tutoring services for grades K-12, or assist with school science fairs. The Blake Lilly Prize is an opportunity to be publicly recognized for these types of physics outreach efforts.

Proposals due April 15

SPS Outstanding Chapter Award

SPS Outstanding Chapter Awards are determined each academic year after a careful review of the information, photos, and supporting material presented in the annual chapter reports. The reviewers include a team of four SPS National Council members, including zone councilors and associate zone councilors, as well as the SPS office staff. chapter reports are due by June 15th each year. Please see the chapter report rubric for a better idea of the review process.

Applications due June 15

For more information and application procedures, visit www.spsnational.org/awards.

SPS Outstanding Chapter Advisor Named for 2014–15

Dr. Kiril Streletzky, or "Dr. S" as he is known by his students, has a reputation at Cleveland State University (CSU) for being "rigorous and fascinating" in the classroom. An associate professor of physics, Streletzky is currently serving as the zone 7 councilor on the SPS National Council. He received his BS from the Moscow Institute of Physics and Technology and his PhD from Worcester Polytechnic Institute.

He has invested endless time, energy, and passion into helping CSU physics students build an effective SPS chapter. His constant challenge to physics students to excel, coupled with his flexibility and compassion, has been key in helping undergraduates develop as leaders in the department and in the community. For his tireless support of student professional development both in and out of the classroom and in a research lab, Dr. Kiril Streletzky was named the 2014–15 SPS Outstanding Chapter Advisor. //

For more information (and a full list of chapter advisors nominated for the award), visit www.spsnational.org/awards/outstanding-chapter-advisor.

KIRIL STRELETZKY (center) is pictured with Sigma Pi Sigma president Willie Rockward (right) and SPS Director Sean Bentley (left). Photo by Courtney Lemon.

Sound Reasons

SHOUTING INTO THE WIND

by Donald Simanek
Emeritus Professor of Physics, Lock Haven University of Pennsylvania

01 Those who spend time outdoors have likely noticed that sounds can be heard at greater distances downwind from their source. And "shouting into the wind" is an idiom for futile attempts to communicate. Why does the wind affect how far away one can hear sounds?

02 Under some weather conditions distant sounds, even on a windless day, seem to be heard at greater distances. When I was a child I remember standing waiting for the school bus at the end of a long country lane in Iowa. On a cold, sunny morning after a fresh winter snow, distant sounds of dogs barking, and other farm animal sounds, could be clearly heard that wouldn't be heard as well on a summer day. You may have had a similar experience in a city, where the sound of passing traffic is louder early in the morning than in the evening (even if the number of cars remains the same). Why is this?

These days one can find answers to such questions on the Internet. But I hope you wouldn't think of looking there before you puzzle them out yourself. In this case, many of the answers on the Internet are simply wrong, but correct treatments can be found with a bit of effort.

Ready for the answers? Turn to page 10.

A SNOWY LANDSCAPE IN IOWA. Photo by Jsayre64.

ANSWERS

01 Wrong answers often say something like this: "The sound downwind travels faster than upwind, so it travels farther downwind." This confuses speed and intensity. It doesn't matter how quickly a sound reaches the listener, but how intense it is when it is heard.

But air speed does play a role. Wind speed is slower near the ground, due to viscous drag. Therefore the downwind wave fronts are refracted, and sound that would normally travel upward at an angle is refracted back downward toward the earth, increasing the sound intensity heard there. Sound traveling upwind is refracted upward, away from the ground.

02 The temperature of air near the ground is mostly affected by the ground temperature, not by direct heating from the sun. The ground heats (and cools) the air near it. Normally the ground is warmer than the air above, so air temperature decreases with height in the troposphere (up to about 8 miles). Sound travels faster in warmer air, so the sound waves are refracted upward, away from the ground.

Various atmospheric conditions can cause a temperature inversion, with air temperature increasing with height. This causes some of the sound energy from a source near the ground to be refracted back toward the ground. Sounds are then heard at greater distances across a landscape. This is most likely in the dawn hours, more so in the winter (when the ground is cold) than in the summer.

Other conditions can affect sound propagation near the earth. Over short distances smooth water surfaces and snow- or ice-covered surfaces can reflect sound back upward. Rough surfaces and vegetation would absorb that sound. But for the large distances implied in this puzzle, the sound energy reaching the nearby ground wouldn't have reached the listener anyway. In some cases sound can be reflected upward at a shallow angle from reflective surfaces, and then refracted downward again, reinforcing the sound at greater distances.

A good treatment can be found at Handbook for Acoustic Ecology, Barry Truax, editor (www.sfu.ca/sonic-studio/handbook/Sound_Propagation.html). Another informative website, with animations, is Acoustics and Vibration Animations (www.acs.psu.edu/drussell/Demos/refract/refract.html), by Dr. Daniel A. Russell, Graduate Program in Acoustics, The Pennsylvania State University. Also, see chapter 30, "Noise in the Environment," in *The Science of Sound*, 2nd edition, by Thomas D. Rossing (Addison Wesley, Reading, MA, 1990).

The illustrations are from chapter 10, "Outdoor Sound Propagation," in *Noise Control* by John Lamancusa, used here by permission. //

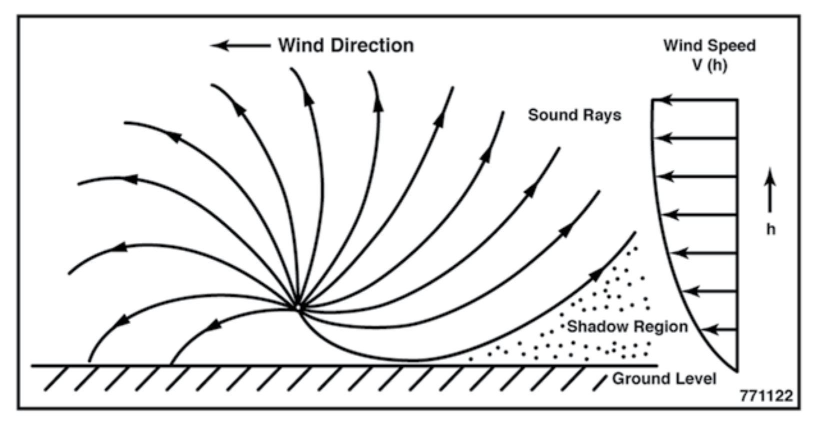


Image by John Lamancusa.

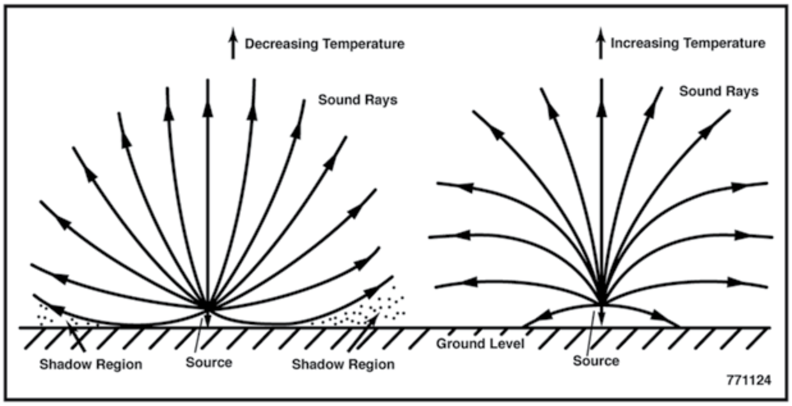


Image by John Lamancusa.

STUDENTS PARTICIPATE IN STEM ACTIVITIES AT THE

Hispanic Engineering, Science, and Technology Week

at the University of Texas Rio Grande Valley.

PHOTOS COURTESY OF JENNILEE GARZA.

SPOOKY EXPERIMENTS AT THE

Indiana University—Purdue University Fort Wayne's **Halloween Science Show.**

PHOTOS COURTESY OF MARK MASTERS.

3M Super Science Saturday

by Dylan Miller[1] and Earl Blodgett[2]

Since 2008 the University of Wisconsin–River Falls (UWRF) SPS chapter has been participating in the 3M Super Science Saturday, a program for children whose relatives work at the company.

Groups such as the Minnesota Herpetological Society and the 3M Visiting Wizards participated and showed off their outreach activities. We had an SPS booth with four hands-on activities! We brought our department's very fancy infrared camera to show people what they look like in the infrared and demonstrated how to measure temperatures from a distance. A big flat-screen display made this visually appealing.

We also gave away UWRF Physics Rainbow glasses, and had a great time showing everyone what bright light reflected off a soap bubble looks like when viewed through a diffraction grating. We had Bristlebot kits that let children mount a pager vibrator on a toothbrush head and watch it scoot around! Finally, we had our ever-popular angular momentum demos with a weighted bicycle wheel and a spinning platform. Some kids really understood how to describe rotation as "spin up" or "spin down" instead of counterclockwise or clockwise. //

1. SPS Chapter President, Class of 2016, University of Wisconsin–River Falls
2. SPS Chapter Advisor, Professor of Physics, University of Wisconsin–River Falls

STANDING IN FOREGROUND, Talen Rabe shines a 150-watt bulb down onto soap bubbles. When viewed thru our diffraction grating (rainbow) glasses, the light is like a swarm of Disney pixies! Photos courtesy of Marium Asif.

KATHLEEN MILLER-CHELL and Tye Williams coach a young man in how to use the spinning wheel on the platform to experience angular momentum.

Heresy at a Science Café

by Todd Baum,[1] Matthew Taber,[2] and Shannon Clardy[3]

We recently presented our first science café at Henderson State University (HSU), an idea that came from another chapter at the nearby University of Central Arkansas. Free and open to the public, the event included a dinner of freshly grilled burgers served with a side of discourse. We invited speakers we hoped would interest the community and paid for the event through the regular fundraising activities that our chapter holds.

Our primary purpose in holding these events is to engage faculty, staff, students, and the overall community in scientific discussion on topics meant to generate discussion, ranging from how religion and science impact one another to antibiotic use and resistance. The topic for our first event was "What is a Heretic? Religion, Music, Science, and Authority."

Our speakers, all HSU professors, included Dr. Megan Hickerson, an expert in the Protestant Reformation who has an active interest in the histories of heresy, persecution, and the early modern witch craze; Dr. David Evans, a former clarinetist in the United States Military Academy Band at West Point who teaches music history and directs the bachelor program in general studies; and Dr. Jules Mollere, who researches general relativity but also has interests in space science and teaches introductory astronomy.

MEGAN HICKERSON speaks about heresy, flanked by David Evans (left) and Jules Mollere (right). Photo by Dillan McNiel.

At the café we talked about what was happening socially and politically in Europe between the 14th and 17th centuries. Religion, music, and science were all interconnected in that time period. A discussion with the audience touched on the means by which information was disseminated with the printing press and similarities to the advent of the Internet. We also talked about the ways in which scientific knowledge is spread and how, sometimes, bad science lingers because of the ease of spreading information.

We were extremely pleased with the turnout at our first café, which drew an audience of approximately 20. We hope to collaborate with the biology and chemistry clubs in our school to present science cafés regularly. //

1. SPS Chapter President, Class of 2016, Henderson State University in Arkadelphia, AR
2. SPS Chapter Vice President, Class of 2016, Henderson State University in Arkadelphia, AR
3. SPS Chapter Advisor, Associate Professor of Physics, Henderson State University in Arkadelphia, AR

Dragon Fire, a Theoretical Study

by Wataru Hashimoto
SPS Chapter President, Class of 2016, Northern Illinois University in Dekalb

"Can a dragon melt a castle with its fire?" That was one of the questions Rebecca Thompson from the American Physical Society tried to answer at our recent event, The Physics of *Game of Thrones*. She observed dragon fire in the show and estimated its temperature based on its color (just as astrophysicists figure out that a blue-colored star is hotter than a red-colored star). Then, she assumed that the material the castle is made of is probably graphite, which has a melting point of a few thousand degrees. Her calculations showed that a red flame would be hot enough to do the job.

As a physicist, I had another question: "How does a dragon contain fire in its mouth that is capable of melting the stone?"

"Sometimes, I don't like to say this," she said, "but it's MAGIC!" It was not possible to explain everything using physics, since the story is fiction. But it was fun to try to understand some of its phenomena—this, after all, is what we physics majors do in the real world. //

Photo by JT Occhialini.

FEATURE

Navigating FAILURE

THE MARS CLIMATE ORBITER DISINTEGRATED in the Martian atmosphere because a subcontractor programmed its thrusters in imperial units instead of the metric units NASA was using. See "Space is Hard" on page 19. Image credit: NASA.

Life in physics doesn't always go smoothly. Mistakes can be mortifying, like the time you accidentally melted that expensive piece of equipment and set your lab bench on fire. They can be hilarious, like the time you accidentally emailed that video of you singing Justin Bieber songs to your professor.

This issue of *The SPS Observer* explores three high-profile projects that failed and what those failures meant for the communities involved.

We start with the story of superconductivity, as told by condensed-matter physicist Jörg Schmalian. This phenomenon stumped the biggest names in physics for years, proving that some problems are inherently hard.

Then John Logsdon will explore the factors that led to the Columbia shuttle disaster; he sat on the board that investigated it. Both projects offer lessons in the human factors that can cause big projects to fail.

We next move on to the tale of the never-fished Superconducting Supercollider by Michael Riordan, who has recently written a book on the subject.

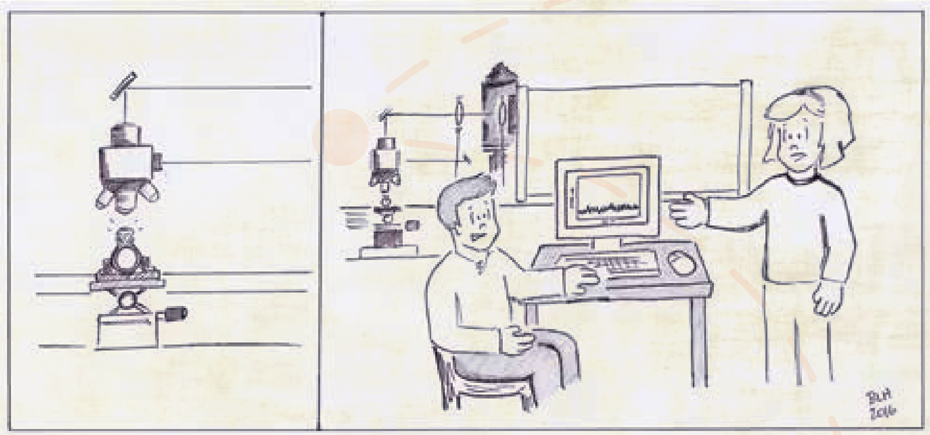
Finally, we asked you, the SPS community: "What's your most epic physics fail?" You wrote in via email and social media with your stories, serious and funny. We picked a selection of them to feature here. Enjoy! //

Epic Physics FAILS

When putting a banana in liquid nitrogen, be careful not to drop it. It might shatter and sort of explode into many smaller banana pieces, which after a few days may give the lab a fruity-tooty smell. Also, when dropping a basketball off the roof of the physics building, spinning the ball can lead to the ball hitting a car that you did not count on.

CHARLES BELL, H47 VICKSBURG (RETIRED)

We use natural diamond as a calibration material for Raman spectroscopy in our laser lab. The gem we use is small but very high quality—optically speaking—so it can be entertaining to compare with other diamonds to see how they stand up. At the time, one of my lab mates had

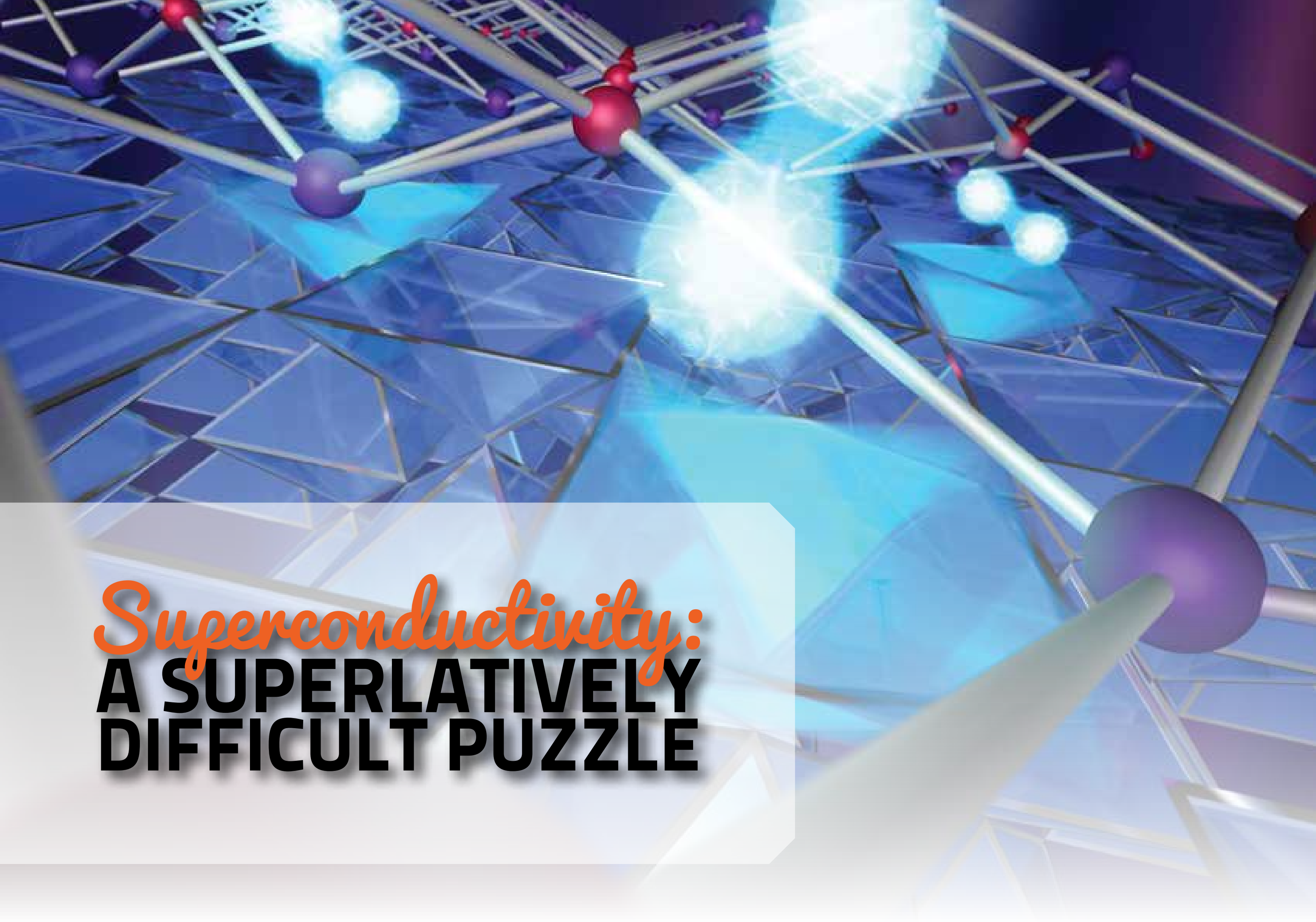


recently gotten married, and our advisor asked if she wanted to give her new shiny ring a test, just for kicks. She agreed it would be fun, so we (carefully) mounted it into the sample stage. The lab was left in a bit of an awkward state when what should have been a very prominent (or at least noticeable) diamond Raman peak on the screen was nothing but flat noise. A few days later we learned there was an alignment issue which had caused the problem and successfully tested her ring again, but nonetheless, I think it was a rather stressful week for her husband.

ANONYMOUS

While doing demos for a fair at our school, we got bored with the conservation of momentum demo we were doing (rotating platform with an individual holding a spinning bike wheel to turn), so we inverted a bike and peddled it to get our hand-held wheel spinning quickly and have a bit of fun. A guy in a tank top came over and asked if he could try. We were reluctant about letting him but told him to turn the wheel slowly. He thought he was strong and didn't listen. He turned it too fast, lost control, and it tore some skin off of his forearm.

JOHN FERRIER, UNIVERSITY OF CENTRAL ARKANSAS



Superconductivity: A SUPERLATIVELY DIFFICULT PUZZLE

HOW THE BRIGHTEST MINDS IN PHYSICS FAILED TO EXPLAIN A NEW STATE OF MATTER

by Jörg Schmalian
Professor of Physics, Karlsruhe Institute of Technology in Germany

PLACING A SINGLE ATOMIC LAYER of iron selenide (balls and sticks) on top of a material called STO (triangles) significantly raises the temperature at which it superconduct. Image by SLAC National Accelerator Laboratory.

In 1911 the Dutch physicist Heike Kamerlingh Onnes discovered that the resistivity of mercury suddenly drops to immeasurably small values below 4.2 Kelvin. He called this new state of matter superconductivity.

During the 48 years between this discovery and the first quantum theory of superconductivity, numerous scientists tried and failed to understand the phenomenon, among them the brightest minds in theoretical physics of the 20th century. Albert Einstein, Niels Bohr, Werner Heisenberg, Max Born, Lev D. Landau, and many others all wrote down highly interesting yet incorrect theories of superconductivity.

Einstein proposed in 1922 that superconductivity is a consequence of the motion of electrons in the valence shell of chemical bonds; he made a falsifiable prediction. It was Kamerlingh Onnes himself who disproved that theory.

Niels Bohr and Ralph Kronig had elegant theories involving electrons that crystallize and then coherently move as an organized electron-solid, a proposal that preceded

> AS LONG AS WE ARE WILLING **to admit them, mistakes and failures** ARE A NATURAL AND HEALTHY PART OF THE SCIENTIFIC DISCOURSE.

What is >> SUPERCONDUCTIVITY? <<

Superconductivity occurs in many metals at low temperatures. It exists in organic conductors and copper oxide–based ceramics at temperatures up to 130 Kelvin. It has recently been observed at high pressure in a compound made up of hydrogen and sulfur at temperatures as high as 200 Kelvin, i.e., above "room temperature" in Antarctica. Superconductors are promising building blocks for future quantum computers and have made their way into hospitals, where they are responsible for the large magnetic fields needed in magnetic resonance imaging. As a macroscopic quantum phenomenon, superconductivity has fascinated and captivated physicists more than any other condensed state of matter.

Epic Physics FAILS

Our department and SPS members were giving a demonstration of sunlight and solar energy to some grade school kids in the courtyard. The first demonstration was a 50-foot black thermal tube that heated up when in the sun and floated. We had it tied down so it wouldn't fly away. The other demonstration was a Fresnel lens that focused a square meter of sunlight to a single point that reached about 2800 F. We were roasting hotdogs and marshmallows with the Fresnel lens when the wind kicked up and snapped the line on the thermal tube. It flew right into the "danger zone" of the Fresnel lens. Thankfully it didn't catch fire, but our thermal tube is now a melted mess, beyond repair.

MICHAEL DOWDING, SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY

the actual theory of electron crystals by Eugene Wigner.

Felix Bloch and Landau proposed that electrons in a superconductor enter a state with spontaneous currents. That theory was shown to be incorrect by Bloch himself, who jokingly formulated a theorem stating that every theory of superconductivity can be disproved. Landau's theory did lead to the correct phenomenology of superconductivity, which he formulated with Vitaly Ginzburg. In addition, energy expansions of the type first used by Landau in his incorrect work are at the heart of every phenomenology of phase transitions, the Higgs mechanism in particle physics, and the theory of the inflationary expansion of the universe.

In 1957 the microscopic theory of superconductivity that holds today was finally formulated by John Bardeen, Leon N. Cooper, and J. Robert Schrieffer at the University of Illinois at Urbana-Champaign. BCS theory—named for Bardeen, Cooper, and Schrieffer—is among the most outstanding intellectual achievements in theoretical physics. It demonstrated that interactions between ions and electrons lead to bound states made up of two electrons, called Cooper pairs. The thermodynamic and electrodynamic properties that follow from the formation of these pairs are in excellent agreement with experiment. Cooper pairing is now believed to occur in all known superconductors, even if for many systems the mechanism for pairing, i.e., the pairing glue, continues to be hotly debated.

Superconductivity was obviously a tough problem. Given that the nature of magnetism was essentially understood as soon as quantum mechanics was formulated by Heisenberg and Schrödinger in 1927, it is amazing that it took another 30 years for the superconductivity puzzle to be resolved. Clearly, even the most beautiful theories emerge in ways that are much less direct than how they are taught in the classroom. A wrong theory can be interesting, inspiring, and may turn out to be useful in another setting. As long as we are willing to admit them, mistakes and failures are a natural and healthy part of the scientific discourse. //

A MAGNET LEVITATES above a piece of superconductor cooled to -196°C. Photo by Julien Bobroff, Frederic Bouquet, Jeffrey Quilliam, LPS, Orsay, France.

Space IS HARD

THE CREW of the space shuttle Columbia. Image credit: NASA.

WHAT TODAY'S SPACEFARERS CAN LEARN FROM NASA'S MISTAKES

by John M. Logsdon
Professor Emeritus, George Washington University's Space Policy Institute in Washington, DC

On February 1, 2003, the Space Shuttle orbiter Columbia tore itself apart as it reentered Earth's atmosphere; all seven crew members aboard were thrown out of the vehicle at very high speed. There was no chance they could survive.

The physical cause of Columbia's disintegration was superheated air entering a hole in the orbiter's left wing. That blast of scorching air melted the wing's aluminum structure, causing the wing to fail and sending Columbia violently out of control. The breach in the wing had occurred 16 days earlier, as Columbia launched. A suitcase-sized piece of insulating foam came off of the external fuel tank and impacted the wing's leading edge. Although the insulating material had the density of only a Styrofoam container, it hit the wing at a velocity of 525 miles per hour, resulting in enough force to rupture the wing's reinforced carbon-carbon thermal protection material.

This proximate cause of the Columbia accident was determined by the 13-member Columbia Accident Investigation Board (CAIB). I was a member of that board. Our August 2003 report, available at http://www.nasa.gov/columbia/home/CAIB_Vol1.html, goes into great detail with respect to all aspects of the accident.

Early on in its investigation, CAIB recognized that the specific technical cause of Columbia's breakup was embedded in a complex mixture of organizational history and management mistakes. As in the 1986 Challenger accident that also killed seven astronauts, a combination of human errors created the conditions under which a catastrophic accident could occur. With Challenger, the human failure was to not heed warnings that launching when the local temperature was significantly colder than during any prior launch could cause rubber seals in the Shuttle's solid rocket boosters to harden and fail.

With Columbia, the human failure was the belief developed over the preceding 112 Shuttle missions that "the foam could not hurt you." Those managing the Columbia mission were aware of the foam impact during the first seconds of the mission. But since there had been foam shedding on many previous missions without causing a problem, they concluded that it was not a safety-of-flight issue and thus made no effort to determine whether the impact had caused any damage. Others at NASA's Johnson Space Center were very concerned about the life-threatening possibility of foam-caused damage; their concern was discounted by mission managers.

The CAIB report concluded that during the history of the Space Shuttle program prior to the Columbia accident, "organizational practices detrimental to safety were allowed to develop." These included "reliance on past success as a substitute for sound engineering practices," including extensive testing, and "organizational barriers that prevented effective communication of critical safety information and stifled professional differences of opinion."

Reacting to this indictment, NASA, after returning the Shuttle to flight in 2005, intensified its efforts to operate the vehicle safely and to change the organizational culture that had led to the accident. The 22 Shuttle flights between 2005 and the system's retirement from service in 2011 proceeded without major incident.

Still, again in the words of the CAIB report, "attempting to manage high-risk technologies while minimizing failures is an extraordinary challenge. . . The risk of these complex systems is increased when they are produced and operated by complex organizations."

These admonitions are well worth keeping in mind as the United States prepares in the next few years to resume launching NASA astronauts and others on US systems operated this time around by private firms providing space transportation services on a commercial basis. There is no a priori reason that this arrangement will be any more prone to human mistakes and organizational failures than was the government-operated Space Shuttle program. But the technological and management challenges of developing and safely operating launch vehicles and crew-carrying spacecraft remain, even if the emerging systems are less complex than was the Space Shuttle. This means that continuing vigilance by both private and public authorities will be a requirement for safety.

> "ORGANIZATIONAL practices detrimental TO SAFETY WERE ALLOWED TO DEVELOP."

It is a cliché to observe that "space is hard." But that cliché is also accurate. We are still far away from the day, if it ever comes, of routine space travel. Avoiding future space accidents will for some time remain an "extraordinary challenge." //

Epic Physics FAILS

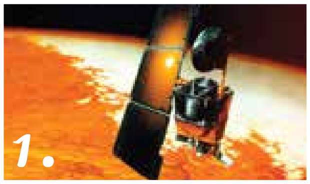
I once had a glass jar filled with near-boiling salt water, which I was using to do corrosion experiments, suddenly shatter. It got about a gallon of hot salt water everywhere and even horribly rusted the heating pad the jar was resting on.

CHARLES BELL, H47 VICKSBURG (RETIRED)

My lab partner and I spent 30 minutes trying to debug our senior research presentation, until we finally realized that it wasn't working because the equipment wasn't plugged in. Another time, when I was working in a team as a postdoc, we thought we had discovered supersymmetry. It turned out to be a reconstruction bug in the software.

LEE SAWYER, LOUISIANA TECH UNIVERSITY

>> *Space* SNAFUS <<



1. Instead of surveying the Red Planet, the Mars Climate Orbiter disintegrated in the Martian atmosphere because NASA subcontractor Lockheed Martin programmed its thrusters in imperial units instead of the metric units NASA was using. Credit: NASA.

2. The disintegration of SpaceX's Falcon 9, on a 2015 mission to resupply the International Space Station, tarnished a company with an otherwise perfect record. Credit: NASA.

3. Failures that plagued the first Russian space station program, Salyut, racked up the equivalent of hundreds of millions of dollars in losses. Credit: Don S. Montgomery, USN (Ret.).

4. South Korea's first rocket, the Naro, failed to reach orbit twice, in 2009 and 2010, before completing its first successful mission in 2013. Credit: Deuterium 001.

The Life of the LHC AND THE DEATH OF THE SSC

A COMPARISON OF TWO HIGH-ENERGY PHYSICS GIGAPROJECTS

by Michael Riordan

AN UNDERGROUND TUNNEL dug for the planned SSC. Courtesy of Fermilab Archives.

In October 1993 the US Congress canceled the Superconducting Super Collider, or SSC. The government had spent $2 billion on this massive project, then the largest basic-science project ever attempted. With a tunnel over 50 miles in circumference located south of Dallas, Texas, the massive proton collider was designed and promoted to reestablish American leadership in high-energy physics by discovering the long-sought Higgs boson.[1]

In retrospect, the Large Hadron Collider (LHC), built from 1997 to 2008 at the CERN laboratory near Geneva, Switzerland, was more appropriately sized to discover this particle, evidence of a field that imbues other elementary particles with mass. When the SSC was proposed in the mid-1980s, the likelihood of finding this particle at a mass as low as 125 GeV was not very well appreciated.[2] Only in the late 1980s did theories involving supersymmetry begin to suggest that such a low-mass Higgs boson might occur.[3] But by then the SSC die had been cast—in favor of a gargantuan 40 TeV (40 trillion electronvolt) collider that would be sure to discover this elusive quarry, or whatever other mass-generating mechanism nature might prefer.[4]

Thus there is much to be learned about how to pursue big science projects by investigating why the SSC failed and the LHC succeeded.

For one, big science projects require strong leadership and project management. The LHC encountered its own set of serious difficulties. Physicist Lyndon Evans guided the project throughout its construction, even as costs of the collider components and additional tunneling increased from 2.8 to over 4.3 billion Swiss francs (not including costs of labor or the tunnel, which already existed). The CERN directorate never lost faith in Evans and his team. In stark contrast, the SSC project witnessed a succession of four project managers before

John Rees, an accelerator physicist from the Stanford Linear Accelerator Center, began to bring the unwieldy project under control in January 1992. But Congress lost patience and killed the project 21 months later, after the SSC's estimated cost surpassed $10 billion.

Despite belated efforts to internationalize it, the SSC was largely a US national project, and major foreign contributions were consequently hard to obtain. This was not such a problem with the LHC, which was billed as an international project from the outset. In the mid-1990s, its CERN advocates lined up funds from Canada, China, India, Israel, Japan, Russia, and the United States before the project received official approval in 1996. That permitted Evans to proceed with a full-scale design aimed at reaching proton collision energies up to 14 TeV.

Another factor in the LHC's success was CERN's governing body or Council, which insulated the project from external political machinations. This kept project control directly in the hands of the physicists, who best understood its scientific goals. Control of the SSC construction was essentially ceded by the physicists to engineering managers from US defense contractors, who treated the huge project more like building an aircraft carrier than establishing a world-class laboratory for high-energy physics.

The CERN Council also allowed other European scientists to have a say in the LHC project. Science ministers from various member nations could hold off on giving approval until its impact on their national science budgets was acceptable. In the United States, there was no way for other scientists—for example, condensed-matter physicists—to have any such say in the impact of the SSC project on their research fields, except to complain publicly before Congress and in opinion pieces published in major newspapers and magazines.

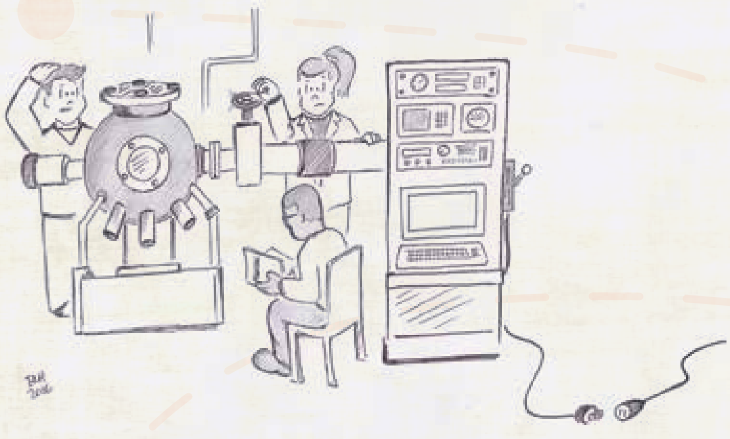
A MAP SHOWING THE PLANNED PATH of the SSC's particle accelerators and tunnels, including the main ring circling Waxahachie. US Department of Energy.

SSC advocates in the Department of Energy and the US high-energy physics community greatly underestimated the difficulties—both managerial and political—of establishing a new scientific laboratory and a multibillion-dollar collider in Texas. By contrast, CERN had been gradually building one machine after another as extensions of its physical infrastructure, realizing the substantial cost savings of recycling old projects into new ones. By reusing an existing 27 km tunnel, LHC builders could concentrate attention on solving the problems of developing the high-field superconducting magnets that had so vexed the struggling SSC project and added to its burgeoning costs.

WEEDS GROW AT THE ABANDONED SITE meant for the Superconducting Supercollider. Photo courtesy of Ich weiß es nicht at the English Wikipedia project.

This conservative approach also meant that, unlike the SSC project, CERN did not have to assemble a new human infrastructure of physicists, engineers, designers, technicians, and other personnel. It turned to the laboratory's well-oiled team of some of the most experienced machine builders in the world. They recognized each other's expertise and worked steadfastly toward a common physics goal, laying the groundwork for the celebrated Higgs boson discovery in 2012. //

1. For details, see M. Riordan, L. Hoddeson, and A. W. Kolb, *Tunnel Visions: The Rise and Fall of the Superconducting Super Collider* (Chicago: University of Chicago Press, 2015).
2. This is equivalent to the mass of a cesium atom, as 1 GeV is equal to 0.938 proton mass, according to Einstein's famous equation $E = mc^2$.
3. By the end of the 1990s, the Fermilab discovery of the top quark with a mass near 175 GeV, when employed in fits to precision measurements of other particle physics parameters, suggested that such a light Higgs boson should occur, with a mass less than 200 GeV. That realization came well after the SSC had been terminated but before the LHC detector designs were completed and their construction had begun.
4. According to Einstein's $E = mc^2$, 1 TeV is approximately 1,065 proton masses, or about the total mass of five bismuth atoms.



One day in my vacuum lab, my setup wasn't working. After I tried to fix it for over 20 minutes, my professor and TA came over to help. After 45 minutes, we were all baffled by why it wasn't working like it had the previous week. We started going over our list of possible problems and realized we never checked if it was plugged in. It wasn't.

CHARLES BELL, H47 VICKSBURG (RETIRED)

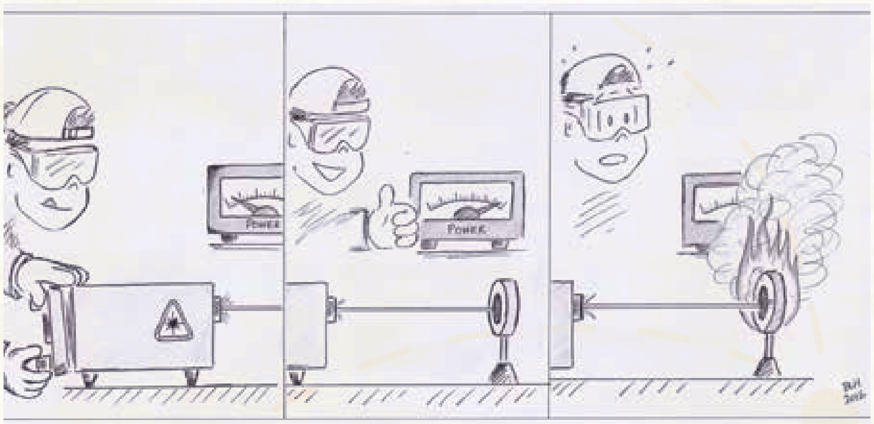
Epic Physics FAILS

CARTOONS BY BOBBY LOGAN HANCOCK

When I was working for the Vitreous State Lab at Catholic University, we were trying to turn nuclear waste into glass. My portion of the experiment was to dissolve the vitrified waste samples in a solvent consisting of boiling hydrochloric, hydrofluoric, sulfuric, and nitric acid. While my solution was cooking in the microwave, it exploded for some unknown reason. I don't work there anymore. These days I make computer models.

MICHAEL FOLKS, GROUP W

I had a side project in my lab of trying to fix a misaligned laser. I wasn't getting the output power we needed, so a professor told me to turn up the input power. It worked, but a little too well! The beam drifted off of the power sensor and onto the sensor's plastic casing,



where it started smoldering, smoking, and melting. Having to tell my advisor I accidentally built a death ray was a little bit awkward.

CELESTE LABEDZ, UNIVERSITY OF NEBRASKA–LINCOLN

I work in a particle physics lab. Once we stress tested our laser diode detection system by seeing how it functions at different temperatures. Unfortunately, instead of increasing the temperature of the diode at 1-degree intervals, a bug in our code decided to skip straight from 29 to 300 degrees Celsius. We thought this readout was spurious, but we soon realized that our laser had been reduced to a several-thousand-dollar paperweight. Obtaining another laser was a bureaucratic ordeal. We learned that lab supplies are replaceable, but our drive for creative inquiry is not.

DANIEL POLIN, NEW YORK UNIVERSITY

Prepping for Congress

REFLECTIONS ON GETTING READY FOR THE BIG EVENT

by DJ Wagner
President, SPS National
SPS Chapter Advisor, Professor of Physics, Grove City College in Pennsylvania

OUR CHAPTER at the 2012 PhysCon. Photo by Glenn Marsch.

My first experience with the Sigma Pi Sigma Quadrennial Physics Congress (also known as PhysCon) was in 2004. I mistakenly believed that only Sigma Pi Sigma members could attend and that each chapter could send only a single representative. I attended with only one student from my chapter. When I arrived in Albuquerque, I found that the conference was open to anyone. Several chapters had attended en masse.

As I realized how amazing the conference was, I thought, "I am bringing a busload of students to the next one!" So I did. Twenty-five students and two other faculty members joined me at Fermilab in 2008. Thirty-three students and the same three faculty members came to Orlando in 2012. Our SPS chapter is currently making plans to fly about 30 students across the country to San Francisco next fall.

I strongly encourage everyone reading this article to do your best to attend what I think is the most awesome conference ever!

WHY PHYSCON IS AWESOME

Sigma Pi Sigma Quadrennial Congresses are awesome on so many levels. The high-profile speakers are phenomenal and deliver engaging presentations tailored to undergraduate physics majors. They also interact with students one-on-one; at the 2012 Congress in Orlando, I frequently saw Freeman Dyson, Jocelyn Bell Burnell, and John Mather chatting informally with students. Recent PhysCons featured exciting tours. In 2004 I visited the site of the first nuclear bomb test with a group including Worth Seagondollar, who worked on the Manhattan Project. Wow! In 2008 we could pick a detector or lab to visit at Fermilab. At the 2012 Congress we took a bus trip through the Kennedy Space Center, with NASA employees as our guides. I'm not sure how to pick between the awesome trips planned for 2016!

Attendees also get to participate in engaging discussions and activities at workshops. At past congresses, I've helped shape ethics-related recommendations for Sigma Pi Sigma, discussed what should and should not be included in the teaching of science, considered what I would do (and should do) in situations where stereotyping might occur, and explored my civic responsibility as a scientist.

PhysCon is amazing. I haven't even mentioned the breakfast with scientists, art contest, grad school expo, and poster sessions!

HOW TO PREPARE FOR PHYSCON

It is not too late for some good fundraising and advertising. Start immediately!

In our chapter, we cobble together funds from many sources to pay for the trip to PhysCon. Our best student fundraiser is "Rent-a-Student." SPSers volunteer to do odd jobs in exchange for a donation. (We ask $25 for ~3 hours of work.) Typically we rake leaves, but we have tutored, painted, cleaned, designed web pages, moved a piano, chopped firewood, and dug up rocks. Our patrons (faculty, friends, members of the community) appreciate our help as well as our thank-you notes.

We also partnered with a local restaurant to have "Physics Club" days. If a customer presents a card that we have distributed (by stuffing faculty and staff mailboxes on campus), the restaurant gives us a portion of that customer's bill. Several national chains do this, so ask around in your area.

REBECCA CREMA describes her research at the 2008 PhysCon at Fermilab. Photo by author.

Our students approach research and internship supervisors about funding, since students present their research at the congress. One company where a student was interning made a significant donation that helped fund the trips of several students! We have also received reporter awards from the SPS National Office, and college funding. Our department contributes, as does a campus student research fund. I have heard of other chapters getting funds from student government, the college president, etc. The key is to ask, ask, ask, and ask folks who else you should ask. Finally, we have sent letters out to alumni (with the blessing and support of the alumni office) and approached the development office about possible donors. Our 2012 alumni letter prompted a response from the first president of our physics club, describing the department in 1960 and telling us how the club originated. A copy of the letter still hangs on our bulletin board.

Be creative in your efforts to keep costs down. Since Fermilab was driveable for us, we hired a school bus from a local church for a fraction of the cost of a charter bus. The all-night drive back wasn't cushy, but it really kept our costs down. Group airline tickets can save money and provide flexibility. (You can change the name on tickets up until shortly before the flight.)

OUR GROUP from Grove City College poses outside Wilson Hall at the 2008 PhysCon at Fermilab. Photo courtesy of the author.

THE CHARITY BUS that carried us to and from the Orlando airport cost half the price of a commercial bus. Photo by author.

I've shared some ideas that have worked for our chapter. But every PhysCon and every SPS chapter is different, so choose and tailor approaches that work for your chapter. The 2016 Congress website has more ideas: www.sigmapisigma.org/congress/2016. Be creative, develop multiple funding and cost-savings sources, and start now. //

FOUR STUDENTS (from left to right: Seth Byard, Dan Seiter, Connor Murphy, and Mercedes Mansfield) help professor Michael Coulter (on the saw) sort and prepare wood for his furnace as part of our Rent-a-Student campaign in 2015. Photo by author.

MORE INFORMATION

Read more about fundraising and planning for the 2016 Quadrennial Physics Congress here:

"Come to Congress,"
***The SPS Observer*, Summer 2015**
www.spsnational.org/the-sps-observer/summer/2015/come-congress

"SPS Chapters Get Creative with Fundraising,"
***Radiations*, Fall 2013**
www.sigmapisigma.org/sigmapisigma/radiations/fall/2013/sps-chapters-get-creative-fundraising

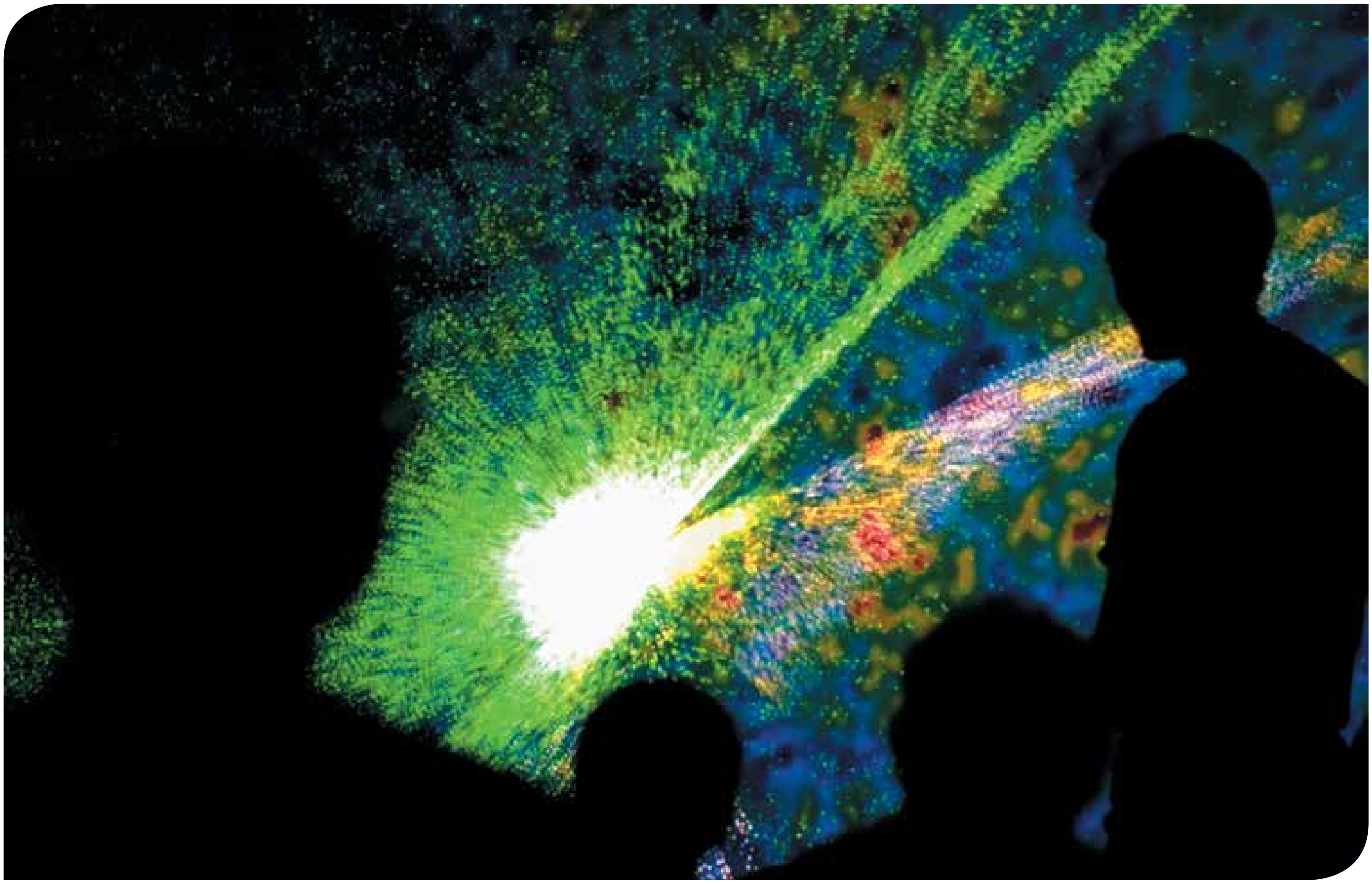


Image courtesy of SLAC National Accelerator Laboratory, a confirmed tour site at PhysCon 2016.

Unifying Fields

Science Driving Innovation

1 Join us in Silicon Valley

Spend a packed weekend making new connections, interacting with scientists, faculty, and distinguished speakers, debating common concerns for the physics community and society, and visiting iconic scientific venues. **Save the date—November 3–5**. Anyone interested in physics is invited to attend.

2 Request a PhysCon Fundraising Kit

Ready to ramp up your SPS chapter's fundraising efforts? This kit contains best practices, case studies, and a variety of goodies to facilitate your efforts and track your progress. Limited supply—chapters must commit to bringing a minimum of three students to PhysCon 2016 to be eligible. See website for details.

physcon

2016 Quadrennial Physics Congress

www.sigmapisigma.org/congress/2016

November 3–5, 2016 • Silicon Valley

AIP American Institute of Physics

Hosted by Sigma Pi Sigma, the physics honor society

Come to Congress! A SNEAK PEEK AT PHYSCON

by Josh Willis
Associate Professor of Physics & Engineering, Abilene Christian University in Texas

TICHNOR BROTHERS, Publisher.

With the 2016 Quadrennial Physics Congress (PhysCon) less than a year away, your planning committee has been working hard to get things ready. You should also start planning now for your trip to San Francisco from November 3–5, 2016. We can't wait to meet you in Silicon Valley!

We've already had a sneak peek at some of the tour sites. Tying into this year's theme, "Unifying Fields: Science Driving Innovation," attendees will choose between a visit to the SLAC National Accelerator Lab, NASA Ames Research Center, or Google's secretive lab X.

Congress itself will feature a slate of talks that continue its tradition of diverse and influential speakers. Confirmed speakers include astrophysicist Jocelyn Bell Burnell, Nobel laureate Eric Cornell, Stanford dean of engineering Persis Drell, and physicist S. James Gates.

Attendees and their peers from across the country will also learn-by-doing in workshops such as "PR for Physicists," "Taking Your Chapter to the Next Level," "Building Up the Community," and "Careers for Physicists." You will be able to question expert panels in "Physicists in the World" and "Life as a Graduate Student." Closing out the 2016 Congress will be a workshop focused on action: specifically, what SPSers will bring away from PhysCon to their local chapters and individual careers.

Students can also attend the "Breakfast with the Scientists" and meet in small groups with physicists who have taken many career paths. Friday night will feature a dance party, and an art contest will showcase the bridge between physics and the visual arts.

Keep an eye on *The SPS Observer* for more information about fundraising ideas, announcements about additional exciting speakers, and when and how to register. Talk to your chapter leaders about your chapter's plans, or become a leader and help develop those plans.

See you in San Francisco! //

Zone 7 Meeting

OHIO, MICHIGAN, WEST VIRGINIA, WESTERN PENNSYLVANIA

by Ilona Tsuper
Class of 2017 / 2018, Cleveland State University in Ohio

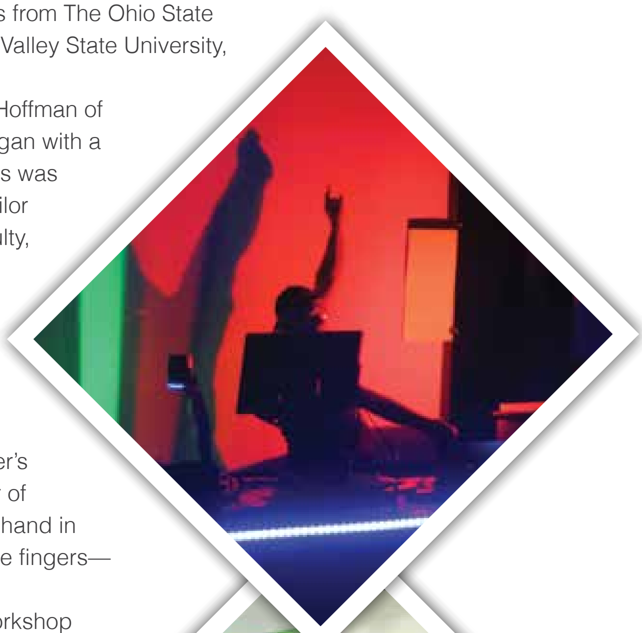
Our SPS chapter was honored to host the 2015 zone 7 meeting for the first time in October. The event launched with a poster session and banquet held with the Ohio-Region section of the American Physical Society (OSAPS). It ended with pizza and physics games, including Fermi problems like estimating the number of drops in Lake Erie.

It was quite an experience! We welcomed chapters from The Ohio State University, Grove City College, Ohio Wesleyan, Grand Valley State University, John Carroll University, and Hiram College.

After a talk about the physics of life from Dr. Peter Hoffman of Wayne State University on the first day, the second began with a complimentary breakfast. Then a round of introductions was made by SPS president DJ Wagner and zone 7 councilor Kiril Streletzky. The interaction between students, faculty, and SPS members facilitated a truly unique dynamic.

Dr. Stanley Micklavzina from the University of Oregon put on a highly anticipated demonstration called the Physics of Rock-n-Roll. He created a concertlike atmosphere to explore music, acoustics, and instruments, all in the name of physics. Another demonstration was CSU professor Jearl Walker's famous Flying Circus of Physics. The renowned author of the textbook *Fundamentals of Physics* submerged his hand in molten lead and astonishingly, walked away with all five fingers—unharmed and intact.

Other activities included an AIP Career Toolbox Workshop presented by SPS director and Sigma Pi Sigma director Sean Bentley, a tour of the physics department, a roundtable with CSU physics alumni, and an improvised Rubens' tube guitar performance. //



ABOVE: Attendees at our zone meeting.
TOP RIGHT: Stanley Micklavzina turns up the volume with the Physics of Rock-n-Roll. Photo courtesy of Kiril Streletzky.
MIDDLE RIGHT: Chapter vice president Dan Terrano (far left) and meeting ambassador Ilona Tsuper (far right) present their research poster to a group of CSU alumni and former SPS officers (from left to right: Jim Pitchford, Phil Dee, and Hannah Dee). Photo courtesy of DJ Wagner.
BOTTOM RIGHT: Jearl Walker's Flying Circus of Physics drew a crowd. Photo courtesy of Kiril Streletzky.

Zone 12 Meeting

OKLAHOMA, KANSAS, AND MISSOURI

by Maranda Clymer and Elizabeth Apala
SPS Chapter Co-Treasurers, Class of 2018 & 2017,
East Central University in Ada, OK

The zone 12 meeting kicked off this year with a tour of General Aviation Modifications, Inc. We were taken to a hangar and shown different jet models from the last four decades. We were also shown a workshop where the company improves plane engines by making fuel injectors that then go to labs to be tested.

Then we traveled to the x-ray diffraction lab of cement manufacturer Holcim and learned how to check for the perfect cement using x-ray diffraction. Diffraction lets you know whether rocks gathered from dig sites have too little or too much of a certain material, such as calcium, helping cement makers to add in other materials to get the proportions right.

It was a great privilege to host this event in October. Students from across Oklahoma (East Central University and Mid-America Christian University), Missouri (William Jewell College), and Kansas (Pittsburg University) came for a weekend of physics fun.

ATTENDEES at the zone 12 meeting gather for a group photo.

Once the tours were done, we met for pizza and learned about each other's goals after graduation. Dr. Rahmat Rahmat told us about his path working for Apple and being part of CERN's team that discovered the Higgs boson. Josh Fausset, manager of renewable energy at Oklahoma Gas & Electric, talked about wind turbines and a newly opened solar farm that should withstand the tennis ball-sized hail that Oklahoma gets. They tested the solar panels by firing baseballs at them at 55 mph.

Other fun activities included games of laser tag and a discussion about the upcoming Sigma Pi Sigma Congress. Students presented their research and competed for the prize of best YouTube demo and best live demo. The winners received $25. The zone meeting ended with a ceremony inducting new Sigma Pi Sigma members. It felt great being there to share in the accomplishments of fellow SPS members. //

See https://www.spsnational.org/meetings/meeting-notes/zone-12-meeting for more information.

Zone 5 Meeting

THE CAROLINAS

by Ryan Kozlowski
SPS Chapter President, Zone 5 Associate Zone Councilor, Class of 2016,
Davidson College in North Carolina

One of the highlights of the 2015 zone 5 meeting in October was the Great T-Shirt Giveaway. Dr. John Hubisz of North Carolina State had collected more than 75 physics-themed T-shirts over the years. He decided to give them away at our meeting. Lucky students received one or two T-shirts of their choosing.

The meeting was held at Davidson College in conjunction with the fall meeting of the North Carolina section of the American Association of Physics Teachers. Thirty undergraduates from institutions across the state—Wingate University, UNC Asheville, UNC Charlotte, Catawba Valley Community College, and Davidson College—attended the meeting. Ten presented research posters.

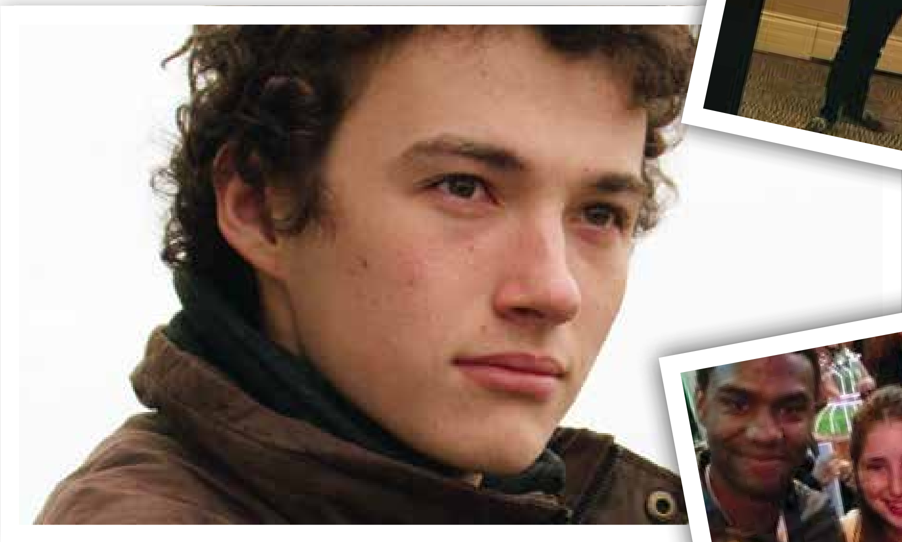
After returning from a hearty lunch, students convened in the basement of the physics building to hear three guest speakers: Davidson physics alumni Evan Welchman, Jessie Barrick, and Grace Watt. The guests first spoke about their undergraduate experiences as physics majors, emphasizing how the problem-solving skills acquired as young physicists carried over into post-undergraduate lives in academia and beyond. The floor was then opened for students to ask the panel questions. Topics ranged from undergraduate stressors (How well did the students perform on the physics GRE? What resources did they consult in searching for graduate programs?) to the pragmatic (Have the students in the PhD programs been able to sustain relationships? Was undergraduate research experience worth it?). The event was a success for younger students and upperclassmen alike. //

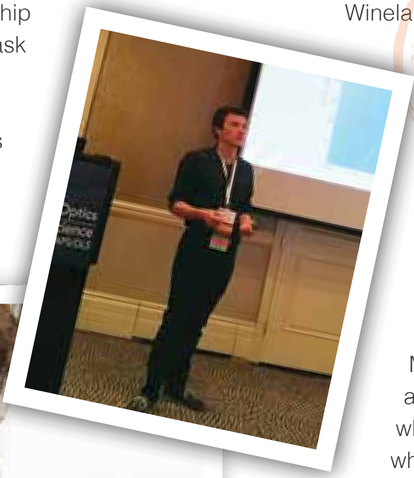
T-SHIRTS given away by John Hubisz at our meeting. Photo courtesy of author.

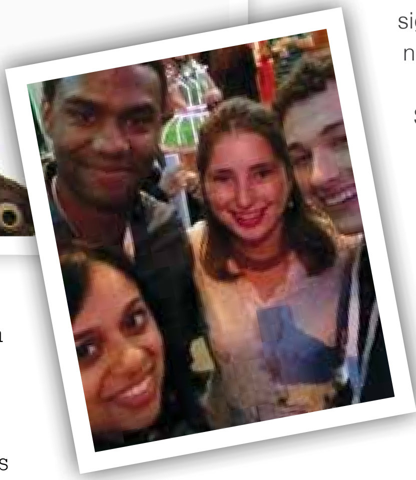
On the Shoulders of Giants

FRONTIERS IN OPTICS/DIVISION OF LASER SCIENCE ANNUAL MEETING, OCTOBER 18–22, 2015, IN SAN JOSE, CA

by Steven Torrisi
Class of 2016, University of Rochester in New York







ABOVE: Steven Torrisi. Photo by Todd Kelmar.
TOP RIGHT: SPS reporter Steven Torrisi presenting his research at the Undergraduate Symposium. Photo by Ananya Sitaram.
BOTTOM RIGHT: From left to right: Ananya Sitaram, Cedric Wilson, and Julia Kent. Ananya and Julia are optics students at the University of Rochester with the author. Cedric is a physics undergraduate at the University of Utah, who did an REU in the author's lab at Rochester. Photo by Steven Torrisi.

The late Charles Townes was a towering figure in science, winning the Nobel Prize in 1964 for inventing the laser and the maser. He mentored dozens of students who went on to make seminal contributions to their fields. It seemed fitting to begin Frontiers in Optics, the annual meeting of The Optical Society focused on cutting-edge research in optical science, with a symposium celebrating his life. Former students lined up on stage to share stories that were funny, touching, and inspiring.

Sitting in the audience, I realized that I, too, had felt the impact of Townes in a much broader way: Lasers have played a key role in each of the research experiences I've been a part of, from atomic physics, to nuclear fusion, to cancer treatment. I decided to celebrate mentorship in my own way and ask some of the people at the conference to share their memories about mentors who had an influence on them.

Chris Monroe, professor at the University of Maryland, is working on building modular quantum computers using a one-dimensional array of trapped ions. Asked about mentors in his life who were particularly influential, he cited David Wineland and his doctoral advisor, Carl Wieman (Nobel laureates of 2012 and 2001, respectively). Monroe said that Wineland "always had a sense for good problems to go after." Wineland and company, in heroic efforts to make the best atomic clocks possible in the 1970s, developed the tools to make the first quantum logic gates in the 1990s. Speaking about Wieman, Monroe explained he had a remarkable intuition about what was important and what was not in experimental data; Wieman could "point at patterns and say 'Why is that there?' and figure out if it was a signal or not, and if it was just noise, if it mattered or not."

SPS national director Sean Bentley also shared a few words with me. He explained that there is a growing level of support for students and mentorship in the physics community. "Good students don't just arrive at graduate school out of nowhere," Bentley said. "You have to train them from the undergraduate level on."

I have been extremely fortunate to benefit from the assistance of many people along the way. In the words of Isaac Newton: "If I have seen farther than others, it is only by standing on the shoulders of giants." My experience at Frontiers in Optics cemented my desire to pay it forward. //

An Experience Catered to Undergraduates

2015 FALL MEETING OF THE AMERICAN PHYSICAL SOCIETY DIVISION OF NUCLEAR PHYSICS, OCTOBER 28–31, 2015, IN SANTA FE, NM

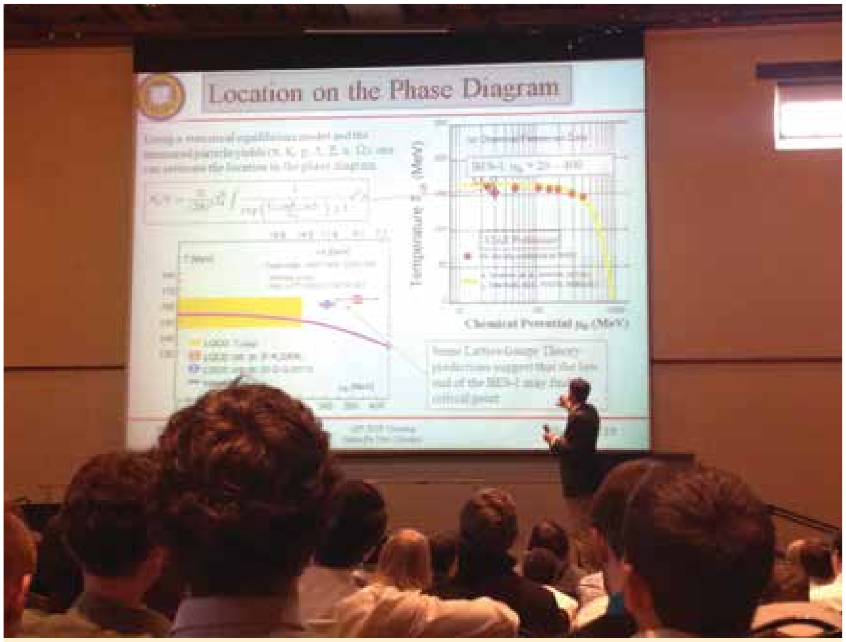
by Hannah Hamilton
Class of 2017, Abilene Christian University in Texas

The first session I attended at the American Physical Society's Division of Nuclear Physics meeting was "The Future of Nuclear Physics I." It started with a talk by Donald Geesaman of Argonne National Laboratory, who presented the long-range plan of the Nuclear Science Advisory Committee. It was reassuring to hear a timeline suggesting that nuclear physics will continue to be a rich field of study throughout my future doctoral work.

I owe my conference experience to the careful planning of Warren Rogers of Westmont College, who each year arranges the Conference Experience for Undergraduates (CEU). The CEU hosted about 150 undergraduates, mostly juniors and seniors, who have conducted research in nuclear physics. It includes a poster session in which undergraduates share their research with nuclear physicists already established in the field. That poster session was my primary motivation and the enabling factor for attending this conference.

Seeing how receptive nuclear physicists are to undergraduates and how interested they are in our research was great. Meeting other undergraduates and learning about their work was also worthwhile.

The CEU provided a great networking opportunity, including an ice cream social that allowed us to meet other like-minded students in a nonacademic environment.



DR. DANIEL CEBRA of the University of California, Davis, gives a CEU talk. Author photo.

It also provided talks catered to the physics knowledge of undergraduates. One such talk, "Exploring the Phase Diagram of QCD," was given by Dr. Daniel Cebra of the University of California at Davis. I found his talk particularly interesting because of how closely tied it was to research I had participated in over the summer. Much of his talk consisted of research at the STAR detector, located at the Relativistic Heavy Ion Collider at Brookhaven National Lab. My research concerned the PHENIX detector at the same collider. The subject matter, as well as his enthusiasm, made for quite an enjoyable talk.

We were also able to attend a fair that exhibited around a dozen physics graduate schools. It was beneficial to talk to faculty and students from the schools, as we were able to hear firsthand what being a physics graduate student entails. In fact, I got to visit with an alumnus from my college who continued his studies at one of the represented graduate schools. //

A Delegate for US Physics

THE INTERNATIONAL CONFERENCE OF PHYSICS STUDENTS, AUGUST 12–19, 2015, IN ZAGREB, CROATIA

by Ariel Matalon, Class of 2016, University of Chicago in Illinois

The International Conference of Physics Students (ICPS) is the largest annual event organized by the International Association of Physics Students (IAPS). It began in 1986 in Budapest, Hungary; the 2015 edition was held in Zagreb, Croatia. I had the opportunity to attend thanks to the SPS Award for Outstanding Undergraduate Research.

ICPS is much more than a conference. It's about the people you meet and ideas you share. I arrived early for "delegate days," a series of workshops and discussions between delegates of different countries. These activities encapsulated the overall goals of the conference to promote international collaboration, exchange ideas, share research, and increase physics outreach worldwide. I represented the USA National Committee: I presented on SPS activities and heard about events organized elsewhere. Workshops prioritized IAPS' goals and improvements. I was actively involved in redesigning the structure of the IAPS Executive Committee.

In all, more than 300 students attended from over 30 countries. As languages blended, there was an energy that continued throughout the opening ceremony during remarks by the organizing committee and the presidents of IAPS and the European Physical Society.

Every day included lectures by distinguished speakers, student presentations, and fun activities. We toured the city and Plitvice Lakes National Park. We visited astrophysics lab facilities. I was impressed at the level of research demonstrated by the other students. I spent many mornings discussing research methods with colleagues and discovering topics with which I wasn't familiar.

I presented my research on the development of a prototype fluorescence detector for ultrahigh-energy cosmic rays. It was wonderful to see how many students were interested.

Every evening there was time for celebration, but the physics never ended. I enjoyed my conversations with colleagues and continued travels in Croatia after the conference, visiting sites such as the Nikola Tesla Memorial. It was an absolute honor to attend ICPS 2015, and I thank SPS for its support. //

ABOVE: A photo of Zagreb Cathedral taken during the ICPS city tour.
TOP RIGHT: The ICPS Delegate Day Workshop.
BOTTOM RIGHT: Ariel Matalon. Photos courtesy of Ariel Matalon.

Beers, Bees, and Becoming a Better Scientist

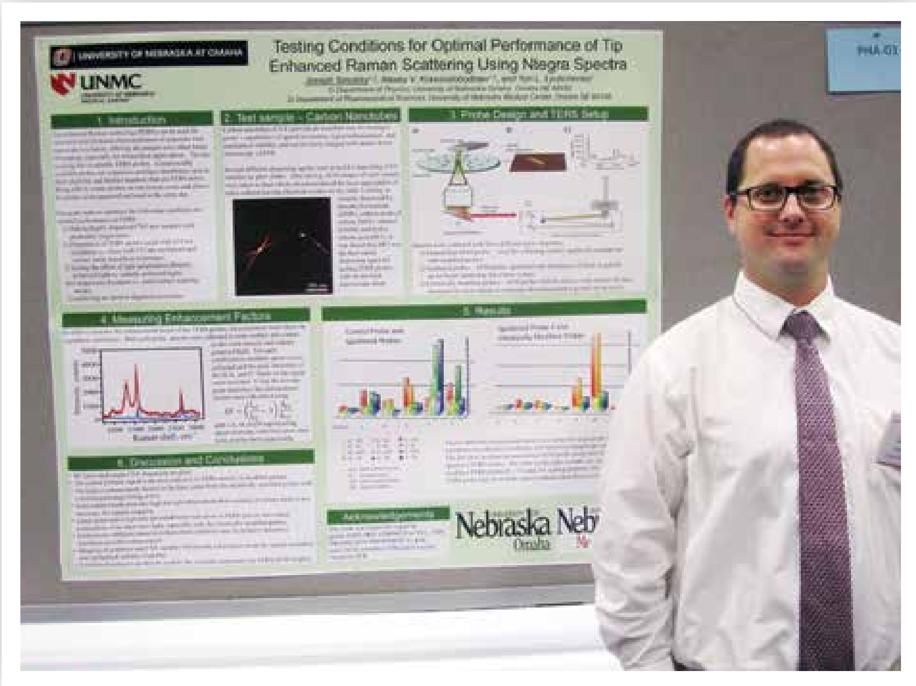
SIGMA XI ANNUAL MEETING AND STUDENT RESEARCH CONFERENCE, OCTOBER 22–25, 2015, IN KANSAS CITY, MO

by Joseph Smolsky
Class of 2017, University of Nebraska at Omaha

Sigma Xi is an international scientific research community that welcomes researchers from all disciplines of science and engineering. When I heard they were having a national meeting with a student research conference, I decided to present some work I had done over the summer. It turned out to be a really fun trip.

The first night, I joined some Sigma Xi members at a "Science Behind the Beer" event at a local brewery near the hotel, where we learned about brewing beer. It was a great way to get things started.

The next morning was the student research conference. Most of the posters were presented by undergraduates, with a few high schoolers, graduate students, and professionals. I was one of only five students presenting research in physics. Our topics covered ultracold atoms, tetraquark decay, graphene films, spin gapless semiconductors, and tip-enhanced Raman scattering. We were joined by presenters from 10 other categories of research. The diverse and friendly crowd made this a great place to get some experience presenting research.



SPS REPORTER JOSEPH SMOLSKY is pictured with his research poster. Photo by Simeon Gilbert.

Among the professional poster presenters was Dr. Philip Baringer of Kansas University. His research is part of the Compact Muon Solenoid experiment at CERN's Large Hadron Collider. The group at Kansas is involved in data analysis as well as the design, programming, and testing of a new detector. Dr. Baringer provided me with some valuable insight into this branch of physics.

After the student research conference, there were several informative events. First up was a talk by entomologist Dr. May Berenbaum entitled "Beenomics: Can Science Save the Honey Bee?" She discussed how colony collapse is putting honey bee populations in danger. Individuals can help by planting pollen- and nectar-producing flowers at home. Following the bee talk, I attended workshops on grant writing and the peer review process. Next up was headliner Dr. David Williams with "Seeing Through the Retina." Dr. Williams discussed adaptive optics, a technique used by astronomers that his group is applying to the human eye, and the progress it is leading to in vision correction.

This was a fantastic experience. I learned about presenting research and met some great people. I encourage anyone who hasn't looked into Sigma Xi to do so. It is an amazing community involved in a wide variety of scientific research across the globe. //

What Does It Mean to Be a Physicist?

by Kimmy Cushman, Class of 2017, SUNY Oneonta in New York

THE CMS COLLABORATION gathers for a group shot. Photo by CERN / CMS Collaboration.

Cushman wrote to The SPS Observer *to tell us all about the impact an international conference recently had on her. If you have thoughts to share about your undergraduate experience, write to us at feedback@sps.org!*

Being a physicist means questioning the world around us and not settling until we can explain every phenomenon. However, this is not done in isolation, because that's not how the universe works. Just as the burning of a star, the origin of the Moon, and the tides of the oceans are interconnected, we scientists must connect and collaborate to progress in finding the answers.

Physics collaborations tend to be international affairs. Experts from around the world come together to create a physics research community that shares advances and brainstorms new solutions to common difficulties.

An undergraduate who plays his or her cards right can integrate into that research community sooner than one may expect by getting involved in student research.

This summer I completed my first research project, as intern at the University of Notre Dame in Indiana. Not only did I work among students who were as passionate about physics as I am, but I collaborated with top researchers in nuclear physics. The fruits of my labor were more than I could have dreamed.

Support from a community network can provide so many opportunities for an undergraduate. Thanks to mine, I just returned from the 8th European Summer School on Experimental Nuclear Astrophysics in Sicily, Italy. I spent a week in a community of influential researchers, as well as graduate students and postdocs. I participated in group discussions and small, friendly debates. I even gave my first presentation at a research conference.

The international nature of the conference allowed me to see physics from a new perspective. Although we all come from different backgrounds, we all work toward understanding the same universe. That thought gave me new motivation to study, do research, and help solve the problems we are all working on.

The conference I attended in Italy may end up being the most influential factor in determining exactly where I go in my career. I am now considering taking my graduate education further abroad using the connections I have made around the world. Never did I think my career would be taking me halfway around the globe.

Is it unbelievable? No, it is my Oneonta life! //

the SPS Observer
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Share Your SPS Activities!

Annual reports due June 15

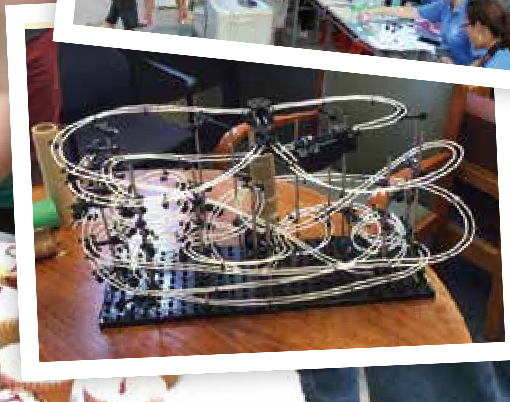
From doing research to spreading the wonders of physics, local chapters are the heart of SPS activities. Submitting an annual chapter report is the prime opportunity to showcase the activities of your chapter, and preparing the report can play an important role in your chapter activities. How?

- Reflecting on the year's events and preparing a report is important for the health, success, and growth of your chapter. By looking back on your year, you will remember accomplishments to celebrate and traditions to keep for next year, and may also see areas for improvement.

- Providing up-to-date chapter information ensures that your chapter will receive materials and communication from the SPS National Office next year.

- Showcasing your events and accomplishments enables your chapter to be nationally recognized for its great work! Chapters that submit an annual report by June 15, 2016, will be considered for the SPS Outstanding Chapter Award. Your chapter activities may also be featured in one of the SPS publications or on the SPS website.

For details on submitting an annual report, see www.spsnational.org/resources/chapters/annual-chapter-reports. We look forward to hearing from you!



PHOTOS ARE FROM 2014-15 SPS CHAPTER REPORTS.

Background: SPS'ers at Union University baked 314 + 1 for the decimal Pi cupcakes and distributed them to the campus community.

Top to bottom: University of Oregon in Eugene SPS partnered with a local chapter of The Optical Society (OSA) for an outreach event at a Title I school inspired by the International Year of Light. Sun-Yat-sen University SPS volunteered to repair appliances in villages around their city. Wesleyan University SPS completed a group outreach project with local elementary and middle schools, building a marble rail. Photos courtesy of AIP.

SOCIETY OF PHYSICS STUDENTS