APSNEWS

A PUBLICATION OF THE AMERICAN PHYSICAL SOCIETY

APS.ORG/APSNEWS

December 2017 • Vol. 26, No. 11

Robert Bragg, Jr. 1919-2017
Page 4

What You Need to Know: APS and SCOAP³

Following extensive discussions and a vote by the APS Board of Directors at its meeting in April, APS recently signed an agreement with CERN, which represents the Sponsoring Consortium for Open Access Publishing in Particle Physics (SCOAP³), to publish high-energy physics (HEP) papers open access. APS leadership took this step in support of the high-energy physics community to offer researchers a convenient route to publish their HEP work open access in Physical Review journals. Starting January 1, 2018, HEP papers published in *Physical Review Letters, Physical Review C,* and *Physical Review D* will be open access, paid for centrally by SCOAP³. Library subscriptions will be modified accordingly. This arrangement will initially last for two years, up to the end of 2019.

Authors: Authors of HEP papers submitted to these journals will notice very little change in procedures.

- HEP papers covered by SCOAP³ are all those posted on arXiv.org prior to publication in any of the primary 'hep' categories: hep-ex, hep-lat, hep-ph, hep-th, and irrespective of the authors' institution or country affiliation.
- HEP papers published in the three participating APS journals on or after January 1, 2018, will be open access, even if the manuscript was originally submitted prior to this date.

SCOAP³ continued on page 4

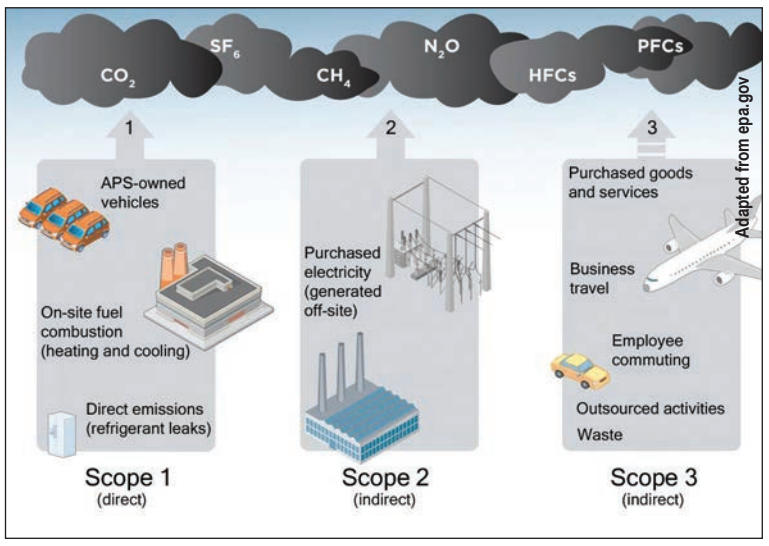
APS Inventories Its Carbon Footprint

By Tawanda W. Johnson

After issuing its Statement on Earth's Changing Climate, APS has conducted a greenhouse gas (GHG) inventory—often referred to as a carbon footprint—of its daily operations. The results were audited by an independent firm and posted online, making APS the first scientific society in the United States to broadly assess and publish its emissions. APS is now exploring ways to reduce the GHG emissions from its day-to-day operations and is evaluating emissions attributable to various activities of the Society, which include APS member travel to and from its national meetings.

"Having issued a statement on Earth's changing climate, we thought it important for the Society to understand its own carbon footprint," said APS Chief Executive Officer Kate Kirby.

The GHG Inventory Advisory Committee, which is overseen by the APS Panel on Public Affairs, has managed the inventory project since last year. Additionally, APS selected Anthesis—a global specialist consultancy skilled in GHG inventory development—to support the committee and assist the Society in determining its inventory. Anthesis was also charged with helping APS develop the tools and institutional knowledge necessary for the Society to continue its own GHG inventory going forward.



The APS greenhouse gas inventory follows established standards: Scope 1 - direct emissions from APS activities; Scope 2 - indirect emissions from purchased energy; Scope 3 - indirect emissions from commuting, business travel, and outsourced activities

The committee used the well established and industry-recognized standards of The Climate Registry (TCR) to develop APS's GHG inventory. TCR is a non-

FOOTPRINT continued on page 4

International News

Physics in Africa: An APS Project Poised for Impact

By James Gubernatis, Brian Masara, Joseph Niemela, and Tajinder Panesor

As physicists, we routinely seek unifying ideas from complex situations about which we often have only limited information. In many respects, the APS Committee on International Scientific Affairs is trying to do the same, in co-operation with the U.K. Institute of Physics (IOP), European Physical Society (EPS), International Centre for Theoretical Physics (ICTP), and South African Institute of Physics (SAIP), in what is called the Physics in Africa project. The objective of this project is quite different from understanding the physical world; rather, it is the identification of programs and activities to promote and enhance physics in Africa. Thus, the project, while not physics, is something about physics, something that we enjoy and enjoy sharing.

Africa however is a vast continent of 54 nations whose economies, political and religious

institutions, population sizes, and geographical areas vary widely. When we say "African," it is merely a label for the people and nations in this continent as opposed to some other unifying characteristic about them. Consequently, the nations of Africa are not candidates for one-size-fits-all "African" programs. What set of programs do the various nations need? Which ones have the highest priority for a specific nation?

AFRICA continued on page 5

Charting a Future for U.S. Physics

APS President Laura Greene, APS President-Elect Roger Falcone, and APS Director of Public Affairs Francis Slakey

Editor's Note: *The following roundtable discussion with 2017 APS President Laura Greene, 2018 APS President Roger Falcone, and APS Director of Public Affairs Francis Slakey is reprinted from a special report on physics in the U.S. published by* Physics World *(Institute of Physics, U.K.) with kind permission.*

The current and future presidents of APS—Laura Greene and Roger Falcone—along with public-affairs director Francis Slakey—talk to *Physics World* about their hopes and fears for physicists under the Trump administration.

What's been your overall impression of Trump's administration?

Laura Greene: There's a tremendous divide in the U.S. and what we'll do as APS is to keep our lines open to the legislature—to members of our Congress and senators—and ensure they understand that a big part of the American economy is supported by science and technology.

Roger Falcone: We live in interesting times politically but there's a broader debate over the importance of science and technology to innovation, which translates into jobs and other benefits to people. It's a much larger discussion and we should focus on that rather than any individual administration.

How well have you communicated with the Trump administration?

RF: There are typically two groups we want to talk to—one is the executive branch, such as the Office of Science and Technology Policy (OSTP), and the other is the legislative branch, or Congress. We still have great communication channels with the members and staffers in Congress, who are very interested in hearing our stories. Our ability to advocate for science and technology through Congress has not diminished. But there are fewer people to talk with in the administration, in the executive branch. That said, we have great communications with the executive branch agencies responsible for providing resources to scientists and engineers, such as the National Science Foundation (NSF) and the Department of Energy (DOE).

Francis Slakey: The administration is simply not staffed up to the extent that Obama's was. The obvious example is the OSTP where there's a skeleton crew there, just a couple of people. Under Obama, it was a robust office and you always found people to whom you had ready access. But those positions have not been filled—and may not be—so part of the trick has been to find ways in to the handful of people at the DOE or in the Office of Management and Budget.

What impact could this lack of communication have?

RF: I see two critical things for science and the country. First, we need science to inform anything our government is doing. We want

FUTURE continued on page 7

Revised 12/06/17

YouTube's *Physics Girl*

By Rachel Gaal

During the 2017 APS March Meeting, *APS News* sat down with Dianna Cowern (aka *Physics Girl)* to find out what it takes to be a physics YouTube star. She received a bachelor's in physics from the Massachusetts Institute of Technology, but now hosts a PBS Digital Studios Channel, which features do-it-yourself experiments and presentations on space and astronomy topics. This interview has been edited for length and clarity.

Dianna Cowern

How did you come up with the idea of *Physics Girl*?

I started my channel in 2012, but it took about two years to really get it going and to actually put videos up. I had maybe three in the first year? ... They were silly skit videos more than physics-related and then it morphed into a science channel. Now, I am sponsored by PBS Digital Studios—I signed in August 2016. It was serendipitous, like a lot of things in life are. I won The Flame Challenge, which was a science video challenge, while I was working at the University of California, San Diego (USCD), doing outreach with their physics department. One of the board members at PBS was a UCSD alum and saw an article about my award, and they wanted to put me in touch with PBS.

Are you a one-woman operation, or does your channel have multiple players?

I have five people but they are less than full time … sometimes I am a one woman team! About a year and a half ago, I was work-

COWERN continued on page 7

This Month in Physics History

December 12, 1921: Death of Henrietta Swan Leavitt

The Harvard College Observatory is justly proud of its Astronomical Photographic Plate Collection, consisting of more than 500,000 photographs of the night sky taken between 1882 and 1992. To take data from these images, the Observatory's then-director Charles Pickering put together a small cadre of women. Among them was Henrietta Swan Leavitt, who would go on to study one of the most important class of stars—the Cepheid variables.

These women, known as "computers," performed the tedious and time-consuming task of measuring and cataloguing the brightness of all the stars captured in Harvard's vast collection of photograph plates of the night sky. Pickering first hired his maid, Williamina Fleming, out of frustration with his male assistants, declaring that she could do a better job. He was right; Fleming wound up working for him for the next 34 years, along with several other women who also proved equal to the task. And since he did not have to pay them at the same rate as men, he could afford to hire more of them and stay within his budget. His team catalogued more than 10,000 stars for the Henry Draper Catalogue, and the preliminary version was published in 1890.

Henrietta Swan Leavitt

The "computers" of Harvard College Observatory

While it was said that Pickering chose the women "to work, not to think," several proved to be highly capable astronomers. They included Annie Jump Cannon, who devised a classification system for stars that is still in use today. And then there was Henrietta Swan Leavitt, who determined how to measure distances to far-off celestial objects.

Born in 1868 to a Congressional church minister, the young Henrietta hailed from a proud Puritan heritage. She attended Oberlin College and what would later become Radcliffe College. It was a rigorous education for a woman of that era, including instruction in ancient Greek, philosophy, analytical geometry, and calculus, as well as science and the fine arts. Leavitt fell in love with astronomy during her senior year while taking a class in the subject.

After earning a bachelor's degree in 1892, she took some time to travel in Europe, but an illness left her largely deaf for the rest of her life. Still, her love of the stars remained, and—blessed with independent means—she became a volunteer "computer" at the Harvard College Observatory a few years later, eventually joining Pickering's permanent staff at the modest salary of 30 cents an hour. She was deemed "hard-working and serious minded … little given to frivolous pursuits and selflessly devoted to her family, her church, and her career."

Pickering assigned Leavitt the task of studying the variable stars—those changing from bright to dim to bright again at periodic intervals—in the Small and Large Magellanic Clouds. By overlaying one plate on top of another to see how the star had changed its brightness between exposures, she meticulously noted 1777 such stars, but also noticed something peculiar about them: the brighter the star, the larger the period. As Leavitt wrote, "A straight line can be readily drawn among each of the two series of points corresponding to maxima and minima, thus showing that there is a simple relation between the brightness of the Cepheid variables and their periods." This is now known as Leavitt's law, or the "period-luminosity relationship." She would ultimately discover more than 2400 variable stars.

Her discovery was significant because the brightness of such stars proved remarkably consistent regardless of their location in the universe. They became a useful "standard candle" in astronomy, enabling scientists to easily compute the distances to galaxies too far away for the prior method of stellar parallax observations to be useful. Within a year astronomers had used her results to determine the distance to several Cepheid variables in the Milky Way. Ultimately, her discovery convinced Harvard astronomer (and future Observatory director) Harlow Shapley that the sun was not the center of our galaxy. It also convinced Edwin Hubble that the Milky Way is not the center of the universe.

Most significantly, Hubble drew on her work with Cepheid variables to measure the distance between Earth and the Andromeda galaxy: at 2.5 million light years away, it is the nearest galaxy beyond our own. And of course, by measuring the redshift of stars, Hubble determined that our universe was not static, as astronomers

LEAVITT continued on page 3

APSNEWS

Series II, Vol. 26, No. 11
December 2017

Editor. . . . . . **David Voss**
Contributing Correspondent . . . . . **Alaina G. Levine**
Design and Production. . . . . . **Nancy Bennett-Karasik**
Copyeditor and Proofreader. . . . . . **Edward Lee**

APS News (ISSN: 1058-8132) is published monthly, 11 times per year, except the August/September issue, by the American Physical Society, One Physics Ellipse, College Park, MD 20740-3844, (301) 209-3200. It contains news of the Society and of its Divisions, Topical Groups, Sections, and Forums; advance information on meetings of the Society; and reports to the Society by its committees and task forces, as well as opinions.

Letters to the editor are welcomed from the membership. Letters must be signed and should include an address and daytime telephone number. APS reserves the right to select and to edit for length and clarity. All correspondence regarding *APS News* should be directed to: Editor, APS News, One Physics Ellipse, College Park, MD 20740-3844, Email: letters@aps.org.

Subscriptions: *APS News* is an on-membership publication delivered by Periodical Mail Postage Paid at College Park, MD and at additional mailing offices.

For address changes, please send both the old and new addresses, and, if possible, include a mailing label from a recent issue. Changes can be emailed to membership@aps.org. **Postmaster:** Send address changes to APS News, Membership Department, American Physical Society, One Physics Ellipse, College Park, MD 20740-3844.

Coden: ANWSEN ISSN: 1058-8132

News from the APS Office of Public Affairs

FGSA Email Campaign Tackles Provision in Proposed Tax Reform Bill

By Tawanda W. Johnson

The APS Forum on Graduate Student Affairs (FGSA), with assistance from the Society's Office of Public Affairs (APS OPA), coordinated an advocacy campaign that led more than 1,000 graduate students to tell their senators to reject a provision in the House tax bill that would tax students' tuition waivers.

On November 9, the morning before the Senate Finance Committee released its bill, FGSA members began making contact through phone calls and emails. By the morning of November 10, the students had made more than 1,200 contacts, reaching 21 of the 26 members of the committee. That Friday afternoon, the Senate announced that it would reject the House provision.

"It is the most responsive email campaign we've ever had, and it was a big win," said Greg Mack, APS government relations specialist. "It was great working with FGSA Chair Joshua Einstein-Curtis to turn this campaign around in a quick timeframe, launching it a day before the Senate released details of its bill."

Einstein-Curtis said partnering with APS OPA was crucial in helping students amplify their voices on the matter.

"Working together with the APS [OPA], we were able to create and send a message that both informed FGSA members of the upcoming bill and was a call to action. Without the APS [OPA], and its tools in place for handling government messaging, it would have been a significant challenge to get the message out in the necessary, expedient manner."

The House of Representatives passed its version of the tax bill on November 16, by a vote of 227-205. For graduate students, the silver lining was the Senate's exclusion of a tax on tuition waivers—and graduate student voices played a role in that. Before a final bill is sent to

FGSA continued on page 4

Cornell University physics graduate students Michelle Kelley (center) and Eliott Rosenberg (right) after discussing the negative impacts of the tuition waiver tax in the House tax reform bill with Molly Safreed (left), a staffer in the office of U.S. House Rep. Tome Reed (NY-23rd)

LEAVITT continued from page 2

previously believed, but expanding. Astronomy would never be the same.

Sadly, Leavitt died from cancer on December 12, 1921, shortly after being named head of the stellar photometry division. In his obituary, her colleague, Solon Bailey, praised not just her science, but also her personal character: She "had the happy faculty of appreciating all that was worthy and lovable in others, and was possessed of a nature so full of sunshine that, to her, all life became beautiful and full of meaning."

As director of the Observatory, Pickering published Leavitt's work under his own name, although she was credited with "preparing" it. But at least one scientist deemed Leavitt's contributions worthy of a Nobel Prize. In 1924, the Swedish Academy of Science's Gösta Mittag-Leffler sought to nominate her for the prize and wrote to Shapley in 1926 requesting more information on her work. The ambitious Shapley informed Mittag-Leffler that Leavitt had died, rendering her ineligible, and suggested he might be a more worthy recipient for his interpretation of her findings. (He never won the Nobel Prize either.) But while Leavitt may not have won the Nobel Prize, there is an asteroid and a crater on the Moon named in her honor, as well as a play about her life and science, *Silent Sky*, by critically acclaimed playwright Lauren Gunderson.

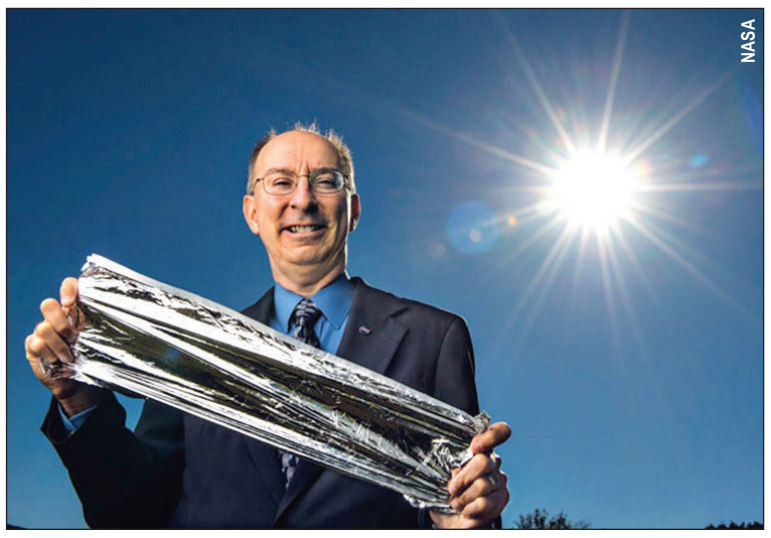
Further Reading:

Johnson, G. 2005. *Miss Leavitt's Stars: The Untold Story of the Woman Who Discovered How to Measure the Universe*. New York: W.W. Norton.

Sobel, D. 2016. *The Glass Universe: How the Ladies of the Harvard Observatory Took the Measure of the Stars*. New York: Penguin.

A Physicist Pushes for Interstellar Travel

By Katherine Kornei



Les Johnson of NASA displaying the material used in solar sails

There's a lot to explore within a couple billion kilometers of the Sun—moons, planets, asteroids—but some scientists like Les Johnson are already looking beyond our solar system. Johnson, who holds degrees in chemistry and physics, is a researcher at the NASA George C. Marshall Space Flight Center in Huntsville, Alabama. He's investigating how a new kind of fuel-less propulsion known as solar sail technology might one day be used to send instruments to faraway worlds orbiting other stars. Johnson is also a published science fiction author, and his day job at NASA is often inspiration for his novels.

Traditional propulsion systems like rockets all suffer from the same limitation: they have to carry their own heavy stockpiles of fuel. On the other hand, solar sails and their payloads can be much, much lighter because the sails draw on energy from the Sun rather than from an onboard fuel source. Solar sails are also cheaper and less dependent on precise launch windows than traditional rockets, Johnson notes.

When large sheets of lightweight, durable materials—like CP1, a proprietary material developed by NASA that resembles a non-sticky version of Saran Wrap©—are unfurled in space and pointed toward the Sun, they act like sails that reflect sunlight. Think about how a sailboat works but replace the wind with sunlight, says Johnson. These sails effectively receive a push from each photon that reflects from them. Over time, all of those tiny pushes acting together accelerate whatever payload is attached to the solar sail, and the direction of movement can be controlled by adjusting the angle of reflection.

As Solar Sail Principal Investigator for NASA's Near Earth Asteroid Scout project, Johnson is currently working on developing and testing a solar sail that is slated to launch in 2019, the first interplanetary solar sail mission led by the United States (Japan launched a mission in 2010). Its destination will be an asteroid within the solar system known as 1991VG, thought to be a rocky world about 50 meters across circling the Sun in an Earth-like orbit. There's been a lot of interest in better understanding the composition of nearby asteroids. For many of them we don't know much more beyond their existence, says Johnson. "Unless there's a low-cost reconnaissance mission beforehand, it'd be too risky to send people in," he says.

That's where NEA Scout comes in—the mission is built around a square of solar sail 9 meters on a side, roughly the length of a school bus. The sail, made of 2.5-micron-thick CP1, is coated in aluminum to increase reflectivity and will be attached to a camera payload designed to fly within a kilometer of 1991VG. By imaging over 85% of the surface of the asteroid in unprecedented detail and sending the data back to Earth, researchers can estimate 1991VG's spin rate and examine whether it has a halo of dust surrounding it. These observations will help scientists decide whether 1991VG would be a safe place for a future human visit.

When Johnson isn't researching solar sails, he's writing about them and other new space technologies. As he started his scientific career, Johnson was often asked to give talks on space and science at science fiction conventions. "I was often told 'you need to write these ideas down'," he says. In the early 2000s, he met Gregory Matloff, an astronomer who had written a few popular science books. The two researchers began to talk about writing a book together, which ultimately became "Living off the Land in Space," published in 2007. This book is about how to use the resources of space to support exploration beyond Earth, says Johnson. He's currently working on "Mission to Methone," a thriller set in the future about the fictional Space Resources Corporation finding an abandoned spaceship when surveying asteroids for possible mining.

Johnson is looking forward to testing solar sail technology with NEA Scout, and he's hopeful that solar sails will one day carry scientific instruments to worlds beyond our solar system. "I would be thrilled to have pictures of any solar system with a potentially habitable planet," he says.

The author is a freelance writer based in Portland, Oregon.

Robert Henry Bragg, Jr. 1919-2017

Materials scientist Robert Henry Bragg, Jr., passed away on October 2, 2017, after a long career in physics and engineering, having made a number of contributions in characterizing materials using x-ray diffraction. Among many honors, he was named a fellow of the National Society of Black Physicists (NSBP) in 1995 and a professor emeritus of the University of California (UC), Berkeley upon his retirement in 1987.

Robert Henry Bragg, Jr.

Bragg was born on August 11, 1919, in Jacksonville, Florida, and attended Tilden Technical High School and Woodrow Wilson Junior College in Chicago before cutting his education short to enlist in the military during World War II.

After the war, he obtained his bachelor's degree in physics from the Illinois Institute of Technology (IIT) in 1949 and his master's degree in 1951. After a stint in industry, where he became an expert in x-ray crystallography, he returned to IIT and completed his Ph.D. in 1960.

From 1961 to 1981, Bragg was a research scientist at the Lockheed Palo Alto Research Laboratory in California. He became the president of the Palo Alto chapter of the NAACP. In 1969, he joined the department of materials science and engineering at UC Berkeley, and served as the chair of the department from 1978 to 1981, the only African American to do so at that time. Beginning in 1969 he became a principal investigator for the Materials and Molecular Division, Lawrence Berkeley Laboratory.

While at Berkeley, Bragg was on the policy advisory board of the Black Studies program, and during the late 1980s he had to struggle against departments that were reluctant to hire minorities. Bragg also managed the Chancellor's Fellowship Program, which provided opportunities for minority faculty.

Bragg's research interests included x-ray diffraction and its application to such topics as the structure and electronic properties of carbon materials, which are used in aircraft, golf clubs, and tennis rackets.

After his retirement in 1989, Bragg was awarded a Fulbright Fellowship in 1992 to conduct research for one year at the Obafemi Awolowo University in Nigeria. He also performed research at the Advanced Photon Source at the Argonne National Laboratory in 1999.

Bragg is remembered for efforts on behalf of African American scientists and engineers. At Berkeley, he worked with the U.S. Department of Energy to survey historically Black colleges and universities and determine their prospects for research funding. He sponsored the first Black Engineering and Science Students Association at Berkeley, and was involved in the Northern California Council of Black Professional Engineers. While on the faculty at Berkeley, he served on the policy advisory board of the Black Studies program.

Additional Information

For more about Robert Bragg, see this oral history interview: thehistorymakers.org/biography/robert-bragg-41 and the oral history page at Berkeley. bancroft.berkeley.edu/ROHO/projects/aa_faculty/bragg_robert.html

FGSA continued from page 3

the President for his signature, the House and Senate must reconcile their respective versions of the bills. APS OPA will continue to work with FGSA to keep the pressure on.

In the meantime, the students are elated that they overcame at least one crucial hurdle.

"Removing the tuition exemption would have caused some graduate students to move from one of the lowest tax brackets to the top tax brackets, with no actual income change for the student. Having such a large tax increase with no increase in actual income would completely destabilize graduate education in the U.S. and effectively bankrupt graduate students," said Einstein-Curtis.

Including the FGSA campaign, APS members have taken more than 10,000 actions to-date toward contacting their congressional representatives. Those actions are op-eds, tweets, emails, letters, and phone calls.

"We are here to support APS members, and we want them to know that when issues break on Capitol Hill, we stand ready with them to take rapid and appropriate action to effectively address their concerns," said Francis Slakey, director of APS OPA.

APS members interested in learning more about science policy and how they can advocate on current issues can access APS OPA's Advocacy Dashboard via the following link: aps.org/policy/issues/

The author is press secretary in the APS Office of Public Affairs.

SCOAP³ continued from page 1

- Papers published under the agreement will be marked as supported by SCOAP³ and will be covered by a Creative Commons CC-BY license. Authors will not be required to pay the open access Article Processing Charges (APC) for their articles as these will be covered centrally by SCOAP³.

Librarians: Because APS HEP articles will be open access, paid for by SCOAP³, all customer libraries will receive a commensurate reduction in subscription fees to offset this arrangement.

- The amount of the reduction will be clearly shown on the renewal notice received by customers, along with the full subscription price and the final amount payable incorporating the SCOAP³ offset. The reduction reflects, and offsets, the proportion of the HEP open access content of their subscription already covered by payments made by SCOAP³ to APS. Libraries already participating in SCOAP³ will receive an immediate reduction. Libraries not yet contributing to SCOAP³ will receive a credit note in 2018 against their 2019 subscription charge.
- SCOAP³ is primarily financed by direct voluntary contributions of these reductions by over 3,000 libraries in 43 countries. More information about how to support the initiative is available at scoap3.org/join.
- The offset reduction has been meticulously calculated to ensure that APS does not "double-dip" on papers published open access under SCOAP³. APS will receive no additional revenue for the HEP papers, apart from that received via SCOAP³.

Readers: The biggest and most obvious change is that HEP papers published in APS journals will be available to anyone to read without any charge, through the appropriate *Physical Review* journal website.

- Papers published under SCOAP³ will carry the Creative Commons CC-BY license, which is the most permissive available. Others may distribute, reuse, remix, or build upon the published work, properly attributed to the authors.

FOOTPRINT continued from page 1

profit group of nearly 300 public and private organizations and 60 states and provinces across North America; it designs and operates voluntary and compliance GHG reporting programs globally and assists organizations in measuring, reporting and verifying their GHG inventories.

Following the TCR protocol, the APS GHG emissions were divided into three categories:

Scope 1: Emissions from direct energy combustion that occurs on-site or from owned vehicle operation; also direct industrial/HVAC gas emissions;

Scope 2: Indirect emissions resulting from purchased energy generation, often in the form of electricity, steam, or chilled water; and

Scope 3: Other indirect emissions that are a result of organizational activities; includes emissions from business travel, employee commuting, waste management and supplier or outsourced activities.

Because there are well-defined protocols by TCR for Scopes 1 and 2, the initial analysis included only Scope 1 and 2 emissions, assessing activities at APS headquarters in College Park, MD, the Society's editorial offices in Ridge, N.Y., and its public affairs office in Washington, D.C. Cameron-Cole, an independent environmental auditing firm and TCR-approved verification body, verified the results from Scopes 1 and 2.

Scope 3 emissions calculations—which have required APS to develop its own methodologies—are ongoing. Preliminary results indicate two Scope 3 emission sources —travel to APS meetings and the Society's investment portfolio—significantly impact overall APS GHG emissions.

The detailed inventory for Scopes 1 and 2 are posted on the APS website and can be found here: aps.org/policy/reports/upload/APS-2015-GHG-Report-Scopes-1-2.pdf

In addition to overseeing the APS GHG inventory, the advisory committee has provided the Society recommendations to reduce and/or mitigate its GHG emissions. The committee's inventory recommendations for Scopes 1 & 2 are:

Consider Purchasing Renewable Energy Certificates (RECs): APS should investigate the possibility of purchasing RECs for the electricity used by APS at each of its three locations. The Office of Public Affairs (OPA) staff should work with the appropriate APS staff in College Park and Ridge to determine the practical and economic feasibility of purchasing RECs at each location.

Improve Buildings' Energy Efficiencies: OPA staff should work with building management at the National Press Building and the co-owners of the American Center for Physics to improve the energy efficiencies of the buildings, where possible.

APS is now exploring avenues to reduce its Scope 1 & 2 emissions, including working with the building managers at its D.C. location to increase energy efficiency. APS plans to present its Scope 3 results and recommended Society actions to APS members during the first quarter of 2018.

"By having its Scopes 1 and 2 emissions independently verified and publicly posted, APS has completed a critical stage of its GHG inventory,"said Bill McCurdy, a chemistry professor at the University of California, Davis, who served as chair of the GHG Inventory Advisory Committee."Not only does APS now have an understanding of the GHG emissions from the Society's day-to-day operations, but it is establishing a path for like-minded organizations to follow; we hope that they will join us."

AFRICA continued from page 1

While these are natural questions, finding their answers is challenging. We lack information about the state of physics in all but a handful of African nations. The first phase of the Physics in Africa project sought more information by sending to physics leaders in various African nations a questionnaire asking about the size of undergraduate and graduate degree programs, research opportunities at the faculty and postdoctoral levels, at academic, government and industrial research centers, the existence and activities of physical societies, employment opportunities, etc.

This task seems straightforward but identifying these leaders was far from it. Even if physics activity exists, in many African nations it lacks visibility. Nonetheless leaders in 32 nations were identified and contacted. These nations have about 94% of the African population. Twenty responded. The responding nations represent about 60% of the population. The survey phase of the project has concluded, the responses have been summarized, and the project's second phase—the definition and prioritization of programs—has begun.

From the survey, we could make several important observations. With several exceptions, physics in each African nation is on a relatively small scale. The nations with universities having advanced degree programs do not span the continent geographically. Of the responding nations, seven had physical societies, some created recently. Again with several exceptions, a common limiting issue to the growth of physics is the lack of employment opportunities in national government-sponsored and industrial-connected research centers. In a number of cases, the national economies are unable to support these centers; in others, industrial and government leaders might not appreciate the value of doing so. Because experimental facilities and instruments are often expensive, physics teaching and research tends to emphasize theoretical physics.

The survey also showed that educational activities have several special roles, such as being an important source, if not the main source, of both student employment and preparation for opportunities elsewhere. Still another role, likely less appreciated and practiced, is educating the general population and students in particular about the importance of science and technology and the special role that physics plays in these areas.

These observations prompted the second phase of the project to target issues associated with the organization and communication of physicists within a nation and between African and non-African nations, physics education spanning all grade levels and boosting activity in "hands-on" experimental physics.

From working with our African colleagues, we also captured information not possible by a survey. This is their commitment and enthusiasm to make physics "happen" in their countries. Accordingly, in the second phase, by working with and listening to them we can fully expect to identify programs and projects that will be well received and poised for success.

The major non-African physical societies, working individually, already have several programs targeting introductory science education and increased research collaborations and exchanges with physicists in specific developing nations. Similar programs will have their place in Africa, but other programs will be needed because of the smaller scale of physics in most nations. This situation, plus opportunities provided by exploiting the Internet and social media, invites the development of novel programs addressing a broader spectrum of needs beyond simply facilitating, for example, scientific exchanges. What is distinctive about the Physics in Africa project is that major non-African physical societies, working collectively among themselves and with leaders in African physics, are seeking to identify these new programs.

The project has a modest website (saip.org.za/index.php/physics-in-africa-survey), hosted by SAIP, which offers a fuller description of the Physics in Africa project, the questionnaire, plus a more detailed summary of the completed questionnaires. Suggestions about programs in the second phase target areas are welcomed, and room on the subcommittees exists for those wanting to enter the dialogue with our African colleagues to help physics "happen" in this intriguing continent.

James Gubernatis is a member of the APS Committee on International Scientific Affairs, an APS Fellow, and a physicist at Los Alamos National Laboratory. Brian Masara is Executive Officer of SAIP. Joseph Niemela is an APS Fellow, Chair of the Physics for Development Group of EPS, and is based at the Abdus Salam ICTP in Trieste, Italy. Tajinder Panesor is Head of International and Member Services at IOP.

Managing the Flood of Space Program Data

By Katherine Wright

In the sweltering sun of the New Mexico desert, Ben Feist held out his cell phone. Snap. The camera on a nearby scientific instrument captured a shot of the phone's screen showing a clock. Click. Another instrument did the same.

The instruments' operators, a handpicked team of NASA geologists and an active astronaut who lived in space for six months, were in the desert testing gadgets for future space explorers. The clock shots, Feist hoped, would provide a way to sync data in chronological order from different instruments. Feist came up with the idea while trying to piece together documents from the Apollo 17 moon-landing mission. But Feist doesn't work for NASA; he's a web-data specialist based in Canada and he didn't expect to be here. "I never dreamed of being in a position where I could contribute to the challenge of helping humanity to leave Earth and visit another planet," said Feist.

Ben Feist and a colleague prepare a drone vehicle for studying data synchronization and management in a simulated space environment.

Space exploration produces an abundance of data. In 1972, Apollo 17 astronauts Eugene Cernan and Harrison Schmitt snapped thousands of photographs, bagged 334 rock samples, and performed numerous experiments, including investigations of the moon's tenuous atmosphere and the electrical properties of its rock. More recently, "robot geologist" Mars Rover has been making scientific observations with nearly a dozen instruments for the last 17 years. Knowing how these extensive datasets fit together is essential if they are to be properly interpreted.

"These missions are extraordinarily complex," said Paul Niles, a planetary scientist at NASA's Johnson Space Center who studies Mars' geochemistry. "Being able to quickly and easily understand what happened in a mission, what data were collected [and where], and how that data fits into everything else, that's key … but we don't do it very well."

For human missions the turnaround time is particularly important. Astronauts should be able to quickly review the day's data so they can plan for their next spacewalk, said Jacob Bleacher, a geoscientist at NASA's Goddard Space Flight Center, who tests geological instruments for use in space by humans. Today they can't. "We don't have a way for the science team and the crew to handle that data in real time," said Bleacher.

So how does NASA manage their data now? Missions like NASA's Mars Science Laboratory dump datasets into a repository called The Planetary Data System (PDS), which according to Niles is "very hard to navigate." Unless you are on the team that took the data, finding and interpreting files on PDS is overly difficult. It can take months to figure out the where, when, and what for each file, said Niles, providing a significant barrier to data analysis. "It's just a couple of steps above raw data," he said. Both Niles and Bleacher think that linking datasets with transcripts, audio recordings, photographs, and videos via timestamps could solve this problem, particularly in a tool that allows you to move seamlessly through documents chronologically or geographically. This is exactly what Feist created with Apollo17.org.

Apollo17.org connects over 300 hours of audio, 22 hours of video, and 4200 photographs from this 1972 moon landing, enabling viewers to experience the mission in real time from launch to splashdown. You can simultaneously watch, listen, and read along as the astronauts journey through space and explore the moon's surface. Feist also added in images from the Lunar Reconnaissance Orbiter and data from samples the astronauts returned to Earth, which are accessible at the click of a mouse. "You can watch the moment Jack picked up the sample, and see images of the rocks, without having to go do a bunch of legwork to figure out when that might have happened and which video file you need to look at," said Feist. "Suddenly you have a research tool."

Feist's work shows the effectiveness of timestamps to organize information. But for it to be a useful research tool the streams of data need to sync automatically, without hours of manual intervention—Apollo17.org was five years in the making, albeit mostly evenings and weekends. Then team members can instantly explore and analyze the footage and measurements being collected with little to no effort.

To field-test (near) real-time synchronization of data, Bleacher invited Feist to the desert. There

DATA continued on page 6

In Recognition of the 2017 APS Fellows

Each year, no more than one half of one percent of American Physical Society members are elected Fellow. APS Fellows have been recognized by their peers for their outstanding contributions to physics, including original research and publication, innovative applications to science and technology, exceptional teaching and outreach, or esteemed leadership and service to the Society. Here are the newly elected 2017 Fellows, listed by the unit who recommended their nomination for election to the APS Council of Representatives. For more information, visit.aps.org/programs/honors/fellowships/

DIVISION OF ATOMIC, MOLECULAR & OPTICAL PHYSICS
David B. Cassidy
Christopher J. Fontes
Markus Greiner
Zoran Hadzibabic
W. Vincent Liu
Miguel Orszag
Zhe Yu J. Ou
Jacob M. Taylor
Xiao-Min Tong
Susanne F. Yelin
Chuanwei Zhang

DIVISION OF ASTROPHYSICS
H. Thomas Diehl
Dan Hooper
Dragan Huterer
Morgan May
Reshmi Mukherjee
James A. Musser
Daniel Schwartz
Nicholas Suntzeff
Risa Wechsler
Rosemary Wyse

DIVISION OF BIOLOGICAL PHYSICS
Chris Adami
Paul A. Janmey
Wolfgang Losert
Thomas T. Perkins
William Ryu
Jun Song
Yang Xia

DIVISION OF CHEMICAL PHYSICS
Mischa Bonn
Eberhard K. U. Gross
Han Htoon
Vitaly V. Kresin
Andrei Sanov
Roland Wester

DIVISION OF COMPUTATIONAL PHYSICS
Gabrielle Allen
Narayana R. Aluru
Nathan Barton
Anatoly B. Belonoshko
Jean Pierre Boon
Paul R. C. Kent
Thomas R. Mattsson
Lev Shchur
Timo Thonhauser

DIVISION OF CONDENSED MATTER PHYSICS
Adrian Bachtold
Alexander L. Chernyshev
Rafael M. Fernandes
Francisco Guinea
Victor Gurarie
Igor F. Herbut
Michael A. Hermele
Kee Hoo Kim
Maxim Mostovoy
Eduardo R. Mucciolo
Shuichi Murakami
Yuval Oreg
Gerardo Ortiz
Johnpierre Paglione
Dmitry Reznik
Takasada Shibauchi
Hermann Suderow
Stuart A. Trugman
Ziqiang Wang
Steffen Wirth
Lilia Woods
Han Woong Yeom

DIVISION OF FLUID DYNAMICS
Louis N.Cattafesta
Suman Chakraborty
Jeff D. Eldredge
Toshiyuki Gotoh
Mihailo Jovanovic
Keith A. Julien
Ho-Young Kim
Lou Kondic
Stefan G. Llewellyn Smith
Surya P. Vanka
Jun Zhang

DIVISION OF GRAVITATIONAL PHYSICS
John Baker
Jolien D. Creighton
Charles R. Evans
Eric K. Gustafson
Daniel Holz
Vuk Mandic

DIVISION OF LASER SCIENCE
Hui Deng
Munira Khalil
Niels Asger Mortensen
Gunter Steinmeyer
Edo Waks

DIVISION OF MATERIALS PHYSICS
Andy Christianson
Anatoly I. Frenkel
Brent T. Fultz
Debdeep Jena
Chun N. (Jeanie) Lau
Michael A. McGuire
Janice L. Musfeldt
Eric A. Stach
Mauricio Terrones
Kang-Lung Wang

DIVISION OF NUCLEAR PHYSICS
Michael P. Carpenter
Richard B. Firestone
Daniel N. Kasen
Toshihiko Kawano
Alexander Kovner
Reiner Kruecken
Rachid Nouicer
Ernst Paul Sichtermann
Peter Steinberg
Remco G.T. Zegers

DIVISION OF PARTICLES AND FIELDS
Christian W. Bauer
Stephen Brice
Christopher David Carone
John W. Cooper
Lisa L. Everett
Adam K. Leibovich
Daniel McKinsey
Yasunori Nomura
Manfred Paulini
Aaron T. Pierce
Frank C. Porter
David M. Strom
Christopher William Walter

DIVISION OF PHYSICS OF BEAMS
Alexander V. Aleksandrov
Alexey Burov
Georg H. Hoffstaetter
John W. Lewellen
Fulvia C. Pilat

DIVISION OF PLASMA PHYSICS
Radha Bahukutumbi
William A. Bertsche
Dustin Froula
William H. Goldstein
Robert K. Kirkwood
Mikhail A. Malkov
Richard A. Moyer
James R. Myra
Juergen Rapp
Raul Sanchez

DIVISION OF POLYMER PHYSICS
Thomas H. Epps III
Raffaele Mezzenga
Ras B. Pandey
Christopher M. Stafford
Francis W. Starr

DIVISION OF QUANTUM INFORMATION
Norbert Lutkenhaus
Margaret D. Reid

FORUM ON EDUCATION
Susan K. Blessing
Harvey S. Leff
Jonathan P. Pelz

FORUM ON THE HISTORY OF PHYSICS
Paul H. Halpern

FORUM ON INDUSTRIAL AND APPLIED PHYSICS
Deji Akinwande
Matthias Bauer
Bruce E. Gnade
Carlos Jesus Gutierrez
Zhenqiang Ma
Patrick I. Oden
A. Albert Talin
Yong Zhang

FORUM ON INTERNATIONAL PHYSICS
Ahmed Ali
Sushanta Mitra
Chilakamarri Rangacharyulu
A. Surjalal Sharma
Bernardo Spagnolo
Shining Zhu

FORUM ON PHYSICS & SOCIETY
William D. Collins
Neil F. Johnson
R. Scott Kemp

TOPICAL GROUP ON ENERGY RESEARCH & APPLICATIONS
Nancy Haegel
Mark A. Prelas

TOPICAL GROUP ON FEW-BODY SYSTEMS
Roxanne P. Springer

TOPICAL GROUP ON HADRONIC PHYSICS
Kawtar Hafidi

TOPICAL GROUP ON INSTRUMENT & MEASUREMENT SCIENCE
Peter H. Grutter
Christian Stoeckl

TOPICAL GROUP ON MAGNETISM
Enrique Del Barco
Stephane Mangin
Robert Stamps
Vivien Zapf

TOPICAL GROUP ON PHYSICS EDUCATION RESEARCH
Rachel E. Scherr

TOPICAL GROUP ON PLASMA ASTROPHYSICS
Nikolai Pogorelov

TOPICAL GROUP ON PRECISION MEASUREMENT & FUNDAMENTAL CONSTANTS
Maynard S. Dewey
David B. Newell

TOPICAL GROUP ON SHOCK COMPRESSION OF CONDENSED MATTER
Thomas Dan Sewell
Laura Beth Smilowitz

TOPICAL GROUP ON SOFT MATTER
Ramin Golestanian
William T. M. Irvine
Pedro M. Reis
Michael J. Solomon
Slobodan Zumer

TOPICAL GROUP ON STATISTICAL & NONLINEAR PHYSICS
Thomas L. Carroll
Michelle Girvan
Bjoern Hof
Corey Shane O'Hern

APS GENERAL CATEGORY
James W. Taylor

DATA continued from page 5

he evaluated a data linkup protocol while Bleacher's team carried out simulated moonwalks around a volcanic crater. The protocol involved capturing a shot of a highly accurate clock, such as those found on phone apps, in the viewfinder of each instrument. The shots embedded "timestamp" markers in each data stream that Feist could use to quickly arrange measurements and recordings in chronological order.

By the end of the week, Feist had stitched together video footage from the first field day (cameras were attached to the chests of the two members of astronaut "crew" carrying out the simulated space walks, and one was attached to a drone, capturing an aerial view of their journey). Since then, he has added in still images the crew shot. In his mock-up website, the recordings play simultaneously, side-by-side on the screen, while the path the team traversed overlays a map of the desert giving the crew's spatial location. Bleacher adds that now the team can sit down and replay any part of the day they need to, a luxury they've never had in the past.

"Ben's approach, his methodology is pretty outstanding," said Noah Petro, a planetary geologist also at NASA's Goddard Space Flight Center, who was responsible for bringing Feist and Bleacher together. "It opens the door for interpretation of data in near real time when we are in the field, or if humans are doing something in space."

With their proof-of-principle data link-up running, Bleacher, Niles, and Feist hope to take this project further and have submitted a grant proposal for funding. Bleacher said this tool has a wide range of possible uses. It could find applications as an educational outreach mechanism for NASA in the form of Apollo17.org-like websites, as a data collection teaching aid in classrooms, or as a tool to coordinate the efforts of rescue crews and aid organizations in regions ravaged by natural disasters. Bleacher added that "The options for use of this type of software are immense."

Katherine Wright is an associate editor of Physical Review Letters *and a contributing editor of* Physics.

FUTURE continued from page 1

to make sure science is included in all those policy discussions, and I'm not sure that is happening without senior scientific advisers in the government. We also need a good policy for science, which means knowing how best to invest precious tax dollars in science. Maybe there, via agencies and Congress, we've found more people to engage with.

Trump's budget proposal for 2018 earmarks big cuts to the likes of the NSF and major national labs. What are the dangers for U.S. physics if those proposals go through?

LG: The repercussions of those cuts need to be thought through and that's what we're trying to get through to our legislators. If you lose a hundred scientific jobs, you're probably losing thousands of jobs for people who work in those locations. At the National High-Magnetic Field Laboratory, for example, most people aren't scientists and the economic impact of the labs to that area is vital. We also have an educational role—training the next generation of students—and a big role in innovation, bringing new techniques to market. The U.S. is still a leader in science and engineering—and deep cuts to science will be bad news.

RF: There's no question the U.S. faces significant challenges with respect to annual deficits in our budget and the integrated national debt. Science and technology comes under a portion of that budgeted funding that's discretionary, which means we have to decide it every year and it's not set in stone. It's our job to argue that our precious dollars should be spent on science and to articulate why those investments are going to lead to innovation and jobs.

FS: The budget was not a surprise. We knew what was coming and had encouraged scientists to make the case for science to their local representatives and senators. We'd also learned from the first budget battle we'd fought in the spring, where we got Congress on our side to push back. To me, the issue is less about the 2018 numbers, but about what happens next February when the 2019 numbers are released and whether we are making any progress with the administration. The question will be: are we seeing better numbers? We'll be fighting every year for the next three years.

How do you feel about Trump's attempts to ban people from certain nations from travelling to the U.S.?

LG: When I talk to young researchers in the U.S. who have to come to work in this country, many of them tell me they are looking to find jobs elsewhere because they are worried about leaving the country and not being able to come back. The long-term impact is that we could have a brain drain of the brightest people in the world not wanting to come to the U.S. any more.

FS: When the immigration ban was first announced, all the companies I talked to were opposed to the ban—not because the numbers coming from any one of those countries was going to impact their business, but because they were concerned with the tone and the complete disregard it showed for the importance of the free flow of talent around the world. American industry needs to be able to hire the best talent wherever they are in the world. The executive branch didn't understand that point.

RF: At APS, we recognize science is an international enterprise. For example, more papers are published in APS journals from scientists in Europe than from those in the U.S. The travel ban is creating bad climate and morale.

Do you think the March for Science was a success? Did it have any impact on the budget or on people not marching for science?

LG: That's a very, very tough question. I know I was hesitant to get involved with it because I didn't want to take a political stance. But when the march became really embraced on a worldwide stage as a pro-science, not a political statement, I think a lot of organizations such as the American Association for the Advancement of Science (AAAS) and APS had a role in making sure it remained non-political. Did it have an effect? Well you've seen the president's budget so it didn't have an effect on that. But it did show just how science impacts on society, how much fun it is, how gorgeous the discovery process is.

RF: What I really liked about the Phoenix march, where I gave a talk, was that the biggest applause came when I thanked the science teachers. Bunches of teachers and their spouses came up to thank me. So I think the march boosted science teachers—gave them a sense of appreciation and recognition. That may not have been the major goal of the march, but the fact that so many regular people, who are not engaged in science and technology, could show their appreciation to schools and teachers was really powerful.

So no regrets about endorsing the march as a society?

RF: No, not at all. It was so much bigger than any individual person or society.

LG: It was not political. There were certain people who tried to politicize it. But it was so vast, so broad, so international. I was really nervous but I'm really happy right now.

Bill Foster is currently the only physicist in Congress. Do you think more physicists should get involved in politics?

LG: Yes we need more people involved. APS, as does the AAAS, has a congressional fellowship programme to help train people to get involved. There were times we had as many as three physicists in Congress and I would definitely like to see more. APS members want to be involved. They're starting to understand how important it is for their own survival.

FS: It depends what you mean by "involvement." I want more physicists to make the case for science to their elected officials and about 1200 APS members have already done so.

RF: The influence of science on social policy is enormous, whether it's just saying that actions need to be data-driven, or we need innovation to create replacement jobs for people who've been displaced from low-skilled jobs by automation. That engagement [with officials] is as important as running for office.

FS: There's no question that the same issues we're addressing in the U.S. politically are happening all over the world. We must work across all societies in the U.S., Europe and Asia to articulate how science can best contribute to the issues we're addressing.

Laura, how do you feel about your presidency so far?

LG: I wanted to take the job on because I care about APS and about physics and science diplomacy, and human rights. I don't look like a calm person but I think I'm a calming influence on people who want to react very strongly and may damage our society and science in general. But yeah I'm having a blast. I love working with the people here.

Are you happy with the overall diversity of APS?

LG: The APS has done tremendous things on diversity. The number of programmes for women in physics is huge. The Conference for Undergraduate Women in Physics started out [in 2006] with a hundred people and it's now grown by orders of magnitude. About a year and a half ago we published an LGBT report that's had a tremendous impact. We have a committee on minorities that's been terrific, offering fellowships and identifying speakers and reminding people to invite minorities as speakers or to nominate them for medals or awards. [APS is a world leader] in pushing diversity and I'm very proud of that.

Roger, what about your plans for your term as president in 2018?

RF: I've been trying to figure out how to follow Laura's great leadership! We have a formal position of past president at the APS, who stays engaged in the decision-making process, so I'm really pleased she'll be continuing to guide us. Her focus has been on science diplomacy, but I'll focus more on how to articulate the role of science and technology in economic development for society.

In a word, how would you sum up the state of U.S. physics?

RF: Optimistic.

LG: Innovative.

Any final message for the world's physics community?

LG: Let's work together.

RF: I'll second that!

The full special report is available at ow.ly/DRge30gSB9n

COWERN continued from page 2

ing by myself. First, I hired an editor, and I have one writer who does research. Sometimes we work on it together—it changes for every video.

Did you always envision yourself in physics, particularly science communication?

I started out loving math, but then I realized physics was just applied math … I became interested in high school, and then in college I decided I wanted to study it. I tried neuroscience, mechanical engineering, and I even took science writing classes to see if I wanted to do science communication. I decided that I really loved physics, *and* I wanted to do science communications. Finally I was like, "Ok, this is gonna happen…", and that's when I started my channel.

Are your video topics your own ideas, or mainly suggestions from viewers?

People do suggest ideas. For example, I grew up in Hawaii and people suggested the formation of Hawaii, so I did a video on that. We found some interesting things, but sometimes I run out of ideas … a lot of the videos are random because I'm constantly thinking about *Physics Girl* … it's in the back of my mind all the time. If I'm talking with someone about something science-related, I think to myself, "that might make an interesting video"! I also used to live with three physics grad students, and they constantly talked about riddles or questions, which serve as starter topics … like "Why are plants not black", but it can also mean "Why are plants always green"?

How do you interact with your audience over the internet?

You filter the comments, and you filter what you listen to or read. I have actual filters of what can or can't be posted on my comments, to remove the "less acceptable words" ... I also can't read every comment, there are over 100 a day. I try to stay on top of Twitter though, that's where I interact with my fans the most.

Have any of your viewers spotted mistakes in your videos before?

Sometimes I get some really great feedback … I do get things wrong from time to time. I have an animator, and things can get a bit lost in translation. But sometimes it's just me, I'll mess up or miss something that looks wrong in the video. So I'll watch the comments for the first couple of hours to double check. I've had to take it down a few times … you have to look at all the details, but as *Physics Girl,* I can't have that kind of error! My audience is ready to point out my errors … but in a critical helpful way.

Speaking of audience, do you have any idea who your biggest fans are?

My audience in general is 83% men. I've asked a lot of other physics channels to see if it's the same, which it is, and biology channels usually have more women. I think that reflects the number of people that are studying those subjects. But then looking at age groups, a lot more girls are interested at a young age. Girls are losing interest as they get older, it seems.

Do those numbers make you want to change your channel in any way?

I think it inspires me to start a new channel, I want to aim it at younger women to retain their interest. I might get better demographic data, but doing *Physics Girl* has been a really fun learning experience. I'm making videos on topics that I'm interested in, not what I was learning in school at age 13… I've been thinking about it for a while, but I'm not sure it will happen in the near future.

For someone who wants to stay in the sciences but become involved in the communications aspects, what advice would you give?

As with any profession you have to practice … I can't emphasize enough how important that is. I have practiced giving talks, writing scripts, working with my camera, and now it's part of my job. I got to learn it on the job, which is awesome, and I'm really lucky. But with just a communications degree, I don't think I would be ready to do that. I think a lot of the skills weren't natural to me, but the passion and science was ... like I said, I'm much better at math, but even I had to practice speaking clearly to engage my viewers.

Rachel Gaal was the staff science writer for APS News *from 2017 - 2017.*

The Back Page

Doublet Dudes: Shaping the Future of Fusion

By: Ryan Chaban

Editor's Note: This article is adapted from the winning entry in the APS Forum on the History of Physics Essay Contest.

Fusion energy research involving confinement of plasma with magnetic fields is the story of a relatively small group of scientists pursuing a paradigm-changing goal while knowing it would most likely not be achieved during their lifetimes. This is less true today than it was 60 years ago, and the field owes a debt to the determined pioneers of the General Atomics (GA) fusion program who persevered through politics, budget cuts, and others' lack of interest in their research. Among those pioneers are Tihiro Ohkawa (1928-2014), a lauded leader, innovator, and risk-taking scientist; and Torkil Jensen (1932-2004), a man whose name is always spoken with a soft undertone of awe inside the gates of GA but seldom mentioned outside the campus save for the innovation award that bears his name. Ohkawa was a powerful visionary with drive to build; Jensen was a kindhearted mentor and innovator [1]. As a pair, the impact they left on the fusion program at GA and the world is rich and lasting.

Ohkawa was the inaugural vice president of the GA fusion program and his name is the first to appear on many public histories and publications from the company. He saw the future machines he wanted to build and pursued them single-mindedly. As an accomplished scientist when he arrived at GA, his team complemented him well—none more so than Jensen, who with his softer friendly style and critical intuition exposed and patched any shortcomings in Ohkawa's experiments. Together the pair operated by proposing unusual ideas, defending them vehemently until implemented, then once proven correct, repeating the process. Their research was relevant not only during their lives, but survives today in the designs and approaches of international fusion programs and in the minds of the students they mentored who are now some of the leaders in physics within and outside of fusion.

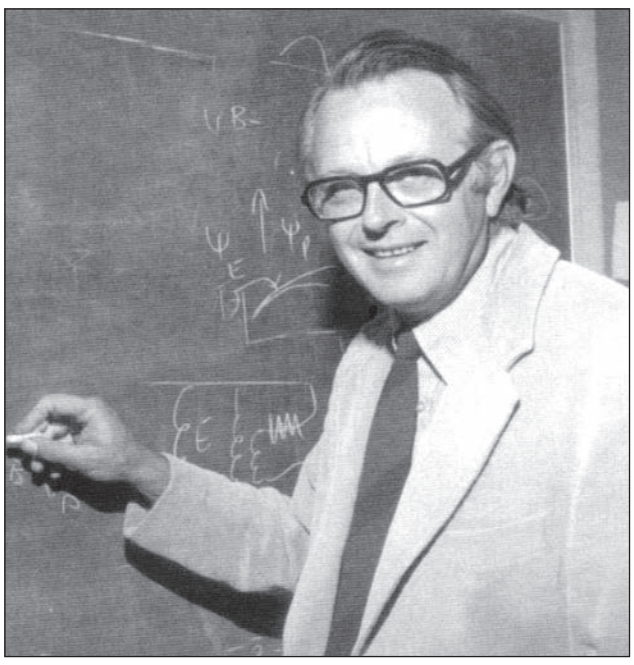
From 1957 until 1965 fusion at GA (then General Dynamics) was supported by the Texas Atomic Energy Research Foundation (TAERF) [2]. Ohkawa and Jensen arrived in 1960, the former from the University of Tokyo and the latter from an electrical engineering research assistantship in his native Denmark. In 1962, Ohkawa assumed the role of primary experimentalist for fusion research. Jensen began at GA familiarizing himself with basic plasma research through a smaller effort on a phenomenon called Landau damping. In 1965 the contract with TAERF ended and the GA fusion program, because of budget and disillusionment, dwindled to 14 scientists who needed to come up with something notable to survive [3].

Around this time, scientists at the Princeton Plasma Physics Laboratory (PPPL) were struggling with their Model-C stellerator, which lost confinement as the plasma diffused across magnetic field lines. Ohkawa managed to secure funding from the Atomic Energy Commission (AEC) to build a machine called the DC Octopole that, although not confining the plasma well, did show diffusion several hundred times lower, and brought enough renown to GA to secure more funding [3].

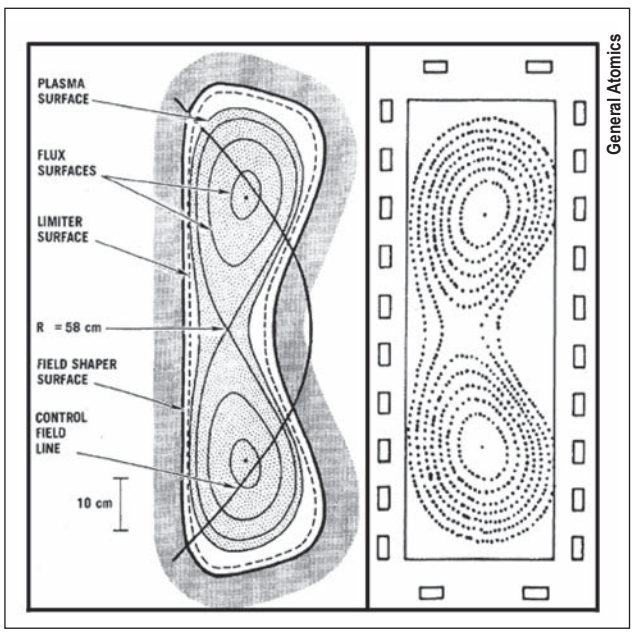
In 1968 impressive progress by Russian researchers in achieving improved confinement time and higher temperature steered the direction of fusion research worldwide towards the tokamak, including at GA with an important twist [4]. Instead of a traditional circular tokamak, Ohkawa put forward the unorthodox idea of the "plasma-current multipole" or doublet. The doublet was a strongly shaped plasma that used two separate currents to create a "figure 8" in the magnetic equilibria (see the diagram). Doublet-I (DI) was a small-scale (8 cm major radius) proof-of-concept model built with thick, shaped copper walls to allow better inductive control, and was so successful it operated for only three months before Ohkawa secured funding for the much larger Doublet-II (DII).

DII was successfully built, ran for two years, and demonstrated longer confinement times with a higher β (the ratio of plasma pressure to magnetic pressure) than comparable tokamaks [4]. Because Ohkawa and most of his staff were working on the DC Octopole, Jensen was placed in charge of many of the operations for DII; there he made some of his most important contributions to magnetohydrodynamic (MHD) theory, such as proving that elongated plasmas achieved inherently better β. Eagerly pressing onward, Ohkawa proposed and built Doublet IIA (DIIA) hoping to show that the large conducting wall, which facilitated eddy currents to correct changes in plasma shape, could be replaced by external shaping coils around a thinner vacuum vessel wall. Designed by Teuro Tamano and troubleshot by Jensen, the shaping coils were a significant step forward in active control of plasma; they forced GA's scientists to develop advanced control techniques which would become the basis of the modern-day plasma control system.

Tihiro Ohkawa



Torkil Jensen



The "Figure Eight": (left) magnetic field equilibria in Doublet II. Shaded region is the thick copper wall to control the plasma. (right) Doublet IIA's equilibria and shaping coils around the thinner vacuum vessel wall.

As DIIA met its objectives, Ohkawa, with the aid of his team of theorists, proposed the significantly larger Doublet III (DIII) in 1974 and construction was completed in 1978. Because DIII was designed as a doublet, it possessed many shaping coils which would prove crucial to its impressive capabilities and versatility in both older and present-day experiments. After the installation of a Neutral Beam Injector heating system, DIII's last great achievement was to create and validate a high-confinement mode plasma discovered in 1982 on the ASDEX in Germany, and now crucial to a the design of fusion reactors. In 1984 the DIII machine, under the supervision of John Gilleland, was upgraded to a D-shaped vessel (nicknamed "Big Dee" by the scientists) to achieve even higher β, closing the chapter on doublet research at GA.

During the heyday of this research at GA (1968-1984), the foundations were laid for a long-lasting energy program that included the training of a new generation of plasma physicists. Spurred by political forces in the late 1970s, the newly created U.S. Department of Energy (DOE) assumed the funding and research roles of the AEC [3]. The new DOE was eager to drive the U.S. towards energy independence through a diversity of energy assets including fusion.

Because of the tremendous amount of capital required to build energy research sites, Ohkawa saw an opportunity and appealed to the DOE for the funding of continued research studies on DIII-D, with the implied promise (carried out by Jensen) that GA would train plasma physicists. Jensen operated as a universal sounding board for ideas from his peers, and during his entire time at GA he always had a mentee. The impact of Jensen's emphasis on mentorship is evident in modern-day GA culture, as the company sometimes privately funds researchers to study DIII-D, and actively recruits undergraduate students into fusion research.

While Ohkawa went on to become a vice chairman of GA, Jensen continued as senior technical advisor, always lending his aid and ideas on new approaches to research and training his mentees. Jensen continued to work and publish papers at GA even after his official retirement in 1994. His influential engineering ideas laid the foundation for Lang Lao's EFIT code, used ubiquitously in fusion research to find the magnetic equilibria in a tokamak, and the concept of "almost ideal MHD," a constraint on the equations that allows for magnetic reconnection. Moreover, he helped create the induction motor model of plasma rotation, which is still used as an straightforward explanation for how a tokamak starts and how the plasma rotation is affected by currents and fields.

To this day, DIII-D remains one of the most capable tokamaks for the investigation of the effects of shaping on confinement. Its success has influenced the design of other programs that have followed and currently serves as America's premier tokamak, devoted to establishing the scientific basis for the next generation machine, and the largest tokamak in the world, ITER.

The author is a first-year Ph.D. student at The College of William and Mary in Williamsburg, VA. His interest in fusion began through a 2016 Summer Science Undergraduate Laboratory Internship at General Atomics in San Diego, CA. During that summer he researched energetic particles on the DIII-D Tokamak, and this experience guided him towards a research career in fusion energy and intrigued him to learn more about the history of the science. The full version of this essay can be found at aps.org/units/fhp/essay

References:

1. Information in this article is derived from interviews the author conducted with Andrea Garofalo, Teruo Tamano, Rob La Haye, Ming Chu, and Alan Turnbull. For detailed citations please see aps.org/units/fhp/essay/
2. Maisel, M. 2007. *Celebrating 50 Years of Fusion at General Atomics* (internal GA document).
3. Bromberg, L. 1982. *Fusion: Science Politics, and the Invention of a New Energy Source*. MIT Press. Cambridge.
4. Jensen, T. et al. 1975. Confinement of Plasma in the Doublet-II Device. *Physical Review Letters*, Volume 34, No. 5.