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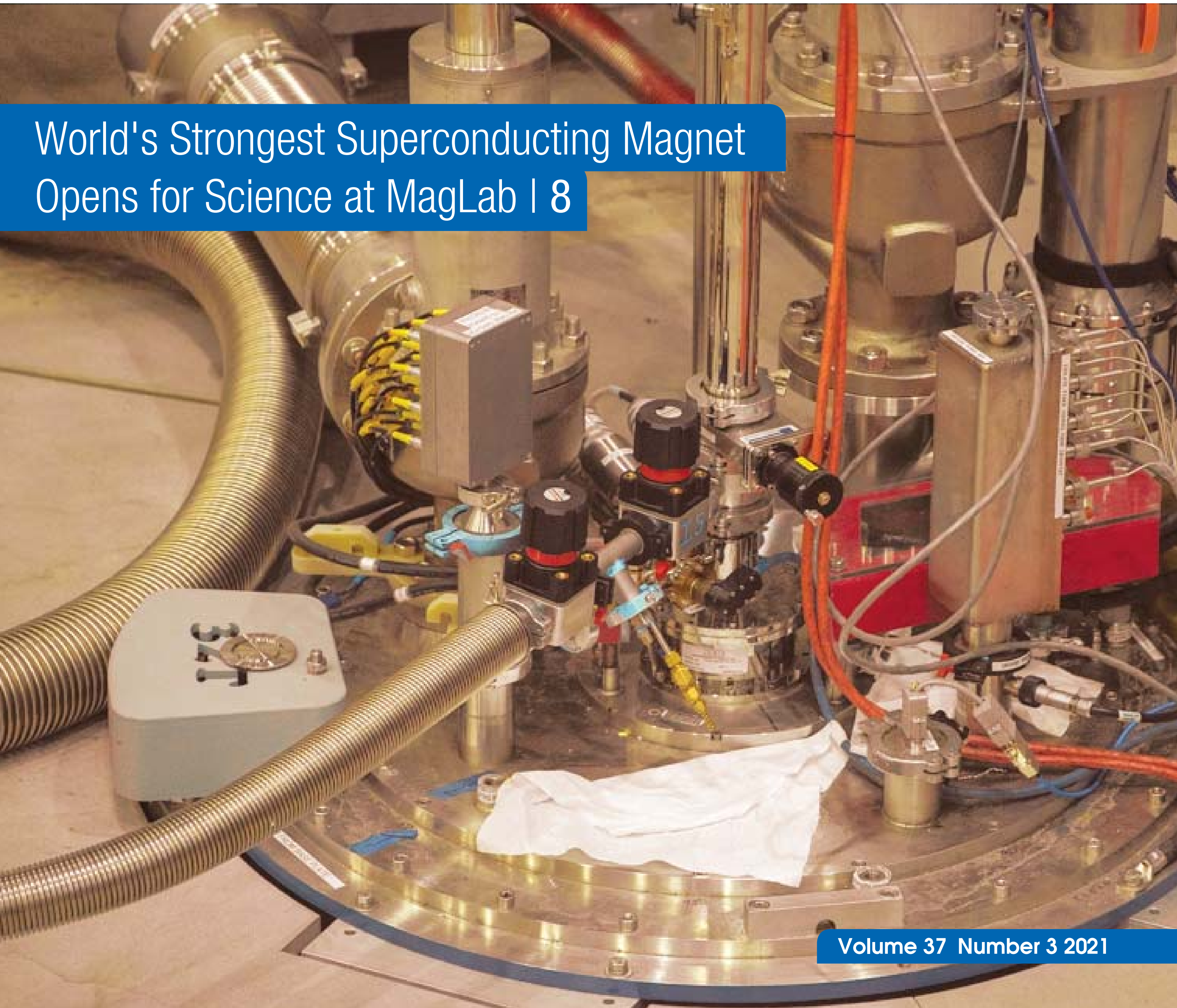

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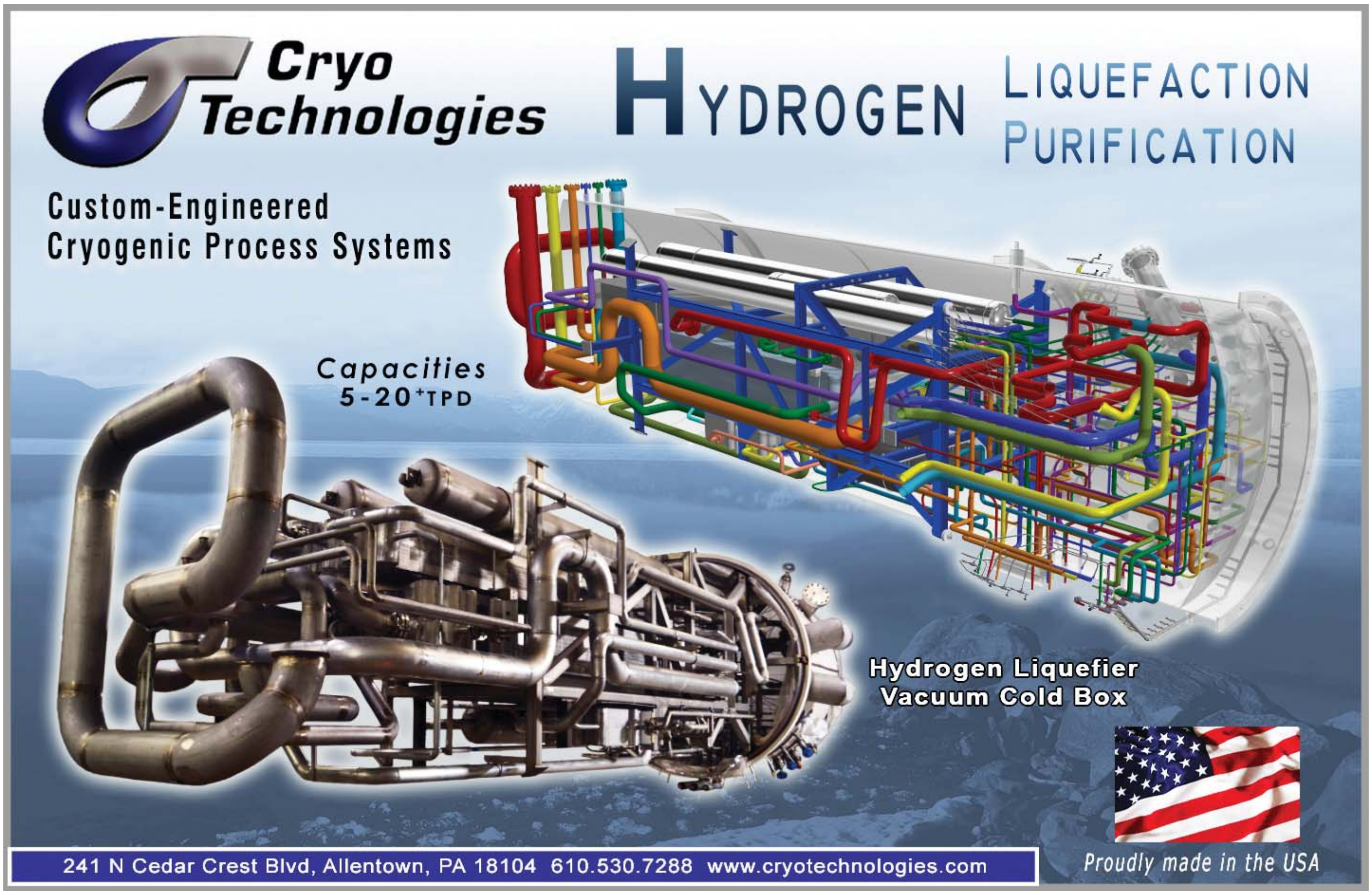
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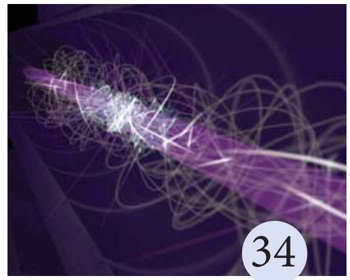
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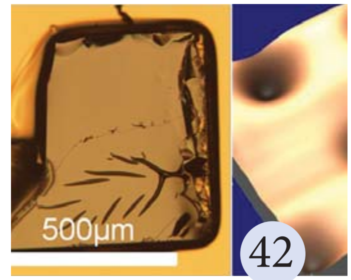

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From the Executive Director

Summer is here, and the world of CSA is bustling with activity!

In the spring, CSA held its bi-annual Board of Directors election. We had an impressive slate of eight director nominees and two president-elect nominees. Thank you to all the members who threw their hat in the race, as well as all the members who voted. The CSA Board of Directors met on June 9 to certify the results.

Newly elected are Al Zeller, NHMFL, FSU, president elect; directors Jason Hartwig, NASA Glenn Research Center; John Jurns, National Institute of Standards and Technology; Jacob Leachman, School of Mechanical and Materials Engineering, Washington State University; and Steven Van Sciver, Florida State University, Mechanical Engineering Department. They will take office immediately, along with President John Pfotenhauer, and Past President Peter Shirron.

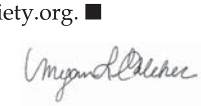
I also want to thank the four outgoing Directors who have spent the last six years serving our society and who extended their terms of service when the pandemic forced postponement of the election. A big thank you to Peter Bradley, Lance Cooley, Eileen Cunningham, and Jonathan Demko for their years of service.

On July 18, CSA will be hosting three virtual Short Courses in conjunction with the CEC/ICMC. Make sure to register before it's too late! The course topics are as follows: Theory, Modeling and Design of Regenerative Cryocoolers; Aspects of Cryostat Design; Getting Started with Cool Fuels: Liquefied hydrogen and natural gas. For registration and full details, visit **http://2csa.us/shortcourses.**

If you haven't done so already, make sure to mark your calendar for the upcoming 29th Space Cryogenics Workshop which will be held virtually on November 15-17, 2021. Abstracts are now being accepted by the SCW co-chairs, Amir Jahromi and Mark Kimball of NASA's Goddard Space Flight Center. Abstracts are solicited in all areas of cryogenics related to space applications, including missions, cryostats, components, sensors, instrumentation, cryocoolers, facilities, launch vehicles and more. Abstracts should be concise statements of no more than 500 words. To submit an abstract, please email the co-chairs at abstracts@SCW2021.org. The deadline for submission is July 30, 2021.

CSA is also soliciting Space Cryogenics Workshop sponsors! We are offering three levels of sponsorship – all of which will provide great exposure for your company. To view all the sponsorship details, visit our website at **www.spacecryogenicsworkshop.org.** Thank you to our current sponsors, Lihan Cryogenics and XMA Corporation.

Lastly, I'm excited to announce a new, fun online feature that CSA has just launched. We have added a page to our website where we will regularly post our favorite photos from around the world of cryogenics. We are lovingly calling it "Frosty's Favorite Fotos." Every other month, the image with the most online views will be featured in the next issue of ***Cold Facts***! Have a photo you think Frosty would love? Submit a high resolution image, caption and credit to editor@cryogenicsociety.org. ■



World's Strongest Superconducting Magnet Opens for Science at MagLab

The newest member of the National High Magnetic Field Laboratory (MagLab, CSA CSM) at Florida State University fleet—the 32 tesla (T) all-superconducting magnet—officially opened for users at the end of March, offering scientists the world's highest superconducting field suitable for sensitive quantum matter experiments.

Housed in an expansion of the lab's specially designed millikelvin research space for experiments conducted down to temperatures within 14 thousandths of a Kelvin above absolute zero, the 32 T has also received its official designation, SCM-32 T, and joins a prestigious team of instruments within the lab's DC Field Facility. "The launch of user operations on this new magnet is like expanding the MagLab family," said DC Field Facility director Tim Murphy. "Of course, with the magnet itself, but also through the new researchers who will now have an opportunity to leverage this instrument to make important research discoveries that will expand our understanding of the physics of complex quantum materials."

SCM-32 T combines a 15 T low temperature superconducting outsert made by industry partner Oxford Instruments (CSA CSM) and a 17 T high temperature superconducting insert designed by MagLab engineers to create a very stable, homogeneous research environment. The magnet system operates in a bath of liquid helium at 4.2 K and has an inner diameter of 34 mm, about the size of the grip on a tennis racquet.

MagLab researchers Troy Brumm and Robby Nowell prepare the SCM-32 T for users. *Image: Maglab*

In order to maximize the magnet's potential as a research tool, MagLab scientists and engineers created two custom designed, very stable and electrically quiet DC magnet power supplies. The magnet currently has two experimental insert options. First is a variable temperature insert (VTI) created by Janis Research (CSA CSM) with a temperature range of 1.5 K to 300 K and a sample space of 27 mm. Second is a top-loading into mixture (TLM) dilution refrigerator (Oxford Instruments Kelvinox® TLM) with a temperature range of 0.014 K to 1.0 K and a sample space of 25 mm that allows users to get very close to absolute zero to provide a clearer picture of the behavior of quantum matter. Specialty probes are also available for SCM-32 T experiments including one probe with a rotation stage that is wired for DC-100 kHz (twisted pairs and SS coax) and a second probe configured for condensed matter Nuclear Magnetic Resonance (NMR) experiments.

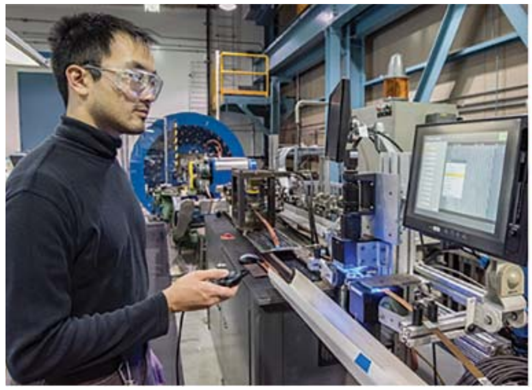
The first users measured NMR of a magnetic system with a spin nematic state. Additional probes with different capabilities (high frequency, optical fiber access, etc.) are currently in the design stage and will be launched in the coming months.

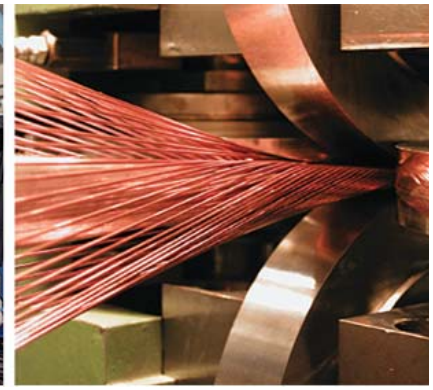
Eight years in the making, the 32 T reached full field in December 2017 and has since been relocated, commissioned and tested. The magnet was funded by the National Science Foundation's Division of Material Research and the State of Florida. There is no cost to scientists to use any of the MagLab's magnets. Interested researchers can submit a proposal for magnet time through the MagLab's online system at **https://users.magnet.fsu.edu**. Proposals will be reviewed for scientific merit and broader impact before magnet time is awarded. ■

Cabling for Large Hadron Collider Upgrade Project Reaches Halfway Mark

by Ian Pong, HL-LHC AUP cabling manager, Lawrence Berkeley National Laboratory, ipong@lbl.gov and
Joe Chew, communication coordinator, Lawrence Berkeley National Laboratory, jtchew@lbl.gov

The US Department of Energy's (DOE) Lawrence Berkeley National Laboratory (Berkeley Lab) has passed the halfway mark in the multiyear process of fabricating crucial superconducting cables as part of a project to upgrade the Large Hadron Collider (LHC) at CERN. This upgrade, now in progress, will greatly increase the facility's collision rate and its scientific productivity.





***Left:* Ian Pong, Berkeley Lab cabling manager for the HL-LHC AUP, works with the machine that forms numerous strands of superconducting wire into "Rutherford-style" cables. Cabling is crucial to magnet performance and a longtime strength of Berkeley Lab's superconducting magnet program. The cabling machine was first developed for the Superconducting Super Collider project and has since been updated with many state-of-the-art quality assurance features designed to address DOE project needs.** *Image: Marilyn Sargent/Berkeley Lab*. ***Right:* A detail of the part of the cabling machine: Strands of superconducting wire enter the rollers of the cabling machine where strands of superconducting wire are shaped and formed into keystoned "Rutherford style" cable.** *Image: Berkeley Lab*

The High-Luminosity LHC Accelerator Upgrade Project, or HL-LHC AUP, is a multi-institutional US contribution to the upgrade of the LHC facility. The project is headquartered at DOE's Fermi National Accelerator Laboratory (Fermilab, CSA CSM). A group of much more powerful focusing magnets, known as the "inner triplet," is to be installed on either side of the LHC's interaction points, where the separate proton beams collide. By squeezing the beams to higher density at the interaction points, these stronger focusing magnets will increase the number of collisions over the lifetime of the machine by at least a factor of 10. This will significantly enhance the opportunities for discovering new physics.

The coils for the HL-LHC AUP focusing magnets are made from advanced niobium-tin (Nb3Sn) superconductor in a copper matrix. One of Berkeley Lab's key contributions is fabricating all the cables to be used in the magnets. The task reached the halfway mark in January 2021. Fermilab's Giorgio Apollinari, AUP project manager, said of the milestone, "This is a great 'turning-of-the-buoy' achievement since it allows the project to continue unimpeded in the production of these critical HL-LHC AUP magnets." Berkeley Lab project lead and Berkeley Center for Magnet Technology (BCMT) director Soren Prestemon added, "This halfway mark is a tremendous milestone for our cabling team, who have delivered exceptionally for the project – even more remarkable given the complexities of on-site work under COVID constraints."

The overall AUP was recently granted Critical Decision 3 (CD-3) approval in the DOE's project management process, giving the go-ahead for series production of the magnets themselves. Cable fabrication had already begun under a management approach in which long-lead-time items, such as wire procurement and cable fabrication, received approvals to go ahead before the series production of the magnets. "The AUP project leverages extensive expertise and capabilities in advanced Nb3Sn magnet technology at Berkeley Lab," said Cameron Geddes, director of Berkeley Lab's Accelerator Technology and Applied Physics (ATAP) Division. ATAP and the Engineering Division formed the BCMT to join forces in advanced magnet design. Geddes added, "This critical milestone demonstrates the Lab's commitment to the project and the team's unique ability to deliver on its challenging requirements."

From conductor to cable to magnet

Most people have seen or even built electromagnets made from coils of individual wire, a familiar item at school science fairs and in consumer products. However, there are many reasons why these would not work well in accelerator magnets. Instead, accelerators use cables formed from multiple strands of superconducting wire. The cables are flat, with a rectangular or very slightly trapezoidal "keystoned" cross section, a profile known as "Rutherford style" after the Rutherford Appleton Laboratory in England, which developed the design.

Rutherford cables are flexible when bent on their broad face, which makes coil winding easy. However, the strands at the thin edges of the cable are heavily deformed and their thermoelectric stability could be degraded, so the shaping must be carefully monitored and controlled.

The overall AUP team is supported by the DOE Office of Science and consists of six US laboratories and two universities: Fermilab, Brookhaven National Laboratory, Lawrence Berkeley National Laboratory, SLAC National Accelerator Laboratory (CSA CSM), and Thomas Jefferson National Accelerator Facility (CSA CSM), along with the National High Magnetic Field Laboratory (CSA CSM), Old Dominion University, and

▶ *continues on page 10*

Cabling for Large Hadron Collider Upgrade... Continued from page 9

Florida State University. Each brings unique strengths to the challenges of designing, building and testing these advanced magnets and their components. Industrial partners supply the superconducting wire.

Berkeley Lab ships the cables to Fermilab or Brookhaven to be fabricated into coils and reacted (heat treated) to activate their superconductivity. The reacted coils are returned to Berkeley Lab, which uses them to make quadrupole magnets. “These magnets are a culmination of more than 15 years of technology development, starting with the LARP (LHC Accelerator Research Program) collaboration,” said Dan Cheng of Berkeley Lab’s Engineering Division.

‘Eagle eyes for quality and big collaborative hearts’

Berkeley Lab, which celebrates its 90th anniversary this year, has a long history of national and international collaboration in designing and building accelerators, and its superconducting magnet expertise goes back to the early 1970s.

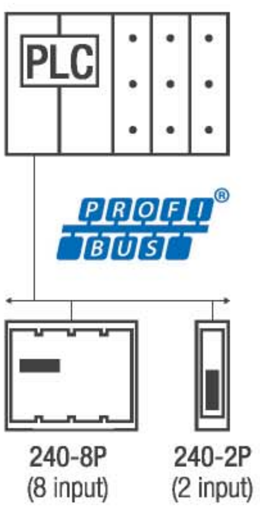
The planetary-motion cabling machine at Berkeley Lab was designed and installed in the early 1980s and has received continual upgrades over the years. It has contributed to a large number of DOE projects such as the Fermilab Tevatron upgrade and then the early development of the Superconducting Super Collider. To this day, the cabling facility is key infrastructure for Berkeley Lab’s superconducting magnet activities.

The cabling facility also boasts a world-class suite of quality assurance systems to monitor cable properties. These include an in-line cable measurement machine that can measure a cable’s dimensional parameters at a set pressure, an in-line camera system that can record every millimeter of all four sides of the fabricated cables and perform image analysis, and a specially designed cryocooler system for reproducibly measuring key parameters.

The people who assemble and use this equipment are in Berkeley Lab’s ATAP and Engineering divisions. Ian Pong, a staff scientist in ATAP and Berkeley Lab cabling manager for the HL-LHC AUP, said, “We have not only world-class equipment for fabricating state-of-the-art superconducting cables, but most importantly, a world-class team of people who have eagle eyes for quality and big collaborative hearts for projects.”

Apollinari concluded, “The Berkeley Lab group led by Ian has been outstanding in the high-quality production of the Nb_3Sn cables, meeting not only the demanding quality assurance and control requirements but achieving a production yield very much above and beyond the expected yield for this kind of activities. This is obviously of great help for the AUP Project, both economically and from the schedule point of view.” ■

Advancing
Large-Scale Cryogenics



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Monolayer Superconductor Exhibits Unusual Behavior

by David Nutt, author, Cornell Chronicle, cunews@cornell.edu

Cornell researchers have discovered a rare "pseudogap" phenomenon that helps explain how the superconducting transition temperature can be greatly boosted in a single monolayer of iron selenide, and how it might be applied to other superconducting materials. The group's paper, "Incoherent Cooper Pairing and Pseudogap Behavior in Single-Layer FeSe/SrTiO3," was published June 10 in ***Physical Review X***. The paper's lead author is Brendan Faeth.

The team was led by Kyle Shen, the James A. Weeks Professor of Physical Sciences in the College of Arts and Sciences, who together with Faeth sought to explore the properties of monolayer iron selenide because, as a high temperature superconductor, it has the potential to help researchers create novel electrical devices that conduct with zero resistance and, therefore, much greater efficiency.

One of the unusual traits of iron selenide is that, when it comes to conducting electricity, less is more. In bulk crystal form, the material becomes a superconductor at around 8 K (or -445.27 °F). But when grown as a single monolayer atop a substrate of strontium titanate, the compound superconducts at a much higher temperature: between 30 K and 60 K (-405.67 °F to -351.67 °F). "The magnitude of the enhancement is really big," Shen said. "Usually making materials really thin makes superconductivity worse. This is the total opposite. But the mechanism by which this enhancement was occurring was basically not known."

That mystery was compounded by mixed results from previous attempts to pinpoint the exact temperature of superconductivity in monolayer iron selenide. "People were doing these different types of measurements, and some people were saying, 'Oh, my Tc (transition temperature) is 20 K or 30 K,' and other people would say, 'No, my Tc is 60 K,'" Shen said. "So it wasn't really understood why people were reporting these Tc's that are completely all over the map. In doing our experiments, we see, 'Oh, actually, you're kind of both right.'"

One reason this phenomenon has been difficult to study is that iron selenide in its monolayer form – which the researchers grow via molecular beam epitaxy – is incredibly fragile. If the material is removed from the ultrahigh vacuum inside the growth chamber, the air will attack and disintegrate it. While scientists have been able to make partial measurements, no one has been able to piece together a complete and coherent picture of why the superconducting transition temperature in monolayer iron selenide is so much higher than in its bulk form, a situation that Shen compares to the parable about the blind men attempting to describe an elephant.

So, Shen's team got creative. Faeth, currently a research associate at Cornell's Platform for the Accelerated Realization, Analysis and Discovery of Interface Materials (PARADIM), custom-built an elaborate system of ultrahigh vacuum chambers docked together around a growth chamber. The system enabled the team to conduct a battery of measurements on monolayer iron selenide samples without removing or disturbing them.

"It's like a space station in reverse, because the vacuum is on the inside," Shen said. "We were able to do a whole sequence of different measurements. And in doing so, we were able to observe this so-called pseudogap phase, which had never been reported before in this system. That's sort of a hallmark of unconventional high temperature superconductivity, also seen in the high-Tc cuprate superconductors. And it gives us some clues as to what might be the mechanism for this enhanced pairing temperature."

For a material to enter the superconducting state with zero resistance, two things must happen: the electrons need to form so-called Cooper pairs and then the quantum-mechanical "phase" of all those pairs must become uniform. In typical superconductors, those two things usually occur simultaneously. However, in some exotic high temperature superconductors there is a lag between the two steps.

Faeth's measurements determined that an "unprecedentedly large" pseudogap begins around 60 K, when incoherent Cooper pairs begin to form. However, the pairs don't actually form a genuine superconducting condensate until about 30 K.

Now that the researchers have a clearer understanding of that mechanism, they can try to enhance the effect by changing the parameters of the substrate, or possibly employ it in other superconductors to boost their performance. "People have been working for 100 years to make high temperature superconductors," Shen said. "If you could actually do that, it would be revolutionary for energy transport, quantum information processing, electronics and any number of very important applications."

Co-authors include Darrell Schlom, the Herbert Fisk Johnson Professor of Industrial Chemistry; former Kavli Institute at Cornell for Nanoscale Science postdoctoral fellows Shuolong Yang and Jason Kawasaki; and doctoral students Jocienne Nelson and Chris Parzyck.

The research was primarily supported through the Air Force Office of Scientific Research, as well as the National Science Foundation and the Gordon and Betty Moore Foundation. The researchers also made use of the Cornell Center for Materials Research, which is supported by the NSF's Materials Research Science and Engineering Center program, and the Cornell NanoScale Science and Technology Facility, also supported by the NSF. ■

SOFIA Upgrading One-of-a-kind Camera

After making numerous discoveries about how magnetic fields shape our universe, an instrument flying on board the Stratospheric Observatory for Infrared Astronomy (SOFIA, ***Cold Facts*** Volume 35, Number 5), is about to get even faster at gathering data. Announced April 23, SOFIA is upgrading the High-resolution Airborne Wideband Camera-Plus, or HAWC+, with four new detectors that will allow it to study magnetic fields in distant galaxies four times faster than its current rate.

The HAWC+ upgrade is expected to be completed by 2023 and is the first step in the proposed outline for future instrumentation of SOFIA, a joint project of NASA and the German Aerospace Center – DLR. Based on feedback from a scientifically diverse group of astronomers, two additional instruments are envisioned that will enhance SOFIA's ability to make new discoveries. "We want to speed up the pace of scientific discovery, and we can do that by making HAWC+ even better," said Dr. Margaret Meixner, director of science mission operations at Universities Space Research Association. "This upgrade is part of a number of initiatives we're implementing to take SOFIA into the future."

HAWC+ is currently the only operating instrument in the world in an observatory that uses both far-infrared light and has a polarimeter, a device that measures polarized light from celestial dust grains, to infer the shape and direction of magnetic fields. Scientists are eager to learn more about the role magnetic fields play in shaping galaxies and the formation of stars, and observations like those SOFIA provides, using far infrared light, are critical to getting a clearer picture.

Flying at 40,000 feet and above the interfering layers of the atmosphere, SOFIA offers a one-of-a-kind platform for observing the infrared universe. Because it returns to the ground after each flight, its instruments can easily be exchanged, serviced or upgraded to harness new technologies that may one day be optimized for flight in space.

The High-resolution Airborne Wideband Camera-Plus, or HAWC+, awaits installation on SOFIA. The aircraft is in the background. *Image: NASA*

As Dejan Stevanovic, lead systems engineer for SOFIA, told ***Cold Facts*** in 2019, infrared radiation is effectively heat. The colder the detector—and the surrounding optics—the more sensitive that detector is to the faint heat signal from these distance cosmic sources. Most instruments on SOFIA operate at or around 4 K, with detectors at less than 1 K, by using a combination of nitrogen and helium cryogens, closed-cycle cryocoolers (mainly pulse tube coolers), helium sorption refrigerators and adiabatic demagnetization refrigerators (ADRs). SOFIA's HIRMES1 (High-Resolution Mid Infrared Spectrometer) utilizes two PTC coolers that provide a stable 4 K environment for the optical elements. It includes an ^{4}He sorption cooler with the sole task of cooling a detector baffle and an ^{3}He/^{4}He two-stage sorption refrigerator coupled with an ADR to achieve a stable detector temperature of 70mK for at least 12 hours.

While all infrared astronomical instrumentation, ground-based or airborne, requires cryogenic cooling to some extent, most of the ground-based telescopes are focused on near-IR (0.8-1.2μm) observations, so detectors generally do not need temperatures lower than 60 K to achieve high sensitivity and low noise. SOFIA is in a unique position with its ability to capture mid-IR and far-IR radiation by flying above 99% of atmospheric water vapor.

However, the ability to capture far-IR radiation comes with its own set of challenges and a set of very specific detector technologies that require 0.1 K or lower operational temperatures. These detectors and their cooling systems are so sensitive that any vibration, even the smallest one, can be detected as heat and adversely affect the science.

Vibration sources are very diverse, coming from usual aspects of aircraft operation (engines, airborne turbulence, etc.) to some that are very specific to SOFIA, like wind buffeting and turbulence around and inside the telescope cavity. The vibrational environment on-board SOFIA B-747SP drives a set of complex design limitations and requirements that are imposed on instrument cooling and vibration isolation systems, requirements that are rarely imposed on ground-based or even spaceborne instrumentation.

According to the roadmap published earlier, two new instruments envisioned for SOFIA include a spectrometer and a terahertz mapper. The highly sensitive spectrometer improves SOFIA's ability to measure faint signals by a factor of 10. With this spectrometer, SOFIA could for the first time measure the mass of gas, water vapor and water ice in the earliest phases of planet formation, enabling astronomers to learn how planetary systems form. The new terahertz mapper would build on the success of another of SOFIA's flagship instruments, the German Receiver at Terahertz Frequencies, or GREAT, by using similar technology with 100 pixels, an increase from GREAT's 14 pixels. This will allow the new instrument to make observations 14 times faster.

SOFIA is a joint project of NASA and the German Aerospace Center. NASA's Ames Research Center in California's Silicon Valley manages the SOFIA program, science, and mission operations in cooperation with the Universities Space Research Association, headquartered in Columbia MD, and the German SOFIA Institute at the University of Stuttgart. The aircraft is maintained and operated by NASA's Armstrong Flight Research Center Building 703, in Palmdale CA. ■

CERN Lays First Stone of Science Gateway

On June 21, CERN held a first stone ceremony for Science Gateway, the Laboratory's new flagship project for science education and outreach (***Cold Facts*** Vol. 35, No. 4). Scheduled to open in 2023, the CERN Science Gateway has environmental sustainability at its core. It will be an iconic, carbon neutral building and a local landmark, surrounded by a 400-tree freshly planted forest. Closely connected to the CERN campus, the Science Gateway will also feature a modular 900-seat auditorium, immersive spaces, laboratories for hands-on activities for visitors from age 5 up, and many other interactive learning opportunities.

Fabiola Gianotti, CERN's director-general; John Elkann, chairman of Stellantis and the FCA Foundation, the main donor; Renzo Piano, architect and founder of Renzo Piano Building Workshop; and Antonio Hodgers, representing the Geneva Canton, were present to mark the successful start of its construction. Ursula Bassler, president of the CERN Council, contributed to the ceremony remotely. Representatives from CERN Member and Associate Member States, Host States and many other partners were also in attendance at the ceremony.

The first stone with the newly unveiled logo of the CERN Science Gateway. Its underlying concept is to anchor the project and its mission to CERN. At the core is a collision, from which the architecture of the iconic building rises. The grey color combined with red highlights the stability and vibrancy of the project. From left to right: Renzo Piano, Fabiola Gianotti, Antonio Hodgers and John Elkann. *Image: CERN*

When the Laboratory opened in 1954, its convention already promoted openness and commitment to education and outreach. Almost 70 years and over two million visitors later, CERN is increasing its capacity to welcome visitors of all ages, from near and far, and extending its educational portfolio with a view to increasingly inspiring future generations towards science and research. Hundreds of thousands of visitors per year will have the opportunity to go on a captivating journey through the science, the discoveries and the technology at CERN, guided by the people who make it all possible. An exhibition on the Esplanade des Particules details the project and its connection to CERN.

"I would like to express my deepest gratitude to the many partners in our Member and Associate Member States and beyond who are making the CERN Science Gateway possible, in particular to our generous donors," said CERN director-general Fabiola Gianotti during her opening speech. "The challenging times we've been through over the past 18 months have demonstrated the enduring value and the necessity of science and the need for cooperation across borders. Science brings people together and shows what humanity can achieve when we put our differences aside and focus on the common good. Science gives hope and trust in a better future. We want the CERN Science Gateway to inspire all those who come to visit with the beauty and the values of science."

"It is with joy and pride that we are launching today this ambitious project where, thanks to the collaboration of different skills, nationalities and languages, we will build a place of exchange and knowledge. A bridge, forever bridges! A glass bridge, which links the different themes and parts of Science Gateway while also allowing a physical encounter between researchers and children, visitors and physicists, tourists and scientists, all driven by curiosity and the thirst for knowledge," said Renzo Piano, the internationally renowned architect, whose notable buildings include the Zentrum Paul Klee in Bern, the Pompidou Centre in Paris, and the Shard in London.

"At Stellantis we strongly believe in the importance of education, with an emphasis in the fields of science and technology," said John Elkann, chairman of Stellantis and the FCA Foundation. "Supporting STEM education has proven to be the most effective way to keep our societies open and safe, as we have learned this last year by overcoming the Covid-19 crisis."

"CERN Science Gateway is a great way to democratize scientific research and a spectacular entrance gate to Geneva," said Hodgers, who is also the Geneva State Councillor in charge of Territorial Planning.

"We will do our best, not only in the construction and operation of the Science Gateway, but also more widely, to ensure that science maintains a place of integrity and trustworthiness, of international collaboration aiming for peace," said Ursula Bassler. ■

WOMEN *in* SCIENCE, TECHNOLOGY, ENGINEERING AND MATH (STEM)

Mechanical Engineer Caitlin Kalinowski on Creating STEM Interest and Opportunities for Women, People of Color

According to the American Association of University Women, females make up only 28% of the workforce in science, technology, engineering and math (STEM), and males outnumber women majoring in most STEM undergraduate majors. This statistic drives engineer and STEM advocate Caitlin Kalinowski to be a guiding voice for women and minorities interested in these industries. Kalinowski actively promotes more women joining these fields while also working as a leader in virtual reality.

"Women entering highly male-dominated places have always had to learn new ways of communicating to be effective. In past roles, I've had to learn how to communicate in a masculine culture in ways that I was not socialized for. Even [STEM] courses for young people use problem sets and projects more appealing to young men, so we need to start at the very beginning to improve diversity," says Kalinowski, who now works as a hardware director for Facebook® Reality Labs' Oculus VR® program.

Kalinowksi points to some of the major factors that contribute to lower interest from females and minorities, saying gender stereotypes, imposter syndrome, male-dominated cultures, and fewer role models all contribute to the current imbalance in the field.

The media has an important role to play. Kalinowski believes that constant discussions in the media about how male-dominated STEM fields are is actually making the problem worse. By constantly discussing these stereotypes, young girls can develop further insecurities. Kalinowski wants the next generation to experience normalcy and confidence in STEM, with fewer gender stereotypes attached. "I worry about how society talks about STEM and how to get more girls to participate because when one focuses on the gap, girls will internalize it. Be careful not to imply that these are predominantly male areas. Telling your daughter that she's smart and capable is really important," Kalinowski comments.

A critical step to help more women and minorities succeed in STEM would be to create greater confidence and interest in STEM in elementary and middle school. Letting college women and schoolgirls know that they have a future in these industries is extremely important. More importantly, if girls seem hesitant to enter the STEM field, it is imperative they receive positive mentoring before and during employment.

In the short term, it's important to diversify the communication and language used in STEM environments in order to be inclusive of female perspectives, thus encouraging young women and girls to be more outspoken.

Longer-term, balancing and diversifying the STEM fields themselves will create cultures that are more welcoming to young women and underrepresented minorities.

Kalinowski indicated her top takeaways for fostering more women and girls in STEM:

1. Make an effort to find and attract more women to STEM—think outside the box

2. Build relationships with colleges, as well as elementary and middle schools, to attract more women to STEM

3. Provide resources for women and girls to succeed in STEM fields

4. Provide mentoring

5. Put more attention on advocating, rather than focusing on the gender gap narrative

"Seeing more women in the field can be a source of inspiration. Girls have to be shown what women can do. The key is to foster their drive with mentoring and the opportunity to follow that dream," Kalinowski concluded.

About Caitlin Kalinowski

Caitlin Kalinowski earned her BS in Mechanical Engineering in 2007 from Stanford University, where she is a guest lecturer at Stanford's School of Engineering and the Hasso Plattner Institute of Design. Currently, Kalinowski is hardware director for Facebook Reality Labs' Oculus VR products—including 2020's Oculus Quest 2®, Oculus Quest®, Oculus Go®, and Oculus Rift®. Previously she was a technical lead for Mac Pro® and MacBook Air® products and was part of the original unibody MacBook Pro® team. Kalinowski has also been instrumental in her support for the arts in California and her work blazing paths to encourage girls to enter STEM. ■

Equal1 Laboratories Announces Breakthrough with Fully Integrated, 3.7 K Quantum Processor Using Commercial Technology

On May 13, Equal1 Laboratories (Equal1), a silicon-based quantum computing company, announced the company is the first to demonstrate a fully integrated quantum processor unit (QPU) operating at 3.7 kelvin—a major milestone with implications for the trajectory of quantum computing.

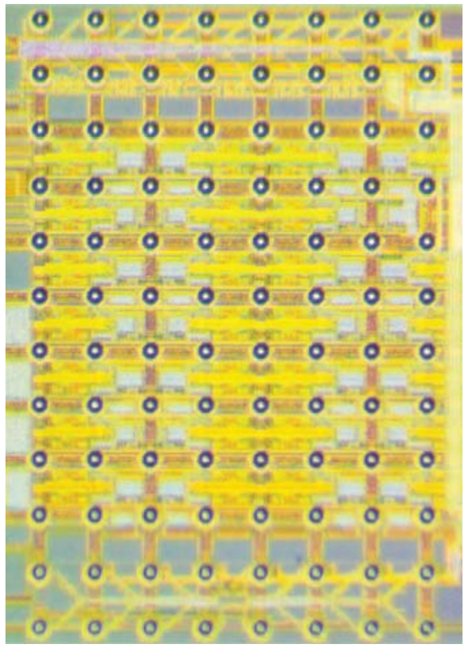
The company is addressing a major challenge for the quantum computing industry of scaling the number of qubits so that a quantum computer can tackle useful, real-world problems. With its QPU, Equal1 has developed a disruptive, scalable and cost-effective quantum computing technology, based on a commercially available silicon semiconductor process.

The QPU employs patented, Equal1-designed, nanometer-scale quantum dots to create qubits (the quantum equivalent to digital bits) on a standard silicon CMOS process. In addition to the silicon qubits, all control and read-out electronics required for a fully functioning QPU are integrated on-chip with over 10 million transistors.

In addition to developing its QPU, Equal1 has designed and manufactured the closed cryogenic and vacuum system, together with the control and communication electronics to maintain the chip at 3.7 K and interface to room temperature.

Due to the operation of the qubits at 3.7 K (referred to as "hot qubits") and the level of integration the team has achieved, the form factor of the quantum demonstrator is far smaller than alternative technologies (rack-sized versus room-sized).

Equal1 was founded by Dirk Leipold, Mike Asker and Professor R. Bogdan Staszewski and is a spin-out from the UCD School of Electrical and Electronic Engineering. The Equal1 team has offices at NovaUCD, the Center for New Ventures and Entrepreneurs at University College Dublin, and in California.



Equal1 QPU fully integrated quantum processor unit (QPU) operating at 3.7 kelvin. *Image: Equal1 Laboratories*

Elena Blokhina, Equal1 CTO, said, "Our team's ability to demonstrate quantum behavior on a fully integrated QPU will enable us to soon solve challenges in AI that cannot be solved today. We are proud of the milestone accomplishment and excited to scale our technology to the next level."

Two Equal1 quantum demonstrator machines ("Alice") each have been running for over 24 cumulative months with no unplanned downtime. On Alice, Rabi oscillations have been observed in three-dot arrays with a coherence time of 150 ns.

Due to the integrated nature of the technology, the electronic pulses that control the qubits are generated on-chip and therefore are extremely fast, enabling a short enough pulse time for the QPU to demonstrate quantum behavior. The team has proven the repeatability of the results and consistency with quantum modeling and simulations. "By taking advantage of shrinking transistor geometries, we have demonstrated that integration into the millions of qubit range is possible, with moderate cooling requirements compared to other qubit technologies," said Equal1 CEO, Dirk Leipold. "Our quantum computing technology delivers affordable AI solutions to our customers at a much lower carbon footprint."

The QPU was manufactured on GlobalFoundries® leading low power 22FDX™ platform, requiring no special process extensions for quantum operation. Employing this ultralow power platform at GlobalFoundries Fab 1 in Dresden, Germany played a key role in enabling Equal1 to achieve the results presented here.

The Equal1 team designed the complex mixed signal circuits, such as high speed pulse generator, ADCs, DACs and cryogenic memory, using EDA software from Cadence Design Systems, Inc., in particular Spectre® Simulation Platform's new support for ultralow temperature models which are key to cryoelectronic design validation.

Commenting on the achievement, Cadence Product Management Director for Circuit Simulation Products Joy Han said, "This is a very exciting result and shows a disruptive and potentially game-changing approach to quantum computing. We hope to continue our collaboration with Equal1 long into the future."

Equal1 has achieved this milestone supported by funding from Atlantic Bridge, Enterprise Ireland and 808 Ventures. Earlier this year Equal1 was named the winner of the 2021 NovaUCD Spin-out of the Year Award. ■

United Vaccines, Inc. Utilizes Hampshire Controls' LN_2-level Detector as Fail-Safe for Protecting Mammalian Vaccines

Headquartered in Verona WI, United Vaccines, Inc. (UV) is known as the leading manufacturer of veterinary vaccines for the fur-bearing animal industry worldwide. Like many manufacturing companies, UV faces a continuing problem; their important biological samples must be properly maintained in ultracold, long-term storage with 24/7 monitoring.

When seeking a solution, facilities engineer Jay Newman and his team evaluated several temperature monitoring companies in search of a new, reliable solution that had the ability to notify staff before the liquid nitrogen in the freezer chambers storing the biologics reached dangerously low levels. This notification system would allow enough time to take corrective action, preventing negative impacts that warm temperatures have on the viability of these materials.

Two Hampshire Controls LD 215 Units.
Image: United Vaccines

Newman and his team weighed the options and eventually chose Hampshire Controls for their industry knowledge and capability to easily integrate into UV's existing EMS Alert Monitoring System. The technical team at Hampshire Controls was able to assist UV with a customizable solution tailored to their specific application.

Now, UV's facility utilizes Hampshire Controls' LD 215: Freezer/Dewar Liquid Nitrogen Level Detector and Alarm Systems to act as a fail-safe for the mammalian vaccines UV is producing. UV also uses Hampshire's Air Flow Monitor/Alarm Systems to monitor UV's Laminar Flow Hoods and Biosafety Cabinets. In the eight months since the implementation of Hampshire Controls' monitoring solutions, there has been no recorded loss of vaccines, and the risk of loss has dramatically decreased.

When asked about the experience working with Hampshire Controls, Newman commented, "We are very happy with these devices. The ability for Hampshire Controls to customize these devices to our liking is an advantage over other companies we evaluated." ■

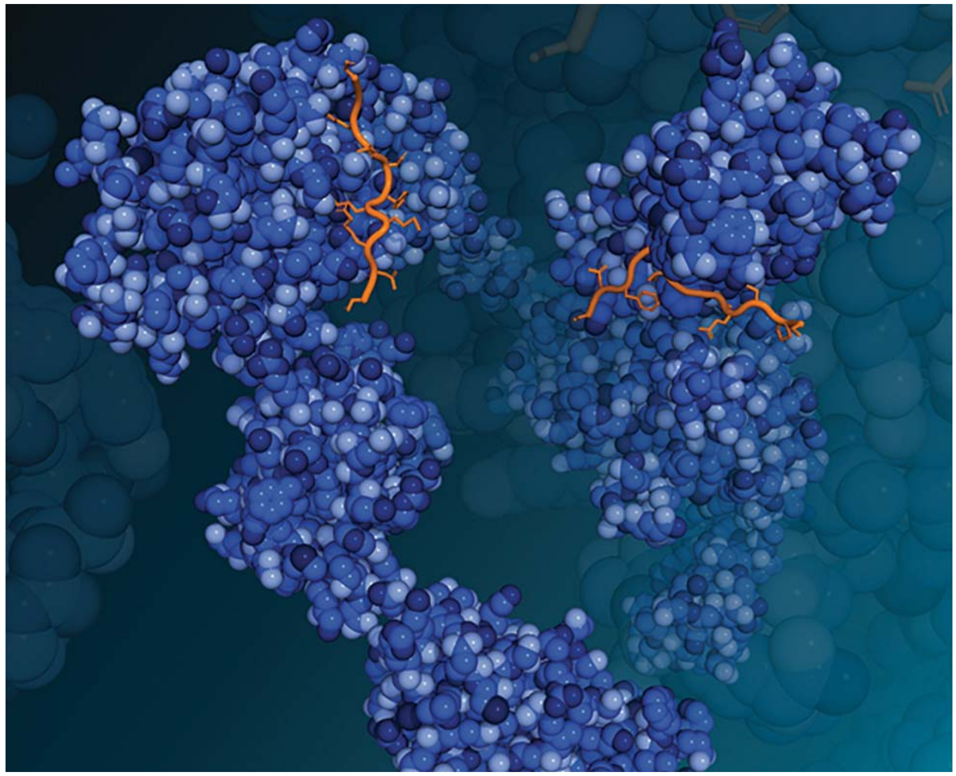
NSF Announces Major Investment in Spectroscopy to Advance Critical Imaging Technologies

The US National Science Foundation is advancing biomolecular research through the establishment of a geographically distributed Network for Advanced Nuclear Magnetic Resonance. This investment of $40 million is made through NSF's Mid-Scale Research Infrastructure II program, an NSF-wide effort to meet the research community's needs for modern research infrastructure to support science and engineering research.

The network will allow researchers to have access to ultrahigh field nuclear magnetic resonance spectrometers to study the structure, dynamics and interactions of biological systems and small molecules. Understanding how these facets interact and how life has evolved and adapted, including under extreme conditions and environments, will advance the scientific community's understanding of biology and may result in the development of new materials, battery components, pharmaceutical ingredients, nanomaterials, surface coatings and catalysts. These new materials can further advance fields such as biology, medicine, engineering, electronics and manufacturing.

"This new infrastructure, along with the network of scientists to support it, will help advance research in biological sciences across the country through innovative experimentation and new biological insights," said NSF assistant director for biological sciences Joanne Tornow. "This project can help us understand more about the world around us and how life has adapted to that world, allowing us to harness those adaptations to biotechnologies and to enable a future vibrant US bioeconomy."

The project creates a centralized network led by the University of Connecticut School of Medicine in partnership with the University of Georgia and University of Wisconsin. Through this network, a broad geographic range of researchers across disciplines will have access to nuclear magnetic resonance spectroscopy. Researchers who currently do not use this technology but whose work could benefit from it will be given the opportunity to engage with this cutting-edge field and expand their research. Remote users at any institution will be able to bring or send their samples to take advantage of the program. Expanding the availability of ultrahigh field nuclear magnetic resonance resources in the US will allow scientists to conduct innovative science and studies in partnership and on par with researchers in other countries.



Proteins play important roles in cellular signaling. The image shows a structural model of a protein enzyme bound to its target molecule as part of the process to modulate the signaling. NMR spectroscopy was used to identify the bipartite binding interface between the enzyme and its substrate. The ultrahigh field NMRs planned for the NAN will provide even better resolution, speed, and sensitivity for similar analyses, leading to new understandings in structural biology.
Image: Irina Bezsonova, Department of Molecular Biology and Biophysics, UCONN Health

The network will also broaden participation in STEM by providing technological resources, training, and access to collaborators for students from backgrounds underrepresented in STEM and those at primarily undergraduate institutions and Historically Black Colleges and Universities. The network will also engage in community outreach and create a set of online tutorials, protocols, and additional technical materials.

For decades, NSF has funded cutting-edge infrastructure that allows scientists to push the frontiers of science and engineering. Through the Mid-Scale Research Infrastructure program, NSF supports experimental research capabilities that have strong scientific merit, respond to an identified need of the research community, demonstrate technical and managerial readiness for implementation, include a well-developed plan for student training in the design and implementation of mid-scale research infrastructure, and involve a diverse workforce in mid-scale facility development.

More information about the Mid-Scale Research Infrastructure-2 program and the Network for Advanced Nuclear Magnetic Resonance project can be found at **nsf.gov**.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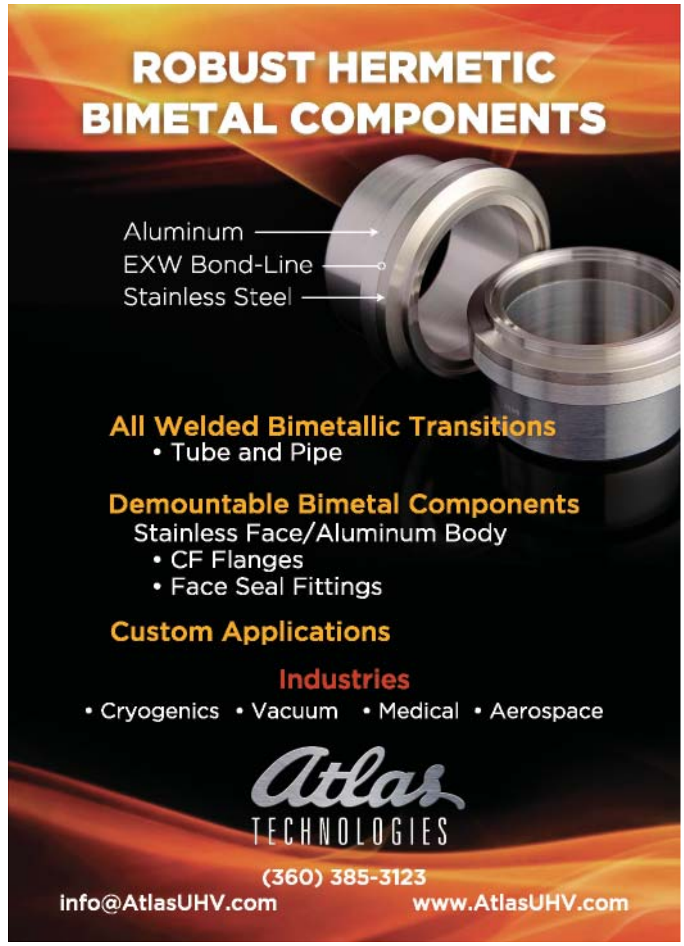
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Space Cryogenics

by J. R. Feller, NASA Ames Research Center, jeffrey.r.feller@nasa.gov

Progress in Low-Gravity Cryogenic Fluid Management

NASA recently announced the selection of four proposals – from Eta Space (Merritt Island FL, CSA CSM), Lockheed Martin (Littleton CO), SpaceX (Hawthorn CA) and United Launch Alliance (Centennial CO) – submitted in response to the competitive "Tipping Point" cryogenic fluid management (CFM) flight demonstration solicitation. The combined investment is over $370 million. Each company brings its own unique experience and perspective, but the overall goal is the same – to demonstrate on-orbit a suite of technologies and capabilities that will allow us to safely and efficiently handle cryogenic propellants in microgravity. The proposed experiments involve long-term liquid oxygen (LO_2), hydrogen (LH_2) and methane (LCH4) storage, liquid acquisition and transfer, liquid quantity gauging and tank pressure control. This program promises a quantum jump in flight CFM technology maturation.

Now that we are entering what looks to be a new era of CFM, it is perhaps a good moment to pause and reflect on the efforts of so many scientists and engineers that have led to this point. Of course, it is impossible to do justice to the subject here. The most that can be done is to present a cursory summary of experimental efforts, and to draw attention to a handful of highlights. On reviewing the history of CFM in space, it is found that the most consequential flight experiments fall into four categories: early low-g experiments, vehicle flight demonstrations, subscale flight experiments and, finally, cryogenic technology flight demonstrations.

Early Small-Scale Low-g Experiments

The earliest experiments were conducted in drop towers and on short parabolic flights [1,2], which allowed researchers to study fluid dynamics at low g-factors, but only for a few seconds. The short time window severely limited the range of possible experiments and applicability to general analytical models. Significantly longer time windows were soon after achieved using sounding rockets. In the early 1960s, a number of nifty little LH_2 dewars (Figure 1) were flown on Aerobee sounding rockets [1], providing up to five minutes of "free-fall" at around 10^{-4} g. The Aerobee dewars were outfitted with a variety of instrumentation, even including film cameras to visually study slosh, tank wall wetting, ullage configurations and boiling. Among other valuable data, measurements of tank pressure rise rates were used to validate LH_2 thermal-fluid models. Such models would soon prove useful in the development of full-scale CFM flight systems.

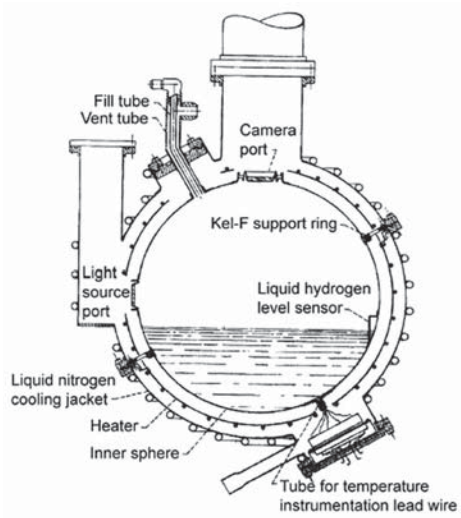

Figure 1. Small (9-inch inside diameter) liquid hydrogen flight dewar [1]. *Image: D. J. Chato*

Vehicle Flight Demonstrations

The 1960s saw a dramatic expansion of NASA's research and development efforts as the nation committed to a manned moon shot, under the Apollo Program, by the end of the decade. A lynchpin of Apollo was Saturn IVB, the moon rocket's LH_2/LO_2 upper stage. In 1966, flight AS-203 was conducted specifically to demonstrate IVB's vital functions. [1] Of particular importance was the ability to reliably restart the engine after coasting in low earth orbit for several hours. All mission objectives were achieved. In addition, flight AS-203 yielded a wealth of data that has been used, even years later, in the validation CFM models. The Centaur upper stage, a long-lived workhorse of the US space program, similarly served as a CFM testbed in the 1960s and beyond.

Subscale Flight Experiments

From the mid-1980s through the 1990s, a series of subscale fluid-dynamic experiments employing non-cryogenic refrigerants (e.g. freon), flew on Space Shuttles [2]: SFMD (Storable Fluid Management Demonstration), TPCE (Tank Pressure Control Experiment), FARE (Fluid Acquisition and Resupply Experiment), VTRE (Vented Tank Resupply Experiment) and PBE (Pool Boiling Experiment). This line of experimentation was continued on the International Space Station (ISS) [3] via MFMG (Miscible Fluids in Microgravity), CFE (Capillary Flow Experiment), NPBX (Nucleate Pool Boiling Experiment), MABE (Microheater Array Boiling Experiment), the SPHERES-Slosh Experiment, CFVib (Control of Fluids in Microgravity with Vibrations), FLUIDICS (Fluid Dynamics in Space), and ZBOT (Zero Boil-Off Tank experiment), among other experiments. The latest addition to the ISS fluid-dynamics arsenal will be FBCE (Flow Boiling and Condensation Experiment), which has yet to launch. FBCE is a multipurpose facility for the investigation of phenomena related to two-phase flow and heat transfer in microgravity. The facility consists of fluid conditioning hardware and three independent test modules: the Flow Boiling Module (FBM); the Condensation Module Heat Transfer (CM-HT) and Flow Visualization (CM-FV). FBCE test data will be used in the development and validation of mechanistic models of flow boiling/condensation under various regimes.

Cryogenic Technology Flight Demonstrations

Unlike the Shuttle and ISS experiments, these demonstrations are much larger in scale, and employ cryogenic fluids. They are meant to mature various CFM technologies, readying them for infusion into future flight systems such as cryogenic upper stages or in-space propellant depots. For many of these technologies – for example, unsettled liquid mass gauges and in-tank propellant management devices – maturation requires sustained operation in a microgravity environment. Nearly all CFM flight demonstration projects, going back to the 1960s, never progressed beyond study phases. [2] Among these are Project THERMO (Thermo and Hydrodynamic Experiment Research Module in Orbit), CFME (Cryogenic Fluid Management Experiment), COLD-SAT (Cryogenic Orbiting Liquid Depot – Storage Acquisition and Transfer) and CONE (Cryogenic Orbital Nitrogen Experiment). CRYOTE (Cryogenic Orbital Testbed) managed to break the study barrier: a ground test article was built and tested in a thermal vacuum chamber in 2011/2012. [4] It never flew, however. The SHOOT (Superfluid Helium On-Orbit Transfer) experiment did fly – on Shuttle in 1993. [5] It was designed to demonstrate technology and techniques required to replenish liquid helium dewars (e.g. for space telescopes) on orbit. All mission objectives were successfully completed. However, because the operation of key technologies – thermomechanical "fountain effect" pump, phase separators and heat pulse mass gauge – rely on the peculiar properties of superfluid helium, SHOOT is largely irrelevant to "proper" CFM, which is concerned with the handling of (mostly) classical cryogenic liquids. RRM3 (Robotic Refueling Mission 3) also flew [6]; it was an exterior payload on ISS that was to demonstrate zero boiloff storage of LCH4, robotic fluid coupling and transfer to a secondary tank. Unfortunately, most of the mission's objectives were not completed due to a malfunction of the cryocooler electronics. All was not lost, however: the radio frequency mass gauge and the propellant management device (used to position the liquid in microgravity) were shown to perform more or less as predicted. Finally, the CPST (Cryogenic Propellant Storage and Transfer) project was an ambitious flight mission meant to demonstrate on-orbit a large suite of CFM technologies. [7] For budgetary reasons CPST was cancelled in 2014, but not before spawning a vigorous technology maturation phase. [8] Notably, a series of propellant storage tests – LO_2 zero boiloff and LH_2 reduced boiloff (Figure 2) – were carried out at NASA Glenn Research Center and Marshall Space Flight Center. These tests employed, among other components, a flight-like cryocooler and coolant circulator, distributed cooling networks and advanced insulation systems. None of these required a microgravity environment for proper maturation. The flight demonstration would have allowed for the maturation of gravity-dependent technologies, including a liquid mass gauge and liquid acquisition devices.

Figure 2. Installation of the CPST LH_2 Reduced Boil-Off test article in Glenn Research Center's SMiRF (Small Multi-Purpose Research Facility) [7]. *Image: M. L. Meyer*

At the beginning of the Space Age, a number of fundamental low-gravity CFM knowledge gaps were identified, including propellant stratification and mixing, tank pressurization, venting, bubble formation, liquid acquisition, liquid-ullage configuration and slosh. It is humbling to realize that, despite all the progress of the past 60 years (and a seemingly endless list of acronyms and abbreviations), we are still grappling with many of the same questions.

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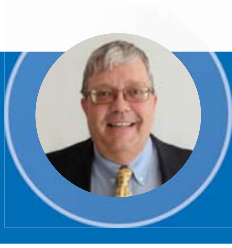


Cryo Bios

by Dr. John Weisend II, European Spallation Source ERIC, CSA chairman, john.weisend@esss.se

Walther Nernst

A significant amount of our understanding of liquid helium can be traced back to an unrelated fundamental question in chemistry. The link here is Walther Nernst.

Walther Hermann Nernst was born on June 25, 1864 in Briesen, West Prussia. He studied physics and mathematics at the Universities of Berlin, Zurich and Graz. In Graz, he studied under Professor Albert von Ettinghausen and together they discovered the Nernst-Ettinghausen effect. This is the creation of an electric field in a conductor in which a magnetic field is applied perpendicular to a temperature gradient. This became the basis for Nernst's doctoral thesis that he defended in 1886 at the University of Wurzberg.

After graduation he moved to the University of Leipzig where he worked in the first established department of the new field of physical chemistry. In 1891, he moved to the University of Göttingen where he was made Director of the Institute for Physical Chemistry and Electrochemistry. In 1905, Nernst went to the University of Berlin as a Professor in Chemistry and became Director of the Physical Chemistry Institute in 1924. He remained in Berlin for the rest of his professional life.

Throughout his career, Prof. Nernst made important contributions on a wide range of topics including the theory of galvanic cells, electrolysis and the excitation of nerves in animals. He also invented a much improved lamp for miners and even developed a new electric version of the piano. His book *Theoretical Chemistry* (1893) became a standard text for chemistry students worldwide during the late 19th and early 20th centuries.

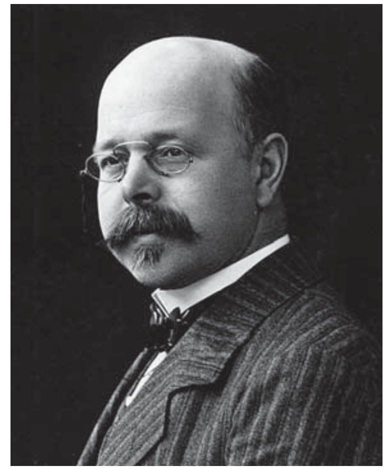
However, for us, his most relevant contribution was the development of

F.A. Lindemann and W. Nernst in Oxford, 1937.
Image: K. Mendelssohn, The World of Walter Nernst (University of Pittsburg Press, 1973)

what we call today the Third Law of Thermodynamics.

This work was driven to a large extent by the question of whether one could predict the spontaneity of chemical reactions. If you knew the free energy of the reactants and compared this to the free energy of the products you could make this prediction. The problem was that it wasn't possible to calculate the absolute free energy of a substance. Nernst proposed that the difference between the free energy and total energy of a substance must approach zero as the temperature approached absolute zero. This statement meant that the free energy of a substance could be calculated as a function of temperature from absolute zero. Nernst's hypothesis also meant that the change in entropy of a substance had to approach zero as the temperature approached 0 K. A practical effect of this statement is that we can never actually reach absolute zero as any cooling method would require changes in entropy.

It's all well and good to have a theory but in order for it to be accepted, one must prove it by experiment. One of the predictions of the Third Law is that both the specific heat of substances and the change in specific heat approach zero at 0 K. Nernst and his team at Berlin started to make precision measurements of properties such as



Walther Nernst

Born June 25, 1864

Died November 18, 1941
Germany

specific heat and expansivity at cryogenic temperatures. Their efforts and those of other researchers have led to the Third Law of Thermodynamics being accepted as a fundamental physical law.

In carrying out this work, Nernst and his team, which included the English scientist F.A. Lindemann, F. Simon (CryoBios, ***Cold Facts*** Vol 37 #2) and K. Mendelssohn (CryoBios, ***Cold Facts*** Vol. 37 #1), became proficient in cryogenic research. They built a hydrogen liquefier, developed new types of small helium liquefiers and learned to make measurements at these temperatures.

Lindemann later returned to England where he became the Director of the Clarendon Physics Laboratory at Oxford University. At the time, the Clarendon had very little in the way of a research program and one of the first groups Lindemann established, based on his Berlin experience, was in cryogenics. With the rise of Hitler, Lindemann recruited Mendelssohn, Simon, Nicholas Kurti and others to come to the Clarendon and work in cryogenics. This group at the Clarendon Laboratory became one of the most productive cryogenic research groups for the next 50 years. Important discoveries in He II films, superconductivity and cryogenics below 1 K all came from this group, whose existence can be directly traced back to Nernst and his development of the Third Law of Thermodynamics.

The success of the Oxford cryogenics group is a good illustration that academic research groups not only produce scientific results but also produce qualified people (in this case Lindemann, Simon and Mendelssohn) who can then go to produce important discoveries of their own.

Nernst had conflicts with the new National Socialist government in Germany and as a result retired from the University of Berlin in 1933. He went back to his country estate where he lived peacefully until his death in 1941.

Professor Nernst received many honors in his lifetime, including the Nobel Prize for Chemistry in 1920 for his work in thermochemistry. In 1937, he was awarded an honorary doctorate from the University of Oxford which allowed him to visit his friend and former student F.A. Lindemann (see photo on opposite page).

Nernst's life is put into the broader context of the development of science in Germany in *The World of Walther Nernst* by K. Mendelssohn. ■

Cool Fuel

by Dr. Jacob Leachman, associate professor, Washington State University, jacob.leachman@wsu.edu

A Deployable Hydrogen Liquefier

One of my favorite finds from the NASA history archives is Project Suntan: "Suntan was an effort by the Air Force to develop a hydrogen-fueled airplane with performance superior to the secret spy plane, the U-2."[1] You should read the history archives if you haven't for the full story. Like many efforts to develop liquid hydrogen-fueled aircraft, the key limiter for Suntan was not the aircraft itself but the logistical challenges of reliably refueling in remote or difficult locations. Commercial scale hydrogen liquefiers were still being developed at the National Bureau of Standards (now NIST) in Boulder and the challenges associated with deploying a resilient, cost-effective system seemed insurmountable to the Air Force at the time. Suntan, like many hydrogen aerospace projects since, was ultimately canceled or changed because of these logistical fuel issues.

With the renewed push for zero-carbon aviation, there is an increased interest in using high performance liquid hydrogen as fuel for everything from personal drones to 80-seat commercial airliners.[2] Somehow though, the technology (at least the thermodynamic cycles) used for large-scale liquefaction of hydrogen have changed little since the Suntan days of the 1950s. When you consider the capital cost (~$3M/tonne) to install hydrogen liquefiers at all of our airports you quickly realize that infrastructure and logistics will yet again become the dominant barrier to use of liquid hydrogen in aerospace. Folks sure like the idea of a pretty airplane with zero emissions, so you don't hear about this barrier often in the popular media.

What has changed since the Suntan days are the small-scale hydrogen liquefier technologies. Cryocooler, dewar and electrolyzer technologies are now available at the laboratory scale that can be integrated together in such a way to produce liquid hydrogen on demand, anywhere you have access to water and electricity. A team in my laboratory has been working for the past two years to develop such a deployable hydrogen liquefier. The team is calling the project the Mobile Hydrogen Generation Unit (MHGU) or simply "magoo" for short. At over 6,000 parts, magoo is the most complex engineered system I've seen accomplished by university students. The photo shows the second generation MHGU with many of the student team members.

The 2nd and 1st generation Mobile Hydrogen Generation Units (MHGU2 and MHGU1) with team members from left to right (Leif Harfst, Glynne Saelid, Dr. Ian Richardson, Jordan Raymond, Sean Dimmer, Mathew Dickson, Drew Boettner, Jordan Kurtz, Hannah Gardner and Mark Parsons.) *Image: Jacob Leachman*

We've been operating these liquefiers for a little over a year now for refueling experimental liquid hydrogen tanks. The biggest challenge we encountered was navigating the NFPA 2020-2 Hydrogen Technologies Code[3] to fit all of the tech in one small box and setting up our controls system to safe everything in the event of a deviation. But we're proud of the end result – a ruggedized, vibration isolated system that only requires water and power for production of liquid hydrogen fuel.

The ability to make liquid hydrogen wherever you have water and electricity is a game changer. No other fuel can claim this convenience. Whether it be a remote field or the deck of an aircraft carrier, the fact that we do not need a refinery and logistical network to transport fuel to the end user makes a difference, even with the relatively poor efficiencies of these smaller technologies.

The next steps include scale-up, increased integration, and improving efficiencies – all things I'm going to be thinking a lot about this summer while getting my own suntan.

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Clean Energy Future

by James E. Fesmire, president, Energy Evolution LLC, 321energy@gmail.com

Low-Cost, At-Scale Energy Storage

How much of the world's renewable energy sources are wasted each day? Nearly all of them. We collect some solar and some wind and a little geothermal, put it to use as we can, and the rest is thrown away. Energy storage is the problem. There are some battery packs that can store a few hours-worth, but it is nowhere close to "at-scale" and certainly not "low-cost" and will most likely never be.

There is low-cost, at-scale energy storage available today, but only in a few select locations. It is called pumped hydro (water dams) and is central to modern life and economy in all such places.

The modern world is chiefly characterized by one thing, and that is electrification. Figure 1 is a composite image of the world at night, illustrating the energy network we take for granted every day. [1] But electrification is a very special thing. It is the world's largest supply chain, and this supply chain operates with zero inventory. [2] Everything electric is just in time: the production is exactly matched with consumption. The exceptions are a few hydroelectric plants that can supply maybe 24 hours worth of electricity at most. The problem is that there exists no ready means of low-cost, at-scale energy storage.

Power is joules per second or watts (W). But what is energy and what is a joule? No one has ever seen a joule; we can only describe its effect on the physical world. However, the scientific description of the word came about separately in two areas: 1) heat energy and 2) laws of mechanics, electricity and magnetism. The proportionality constant between these two worlds, between these two forms of energy, is called the *Joule equivalent of heat* after Sir James Joule. [3]

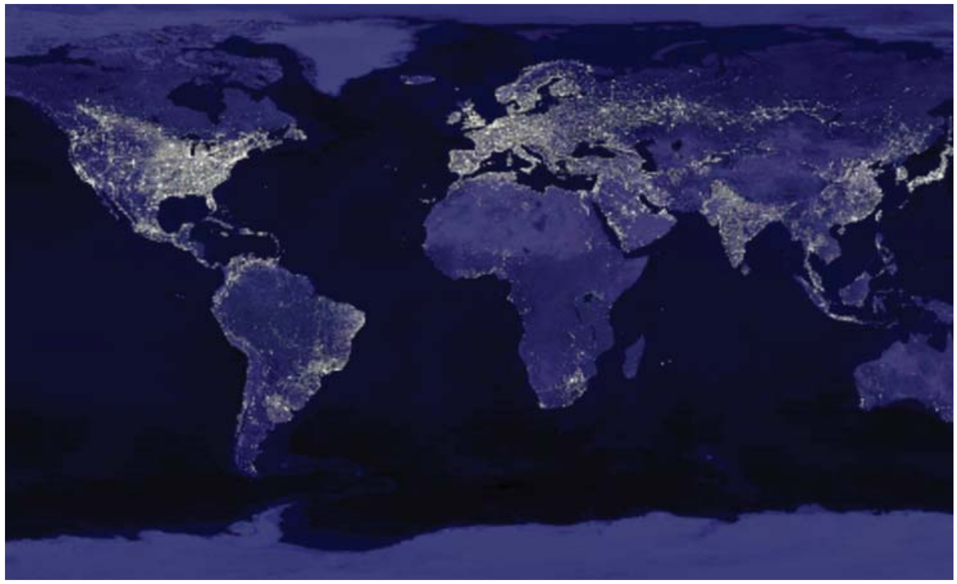

Figure 1. Composite image of the Earth at night: the world's supply chain of electrification. *Image: NASA*

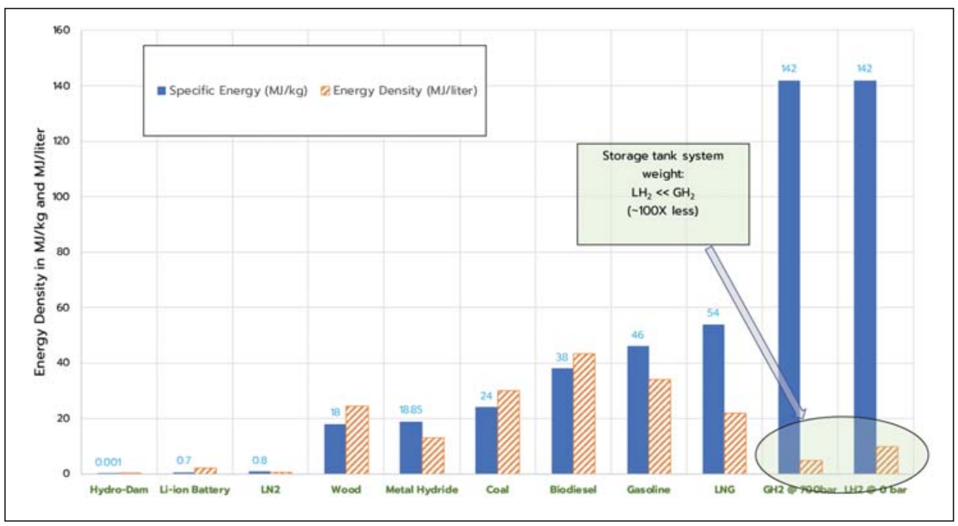

Figure 2. Energy density of different sources in both MJ/kg and MJ/liter. *Image: Fesmire*

At-scale energy infrastructure means gigawatts of power and gigajoules of energy. Energy density, important for transportation – land, sea, air or space – is another issue. Some typical energy storage densities for different storage media are presented in Figure 2. The data are given in terms of both the specific energy density, in megajoules per kilogram (MJ/kg) and volumetric energy density, in megajoules per liter (MJ/l). While the energy density of pumped hydro is terrible, it remains the only current way for low-cost, at-scale energy storage (its efficiency is 70%). Beside nuclear power, hydrogen is the absolute king of specific energy density at up to 142 MJ/kg, or about three times that of gasoline. [4] For comparison, lithium-ion batteries are about 0.7 MJ/kg.

What are options for energy storage from the cryogenic engineering world? One option is liquid air. Liquid air can be readily produced at scale anywhere in the world. The cost is mainly the electricity. If the electricity comes from solar, wind or geothermal, then, while the source is still somewhat geographically limited, the energy cost beyond the capital expense is very low. The liquid air becomes the store of that energy (the goal), and its production is from renewable energy, making it a (potentially) green solution. What is the real cost? We will see, but the potential is there.

Another option is liquid hydrogen (<5 bar) and its cousins, cryo-compressed (<65 bar) and cryo-adsorbed (<10 bar). The operating pressure is crucial to the true (real-world) energy density of the systems required for storing the hydrogen. The issue with hydrogen is of course its low volumetric energy density as also indicated in Figure 2. However, these challenges are addressed with engineering solutions. Why is hydrogen gas stored at 700 bar not a solution for anything but small-scale equipment? Because the weight and footprint of 700-bar systems become huge when more than 100-kg of hydrogen is involved. For a modest amount of stored energy in the form of five metric tons of hydrogen, the system weight and footprint are both about 100 times less for liquid hydrogen than for gaseous hydrogen at 700 bar. For larger industrial-scale quantities, the comparison becomes even more absurd.

Hydroelectric energy storage is incredibly important around the world. Yet it has the worst metrics in terms of energy density. Hydrogen produced from nuclear power is even more green and is now called pink hydrogen. In general, nuclear is 70,000 times better than anything else, but is not in vogue, to say the least. Hydrogen comes from water and just about anything else. But gaseous hydrogen storage is not good except for small devices. Liquid hydrogen fits the bill for the future in terms of what it makes possible: the storage and conveyance, locally and abroad, of the vast renewable energy available. Remembering that the vast renewable energy sources are thrown away every day, liquid hydrogen, and/or its cryogenic cousins, represents the pathway for low-cost, at-scale energy storage.

The singularly unique thing about hydrogen as an energy carrier is that it can work across the spectrum of locations, sizes and end-use applications. Thinking about storing hydrogen at scale means not only large-size industrial infrastructure (centralized) but also small-size residential devices (decentralized). For example, a home energy system, now commercially available, is designed to connect to a standard water supply and solar panels, produce hydrogen and store 144 MJ of energy in cylinders of metal hydride. The LAVO™ Hydrogen Battery System can power the average US home for 34 hours.

So, what is the best energy source? The answer is always the same: it depends.

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Baker Hughes, Borg CO_2 to Develop Carbon Capture, Storage Hub for Industrial Cluster in Norway

Baker Hughes, an American-based energy technology company, and Borg CO_2 AS, a Norwegian carbon capture and storage developer for industrial clusters, announced a memorandum of understanding (MOU) on June 22 to collaborate on a carbon capture and storage project to serve as a hub for the decarbonization of industrial sites in the Viken region of Norway. The project aims to capture, liquefy and store up to 90% of the CO_2 emissions from the involved industrial sites, playing an important role in contributing to the Paris Agreement goals, the United Nations Sustainable Development Goals and the Norwegian national emissions reduction targets.

The Borg CO_2 project includes several industry partners, as well as the Port of Borg, and aims to capture and store emissions from industrial facilities located in the cities of Fredrikstad, Sarpborg and Halden. The combined industrial cluster is currently responsible for approximately 700,000 tonnes of CO_2 emissions annually. After being captured, the CO_2 will be liquified, shipped and eventually stored underneath the seabed of the North Sea. In April 2021, Borg CO_2 announced an MOU with Northern Lights JV, who will provide shipping and storage of CO_2 as a service provider for Borg CO_2.

Borg CO_2 and its partners have completed a first feasibility study and are proceeding with an extended feasibility study (pre-FEED) to be completed by the end of 2021 which Baker Hughes will support with its portfolio of carbon capture technologies and engineering services for the study and development of the hub. In addition, Baker Hughes and Borg CO_2 will jointly evaluate the optimal structure for implementation of the carbon capture plants and pursue grant and incentive opportunities both in Norway and at the EU level.

Borg CO_2's "industrial cluster" approach provides a prime opportunity for Baker Hughes to test and scale its wide-ranging carbon capture, utilization and storage (CCUS) technologies portfolio on several types of processes including its Chilled Ammonia Process (CAP) and Compact Carbon Capture (CCC) solutions.

"With the technology competencies and experience of Baker Hughes supporting us, we believe that Borg CO_2 is better positioned to take the next steps towards commercialization and achieve our goals for the project," said Tore Lundestad, managing director of Borg CO_2 and Harbor Master for the port of Borg. "A project like this showcases a win-win approach where permanent storage combined with the possibility of sustainable usage of smaller volumes of biogenic CO_2 will help to achieve net-zero, and with the industrial facilities potentially receiving revenue by selling negative CO_2 emissions."

The Baker Hughes CCUS portfolio features advanced turbomachinery, solvent-based state-of-the-art capture processes, well construction and management for CO_2 storage and advanced digital monitoring solutions. Baker Hughes has a longstanding presence in Norway with six facilities and approximately 2,000 employees. ■

Look who's NEW in the Cold Facts Buyer's Guide

Cold Facts Buyer's Guide is the place to find suppliers in every area of cryogenics and superconductivity. Below is a listing of our new Corporate Sustaining Members and new suppliers added to the Buyer's Guide since the April 2021 issue of ***Cold Facts***. Find it online at **csabg.org**.

New Suppliers

Atlas Technologies

A leader in hermetic bimetallic couplings, flanges, fittings and custom dissimilar metal joining. Atlas Technologies' joints are used in cryogenics and ultrahigh vacuums. Al/SS, Ti/Al, Cu/Ti and many other dissimilar metal combinations are available.

CTP Cryogenics

Offers deep cryogenic treatment services and stress relief at three locations. Serving the aerospace industry requiring stress relief, temperature excursions at controlled rates and "uphill quenching" process. Manufacturer of custom cryoprocessors.

Edwards Vacuum

The Edwards CTI-Cryogenics and Polycold lines offer a wide range of high-performance and energy-efficient cryopumps, cryopump systems and cryochillers for the semiconductor, display, R&D and general vacuum industries.

Kistler Instrumente AG

Global leader in dynamic measurement technology for measuring pressure, force, torque and acceleration. Also offers solutions for space applications with maximum stability at very high temperatures, and most sensitive cryogenic capability.

OmegaFlex

OmegaFlex® supplies proprietary metal hose assemblies for a broad number of applications and markets, which include cryogenic application, semiconductor, medical, pharmaceutical, petrochemical and power generation.

The Aerospace Corporation

The Aerospace Corporation is a national leader in independent research and development. With over 80 specialized labs, the company is able to provide world class testing, analysis, and troubleshooting for many aspects of cryogenic engineered systems. ■

***CSA CSM**

New 2-D Superconductor Forms at Higher Temperatures than Ever

Researchers at the US Department of Energy's Argonne National Laboratory announced on April 27 that they had discovered a new way to generate 2-D superconductivity at a material interface at a relatively high – though still cold – transition temperature. This interfacial superconductor has novel properties that raise new fundamental questions and might be useful for quantum information processing or quantum sensing.

Interfaces in solids form the basis for much of modern technology. For example, transistors found in all our electronic devices work by controlling the electrons at interfaces of semiconductors. More broadly, the interface between any two materials can have unique properties that are dramatically different from those found within either material separately, setting the stage for new discoveries.

Like semiconductors, superconducting materials have many important implications for technology, from magnets for MRIs to speeding up electrical connections or perhaps making possible quantum technology. The vast majority of superconducting materials and devices are 3-D, giving them properties that are well understood by scientists.

One of the foundational questions with superconducting materials involves the transition temperature — the extremely cold temperature at which a material becomes superconducting. All superconducting materials at regular pressures become superconducting at temperatures far below the coldest day outside. In the study, Argonne postdoctoral researcher Changjiang Liu and colleagues, working in a team led by Argonne materials scientist Anand Bhattacharya, discovered that a novel 2-D superconductor forms at the interface of an oxide insulator called $KTaO_3$ (KTO). These results were published online in the journal ***Science*** on February 12.

In 2004, scientists observed a thin sheet of conducting electrons between two other oxide insulators, $LaAlO_3$ (LAO) and $SrTiO_3$ (STO). It was later shown that this material, called a 2-D electron gas (2DEG), can even become superconducting – allowing the transport of electricity without dissipating energy. Importantly, the superconductivity could be switched on and off using electric fields, just like in a transistor.

However, to achieve such a superconducting state, the sample had to be cooled down to about 0.2 K – a temperature that is close to absolute zero (– 273.15 °C), requiring a dilution refrigerator. Even with such low transition temperatures (T_C), the LAO/STO interface has been heavily studied in the context of superconductivity, spintronics and magnetism.

In the new research, the team discovered that in KTO, interfacial superconductivity could emerge at much higher temperatures. To obtain the superconducting interface, Liu, graduate student Xi Yan and their coworkers grew thin layers of either europium oxide (EuO) or LAO on KTO using state-of-the-art thin film growth facilities at Argonne. "This new oxide interface makes the application of 2-D superconducting devices more feasible," Liu said. "With its order-of-magnitude higher transition temperature of 2.2 K, this material will not need a dilution refrigerator to be superconducting. Its unique properties raise many interesting questions."

A strange superconductor

Surprisingly, this new interfacial superconductivity shows a strong dependence on the orientation of the facet of the crystal where the electron gas is formed.

Adding to the mystery, measurements suggest the formation of stripe-like superconductivity in lower doping samples where rivulets of superconducting regions are separated by normal, nonsuperconducting regions. This kind of spontaneous stripe formation is also called nematicity and is usually found in liquid crystal materials used for displays. "Electronic realizations of nematicity are rare and of great fundamental interest. It turns out that EuO overlayer is magnetic, and the role of this magnetism in realizing the nematic state in KTO remains an open question," Bhattacharya said.

In their ***Science*** paper, the authors also discuss the reasons why the electron gas forms. Using atomic resolution transmission electron microscopes, Jianguo Wen at the Center for Nanoscale Materials at Argonne, along with Professor Jian-Min Zuo's group at the University of Illinois at Urbana-Champaign, showed that defects formed during the growth of the overlayer may play a central role.

In particular, they found evidence for oxygen vacancies and substitutional defects, where the potassium atoms are replaced by europium or lanthanum ions — all of which add electrons to the interface and turn it into a 2-D conductor. Using ultrabright X-rays at the Advanced Photon Source (APS), Yan, along with Argonne scientists Hua Zhou and Dillon Fong, probed the interfaces of KTO buried under the overlayer and observed spectroscopic signatures of these extra electrons near the interface. "Interface-sensitive X-ray toolkits available at the APS empower us to reveal the structural basis for the 2DEG formation and the unusual crystal-facet dependence of the 2-D superconductivity. A more detailed understanding is in progress," Zhou said.

Beyond describing the mechanism of 2DEG formation, these results point the way to improving the quality of the interfacial electron gas by controlling synthesis conditions. Since the superconductivity occurs for both the EuO and LAO oxide overlayers that have been tried thus far, many other possibilities remain to be explored. **www.anl.gov** ■

Chart Invests, Signs Commercial Agreement with Cryomotive for Cryogenic Storage, Refueling Technology

On May 20, Chart Industries, Inc. (CSA CSM), a leading global manufacturer of liquefaction and cryogenic equipment serving multiple applications in the energy and industrial gas end markets, including hydrogen, announced the completion of a minority investment in Cryomotive GmbH ("Cryomotive") for the amount of $7.9 million and offers an in-kind contribution to develop Cryomotive's cryogenic storage and refueling technology.

Cryomotive is a leading green-tech mobility startup in Germany developing a disruptive clean hydrogen storage and refueling technology platform focused on compressed cold hydrogen and cryogenic high pressure storage. Cryomotive's proprietary CcH_2 CRYOGAS technology aims to decarbonize long-haul commercial vehicles while keeping the range and fueling times similar to diesel-powered vehicles and reaching parity in costs of ownership before 2030. The market for fuel-cell-powered long-haul commercial vehicles is expected to grow rapidly to more than 700,000 units by 2035 in Europe and China alone, and this does not include additional application areas such as coach buses, trains, ships and aircraft.

Cryomotive and Chart have entered a strategic partnership (the first for Cryomotive), including Chart's minority investment and in-kind contribution, as well as a commercial agreement. The development and supply partnership will enable Cryomotive to leverage its proprietary technology jointly with Chart's established position in the refueling and hydrogen station market. As the options for heavy duty hydrogen fueling continue to be analyzed by the end users, this supply partnership provides another option for Chart's customers, as Chart is now offering both liquid hydrogen and CcH_2 cryogenic high pressure refueling and storage.

Chart storage tank. *Image: Chart*

"This investment in and commercial agreement with Cryomotive adds another option for our customers looking at renewable fuel sources and another near-term application for our liquid hydrogen pump," stated Jill Evanko, Chart's CEO and president. "Cryomotive's strong hydrogen commercial relationships in Germany, Japan and China, in particular, with vehicle manufacturers, brings us access to more commercial opportunities for our hydrogen equipment. As the first strategic partner for Cryomotive, we are excited to support them as they develop, grow and bring on more strategic partners this year."

As the result of this investment and agreement, Chart is increasing its hydrogen addressable market by $100 million to include the application of the liquid hydrogen pump, hydrogen storage tanks and transportation systems specifically on Cryomotive applications in the next five years. **www.chartindustries.com** ■

Fermilab's Argonaut Project Launches Design Effort for Supercold Robotics

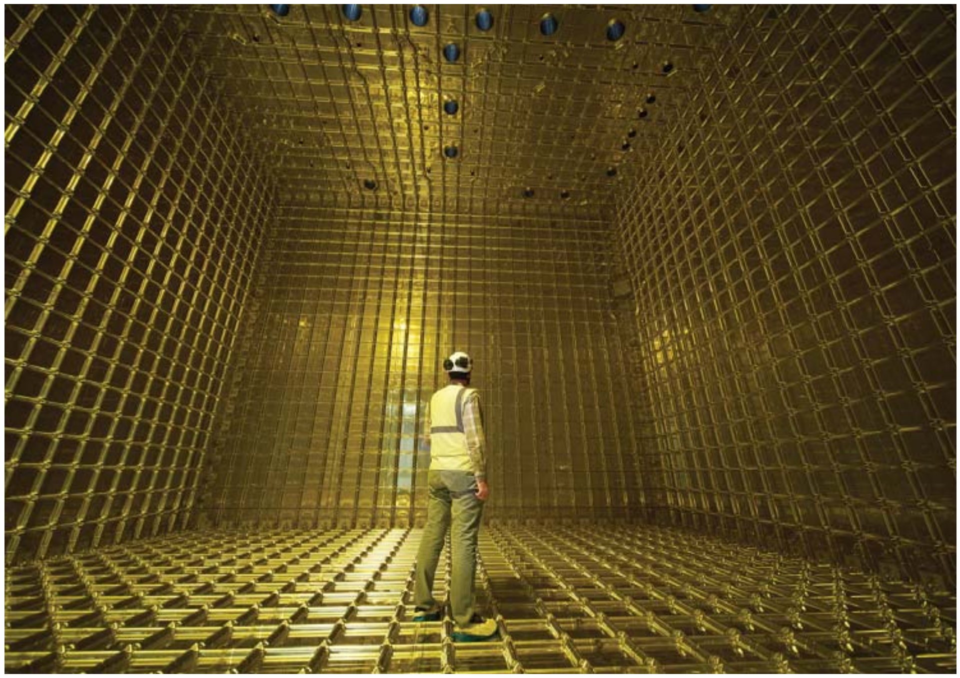
by Brianna Barbu, staff writer, Fermilab

A new robotics project at the Department of Energy's Fermi National Accelerator Laboratory (CSA CSM) in Batavia IL will share that same name and spirit of adventure from the Argonauts of Greek mythology. Argonaut's mission will be to monitor conditions within ultracold particle detectors by voyaging into a sea of liquid argon kept at -193 °C – as cold as some of the moons of Saturn and Jupiter. The project, funded in March, aims to create one of the most cold-tolerant robots ever made, with potential applications not only in particle physics but also deep space exploration.

Argon, an element commonly found in the air around us, has become a key ingredient in scientists' quests to better understand our universe. In its liquid form, argon is used to study particles called neutrinos in several Fermilab experiments, including MicroBooNE, ICARUS, SBND and the next-generation international Deep Underground Neutrino Experiment (DUNE). Liquid argon is also used in dark matter detectors like DEAP 3600, ARDM, MiniCLEAN and DarkSide-50.

Liquid argon has many perks. It's dense, which increases the chance that notoriously aloof neutrinos will interact. It's inert, so electrons knocked free by a neutrino interaction can be recorded to create a 3D picture of the particle's trajectory. It's transparent, so researchers can also collect light to "time stamp" the interaction. It's also relatively cheap – a huge plus, since DUNE will use 70,000 tons of the stuff.

But liquid argon detectors are not without their challenges. To produce quality data, the liquid argon must be kept extremely cold and extremely pure. That means the detectors must be isolated from the outside world to keep the argon from evaporating or becoming contaminated. With access restricted, diagnosing or addressing issues inside a detector can be difficult. Some liquid argon detectors, such as the ProtoDUNE detectors at CERN, have cameras mounted inside to look for issues like bubbles or sparks. "Seeing stuff with our own eyes sometimes is much easier than interpreting data from a sensor," said Jen Raaf, Fermilab physicist who works on liquid argon detectors for several projects including MicroBooNE, LArIAT and DUNE.



Argonaut is a robotic system being designed to monitor the interiors of liquid argon particle detectors, which are kept at minus-193 degrees Celsius. The ProtoDUNE neutrino detector at CERN uses fixed internal cameras to look for issues like bubbles and sparks when filled with 800 tons of liquid argon. *Image: CERN*

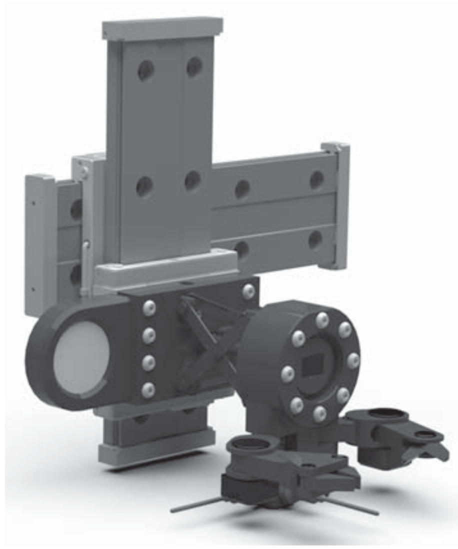
The idea for Argonaut came when Fermilab engineer Bill Pellico wondered if it would be possible to make the interior cameras movable. A robotic camera may sound simple – but engineering it for a liquid argon environment presents unique challenges.

All of the electronics have to be able to operate in an extremely cold, high voltage environment. All the materials have to withstand the cooling from room to cryogenic temperatures without contracting too much or becoming brittle and falling apart. Any moving pieces must move smoothly without grease, which would contaminate the detector. "You can't have something that goes down and breaks and falls off and shorts out something or contaminates the liquid argon, or puts noise into the system," Pellico said.

Pellico received funding for Argonaut through the Laboratory Directed Research and Development program, an initiative established to foster innovative scientific and engineering research at Department of Energy national laboratories. At this early stage of the project, the team – Pellico, mechanical engineers Noah Curfman and Mayling Wong-Squires, and neutrino scientist Flavio Cavanna – is focused on evaluating components and basic design aspects. The first goal is to demonstrate that it's possible to communicate with, power and move a robot in a cryogenic environment. "We want to prove that we can have, at a bare minimum, a camera that can move around and pan and tilt in liquid argon, without contaminating the liquid argon or causing any bubbles, with a reliability that shows it can last for the life of the detector," said Curfman.

The plan is to power Argonaut through a fiber optic cable so as not to interfere with the detector electronics. The fist-sized robot will only get about five to 10 watts of power to move and communicate with the outside world. The motor that will move Argonaut along a track on the side of the detector will be situated outside of the cold environment. The camera will be inside the cold liquid and move very slowly; but that's not a bad thing – going too fast would create unwanted disturbances in the argon. "As we get more advanced, we'll start adding more degrees of freedom and more rails," said Curfman.

Other future upgrades to Argonaut could include a temperature probe or voltage monitor, movable mirrors and lasers for calibrating the light detectors, or even extendable arms with tools for minor electronics repair. Much of the technology Argonaut is advancing will be broadly applicable for other cryogenic environments – including space exploration. The project has already garnered some interest from universities and NASA engineers.



To keep power requirements low and avoid disturbances in the liquid argon, Argonaut will move slowly along tracks on the side of the detector. Its main function is a movable camera, but the engineers working on it hope to add other features like extendable arms for minor electronics repair.
Image: Bill Pellico, Fermilab

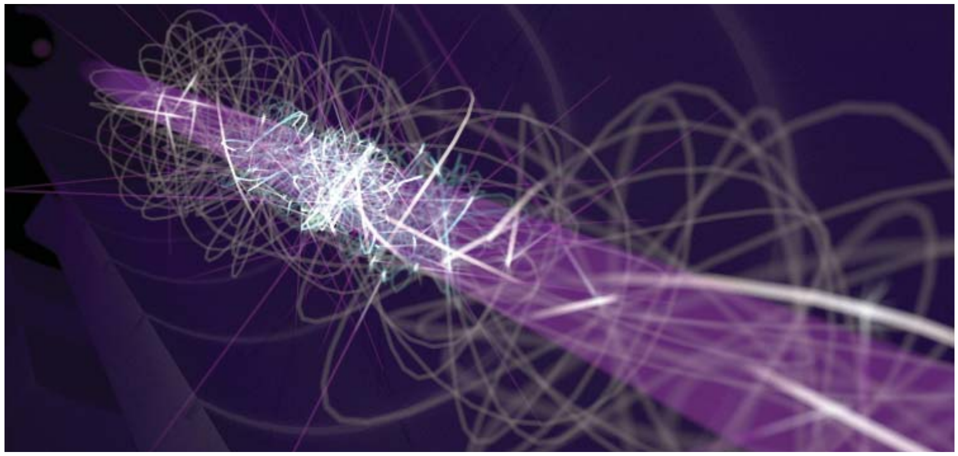
Deep space robots "are going to go to remote locations where they have very little power, and the lifetime has to be 20-plus years just like in our detectors, and they have to operate at cryogenic temperatures," Pellico said. The Argonaut team can build on existing robotics know-how along with Fermilab's expertise in cryogenic systems to push the boundaries of cold robotics.

Even the exteriors of active interstellar space probes such as Voyagers 1 and 2 don't reach temperatures as low as liquid argon – they use thermoelectric heaters to keep their thrusters and science instruments warm enough to operate. "There's never been a robotic system that operated at these temperatures," said Pellico. "NASA's never done it; we've never done it; nobody's ever done it, as far as I can tell." **www.fnal.gov** ■

SPOTLIGHT ON A CORPORATE SUSTAINING MEMBER (CSA CSM)

Canadian-built Laser Chills Antimatter to Near Absolute Zero for First Time

On March 30, the CERN-based ALPHA (Anti-hydrogen Laser Physics Apparatus) collaboration, including team members from TRIUMF, announced the world's first laser-based manipulation of antimatter, leveraging a made-in-Canada laser system to cool a sample of antimatter down to near absolute zero. The achievement, detailed in an article published and featured on the cover of the journal ***Nature***, will significantly alter the landscape of antimatter research and advance the next generation of experiments.



An artistic rendering of the movement of an antihydrogen atom in the ALPHA magnetic trap, before and after laser cooling [in grey before, and blue after] The images show various lengths of the antihydrogen tracks.
Image: Chukman So/TRIUMF

Since its introduction 40 years ago, laser manipulation and cooling of ordinary atoms have revolutionized modern atomic physics and enabled several Nobel-winning experiments. The results in ***Nature*** mark the first instance of scientists applying these techniques to antimatter. "Today's results are the culmination of a years-long program of research and engineering, conducted at UBC but supported by partners from across the country," said Takamasa Momose, the University of British Columbia (UBC) researcher with ALPHA's Canadian team (ALPHA-Canada) who led the development of the laser. "With this technique, we can address long-standing mysteries like: 'How does antimatter respond to gravity? Can antimatter help us understand symmetries in physics?' These answers may fundamentally alter our understanding of our Universe."

Antimatter is the otherworldly counterpart to matter; it exhibits near-identical characteristics and behaviors but has opposite charge. Because they annihilate upon contact with matter, antimatter atoms are exceptionally difficult to create and control in our world and had never before been manipulated with a laser. "It was a bit of a crazy dream to manipulate antimatter with laser," said Makoto Fujiwara, ALPHA-Canada spokesperson, TRIUMF scientist, and the original proponent of the laser cooling idea. "I am thrilled that our dream has finally come true as a result of tremendous teamwork of both Canadian and international scientists."

By cooling antimatter, researchers will be able to perform a variety of precision tests to further investigate the characteristics of antimatter, including experiments that may shine a light on the fundamental symmetries of our Universe. These tests could offer clues as to why the Universe is made primarily of matter and not equal parts matter/antimatter as predicted by Big Bang models.

The successful laser cooling also opens the door to a variety of leading-edge physics innovations. Momose and Fujiwara are now leading a new Canadian project, dubbed HAICU, to develop new quantum techniques for antimatter studies. "My next dream is to make a 'fountain' of anti-atoms by tossing the laser-cooled antimatter into free space. If realized, it would enable an entirely new class of quantum measurements that were previously unthinkable," said Fujiwara. "Furthermore, we are one step closer to being able to manufacture the world's first antimatter molecules by joining anti-atoms together using our laser manipulation technology," added Momose.

The results mark a major success for ALPHA-Canada, the Canadian contingent that makes up about one-third of the wider ALPHA collaboration, and contributors the University of Victoria and BCIT. As lead institution for ALPHA-Canada, TRIUMF has spearheaded collaborative efforts on several key experimental technologies and analyses, including the upgraded ALPHA-2 cryostat that enabled the first laser spectroscopic measurements of antimatter and the design and fabrication of the detector apparatus for ALPHA-g, the experiment that will determine the effect of gravity on antimatter.

After creating and trapping antihydrogen for a world-record 1,000 seconds in 2011, the ALPHA collaboration's achievements have included providing a first glimpse of the antihydrogen spectrum in 2012, setting guardrails confining the effect of gravity on antimatter in 2013, and showcasing an antimatter counterpart to a key spectroscopic phenomenon in 2020.

The laser cooling achievement leveraged the work of many across the TRIUMF community: postdoctoral researchers Rob Collister, Alex Khramov and Daniel Siveira; Chukman So contributed on the analysis of the cooling measurement; co-op students Alexandre Thilbeault and Matt Grant contributed as part of the laser team. Further, Andrea Capra, Joseph McKenna, Art Olin, David Gill, Konstantin Olchanski and Leonid Kurchaninov contributed to the antihydrogen detector and its analyses; Cam Marshall and Rob Thompson (University of Calgary) worked on the ALPHA-2 cryostat; and Art Olin co-led the physics analysis of the spectroscopy measurement. ■

Meyer Transforms Weldments into Precision Parts with Post Weld Machining

At Meyer Tool & Mfg, developing the manufacturing processes required to transform raw metal into the complex, precision components that support customers' endeavors is one of the daily challenges solved by the team of engineering and manufacturing professionals. Common across all customer segments, whether semiconductor, advanced instruments or superconducting particle accelerators, is the need to transform weldments into precision machined parts through a process called post weld machining.

Post weld machining is required when the tolerances on a finished weldment are tighter than can realistically be achieved from pre-machined components fit and welded together. Ideally the component parts of a weldment can be machined individually to final dimensions, fit together and can be welded. This is often possible; a common example is a commercial CF knife-edge flange welded to a pipe.

However, material, weld design requirements and final tolerances can all contribute to the need to perform machining steps after welding. These factors can even necessitate manufacturing sequences with intermediate weld and machining steps leading to the finished product. Understanding the factors and the proper mitigation strategies is fundamental to developing a robust repeatable manufacturing process.

Welding design to meet structural strength or pressure vessel code requirements can require weld sizes and configurations that can change the shape, shrink or otherwise affect the dimensions of a weldment. The two most common materials used by customers, aluminum and stainless steel, are more affected by weld shrinkage and distortion than carbon steel. But even a carbon steel pressure vessel with critical tolerances might require post weld machining.

Features to consider in evaluating post weld machining requirements include:
- Size and configuration of welds
- Effect of required weld sequencing
- Quantity being built—cost of fixturing vs. machining
- Critical sealing features, e.g., O-ring grooves, knife-edge seals
- Positional, profile, straightness, circularity, etc. tolerance requirements of features
- Relationships between features located on different surfaces of the weldment

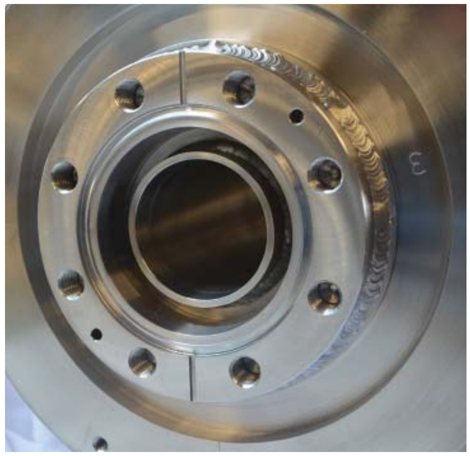


Figure 1. Post weld machine of knife edge flange on ASME weldment. *Image: Meyer Tool*

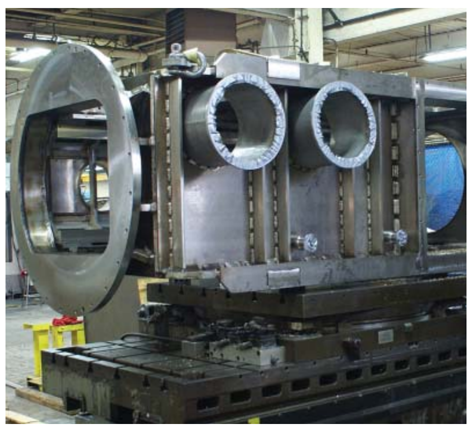


Figure 2. Rectangular vacuum vessel for LLNL. *Image: Meyer Tool*

The need to post weld machine is not limited to larger components. Critical surfaces, such as the knife-edge seal and fiducial datums of the ASME Code pressure vessel designed to maintain a liquid helium bath around a superconducting solenoid magnet, illustrate how weld design can make post weld machining necessary even on smaller parts (Figure 1).

Post weld machining is often easier to understand when seeing a large complex weldment like the vacuum vessel in Figure 2. This vessel was designed to withstand seismic loading. The large welds around seal faces make it easy to understand why post weld machining is necessary. When developing an optimum manufacturing process, one should also review whether post weld machining can be eliminated.

Factors that should be considered are:
- Can weld sizes be reduced?
- Can weld configurations be changed to reduce distortion?
- Can proper sequencing or fixturing be used to reduce distortion?
- Can tolerances be relaxed?

Generally, the prints and designs customers provide show final desired dimensions. When Meyer's reduce project risk process determines the need for post weld machining, engineers develop the component level fabrication prints and manufacturing routings necessary to meet those final desired dimensions.

Manufacturing risk considerations include:
- Determine machining stock on critical surfaces.
- Design appropriate weld fixturing to reduce distortion.
- Carefully plan weld order.
- Include intermediate inspection steps to ensure key tolerances are always achievable.
- Determine the machining plan to adjust for welding effects.

Experience and implementation of a reduce project risk process allow for the transformation of weldments into precision components. Whether it's a first-stage prototype or a production run of custom pressure vessels or precision vacuum chambers, post weld machining enables delivery of the quality that any project requires. **www.mtm-inc.com** ■

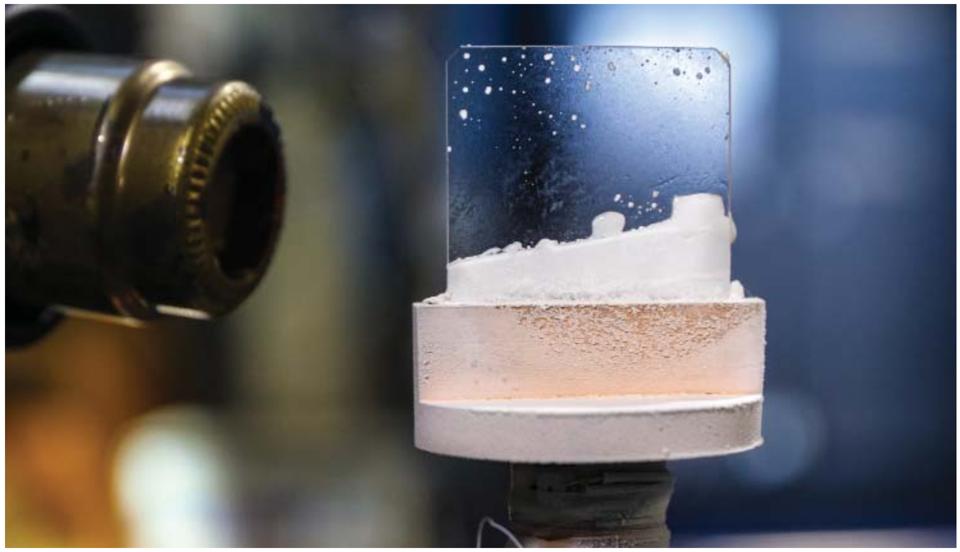
ORNL Researchers Create Exotic 'Outer Space' Ice at SNS

On May 20, researchers from NASA's Jet Propulsion Laboratory and Oak Ridge National Laboratory successfully created amorphous ice, similar to ice in interstellar space and on icy worlds in our solar system. They documented that its disordered atomic behavior is unlike any ice on Earth. The findings could help interpret data from future NASA missions such as Europa Clipper, which will assess the habitability of Jupiter's moon, Europa.

Using the ORNL Spallation Neutron Source's (SNS) Spallation Neutrons and Pressure (SNAP) instrument, the scientists replicated the cold vacuum of space and added a few molecules at a time of heavy water to a plate cooled to 25 Kelvin to produce amorphous ice. They then used neutron scattering to observe the ice's structural changes at varying temperatures before it transitioned to crystalline ice. "Amorphous water ice is ubiquitous in the universe yet isn't well understood. Our data could help understand exotic ice forms in our solar system and beyond," said Chris Tulk, ORNL's neutron scattering scientist and lead researcher on the project.

The search for life beyond Earth typically focuses on first looking for water, the basis for life as we know it. Whether the water is a gas, liquid or solid, its presence and composition can tell researchers a lot about the planet, moon, comet or asteroid on which it is detected and whether it could support life.

Because interstellar space is so cold and is primarily a vacuum, the water we detect from Earth is usually in the form of amorphous ice, meaning its atomic structure is not arranged neatly into a crystalline lattice like ice on Earth. How the transition between the crystalline and amorphous ice phases occurs on icy bodies like Europa or on Kuiper Belt Objects beyond Pluto, is difficult to study—unless you can mimic the cold, dark vacuum of outer space, under intense radiation in a laboratory.



Scientists created this exotic "outer space" ice by freezing a stream of heavy water (D_2O) molecules on a sapphire plate that is cooled to about -414 °F in a vacuum chamber. *Image: ORNL/Genevieve Martin*

The researchers lowered the temperature of a single crystal sapphire plate to 25 K (about -414 °F), placed it in a vacuum chamber and added just a few molecules at a time of water—in this case, heavy water (D_2O)—to the plate. Then they observed how the ice structure changed with varying temperatures before it finally formed crystalline ice. The team next plans to simulate the solar system's icy bodies by bombarding the sample with electron radiation to determine how this influences the ice structure.

"The experiment produced a layer of amorphous ice similar to the ice that makes up most of the water throughout the universe," said Tulk. "This is the same type of ice that could have formed on the extremely cold permanently shadowed regions of the Moon, on the polar regions of Jupiter's moon Europa, and within the material between the stars in our galaxy, known as dense molecular clouds. Although much of the ice has by now probably crystallized on the warmer bodies, the fresh ice on colder bodies and in deep space is likely still amorphous."

The scientists hope to answer questions such as how much of the ice on the surface of Europa, Jupiter's second smallest moon, could be amorphous ice as a result of the surface being irradiated by charged particles produced by Jupiter's magnetic field.

"This information could help us better interpret the science data from the Europa Clipper spacecraft and also provide some clues about how water ice evolves in various parts of the Universe," said Murthy Gudipati, senior research scientist at JPL. "With a launch date planned for 2024, the goal of the Europa Clipper mission is to assess Europa's habitability by studying its atmosphere, surface and interior, including liquid water beneath the icy crust that could potentially support life."

The team's initial experiments were performed on the SNAP diffractometer at SNS, an instrument typically used for high pressure experiments, but which the scientists configured to mimic the low pressure, extreme cold and high radiation environment of space. Future experiments will employ inelastic neutron scattering on the VISION instrument to study the dynamics of the amorphous ice as it forms. The experiments will also employ electron bombardment to study the changes in these exotic ice forms in a space radiation environment. **www.ornl.gov** ■

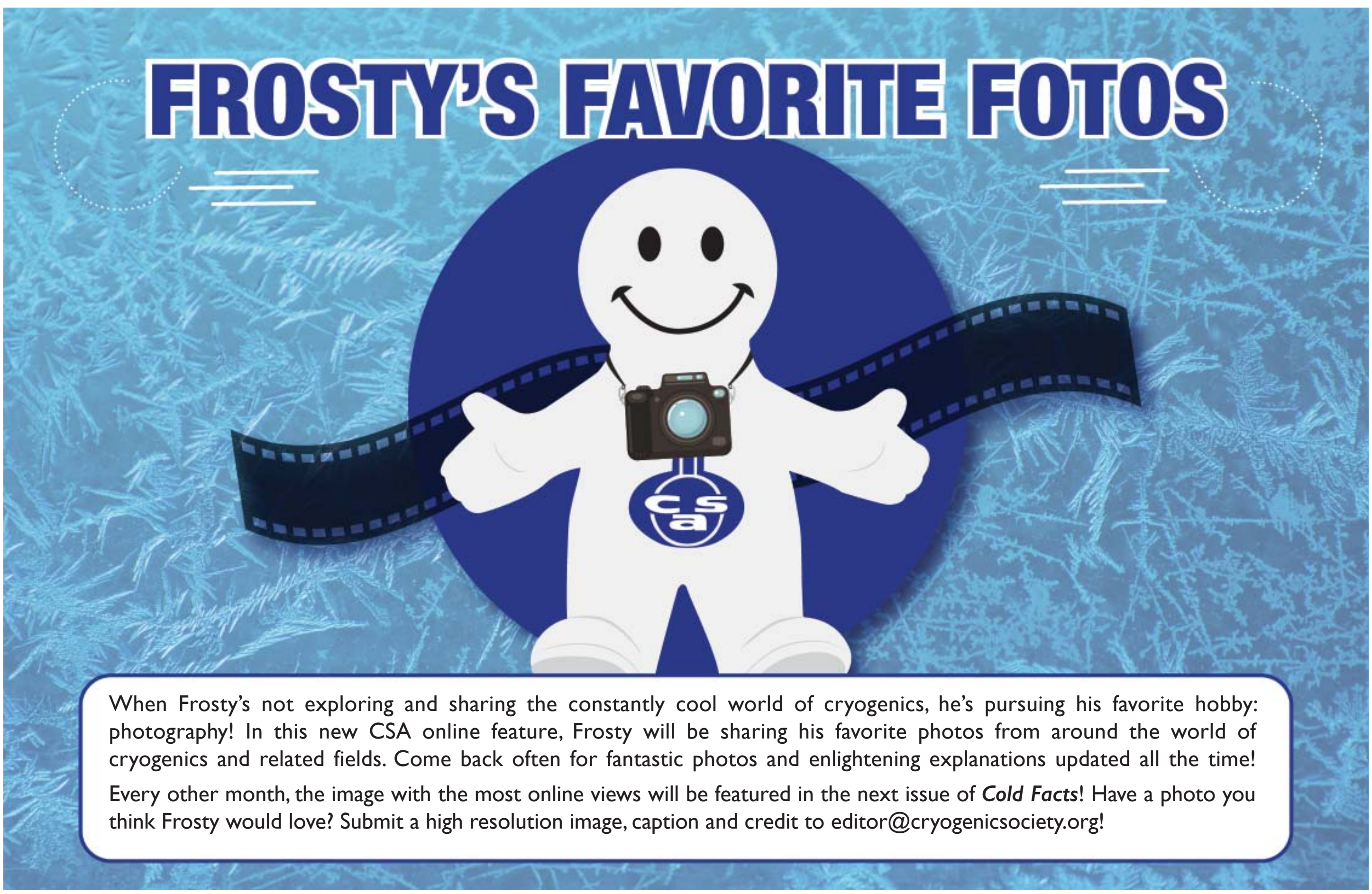
SPOTLIGHT ON A CORPORATE SUSTAINING MEMBER (CSA CSM)

Nikkiso Cryogenic Services Announces Saudi Arabia's Asas Aljood as Authorized Service Provider

On June 15, Nikkiso Cryogenic Industries' Clean Energy & Industrial Gases Group ("Group", CSA CSM), a subsidiary of Nikkiso Co., Ltd of Japan, announced that they had signed an agreement for Asas Aljood, a Saudi-based engineering group, to become the Authorized Service Provider for Nikkiso Cryogenic Services (NCS) in the Kingdom of Saudi Arabia.

With the growth of the Middle East market, this agreement allows the Group to extend their regional presence for the industrial gases, hydrogen, natural gas processing and petrochemical industries. Beginning July 1, 2021, Asas Aljood will utilize their local workshops to offer aftermarket service and support for both pumps and turbo expanders including packaging, repairs, spare parts and field service.

Based in Dammam, Asas Aljood will serve to strengthen their existing regional presence in addition to the Group's Middle East operation in Sharjah (UAE). "The newly formed partnership with Nikkiso and Asas Aljood gives us strong regional presence in Saudi Arabia and strengthens our ability to better serve the Middle East markets," according to Jim Estes, President, Nikkiso Cryogenic Services. "I am looking forward to continuing to provide Nikkiso's customers top quality service and support by eliminating costly downtime to their operations and processes." **www.nikkisoceig.com** ■



New Combination of Materials Provides Progress Toward Quantum Computing

In research published June 14 in ***Nature Communications***, engineers from Rensselaer Polytechnic Institute demonstrated how, when semiconductor materials known as the transition metal dichalcogenides (TMDCs) materials they make are stacked in a particular geometry, the interaction that occurs between particles gives researchers more control over the devices' properties. Specifically, the interaction between electrons becomes so strong that they form a new structure known as a correlated insulating state.

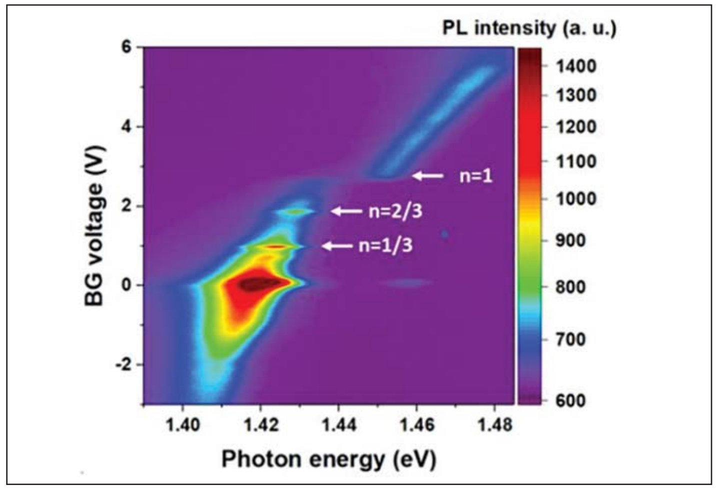
This is an important step, researchers said, toward developing quantum emitters needed for future quantum simulation and computing. The future of quantum computing may depend on the further development and understanding of TMDCs. These atomically thin materials develop unique and useful electrical, mechanical and optical properties when they are manipulated by pressure, light or temperature. "There is something exciting going on," said Sufei Shi, an assistant professor of chemical and biological engineering at Rensselaer, who led the work. "One of the quantum degrees of freedom that we hope to use in quantum computing is enhanced when this correlated state exists."

Much of Shi's research has focused on gaining a better understanding of the potential of the exciton, which is formed when an electron, excited by light, bonds with a hole – a positively charged version of the electron. Shi and his team have demonstrated this phenomenon in TMDC devices made of layers of tungsten disulfide (WS2) and tungsten diselenide (WSe2). Recently, the team also observed the creation of an interlayer exciton, which is formed when an electron and hole exist in two different layers of material. The benefit of this type of exciton, Shi said, is that it holds a longer lifetime and responds more significantly to an electric field – giving researchers greater ability to manipulate its properties.

In their latest research, Shi and his team showed how, by stacking TMDCs in a particular manner, they can develop a lattice known as a moiré superlattice. Picture two sheets of paper stacked on top of one another, each with the same pattern of hexagons cut out of them. If one were to shift the angle of one of the pieces of paper, the hexagons would no longer perfectly match up. The new formation is similar to that of a moiré superlattice.

The benefit of such a geometry, Shi said, is that it encourages electrons and interlayer excitons to bond together, further increasing the amount of control researchers have over the excitons themselves. This discovery, Shi said, is an important step toward developing quantum emitters that will be needed for future quantum simulation and quantum computing. "It has essentially opened the door to a new world. We see a lot of things already, just by peeking through the door, but we have no idea what is going to happen if we open the door and get inside," Shi said. "That is what we want to do, we want to open the door and get inside."

Shi said his team's collaboration with the Center for Materials, Devices, and Integrated Systems at Rensselaer has enabled the development of the TMDC devices needed to study these atomically small interactions. This serves as an example of the interdisciplinary model that drives education and research at Rensselaer. ■



Results of PL Intensity in TMDC. *Image: Rensselaer Polytechnic Institute*

Montana Instruments Introduces CryoCore™ for High-Throughput Electrical and Optical Materials Characterization

The CryoCore Platform. *Image: Montana Instruments*

This April, Montana Instruments Corporation, a manufacturer of high precision, fully automated closed-cycle optical cryostats, introduced CryoCore™, a new streamlined cryogenic platform built for high-throughput electrical and optical materials characterization. Using advancements in thermal and low vibration design, the cryostat is a low vibration, cryogen-free system that allows users to access cryogenic temperatures from 4.9 K - 350 K.

The CryoCore platform includes a touchscreen user interface along with all control electronics, vacuum pumps and monitoring systems required to automate the temperature control across the entire range. "Despite the many application benefits of working at low temperatures, not all researchers are experts in cryogenics or have the budget for complex cryogenic systems," said CEO Mark Carroll. "With CryoCore, we're offering a streamlined version of our standard technology, which allows more labs access to Montana Instruments' cryogenic expertise to accelerate quantum research."

The system provides five window ports, 12 low frequency DC lines and two high frequency RF coax lines to accommodate a range of optical and electrical measurements while jump-starting research right out-of-the-box. Push-button cooling, automated temperature control and an integrated vacuum system gets users up and running quickly without the need to monitor multiple pieces of equipment. "Traditional low cost, closed-cycle systems require heavy time investment by the end user to get them running and keep them running optimally," explains VP of Engineering Josh Doherty. "We already know how to design usability into a high performance system, and now we've made this more accessible for a larger group of potential users." In addition to CryoCore, Montana Instruments plans another new product roll-out in September.

"There is a lot of work happening behind the scenes in the quantum research space," notes Carroll. "Montana Instruments is positioned to serve users at all ends of that spectrum–from quantum computing to quantum networking, materials research and workforce development. We're excited about the opportunities for CryoCore to meet some of those needs." ■

CryoWorks Names New CEO, Timothy Mast, Jr.

On June 1, California-based CryoWorks, Inc. announced that the company's board of directors has named Timothy Mast, Jr. as chief executive officer and president, effective immediately. Mr. Mast, Jr. has worked at CryoWorks since 2011 and has served as vice president of operations since February 2019. He succeeds Timothy Mast, Sr. and Donna Mast, who are transitioning into board of director roles.

In their newly established board of director positions, Timothy, Sr. and Donna Mast have been elected chairman and director, respectively. Mast, Sr. and Mrs. Mast founded CryoWorks in 2009, pursuing their entrepreneurial dreams with their desire to take control of product quality and company culture. They will continue their presence at CryoWorks, as they mentor, set goals, guide, oversee management decisions and remain part of CryoWorks' ongoing operations.

"Donna and I are excited to welcome Tim, Jr. into his new position. From day one, he has established processes and procedures that have enhanced our products and services," said Mast, Sr. "He has had a significant impact on meeting our growing demands, growing our operations, taking care of our existing and emerging markets, while staying true and vigilant to our founding recipe."

"I am very excited to be taking on this new position and appreciate the opportunity and the continued mentorship and support I receive from my parents," said Mast, Jr. "We have a very talented team that allows us to continue providing high end products and services to our existing partners and positions us to continue ventures into emerging markets. I plan to continue the growth and development of the family business while honoring the key values that my parents have instilled in CryoWorks. We Make It Happen, We Make It Easy, and We Make It Fun!" **www.cryoworks.net** ■

Jobs in Cryogenics

Cryogenic / Industrial Gas Field Service Technician
Acme Cryogenics

Cryogenic Sales Engineer
kiutra

Lead Cryogenic/Mechanical Engineer
ETA Space

Lead Engineer – Superconducting Magnets
General Electric

Senior Engineer – Superconducting Magnets
General Electric

Job openings from CSA Sustaining Members and others in the cryogenic community are included online, with recent submissions listed above. Visit http://2csa.us/jobs to browse all current openings or learn how to submit your company's cryogenic job to our list of open positions. Listings are free for Corporate Sustaining Members.

Ballard Announces Rebranding as Industry Enters Next Phase of Development

On June 24, Vancouver-based Ballard Power Systems announced a rebranding to reflect the next phase of the company's journey as a global provider of zero-emission fuel cell technology. The hydrogen and fuel cell industry has reached an important inflection point with scaled commercialization expected over the next decade. With a leading position in the fuel cell industry, Ballard is forecasting significant growth and development through 2030 and this change reflects that growth.

Ballard PEM fuel cell technology provides zero-emission power to commercial vehicles that have traveled an industry-leading total of more than 88 million kilometers in more than 20 countries. This includes more than 3,500 fuel cell electric buses and commercial trucks currently in operation.

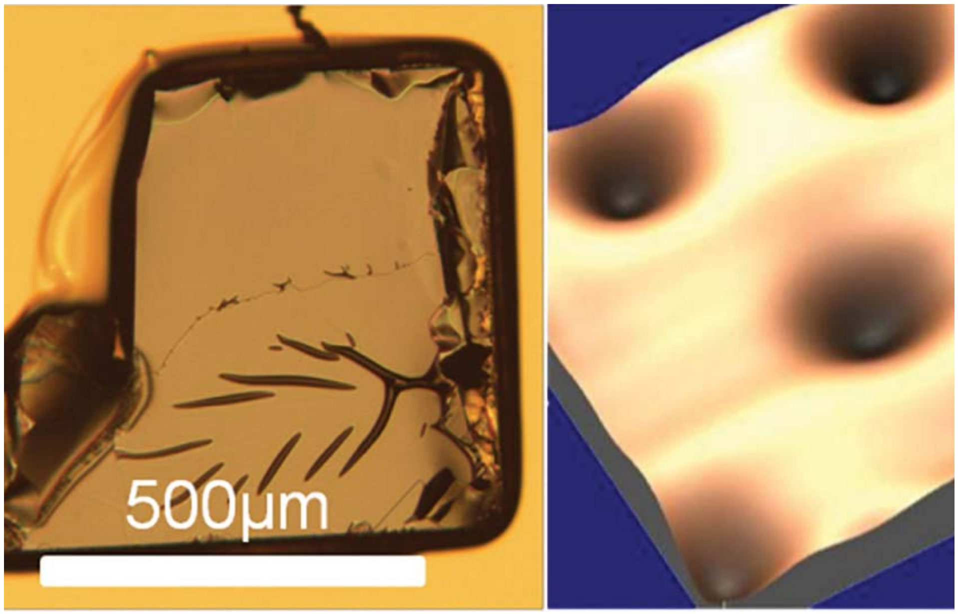
"Since the company's founding in 1979, Ballard has been dedicated to zero-emission energy," said Randy MacEwen, president and chief executive officer. "Now the global transition to clean energy is clearly underway. With over 30 countries having announced hydrogen strategies, there is a strong commitment globally that hydrogen will play a critical role in the decarbonization of energy, mobility and industry. We are particularly excited with the expected volume adoption of hydrogen fuel cells to decarbonize hard-to-abate mobility sectors, including bus, truck, train and marine applications. As we enter a new era with a growing opportunity set and investment, it is timely for a brand refresh."

The rebranding includes a redesign of the company's logo, tagline, website and communication tools. Ballard's new logo is familiar but refreshed. The sense of forward motion reflects its ability to advance and innovate while holding to the company's values. The new tagline, *Here for life*™ "reflects our vision to deliver fuel cell power for a sustainable planet. It connotes our purpose to decarbonize mobility to mitigate the existential threat of climate change and pass on to the next generation a more livable planet." The company says the new rebrand shows customers that Ballard's support will remain throughout the lifetime of a project. ■

Why Deep Freezing Iron-Based Materials Makes Them Both Magnetic and Superconducting

On June 1, physicists at the University of Bath in the United Kingdom, in collaboration with researchers from the United States, announced that they had uncovered a new mechanism for enabling magnetism and superconductivity to co-exist in the same material. Until now, scientists could only guess how this unusual coexistence might be possible. The discovery could lead to applications in green energy technologies and in the development of superconducting devices, such as next-generation computer hardware.

As a rule, superconductivity (the ability of a material to pass an electrical current with perfect efficiency) and magnetism (seen at work in fridge magnets) make poor bedfellows because the alignment of the tiny electronic magnetic particles in ferromagnets generally leads to the destruction of the electron pairs responsible for superconductivity. Despite this, the Bath researchers have found that the iron-based superconductor RbEuFe4As4, which is superconducting below -236 °C, exhibits both superconductivity and magnetism below -258 °C.



On the left: a crystal coated in gold – the gold coating allows the magnetic imaging tool to get within nanometers of the material's surface. On the right: a magnetic picture of a segment of the crystal showing the vortices (dark holes) that were studied. *Image: University of Bath*

"There's a state in some materials where, if you get them really cold – significantly colder than the Antarctic – they become superconducting. But for this superconductivity to be taken to next-level applications, the material needs to show co-existence with magnetic properties. This would allow us to develop devices operating on a magnetic principle, such as magnetic memory and computation using magnetic materials, to also enjoy the benefits of superconductivity," explained physics postgraduate research student David Collomb, who was a key member of the research team led by Professor Simon Bending. "The problem is that superconductivity is usually lost when magnetism is turned on. For many decades, scientists have tried to explore a host of materials that have both properties in a single material, and material scientists have recently had some success fabricating a handful of such materials. However, so long as we don't understand why the coexistence is possible, the hunt for these materials can't be done with as fine a comb."

In a study published in ***Physical Review Letters***, the team investigated the unusual behavior of RbEuFe4As4 by creating magnetic field maps of a superconducting material as the temperature was dropped. To their surprise, they found the vortices (the points in the superconducting material where the magnetic field penetrates) showed a pronounced broadening near the temperature of -258 °C, indicating a strong suppression of superconductivity as the magnetism turned on.

"This new research gives us a material that has a wide temperature range where these phenomena co-exist, and this will allow us to study the interaction between magnetism and superconductivity more closely and in great detail. Hopefully, this will result in us being able to identify the mechanism through which this co-existence can occur," said Collomb.

These observations agree with a theoretical model recently proposed by Dr. Alexei Koshelev at Argonne National Laboratory (CSA CSM), one of three American institutions, including Hofstra University and Northwestern University, which contributed to the research. This theory describes the suppression of superconductivity by magnetic fluctuations due to the europium (Eu) atoms in the crystals. Here, the magnetic direction of each Eu atom begins to fluctuate and align with the others, as the material drops below a certain temperature. This causes the material to become magnetic. The Bath researchers conclude that while superconductivity is considerably weakened by the magnetic effect, it is not fully destroyed.

"This suggests that in our material, the magnetism and superconductivity are held apart from each other in their own sub-lattices, which only minimally interact," added Collomb. "This work significantly advances our understanding of these rare coexisting phenomena and could lead to possible applications in the superconducting devices of the future. It will spawn a deeper hunt into materials that display both superconductivity and magnetism. We hope it will also encourage researchers in more applied fields to take some of these materials and make the next-generation computing devices out of them." ■

Product Showcase

This Product Showcase is open to all companies and related manufacturers offering new or improved products for cryogenic applications. We invite companies to send us short releases (75 words or fewer) with high resolution JPEGs of their products to editor@cryogenicsociety.org.

Ability Engineering Technology, Inc.

Cryogenic Gas Purifiers

Ability Engineering Technology, Inc. (AET) designs and fabricates equipment for gas purification and recovery systems for helium, hydrogen and argon. The systems utilize cryogenic adsorption and achieve up to 7N purity. AET offers standard models as well as customized solutions to fit individual needs. Advantages include robust and modular systems, gas flexibility, inlet/outlet gas sizing and specifications, 24/7 runtime operations, pressure vessel code compliance (national or international), PLC controls that can be seamlessly integrated with existing systems, remote monitoring and diagnostics, on-site commissioning and the newly introduced remote commissioning. **www.abilityengineering.com** ■

Hampshire Controls Corp.

MPS-LV Multi Probe Alarm System for LN_2 Level Detection and Vacuum Breach of Dewars

Protect valuable samples stored in LN_2 Dewars and freezers by monitoring LN_2 liquid level and vacuum breach of the container. It includes a system relay output to central alarm systems or automatic telephone dialers, battery back-up, e-mail alarm notification – providing there is network connection. The system can be configured to monitor one to four freezers. This unit can also be connected to Hampshire's Alert Monitoring System for reporting and data storage. **www.hampshirecontrols.com** ■

The Phoenix Company of Chicago

High Frequency Blindmate Microwave PkZ® Contacts for the Mighty Mouse Housings

The Phoenix Company of Chicago has expanded its Mil/Aero Blindmate Microwave Contact offering through the launch of two new PkZ® RF contacts designed for Series 80 Mighty Mouse Connectors and equivalent housings. Available in size 12 and 8, these contacts feature operating frequency to 40 GHz, lower insertion forces compared to spring-based solutions, axial mating tolerance to 0.090″ and the ability to accommodate a wide range of coaxial cables such as: RG-142, 316, 402, 405 and more. Ensuring top performance and high quality, The Phoenix Company of Chicago designs and manufactures all microwave blindmate contacts, connectors, and cable assemblies in the US and can provide custom designs to meet the mechanical and electrical requirements of demanding military and commercial applications. **www.phoenixofchicago.com** ■

Quantum Design

NexGen Helium Liquefiers

Quantum Design's newly redesigned NexGen helium liquefier improves past benefits of easy mobility and high performance while adding several new features. It is now offered in a 250-liter capacity dewar (in addition to the standard 160-liter model) for users who prefer larger transfers. Industry-leading liquefaction rates are now attained while at 1 PSIg, so helium is always ready to transfer when needed. In addition, the software and GUI have been completely redesigned to make operation even more simple and straightforward. **www.qdusa.com** ■

People, Companies in Cryogenics

On May 12, the International Space Station's external robotic arm, Canadarm2, was hit by orbital debris. Noticed by **NASA**

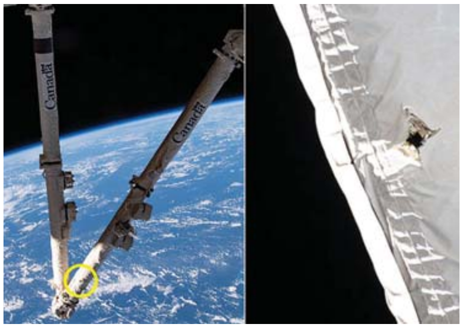


Image: NASA

and the **Canadian Space Agency**, the debris ruptured the arm boom and its thermal blanket. "Despite the impact, results of the ongoing analysis indicate that the arm's performance remains unaffected," said the Canadian Space Agency in a release.

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On May 2, four astronauts splashed down off Florida's gulf coast after returning from a trip in a **SpaceX** capsule marking **NASA**'s first nighttime water landing since 1968. This was the successful end of the first NASA mission led by a private company. SpaceX has been slated to take NASA's astronauts to and from the International Space Station on what the space agency calls an operational mission.

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On June 17, the management team of **WITec GmbH** announced that WITec was acquired by UK-based **Oxford Instruments plc** and will be part of their Materials Analysis Group. WITec's founders **Dr. Joachim Koenen** and **Dr. Olaf Hollricher** will continue as managing directors and the WITec brand will be retained in the new organizational structure.

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B dot Medical Inc. has confirmed the superconductivity of a superconducting bending magnet designed and manufactured at its factory by cooling and conducting an energization test on a compact proton cancer therapy system under development, and confirmed the generation of a high magnetic field similar to CERN's breakthrough in 2019 (***Cold Facts***, Vol. 35, No. 5).

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Image: NASA

On April 28, Apollo 11 orbiter commander **Michael Collins** passed away. He was 90 years old. Collins piloted the module while Armstrong and Aldrin left the first human footprints on the Moon.

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On June 12, **Blue Origin** concluded the online auction for the very first seat on the New Shepard space flight with a winning bid of $28 million. Nearly 7,600

Image: Blue Origin

people registered to bid from 159 countries. The winning bidder will fly to space on New Shepard's first human flight on July 20, and will join Blue Origin founder Jeff Bezos and his brother, Mark. The winning bid amount will be donated to Club for the Future, Blue Origin's foundation, whose mission is to inspire future generations to pursue careers in STEM and to help invent the future of life in space.

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On May 25, **Atlas Copco** announced that they have acquired the operating assets of **Medigas Service & Testing Co. Inc.** The company services, sells, verifies and installs piped medical and laboratory gas equipment and systems.

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On March 17, **Fermi National Accelerator Laboratory** (CSA CSM) hosted a "Doing Business with Your National Labs" event in partnership with **Argonne National Lab** (CSA CSM). The event drew nearly 200 diverse small business leaders who came to hear about how to prepare and submit proposals for contracts, as well as some key opportunities that exist for suppliers located throughout Chicagoland and Illinois at-large.

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On June 19, **INOXCVA** installed its second medical oxygen storage tower at the National Sports Club of India in Worli, exactly one year after installation began. The twin towers will now serve as oxygen supply sources for India's COVID-19 crisis.

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Image: Jiyong Zhao

On June 9, **Argonne National Laboratory**'s (CSA CSM) **Jiyong Zhao** received the 2021 Gopal K. Shenoy Excellence in Beamline Science award. The annual award is given to a beamline scientist at the Advanced Photon Source (APS), a DOE Office of Science User Facility at Argonne. It is presented by the APS Users Organization and is intended to recognize scientists who make significant contributions to research or instrument development and promote that work to the user community.

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A meeting of the **Sustainable Development Council** led by **Oleg Aksyutin**, Deputy Chairman of the Management Committee at **Gazprom**, and **Nikolai Kasimov**, Member of the **Russian Academy of Sciences**, took place in St. Petersburg to dicuss the completed and planned joint studies conducted by Gazprom and the RAS in the field of hydrogen energy. The aim is to solve scientific challenges in the area of hydrogen production in the most environmentally-friendly and cost-efficient way, i.e. by producing hydrogen from natural gas, as well as challenges pertaining to hydrogen transportation.

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On June 25, Turkey's first publicly owned floating LNG storage and regasification vessel (FSRU) was inaugurated in

Image: botas.gov.tt

Hatay. The *Ertugrul Gazi* will add 110 million cubic meters of storage and 28 million cubic meters of gasification capacity to Turkey's energy supply chain, enough to meet 8.2% of the country's daily LNG supply. The ship will undergo its first ship-to-ship transfer on June 29.

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Image: TRIUMF

On May 17, **Dr. Nigel Smith** began his five-year term as **TRIUMF** (CSA CSM) director. Dr. Smith arrived in Vancouver and began on-site work the same week. Nigel succeeds Dr. Bagger, who departed TRIUMF in January 2021 to become CEO of the American Physical Society.

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James Glickenhaus has challenged **Elon Musk** to pit **Tesla's** Cybertruck against Glickenhaus' proposed hydrogen fuel-cell-powered Boot in the Baja 1000 race to prove the superiority of hydrogen power over electric vehicles.

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Image: Fermilab

The Cryogenic Engineering Conference has awarded **Jay Theilacker** the 2021 Samuel C. Collins Award. Theilacker is the cryogenic sector head in the Applied Physics and Superconducting Technology Division at **Fermilab** (CSA CSM). The award honors Theilacker's technical problem-solving and his "dedicated and unselfish" leadership and service within the cryogenic community over the last 40-plus years.

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Image: Carlos Jones

Kathy McCarthy, associate laboratory director for Fusion and Fission Energy and Science at the Department of Energy's **Oak Ridge National Laboratory** (CSA CSM), has been elected fellow of the American Nuclear Society for her nationally and internationally recognized leadership in nuclear energy and fusion. The award citation noted her leadership at ORNL as associate laboratory director and director of the US ITER Office, as well as her past positions.

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Through the Green Shipping Program, Norwegian-based companies

Image: HeidelbergCement and Felleskjøpet

HeidelbergCement and **Felleskjøpet** announced a tender to supply green hydrogen for a zero-emission bulkship. The ship will transport grain from Eastern Norway to Western Norway and rock/gravel on its way back. It will be operated using emission-free green hydrogen in the combination with rotor sails.

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Greg Boebinger, director of Florida State University's **National High Magnetic Field Laboratory** (CSA CSM), has been named a member of the National Academy of Sciences. He joins eight current and retired FSU faculty as members of the national academy, including current MagLab Chief Scientist Laura Greene. ■

Meetings & Events

CSA Short Courses at CEC/ICMC
July 18
Virtual
http://2csa.us/shortcourses

CEC-ICMC 2021
July 19-Jul 23
Virtual
https://www.cec-icmc.org

Cryogenic Engineering and Safety Annual 5-Day Course
August 2-6
Golden, Colorado
http://2csa.us/kf

15th European Conference on Applied Superconductivity
September 5-6
Virtual
http://2csa.us/kd

Gastech Exhibition & Conference
September 13-16
Singapore
http://2csa.us/jt

5th Annual LNG Summit USA 2021
September 29-30
Houston, Texas
http://2csa.us/kg

Space Tech Expo & Conference
October 6-8
Long Beach CA
http://2csa.us/ij

Space Cryogenics Workshop
November 15-17
Virtual
https://spacecryogenicsworkshop.org

29th International Conference on Low Temperature Physics
August 15-2
Sapporo, Japan
http://2csa.us/ha

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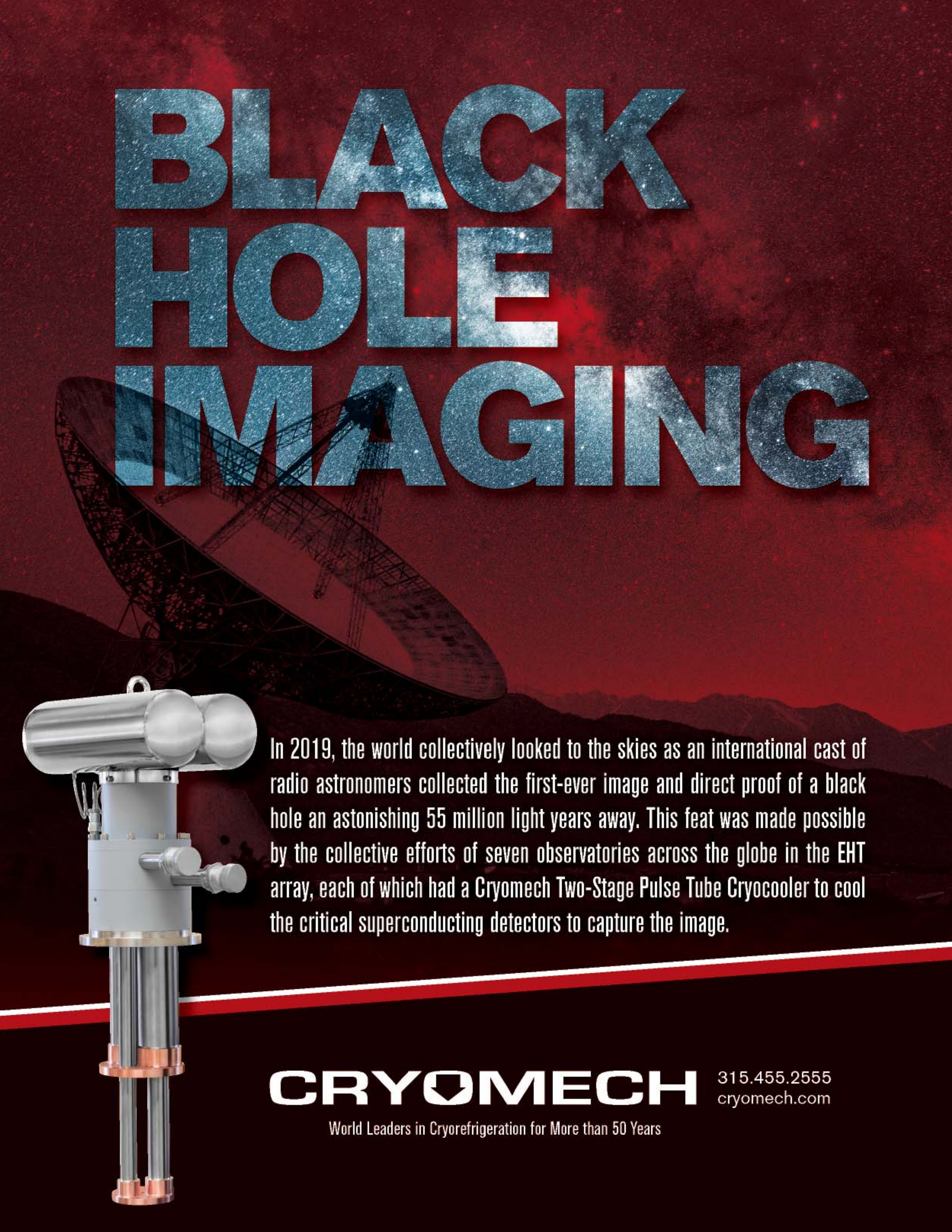
BLACK HOLE IMAGING
In 2019, the world collectively looked to the skies as an international cast of radio astronomers collected the first-ever image and direct proof of a black hole an astonishing 55 million light years away. This feat was made possible by the collective efforts of seven observatories across the globe in the EHT array, each of which had a Cryomech Two-Stage Pulse Tube Cryocooler to cool the critical superconducting detectors to capture the image.
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