

# UPWARD

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## Exotic Glass Fibers From Space

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THE ULTIMATE  
SCIENCE FAIR

TOUGH ENOUGH  
FOR SPACE

ENCOURAGING  
GIRLS IN STEM

 **ISS**  
U.S. NATIONAL LABORATORY

# THE VIEW FROM THE CUPOLA

BY CAROLINE SMITH, SEEKER



Caroline Smith is the Chief Content Officer of Seeker

When we launched Seeker Universe a little over a year ago, we also established an exciting partnership with the ISS National Lab, as a way to lean in on the content that is most popular with Seeker's online viewers. Of our more than 200 million monthly video views, roughly a third are space related. Our audience just can't get enough of space.

The world today has a deficit of relatable science communication. What currently exists is frequently too technical, dry, or lofty, and public perception is often that science must be nerdy. At Seeker, we focus on science, curiosity, and innovation in a way that inspires and entertains. We humanize the world of science, shedding light on the minds that push boundaries and invent bold new solutions to make our world better. The public has an appetite to understand how the world works, and we feed that in a way that is relatable and attainable.

Working with the ISS National Lab, we are able to bring untold space stories to life across a variety of content formats, including short, socially-optimized video, mid-form documentaries, and re-publishing of articles from *Upward*. Our storytelling arc needs to capture audiences specific to the platform where they're consuming Seeker content. Across the board, regardless of platform, viewers are keen to understand how the work onboard the ISS will directly influence life on Earth. In this issue of *Upward*, for example, readers can learn about how the ISS is improving our ability to make advanced materials and to transmit data using exotic optical fibers, which will have a substantial impact here on Earth.

Drawing this connection to the real world is particularly important, because when it comes to space, our audience is particularly fascinated by how activities in space affect our everyday lives. They want to understand how space exploration affects them *today*. Our partnership with the ISS National Lab allows us to profile science experiments in space in a way that makes very clear the impact they will have on the Earth—on the lives of our viewers today and the lives of their children.

In addition, one of our goals at Seeker is to inspire the next generation of leaders in science, technology, engineering, and mathematics (STEM). To do this, we've made a conscious effort to broaden the public's awareness of how every aspect of our world can be viewed through a lens of science. In this issue of *Upward*, several stories focus on the ways that the ISS National Lab is addressing the urgency of supporting science literacy in today's youth.

Read on to learn more about the current, relevant research going on in space, and to see more of what our audience at Seeker craves, visit [www.seeker.com](http://www.seeker.com). ■

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\*Source: Tubular Labs, Inc., a company that provides video intelligence and analytics to help measure performance over time.



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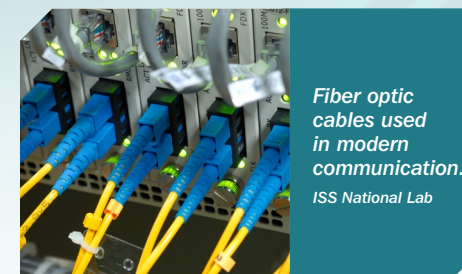
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# Exotic Glass Fibers FROM SPACE

## The Race to Manufacture ZBLAN

BY HAYLIE KASAP, *Contributing Author*

**O**ptical fibers are the thread that connects our modern digital world. Smaller in diameter than a human hair, these fibers can transmit light pulses of information at billions of pulses per second and over distances of several thousand kilometers, eclipsing what is possible with electrical cables.



Fiber optic cables used in modern communication.  
ISS National Lab

These optical fibers are most commonly made of silica ( $\text{SiO}_2$ ) glass. While silica fibers are easily produced using well-established methods, optical losses in the fiber requires the use of expensive repeaters to boost the signal across long transmission distances.

The fluoride glass optical fiber,  $\text{ZrF}_4\text{-BaF}_2\text{-LaF}_3\text{-AlF}_3\text{-NaF}$ , commonly known as ZBLAN, at its theoretical best can have 10 to 100 times lower signal loss than silica fiber. However, when ZBLAN is produced on Earth, convection and other gravity-driven phenomena can cause imperfections because of the nonuniform distribution of the various chemical components within the fiber. These defects that occur during the process of solidification result in the formation of microcrystals that render the fibers unusable for many commercial applications.

To avoid the adverse effects of gravity, scientists have turned to the ISS National Lab to produce ZBLAN fiber in microgravity.

High-performance ZBLAN fibers would be extremely valuable back on Earth, and several commercial companies such as Fiber Optics Manufacturing in Space (FOMS), Made In Space (MIS), and Physical Optics Corporation (POC) are currently pursuing in-orbit production of ZBLAN fiber. Initial results have been promising, and successful ZBLAN fiber production on the ISS National Lab could pave the way for future large-scale commercial manufacturing of ZBLAN in low Earth orbit.

$\text{ZrF}_4\text{-BaF}_2\text{-LaF}_3\text{-AlF}_3\text{-NaF}$



### ZBLAN IS FRENCH?

The history of ZBLAN takes us back to 1974 in Rennes, France, when Professor Marcel Poulain of the University of Rennes and his brother Michel accidentally discovered this series of heavy metal fluoride glasses. Four years from their revolutionary find, the brothers formed their own company Le Verre Fluoré, putting the duo at the forefront of specialty fiber production.

However, interest in ZBLAN diminished in the 1980s because no one could pinpoint how to prevent microcrystals from forming in the fiber during production. These crystals greatly reduce the transmission ability of the fiber, making it unsuitable for many applications.

But ZBLAN was too great a revolution to disregard. That is why the U.S. Air Force and the U.S. Naval Research Laboratory started the research back up again in the 1990s, including parabolic arc test flights on NASA's KC-135 aircraft. On these flights, ZBLAN glass experiments were run during the 22-second period of aircraft freefall. Although these few seconds were not enough to produce proper fiber, they were enough to obtain promising preliminary test results.

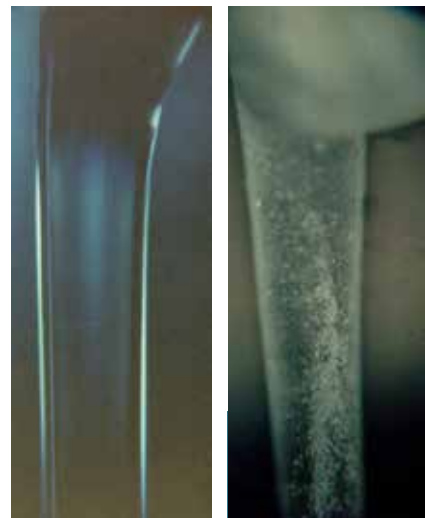
**WHY MICROGRAVITY?**

To understand why microgravity is preferable over normal gravity for ZBLAN production, it is important to understand what about Earth's gravity causes defects in the fibers. The production process on Earth involves draw towers that can be up to several stories tall. At the top of the tower is a preform, a large-diameter rod of the glass mixture, which is heated up so that a bead of glass falls, pulling a glass fiber behind it. Reaching the bottom of the tower, the fiber is wound on a spool to continue the draw from the preform. The whole process has been compared to that of pulling taffy.

When scientists talk about defects in ZBLAN optical fibers, they are mainly referring to crystallization and phase separation within the fibers. Due to convection-induced effects in molten ZBLAN glass, as well as other reasons researchers are still trying to determine, ZBLAN optical fibers made in Earth's gravity are prone to having crystals form during the transition from a molten liquid state to a solid-like state.

"ZBLAN is desirable for many applications because it has a very large wavelength transmission window; even the current fibers with defects from ground production are used for transmission of infrared light," said Michael Snyder, chief engineer and cofounder of MIS. "In theory, if you could suppress most or all of the crystallization in ZBLAN, the advantages of ZBLAN fiber, which include repeaterless transoceanic transmission of light, are huge compared to silica fiber."

Using estimates for the theoretical loss limit of ZBLAN glass, a 2,000-km length of ZBLAN fiber could have the same optical loss as 10 km of silica fiber, which would be an extraordinary performance gain.



ZBLAN produced in microgravity  
NASA

ZBLAN produced in normal gravity  
NASA

Because ZBLAN is made of five different elements (zirconium, barium, lanthanum, aluminum, and sodium) while silica fiber consists of only one (silicon), phase separation (boundary layers in the microstructure of a material) is more prevalent due to zirconium, barium, and lanthanum being denser than aluminum and sodium. Microgravity helps minimize this effect as well.

**“**It's sort of like your favorite ice cream with a bunch of toppings inside," Snyder said. "If you let that ice cream melt on Earth, all that heavy stuff sinks and the light stuff floats, and the same thing happens with fiber. In space, those density-related separations don't happen."**”**

**THE PATH TO ZBLAN PRODUCTION ON THE ISS**

Before taking ZBLAN production to the ISS National Lab, POC used parabolic flight studies to test microgravity's effects on ZBLAN production and optimize their hardware. "Results were encouraging," said Ranjit Pradhan, vice president of applied technologies at POC. "The cross section of the glass pulled during parabolic flights was significantly more homogeneous than glass pulled on the ground."

These promising results led to the development of POC's Orbital Fiber Optic Production Module, which is scheduled for launch to the ISS on SpaceX's Commercial Resupply Services (CRS)-17 mission in 2019. POC will first operate the system in microgravity to identify any unknown factors that could adversely affect the in-orbit production of high-quality ZBLAN fibers. Once optimization of the system is complete, the company plans commercial operations for in-orbit fiber manufacturing.



The FOMS Space Facility for Orbital Remote Manufacturing (SpaceFORM) experiment, supported by the ISS National Lab, NASA, the Small Business Innovation Research program, and private funding, is scheduled to launch on SpaceX CRS-17. SpaceFORM, which is covered by an issued U.S. patent, is capable of producing up to 50 km of optical fiber in a single flight.

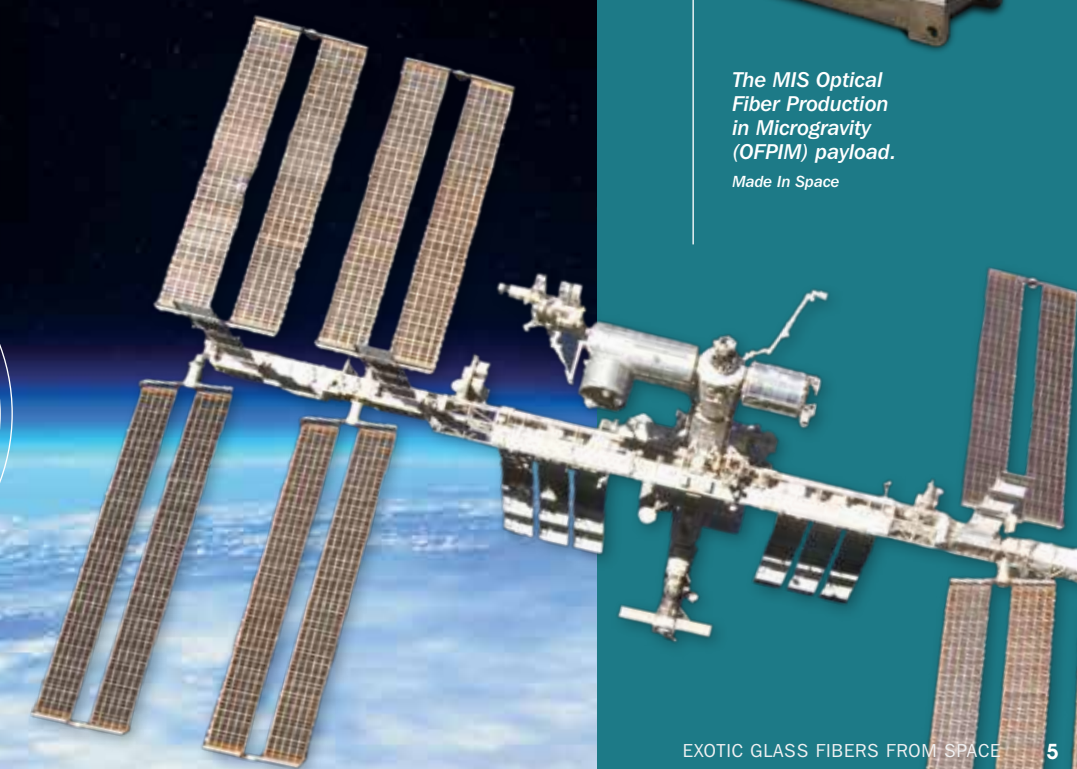
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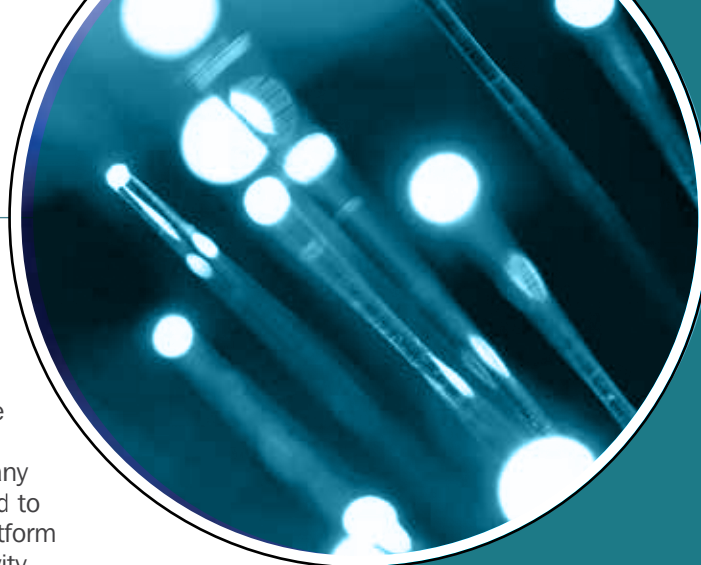
The MIS Optical Fiber Production in Microgravity (OFPIIM) payload. Made In Space

**MADE IN ORBIT. USED ON EARTH.**

Diagram courtesy of Made In Space



Close-up of optical fiber manufactured in microgravity  
NASA



Similarly, FOMS leveraged its knowledge of past studies in the development of ruggedized hardware to develop the Space Facility for Orbital Remote Manufacturing (SpaceFORM), for which the company has an issued U.S. patent. SpaceFORM is intended to serve as not only a proof of concept but also a platform for volume production of optical fibers in microgravity.

**“We were able to commercialize the hardware development and scientific development on the materials side even before we were able to bring our hardware and experiments to an orbital platform, which is quite exciting,” said Dmitry Starodubov, chief scientist at FOMS. “Our ultimate goal is to scale up production and commercial revenue and to establish a sustainable manufacturing platform in orbit through use of this technology.”**

SpaceFORM, which is capable of multi-kilometer fiber production, is scheduled to launch to the ISS on SpaceX CRS-17 in 2019, after which FOMS plans to conduct several in-orbit experiments aimed at testing and optimizing their hardware. FOMS hopes to gain insight into the fundamental physics of material processing in microgravity and the improvement pathways for the properties of the fiber produced in orbit. This knowledge will help in operationalizing a commercial in-orbit optical fiber manufacturing facility.

For MIS, successful parabolic flight testing led to the development of the company’s initial demonstration optical fiber puller, which launched to the ISS on SpaceX CRS-13 in December 2017. As part of their multi-flight Optical Fiber Production in Microgravity (OPFIM) experiment, this first investigation from MIS focused on evaluating the puller’s temperature settings.



The MIS OPFIM payload undergoing acoustics testing.  
Made In Space

The OPFIM hardware is entirely automated, which holds great promise for long-term commercial use due to the minimal crew time needed for unloading and plugging in samples—but perfecting the operation of the industrial process itself takes iteration. To this end, a second investigation from

MIS that launched on SpaceX CRS-14 in April focused on testing several approaches for fiber-pulling techniques, and a third investigation on SpaceX CRS-15 in June further optimized the industrial process settings. A fourth investigation that launched on SpaceX CRS-16 earlier this month seeks to shift from pulling only test-length fibers to pulling fibers reaching up to 100 m in length for analysis.



The MIS OPFIM payload atop the Additive Manufacturing Facility with JAXA astronaut Norishige Kanai onboard the ISS.  
NASA

Michael Snyder (second from right), chief engineer and cofounder of MIS, receives the 2018 ISS Innovation Award in Physical Sciences and Materials Development.  
ISS National Lab



**INNOVATION AWARD**  
**At the annual ISS Research and Development Conference in July, MIS won the 2018 International Space Station Innovation Award in Physical Sciences and Materials Development for their innovative work on ZBLAN optical fiber production in microgravity.**



The MIS OPFIM mission patch from the SpaceX CRS-13 launch.  
Made In Space

This shift from validation to production of fibers for characterization and attenuation is an important step toward optimizing the OPFIM for commercial production of ZBLAN fibers in space for use back on Earth. The fibers pulled in testing so far have not been long enough for critical evaluation, but according to MIS, preliminary visual analysis of the fiber’s microstructure indicates an absence of the level of microcrystallization and flaws typically seen in terrestrially produced fiber.

**COMMERCIAL INTEREST AND THE FUTURE OF SPACE MANUFACTURING**

The core technology needed to produce commercial quantities of ZBLAN in microgravity is currently in development, and FOMS, MIS, and POC are each fine-tuning their methods of drawing optical fibers in space. For now, the ISS is the ideal platform to support the current level of space-based ZBLAN production. However, depending on the growth of the industry, the future could involve a new ISS module specifically dedicated to fiber pulling or even a new station or other platform for optical fiber manufacturing in low Earth orbit.

**“The ISS is a great learning tool for mastering production of ZBLAN fibers,” said Pradhan. “It offsets some of the risks in developing these sorts of high-value optical materials for the commercial sector.”**

However, before large-scale commercial ZBLAN production in space can really take off, in-orbit manufacturing must become price competitive. “We are thankful to the ISS Commercial Space Utilization Program Office for funding this unique opportunity,” said Pradhan. The current round-trip costs of launching cargo to the ISS, performing experiments and procedures, and sending the cargo back down are prohibitive without NASA and the ISS National Lab subsidizing costs. According to Starodubov, though, this may not always be the case.

“The ongoing revolution of the space industry is making orbital processing amazingly affordable,” said Starodubov. “The costs will be dropping from the

existing space trip cost, which is comparable to the price of platinum per kilogram, by roughly a factor of 10 in the near future.”

As costs start to come down, in-orbit manufacturing will become more accessible to smaller companies. And as more companies get involved, whether through the production of ZBLAN or other products, the cost of flying and returning cargo will continue to be driven further down, spurring an expansion of commercial manufacturing of products in space that have high value back on Earth.

In terms of the future Earth benefits of space-produced ZBLAN, Pradhan said that “given that ZBLAN performs closest to the theoretical best, space fibers could be used to wire up different continents.” Trans-oceanic telecommunication lines currently made of silica optical fibers could be replaced with high-performance microgravity-produced ZBLAN fibers.

“With such low optical loss,” said Pradhan, “the world could be connected like never before.” ■

# THE ULTIMATE Science Fair

## Participating in the Student Spaceflight Experiments Program

BY JESSICA SCARFUTO, *Contributing Author*

*Scientists with swag: Members of SSEP Team Penicillium Mold Growth show they've got what it takes to send an experiment to space.*

Burleson ISD



Rocket scientists, real meteorite pieces, big telescopes on loan from astronomical societies—and mixed in with it all, students in grades 5 through 12 presenting their own experiments, each hoping to be selected as a finalist to possibly have their experiment fly to the International Space Station (ISS).

This is the scene at Space Night in Burleson, Texas, a community event put on by the Burleson Independent School District (ISD) designed to get families, students, and community members excited about science and spaceflight research and to allow students an opportunity to present the experiments they are submitting for Step 1 Review as part of the National Center for Earth and Space Science Education's (NCESE) Student Spaceflight Experiments Program (SSEP).

Burleson ISD began participating in SSEP during the 2014–2015 school year, a year after the new superintendent Bret Jimerson came onboard with the mission of getting more students engaged in science, technology, math, and engineering (STEM). “He wanted to unify everyone around an idea of STEM and progress and innovation. That’s where SSEP comes in,” said Leslie Bender Jutzi, Burleson’s chief academic innovation officer.

Recognizing the power of space to inspire and engage students, Jimerson’s first project for the district was SSEP, a program in which they have participated and excelled every year since. With the success of SSEP within their community, the Burleson ISD Academic Innovation Department has expanded their program offerings to include options in robotics, drones, xeriscaping (a landscaping method that reduces the need for irrigation), and additional space topics and research opportunities, covering a wide range of age groups.

### ENGAGING STUDENTS IN REAL SCIENCE

The primary mission of the ISS National Lab is to benefit life on Earth, something that SSEP tackles through inspiring young scientists. SSEP is unique because it engages students in every aspect of STEM through a research competition in which the winners get to imagine, design, and send an experiment to space—an immersive learning experience that aligns well with Next Generation Science Standards.

The thought of designing a spaceflight experiment is an irresistible lure for students in grades 5 through 12, who are the primary focus of the program. Instead of the traditional model of doing well-established experiments in science class, students are challenged to research a topic and come up with an experiment worthy of microgravity study.



*Student principal investigator Gabriel McCarthy working with penicillium mold in potato agar slants in the Texas Christian University Microbiology Laboratory.*

Burleson ISD

“I think the idea of flying an experiment to the International Space Station is what draws them in initially, but what we found from most of our students is that being treated as professional scientists was a better experience for them than anything in terms of actually flying the experiment,” said Stacy Hamel, SSEP Senior Flight Operations Manager for NCESE.



*Burleson ISD students with SSEP National Program Director and NCESE Center Director Jeff Goldstein.*  
Burleson ISD

### MORE ABOUT SSEP

*SSEP was started in 2010 by NCESE in partnership with in-orbit commercial service provider NanoRacks, LLC. SSEP is a partner in the Space Station Explorers consortium, a growing community of ISS National Lab partner organizations that aims to leverage the space station to engage learners in valuable STEM education experiences. The program is offered to students in grades 5 through 12, as well as undergraduates in colleges and universities. Students can design experiments spanning many research areas, including cell biology, the physiology and life cycles of microorganisms, crystal growth, seed germination, and food studies. Since its inception, SSEP has engaged more than 86,000 students in the U.S., Canada, and Brazil in authentic research experiences.*

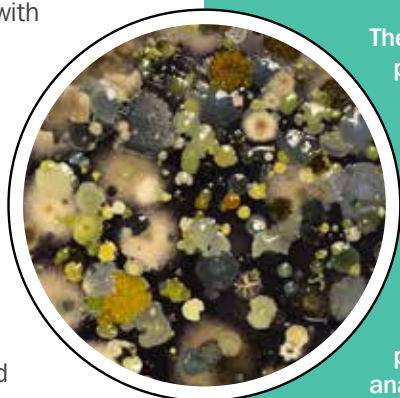


Members of SSEP Team Penicillium Mold Growth present their research at the 2018 SSEP National Conference in Washington, D.C.  
Burleson ISD

For each SSEP mission, a call is put out for interested communities to submit an implementation plan detailing how SSEP will be used to meet strategic needs in STEM education for their community. Once communities join the program, students are required to submit proposals just like those written by practicing scientists. With the help of their teachers, students split into small teams of typically three to five students and learn how to do the most basic and often overlooked part of science: experimental design and proposal writing.

Over a nine-week period, students come up with research questions and think of ways to answer the questions within certain parameters set as part of the competition. Students must also plan a ground control experiment that is conducted simultaneously on Earth to understand how spaceflight affects experimental outcomes. This allows students to compare experimental results in microgravity with results from Earth-based controls.

Typically, only one experiment flies from each participating community, so the competition is tough. Once students craft proposals, a local review board composed of experts within the community selects three finalists to be moved on to national review, where a committee of experts assembled by NCESE selects the winning experiment for flight.



While studying swab sample growths, SSEP Team Penicillium Mold Growth students were in awe of the microscopic world that lives around them.  
Burleson ISD

### A NEXT-GENERATION PROGRAM FOR THREE-DIMENSIONAL LEARNING

SSEP aligns powerfully with the new national Next Generation Science Standards (NGSS) because it stimulates critical thinking and problem solving within the sciences. NGSS was created by states to promote science literacy in students in a way that extends beyond mere knowledge of facts. Science is not just a subject—it is a field of study.

The NGSS framework, published by the U.S. National Research Council, describes an approach to learning science that is “three-dimensional.” Instead of expecting students to merely process existing science knowledge, the NGSS challenges students to learn how to think and act like a scientist and understand the fundamental nature of science: that our understanding of the universe is continually being revised as we advance in our ability to conduct new investigations.

The three dimensions of NGSS include the following.

1. **Practices** are focused on critical thinking—for example, how to ask questions, develop models, execute experiments, interpret data, and use other skills that are part of the scientific process.
2. **Crosscutting Concepts** are fundamental principles that apply frequently to the diverse topics in the science classroom—for example, cause and effect, stability and change, and structure and function.
3. **Disciplinary Core Ideas** are the overarching concepts within scientific knowledge that students should know to be good future citizens and career professionals—for example, heredity, Earth’s systems, and matter and its interactions. Within these core ideas, specific topics are taught and built upon within each subsequent grade.

These three dimensions are equally important within each performance expectation, or written standard for what a student should be expected to know and be able to do at a given grade level. Because the NGSS is fairly new to instructors, science-based learning initiatives and lesson plans that embrace these three dimensions of science education are still being developed and are valuable to and needed within the education community.

SSEP meets this need by challenging students to perform science from the brainstorming and proposal writing phases of a research investigation through its execution and analysis—requiring students to practice the scientific method, internalize crosscutting concepts and predict how they will influence their experiment, and learn about specific science topics within disciplinary core ideas. The program is thus on the leading-edge of national approaches to science education while also inspiring and exciting students through the wonder of space.

### FITTING INTO TIGHT SPACES

Perhaps the most challenging part of the competition is that students must come up with an experiment that can fit within the parameters of the lab space available on the ISS. The NanoRacks Fluid Mixing Enclosure (called “MixStix”), the mini-laboratory utilized by SSEP, is essentially a silicone tube that can hold small amounts of fluids or solids in up to three separate compartments.



NanoRacks MixStix  
NanoRacks, LLC

Students may use either one or two clamps to separate samples. Once in space, ISS crew members can open the clamps at different time intervals to start and stop the experiment. The MixStix can hold up to 10 mL of samples or up to 8.2 mL total with the use of two clamps.

“So, for example, students can load a seed and a substrate in volume 1, water and a liquid fertilizer in volume 2, and a fixative in volume 3,” said Hamel. Students then write a protocol for ISS crew members with instructions on when to open the clamps and any other simple tasks that may be needed, such as shaking the sample on a certain day.



Ector County students, including Deidre Morales (second from left), working with MixStix prior to sending to NanoRacks for launch to the ISS National Lab.  
Ector County ISD

For tenth grader Deidre Morales from Ector County, Texas, designing her experiment to fit within the confines of the MixStix meant rethinking the entire experiment in a more creative way. Morales wanted to study ways to get rid of space trash, and while doing her preliminary research, she found a worm that degrades polyethylene (the most common plastic). However, the worm did not fit in the MixStix, so Morales had to go back to the drawing board.

“At the very last minute before proposals were due, she found a bacterium that had been discovered in Japan in 2016 that is known to degrade plastic,” said Elizabeth Gray, the teacher facilitator for the project.

The bacterium would fit in the MixStix, but first Gray and her students needed to figure out how to get it to the United States. By reading through the scientific literature, they were able to track down the lab in Japan, and with the help of the Ector County ISD Innovation Department, they were able to collaborate internationally to get the bacterium from Japan to Texas.

“It took us five weeks to get it because we had to order it online and get approval from the United States Department of Agriculture to make sure it would not be harmful to anyone,” said Gray. It was a unique opportunity that allowed the students to not only learn about a new bacterium but also learn about government policies and international collaboration in the sciences.



Members of SSEP Team Penicillium Mold Growth prepare their MixStix sample to launch to the ISS National Lab.  
Burleson ISD

### A NEW APPROACH TO SCIENCE EDUCATION

Perhaps the most important goal of SSEP is that for many students, the program fosters true engagement in STEM subjects that goes beyond merely achieving high test scores. Getting good grades, while important to many students, does not necessarily lead to an increased interest in a subject.

“You have to make sure it’s relevant, and then you can get them engaged to the highest rigor you like,” said Bender Jutzi.

As an authentic learning competition, SSEP does just that. Through the hook of helping astronauts onboard the ISS, or someday on Mars, students learn how to design an experiment, write a proposal, present their idea to local review boards, and, if selected to fly their experiment to the ISS, present the outcomes of their research at a national conference, typically held at the Smithsonian National Air and Space Museum.

These are skills that many scientists do not learn until college or even graduate school. "It's definitely a novel approach to science education, and it takes students from learners to actual practicing scientists," said SSEP's Hamel.

For the students, it is exciting to be treated like a scientist, even though it is hard work. For sixth-grade student researcher and SSEP principal investigator Gabriel McCarthy from Bureson ISD, participating in SSEP had been a dream since he was in third grade. McCarthy's career goal is to become an astrophysicist, and he had been looking forward to competing in SSEP since he first heard about the competition.

In participating in SSEP and having his experiment "The Effects of Microgravity on Penicillium Mold Growth" selected for flight, McCarthy not only grew to understand just how much work goes into science, but he also got to experience new opportunities that were never available to him before.

**“It helped me get a grip on how much work goes into a project and how many variables can be surrounding a project,” McCarthy said of the experience. But for him, it was totally worth it. “The most exciting parts of this experience were going to Washington, D.C., getting to present at the Smithsonian, being part of the launch party, and getting to work so closely with Texas Christian University (TCU) and college professors,” he said.**

Working with local universities is a unique opportunity and often one of the most valued experiences for students. McCarthy and his team worked with Clark Jones, a biology instructor at TCU, in his microbiology lab while preparing their sample for launch to the ISS. McCarthy also had the opportunity to work with Hana Dobrovolny, an assistant professor of biophysics at TCU, and to participate in TCU's Student Research Symposium.

"Dr. Dobrovolny taught me more about cell growth, and it has been a unique experience," McCarthy said. "She's challenged me in math and coding in order to make graphs and taught me how to model cell growth within equations."

The Atlas XII SSEP team from Ector County ISD taken right after it was announced that their school won all three finalist spots for their district. Ector County ISD



SSEP Team Penicillium Mold Growth, including student Gabriel McCarthy (second from left), with teacher Laura Smith in front of the Smithsonian National Air and Space Museum. Bureson ISD

McCarthy also learned how different concentrations of chemicals, like medications or nutrients, can affect tumor cell growth and has been invited to participate in TCU's Student Research Symposium this year for the second time. For a sixth-grade student, this is typically an unheard-of opportunity.

**INSPIRING YOUNG SCIENTISTS**

Although the draw of flying an experiment to space is powerful, the benefits of SSEP extend beyond any single student or any one winning team. "SSEP touches every single aspect of STEM literacy," said Gray, who reported higher interest in STEM subjects among her students after participation in SSEP.

**more than 12,000 STUDENTS PARTICIPATED** For many other communities, the results were similar. More than 12,000 students participated in microgravity experimental design and proposal writing for SSEP's Mission 12. In the end, even though only some students had their experiment chosen to fly to the space station, the impact on all participating students was significant. Through the process of being treated like actual scientists and conducting real science, SSEP instills in students the idea that anyone can be a scientist. ■

*STEM Education through Space Exploration!*



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# TOUGH ENOUGH FOR SPACE

## Accelerating Materials Testing With a New Permanent Platform

BY ANNE WAINSCOTT-SARGENT, Contributing Author



In microgravity, even seemingly indestructible materials degrade. Just look at the Hubble telescope, where its outer layer of insulation and thin layer of aluminum encasing have become so embrittled they are cracking and curling.

Without question, space is a harsh place where radiation, temperature extremes, orbital debris, and atomic oxygen (the presence of highly reactive single-oxygen atoms) flourish.

A new permanent test bed is now available on the exterior of the International Space Station (ISS) that allows investigators to analyze the durability of materials one sample or experiment at a time in the extreme space environment. The remotely controlled platform, the Materials ISS Experiment Flight Facility (MISSE-FF) from in-orbit commercial services provider Alpha Space Test & Research Alliance, LLC, aims to accelerate the testing of materials and components that have utility both in space and on Earth.

### BUILDING ON NASA'S LEGACY OF INNOVATION

MISSE-FF, which launched on the 14<sup>th</sup> SpaceX commercial resupply services mission in April 2018, builds on two decades of innovation by NASA. When the space shuttle was operating, NASA flew eight MISSE missions to the ISS, the last of which returned to Earth in 2014. The new MISSE design uses carriers to hold the experiments, which are launched and returned with each mission. Carriers from the current mission, MISSE-9, using the new MISSE-FF platform, are currently scheduled to return to Earth in December 2018 and April 2019.



Robotic transfer of the MISSE-9 MISSE sample carriers from the JEM Airlock to the MISSE-FF on ELC-2.  
NASA

In contrast to earlier MISSE missions, in which astronauts installed MISSE payloads on the outside of the ISS during a spacewalk and then later retrieved the experiments the same way for return to the ground, MISSE-FF is a permanent fixture on the space station. The platform's

individual experiment carriers are installed and removed using the robotic Canadarm2. Approximately 40 percent of the platform is reserved for NASA experiments, with the remaining 60 percent available for commercial use.

**“**Our business model and the MISSE-FF platform significantly broaden access to space and enable commercial enterprises to get to low Earth orbit (LEO),” said Mark Gittleman, president and CEO of Alpha Space. “We make it inexpensive and easy to test new materials, components, and technologies in space with help from NASA and the ISS National Lab, which, together with Alpha Space’s great team, enable our business model.”

(Left) Preflight photos of the MISSE-9 experiment decks in the Alpha Space clean room.

Kim de Groh, NASA's Glenn Research Center



MISSE-FF with the zenith MISSE sample carrier open and the samples exposed to space.  
NASA

Research and development projects included in MISSE-9 will advance both space exploration and Earth-based innovations in solar technology, remote sensing, telecommunications, and other fields. MISSE-9 includes a suite of investigations, with samples including 3D-printed materials, sensors, sensor components, textiles, carbon-fiber laminates, paints, coatings, polymers, and composites. Within the first few weeks of MISSE-FF operation, Alpha Space had already received 1.2 million data packets (a unit of data made into a single package for transmission), including imagery of samples in various flight orientations.

“We built the MISSE-FF platform in less than three years, and now that it’s onboard the ISS, it’s running spectacularly,” said Alpha Space founder Stephanie Murphy, who brought together a team of engineers with prior MISSE experience to build the platform.

Murphy also leads MEI Technologies, a government contracting firm established in 1992 by Murphy’s father as Muñiz Engineering, Inc. MEI Technologies originally won the contract to privatize the MISSE platform, but it was Murphy’s idea to spin off Alpha Space into a standalone firm.

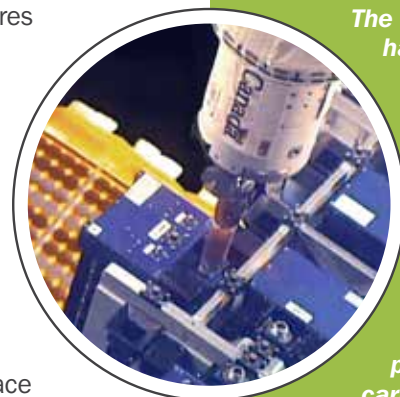
## DRIVING NEW UNDERSTANDING AND BREAKTHROUGHS

Results from MISSE-9 investigations will not be fully realized until after the MISSE sample carriers housing the experiments return in winter 2018 and spring 2019 and samples or components are analyzed, but historical MISSE investigations have a legacy of advancing understanding and innovation in several industries on Earth.

For example, research on surface oxidation by atomic oxygen informs the design of fire-retardant and rust-resistant materials on Earth. Interactions between various materials and solar ultraviolet radiation could lead to better protective designs for communications and weather satellites and may help improve terrestrial structures, such as plastic siding for houses.

In addition, because true space environmental conditions are difficult to replicate on Earth, MISSE provides a valuable test platform that enables methods for correlating and extrapolating ground results. “That means that MISSE experiments can make ground testing more accurate and reliable,” said MISSE researcher Kim de Groh from NASA’s Glenn Research Center.

Most notably, of course, MISSE missions have provided space-environment durability data that enables the design of new, even more reliable spacecraft and innovative new structures for use in harsh environments both on and off Earth. Today’s satellites that are relied upon by hundreds of millions of people for Earth observation, weather, and communications were developed with materials tested in space on earlier NASA-led MISSE and related exposure missions.



NASA



Kim de Groh at the NASA Glenn Research Center with the MISSE-9 experiment decks, shortly after sample integration into the MISSE-9 R2 (ram), W3 (wake), and Z3 (zenith) MISSE sample carrier decks.

Kim de Groh, NASA's Glenn Research Center

## PROVIDING FOUR SIDES OF EXPOSURE

*The MISSE-FF platform, which resembles a futuristic four-sided cube, provides four sides of environmental exposure relative to the space station’s orbit—in the wake, zenith, ram, and nadir orientations. This is an important feature that provides advantages beyond the historical MISSE missions by allowing testing related to specific aspects of the external environment.*

*The wake orientation approximates the lunar environment because in this orientation, the facility itself shields the experiments. Materials placed in the MISSE wake orientation would be exposed mostly to the plasma particles in LEO and to solar ultraviolet radiation.*

*The zenith side faces the sun, and the nadir side is Earth facing. The zenith side supports solar-cell or radiation testing. Significant radiation comes from this view because there’s no atmosphere that blocks or slows down radiation. The ram side provides a premium spot for atomic oxygen exposure or analyzing the degradation rate of materials.*

“A big advantage of the new facility is the inclusion of environmental sensors that provide us with information on the amount of exposure in each flight orientation, such as solar exposure, which we didn’t have before,” said de Groh, who has samples on MISSE-9 in the zenith, ram, and wake orientation.

*The MISSE-FF platform itself is permanent. To avoid astronauts having to do spacewalks to retrieve MISSE experiments from the station, NASA required that the platform’s plug-in carriers all be robotically re-serviceable. The robotic Canadarm2 special-purpose dexterous manipulator can plug in or remove MISSE-FF sample carriers containing materials or other experiments.*

*The carriers pick up power and data from the platform, which means that active experiments can be powered and commanded, and data can be read back to Alpha Space’s payload operations control center in Houston. Each of the platform’s four sides has space for three carriers, and each carrier provides 181 square inches of area exposed to space, offering a large capacity. Each carrier also has more than 270 cubic inches of below-deck space available for experiments and extra electronics.*

These established benefits are appealing to a broad customer base. “We’ve attracted some really diverse initial clients,” said Murphy. “We’re in a lucky place where we can invite new users to the ISS National Lab, but our expenses are still being subsidized through the ISS National Lab and NASA. It’s a short-term incentive to bring entities and entrepreneurs into the fold that haven’t been there before.”

Besides traditional materials testing (e.g., paint, coatings, fabrics, and materials for 3D printing), Murphy noted that Alpha Space has had strong interest from customers studying “exobiology,” or the behavior of living things in the external space environment; for example, biological firms focused on medical applications.

“We’ve got people who want to fly biofilms and neurological cells for radiation testing,” Murphy said. “Others have interest in flying plants and seeds to test radiation exposures. They want to see if they grow plants on Mars and how radiation will affect their plant growth or seed germination.” This diversity of interest has led the company to embrace the slogan: “If it fits, it flies.”

**A biofilm** is an assemblage of microbial cells attached to a surface and enclosed in a self-produced matrix of compounds that protect the microbes from the environment.

## AN UNPARALLELED PLATFORM FOR TECH DEMO

Firms wishing to demonstrate or test their space technology components and equipment in LEO are particularly drawn to the MISSE-FF platform. Two such technology demonstration experiments on MISSE-9 involve testing glass-free packaging for solar cells and assessing the robustness of optical receivers for communication in the harshness of space.

One experiment is from New Jersey-based Discovery Semiconductors, Inc., which makes fiber-optic modules and receivers for telecommunications, the military, and now LEO space applications.

“Demand for data bandwidth, which has been strong for terrestrial applications for many years, has started to migrate to space platforms,” said Abhay Joshi, owner of Discovery Semiconductors.

Joshi previously flew his fiber-optic components on MISSE-7 and has continued with the current MISSE-9 mission. He hopes the latest tech demo—involving two indium gallium arsenide high-end space receivers—will enhance the technology readiness level (TRL) of his company’s components.

**Technology readiness level (TRL)** is a system used to rate the maturity level of a technology on a scale from one to nine, with TRL-1 being observation of basic principles and TRL-9 being proven through successful operations.

“The MISSE-FF platform is highly desirable because it allows me to get some of my components up in space and see how they withstand vibration, shock, rocket launch, and re-entry, as well as the extreme vacuum and temperatures of space,” said Joshi, whose receivers are used for communications and remote-sensing applications. “MISSE-FF is an ideal platform to check the space worthiness of new devices.”

An Alta Devices solar cell.  
Aarohi Vijh



The materials of the future and the component systems in which they are used are going to need to pass even more rigorous testing in extreme environments in order to operate and remain functional as they shrink in size and power consumption but increase in complexity and capability. The small satellite revolution is driven by advances in material performance and technologies proven in the harshness of space.

Like Joshi, Aarohi Vijh also sees value in the MISSE-FF platform for his technology components. Vijh heads new product definition and technical marketing for Alta Devices, a solar technology company in Sunnyvale, California. The company was founded 10 years ago by two researchers: Harry Atwater, of the California Institute of Technology, and Eli Yablonovitch, of the University of California, Berkeley.

**ALTA DEVICES** already supplies its thin and flexible solar cells to the automotive sector and to the unmanned aerial vehicle market, especially for single-junction solar-powered aircraft. Alta Devices holds the world record for solar efficiency, generating very high power per unit area. For small, unmanned systems, Alta Device’s AnyLight™ power technology provides unmanned systems as much as five times more daytime endurance, and at one gram per watt of power, it has virtually no impact on weight or aerodynamics.

Vijh and his team are studying a special kind of solar cell based on gallium arsenide (GaAs). GaAs solar cells were first developed in the early 1970s and have several unique advantages. GaAs is naturally robust to moisture and radiation, making it very durable. It has a wide and direct band gap allowing for more efficient photon absorption and high-output power density.

To create glass-free packaging for these solar cells so that they are lighter, less fragile, and better able to operate in space, Alta Devices tapped into years of NASA performance data on various plastics and polymers flown in space on MISSE missions. “In developing our own packaging solution, it made it a lot easier to look at what had already been done and proven,” Vijh said.

Vijh plans to continue to use the MISSE platform to evaluate his firm’s innovative solar arrays. “It’s a very powerful statement to make to our customers that our solar panels and packaging have actually been on a space flight with a credible provider,” he said.

Vijh sees applications on the ground as well. “The solar cells receive very high environmental exposure in space—ultraviolet rays and temperature cycling,” Vijh said. “The materials and our manufacturing techniques that we’re qualifying on MISSE will carry over to applications on the ground in the automotive industry and near-space applications such as high-altitude aircraft.”

#### LOOKING TO THE FUTURE

On the NASA side, both de Groh and Sheila Thibeault, a member of the Advanced Materials and Processing Branch in the Research Directorate at NASA’s Langley Research Center, have experiments not only on MISSE-9 but also on MISSE-10, which recently launched to the ISS on Northrop Grumman CRS-10.

Thibeault served as an original founder of the MISSE project back in 1999, building the initial hardware used on MISSE-1 through MISSE-8. She also assisted with the redesign of MISSE to be remotely controlled, eliminating the need for spacewalks, and she and de Groh both advocated for a permanent MISSE platform on the space station.

“I’m really excited about MISSE missions continuing under Alpha Space leadership,” said Thibeault. She recalls how her team often had to take the machining of the carriers to NASA Langley’s machine shop, which was time consuming and involved some cost, and had to oversee quality control for incoming specimens from external partners, which also took time and resources.

“Alpha Space is making our life easier,” Thibeault said. “I can focus on my materials and the science and don’t have to worry about the platform or the specimen holders, which is all being taken care of for me.”



The MISSE-FF platform, developed by Alpha Space, on the ISS.  
Alpha Space/NASA

While it is still early in the platform’s performance history, Alpha Space executives believe the future is bright for MISSE-FF as a permanent test bed that will have a lasting impact on the quality of life at home and in space.



#### THE STEM CONNECTION

*MISSE has and will continue to serve as a vehicle for science, technology, engineering, and mathematics (STEM) education, with students collaborating on several NASA MISSE experiments. Under NASA’s two-year MISSE-X project (the predecessor to MISSE-FF), Thibeault and de Groh contributed to the development of a STEM education teacher’s guide (see: [nasa.gov/sites/default/files/best\\_misse-x\\_workbook.pdf](http://nasa.gov/sites/default/files/best_misse-x_workbook.pdf)).*

*“All my prior missions on MISSE-1 through MISSE-8 were collaborative efforts with students at Hathaway Brown, an all-girl high school,” noted de Groh.*

*Over the last 20 years, de Groh has mentored 31 young women on MISSE projects. The students worked in small teams once a week after school and full time during summer throughout their high school careers.*

“Space represents a crucial economic sector for the United States, and Alpha Space is leading the way to help NASA and the country achieve the very important policy of commercializing LEO,” said Gittleman. “We are doing it alongside traditional NASA space science, which I think will enable improvements to the U.S. space-industry supply chain while simultaneously making LEO more accessible than ever before.” ■

## Encouraging Girls in STEM: Astronaut Reads American Girl Book on the ISS

BY TERE DARDON, Staff Writer

SPOT  
LIGHT

According to the National Science Foundation, studies have shown that by the time children reach the second grade and are asked to draw a scientist, they typically draw a man in a lab coat. Additionally, several studies have found that girls lose interest in science and math during their middle school years. These data underscore the importance of highlighting women and girls in science—and one effective avenue may be through popular children’s media, such as in books and TV shows, providing powerful affirmation outside the classroom that girls can and do pursue science.



NASA astronaut Serena Auñón-Chancellor reads an excerpt from the American Girl book *Luciana: Braving the Deep* onboard the ISS as part of Story Time From Space.  
Story Time From Space

Recently, from inside the cupola onboard the ISS, NASA astronaut Serena Auñón-Chancellor was videoed reading an excerpt from the American Girl book *Luciana: Braving the Deep* as part of Story Time From Space, a Space Station Explorers education partner program. In the book, written by Erin Teagan, Luciana Vega™—American Girl’s 2018 Girl of the Year™—dreams of one day becoming an astronaut and traveling to Mars.

Watching a female astronaut read a book about a young girl who also aspires to become an astronaut can provide valuable motivation for young girls to engage in science, technology, engineering, and mathematics (STEM) activities and perhaps



American Girl

even strive toward a career in a STEM field. Having a relatable representation like Luciana really brings to life the idea that girls can be actively involved in STEM.

In the book excerpt read by Auñón-Chancellor, Luciana attends a youth astronaut training camp, where she grows hydroponic plants

like astronauts do on the space station. The fictional Luciana details some of the challenges involved in working together on a team to complete a project—something all scientists face when working collaboratively to advance science. During the reading, Auñón-Chancellor compared the scenarios in the excerpt to her real-life experiences working as an astronaut on the ISS.

The Story Time From Space reading of *Luciana: Braving the Deep* was officially released during a special live downlink at the Riverside Library and Cultural Center in Colorado. During the downlink—which also aired live through several NASA outlets—students were able to speak with Auñón-Chancellor while she was onboard the ISS, asking her questions about what it’s like to live and work in space.

American Girl, an iconic brand since 1986, continually introduces dolls, books, and other accessories that represent a variety of female characters in stories that aim to instill important values in young girls. As American Girl’s 2018 Girl of the Year, Luciana helped bring visibility to the importance of encouraging girls in STEM and showed girls that science is not just for men in lab coats. ■

## Igniting Interest Through Inquiry

BY DAN BARSTOW, *Staff Writer*  
AND SARA CARNEY, *Contributing Author*

SPOT LIGHT

**J**ulissa Herrera loves science. As a current student at Evergreen Community College in San Jose, California, she is working her way toward a career in a science, technology, engineering, and mathematics field. But not so long ago, it seemed that Hererra was headed on a different path.

In high school, science was one of Herrera's least favorite subjects. The traditional science courses offered at her school did not appeal to her. She was even at risk for dropping out. However, thanks to a unique opportunity to design and test a science experiment on the ISS, Herrera's passion for science was ignited.

**QUEST**  
for SPACE

Quest for Space, a Space Station Explorers partner program led by the Quest Institute for Quality

Education, aims to help elementary through high-school students like Herrera who are not excelling at science in a traditional classroom environment. Students selected to participate must express interest in the program and must have previously failed a science course.

Through the program, students design experiments using two almost-identical kits: a spaceflight unit and a ground-based unit. Students use the ground-based unit in their classroom and write simple code to control the experiment and collect data. Then, Quest for Space sends the students' code to the ISS to run the experiment on the spaceflight unit, downlinking the data to allow students to compare space and ground results.

Quest for Space experiments range widely in discipline—from plant health to ant behavior, bacterial growth, and radiation effects—and allow students to gain experience in software engineering, electrical engineering, mechanical engineering, project management, and teamwork. Students and teachers also receive technical support, educational resources, and access to ISS data.

The experiment that Hererra participated in used fans, heaters, and sensors to measure how heat flows in a contained environment. She quickly became motivated by the hands-on learning approach and enthusiastically took on the role of mechanical engineer for the project.



Julissa Herrera speaks at the 2018 ISSR&D Conference about her Quest for Space experience.

ISS National Lab/Mauricio Hoyos



Julissa Herrera is awarded the 2018 Space Station Explorers Exceptional Student Award.

ISS National Lab/Mauricio Hoyos

For Hererra, participation in the program ultimately meant a change in scholastic trajectory. In recognition of this transformation, she was awarded the 2018 Space Station Explorers Exceptional Student Award at the ISS Research and Development Conference.

Since 2010, Quest for Space has helped send more than 100 student-designed experiments to the ISS. Hererra is just one example of the program's impact. Her story illustrates how hands-on experiences with ISS research can not only help spark students' passion for science but also significantly change their lives. ■

## An Expanding Market of Nontraditional ISS Users

BY PATRICK O'NEILL, *Staff Writer*

SPOT LIGHT

**P**art of the role of the ISS National Lab is to expand the utilization of the orbiting facility to nontraditional research partners, such as those representing commercial brands or interests. Over the years, unique entities including Budweiser, Cobra Puma Golf, Google, and Apple have all become part of the ISS National Lab community. While each company has had different interests in using the space station, each has helped to craft case studies to entice others to take their research and development to new heights.

At the 2018 ISS Research and Development Conference in July, two additional companies announced their intention to become part of this burgeoning commercial space science community—Delta Faucet Company and Goodyear Tire & Rubber Company, both with investigations anticipated to launch in the coming year.

Delta Faucet is widely recognized within the home improvement community, as their kitchen and bathroom appliances are featured in thousands of households worldwide. Now, the company seeks to leverage the microgravity environment onboard the space station to enhance their product line and save the consumer money, all while promoting efficient water usage.

Delta Faucet plans to conduct an experiment in association with its proprietary H<sub>2</sub>Okinetic® shower head technology—which controls water droplet size and speed to create a feeling of increased pressure for the end user while using less water. It does this by enlarging the size of the water drops and increasing their speed. But scientists do not fully understand how gravity affects the formation of water droplets, which could impact the performance of the technology.

By studying water droplet formation and water flow in microgravity, Delta Faucet hopes to learn how they might better control droplet formation and flow to improve their H<sub>2</sub>Okinetic® technology back on the ground. Their goal—to both enhance the shower experience for customers while also conserving water and energy.

Goodyear is also aiming to leverage the microgravity environment of the space station to potentially improve its product lines. Materials science research plays a critical role in the development of Goodyear's tires, and the company is interested in studying silica—a key material used to manufacture consumer tires—in microgravity.

Specifically, Goodyear will examine whether silica particle formation in microgravity might reveal new molecular structures of silica that could be used in tire production to improve performance. Goodyear's investigation could pave the way (*pun intended*) for the development of consumer tires that are both more reliable and more fuel efficient than those currently available.

Both Delta Faucet and Goodyear represent a growing market of nontraditional users that are seeing the value in sending their research and development to the ISS National Lab to advance their consumer products back on the ground. The hope is that as more of these partnerships are forged, the concept of “nontraditional users” falls by the wayside, revealing these companies as trailblazers of major commercial utilization of the ISS to benefit life on Earth. ■



Commercial utilization panel participants at the 2018 ISS Research and Development Conference (from left to right): Jackie Wattles, panel moderator and reporter, CNNMoney; Blair Bigelow, co-founder and vice president of corporate strategy at Bigelow Space Operations; Derek Shuttleworth, manager of external science and technology for Goodyear Tire & Rubber Co.; and Garry Marty, principal product engineer at Delta Faucet Co.

ISS National Lab/Mauricio Hoyos

# News & Notes

FROM THE ISS NATIONAL LAB



## **DESTINATION STATION BOSTON**

In August, the ISS National Lab and the NASA Program Science Office, along with NASA astronaut Kate Rubins, traveled to Boston as part of Destination Station outreach. The Destination Station team met with local companies to showcase ISS research capabilities.

## **BEYOND HUMAN: NIGHT AT THE MUSEUM WITH SEEKER**

In continued collaboration with science content publisher Seeker, ISS National Lab Associate Program Scientist Liz Warren spoke at Seeker's "Beyond Human Nightlife" event about tissue engineering on the space station and advancements in the field of regenerative medicine. The event was held at the California Academy of Sciences in San Francisco. Warren was also a featured guest on Seeker's "Bad Science" podcast to discuss the science of the movie Gravity.

## **MASSCHALLENGE AWARDS**

In partnership with Boeing, three projects from two startups associated with the MassChallenge accelerator program were selected for the 2018 "Technology in Space" prize. The projects—one from Kernal Biologics, Inc. and two from MicroQuin—will use the microgravity environment on the ISS for cancer research. This is the sixth year the ISS National Lab has supported the Technology in Space prize and the fifth year Boeing has co-sponsored the prize.

## **LAUNCHING NEW SCIENCE**

Two recent launches, Northrop Grumman (NG) CRS-10 in November and SpaceX CRS-16 in December, brought a combined total of more than 30 ISS National Lab payloads to the orbiting lab. NG CRS-10 included an experiment from The Michael J. Fox Foundation to optimize crystallization of the LRRK2 protein associated with the development of Parkinson's disease and a project from Micro-gRx that uses a lab-on-a-chip platform to study muscle wasting in microgravity. Included on this mission was the first tissue chip investigation funded through the Tissue Chips in Space initiative in partnership with the National Center for Advancing Translational Sciences, which is part of the National Institutes of Health. Also on SpaceX CRS-16 was an experiment from Budweiser looking at microgravity's effects on malting barley and two student projects from the Marvel Guardians of the Galaxy Space Station Challenge.

Read UPWARD online at [Upward.ISSNationalLab.org](http://Upward.ISSNationalLab.org)

# UPWARD

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