UPWARD

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Space Tango
RESEARCH IN A BOX

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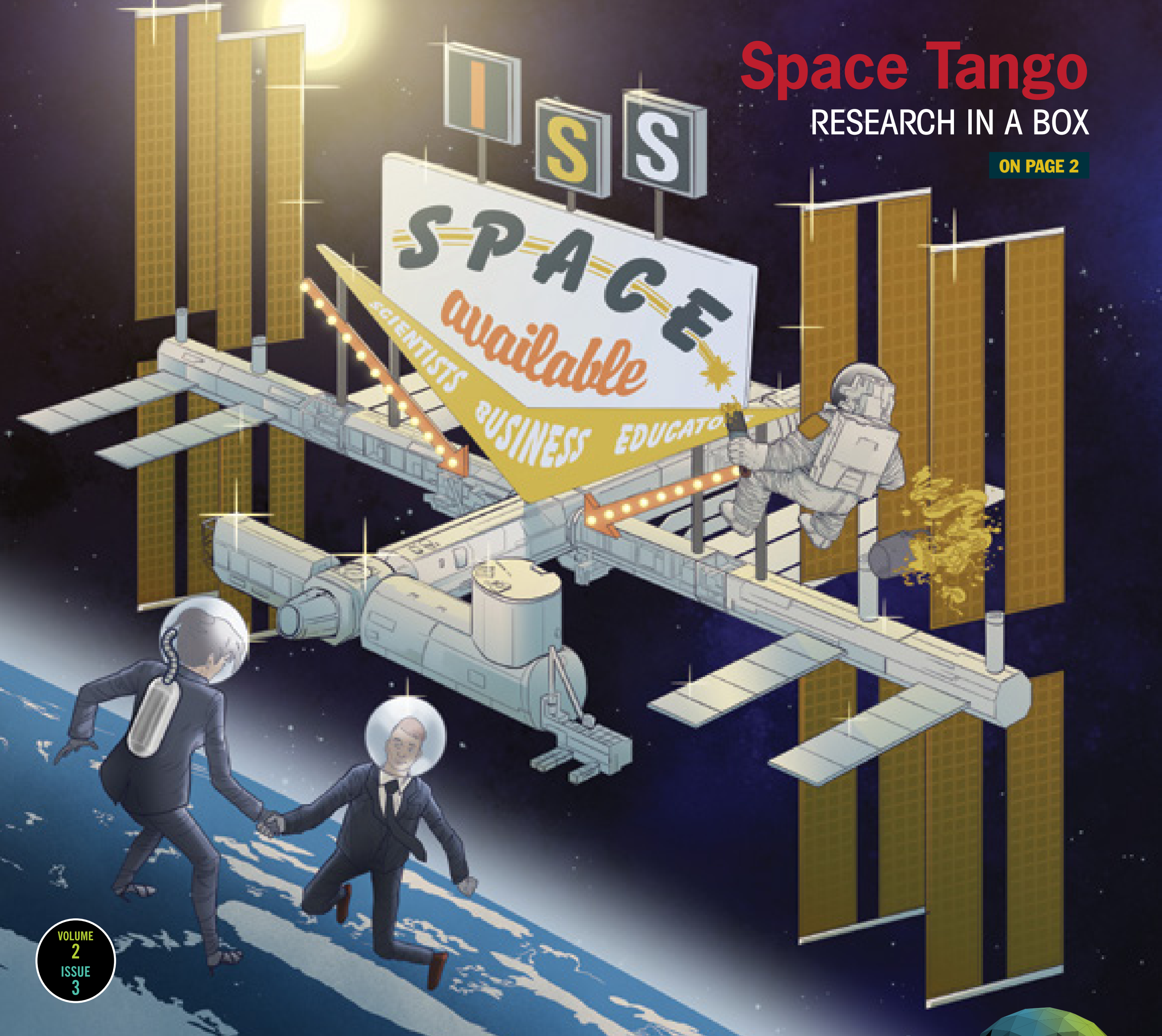

VOLUME 2 ISSUE 3

THE LITTLE FURNACE THAT COULD

HOW MICROGRAVITY IS IMPROVING CARDIAC CELL QUALITY

MICROGRAVITY MOLECULAR CRYSTAL GROWTH

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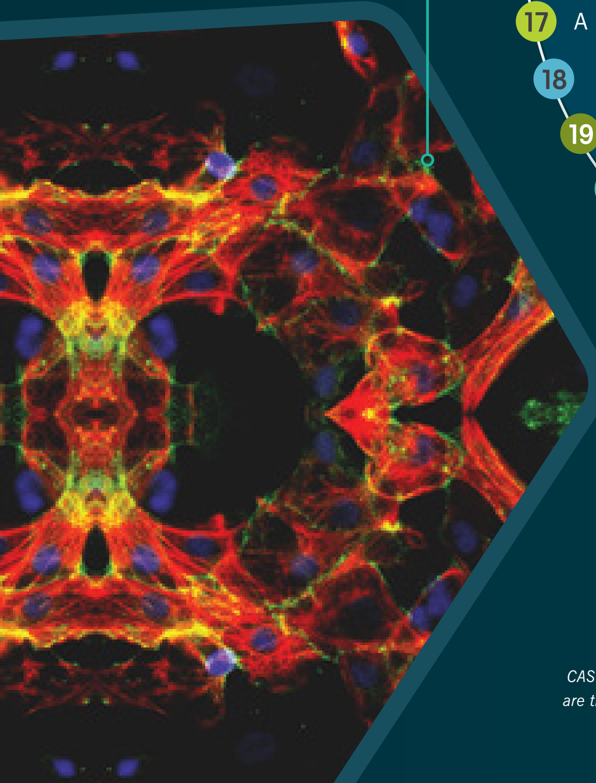

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THE VIEW FROM THE CUPOLA

BY KEN SHIELDS, CASIS

Ken Shields is the Director of Operations and NASA Liaison of CASIS

NASA's recent signing of an updated cooperative agreement with the Center for the Advancement of Science in Space (CASIS) extends our role as manager of the U.S. International Space Station (ISS) National Lab through 2024, the budgeted life of the space station.

This long-term commitment signals to commercial entities and other organizations interested in leveraging the ISS National Lab that this R&D platform is available for use through at least 2024 and that there has never been a better time to pursue scientific, technological, or business interests in low Earth orbit (LEO).

As the U.S. continues to strive toward executing larger space missions, we hope the commercial sector will be a pivotal driver of the supply chain in LEO—and we hope that CASIS and the ISS National Lab can evolve to play a role in this future as well. The extension of the cooperative agreement is one more step toward a larger national goal to develop a non-NASA, private sector commercial presence in LEO. The ISS National Lab represents a valuable pathfinder for these activities—serving as part-research park, part-small business incubator, part-investor network. In the six years since NASA originally signed the cooperative agreement with us, CASIS has helped stimulate private sector demand and use of the ISS, which will enhance life on Earth and demonstrate a return on investment for taxpayers.

When CASIS began managing the ISS National Lab, two companies offered commercially available and operated facilities onboard the space station. Now we are up to seven. Space Tango, featured in this issue of *Upward*, is a great example of a new company providing a platform for supply-side commercial investment in LEO. Space Tango's TangoLab facilities give users the opportunity to perform R&D experiments in a variety of potential configurations in microgravity. This Kentucky-based startup invested in its own infrastructure onboard the ISS and will sustain its operations by offering customers high-throughput, high-volume, and rapid-response services using a commercial schedule and budget—helping companies launch their experiments to the ISS in under a year. That is a dramatic change from the three-to five-year timeframes typically experienced by microgravity researchers in years past.

The work CASIS does through partners directly supports additional national priorities, including our country's security, prosperity, energy dominance, and health goals. Many of the R&D investigations on the ISS cut across these priorities. For example, this issue of *Upward* features an article on biomedical advancements using microgravity cell cultures and an article on investigators' use of the updated SUBSA facility on the ISS to study microgravity's role in the synthesis of semiconductor and scintillator crystals. Such crystals can be used to detect radiation, with applications in homeland security, safety, and human welfare on Earth. In addition, many primary users of the ISS National Lab include government agencies, with projects supporting the Department of Defense, the Department of Energy, the National Science Foundation, the National Institutes of Health and, of course, NASA.

With the extension of NASA's cooperative agreement with CASIS, the U.S. is at a pivotal point in building a private sector commercial presence in LEO. NASA is responding to the growing user demand by adding a fourth U.S. crew member, which will enable the ISS National Lab to host and operate even more flight projects. Commercial Resupply Services (CRS) missions now launch to the ISS four to six times each year, providing multiple opportunities for payloads to launch, and NASA's CRS-2 contract assures ISS National Lab users that a robust and diverse transportation solution from Earth to the ISS will continue through at least 2024.

Investigators can now conduct experiments onboard the ISS National Lab with cutting-edge capabilities enabled by commercial service providers including NanoRacks, Space Tango, Techshot, and others—offered on a commercial cost and schedule. If you want to accelerate your product-to-market, test your technology in the environment of space, or gain invaluable, keen insights in the fundamental areas of science and discovery in microgravity, now is the time to participate in the evolution of a growing LEO economy. ■

SPACE TANGO RESEARCH IN A BOX

BY SARA CARNEY

Space is synonymous with possibility and growth. Since the Big Bang 13 billion years ago, the edges of our universe have pushed beyond the known limits and expanded to fill the void. However, you don't have to go to the edge of the universe to find growth and expansion. Increased access to space in low Earth orbit is bringing technological advancements, increased investment in innovative approaches to goods and services, and exciting opportunities in space commerce.

New-to-space companies and investors who have never explored space's resources are using the ISS National Lab as a platform for innovation, discovery, and commerce. To support this growth, Kentucky-based startup Space Tango is filling new demand for expanding space-based research and development by paradoxically shrinking labs into something small enough to be held in both hands.

An individual CubeLab

Space Tango

The space available for R&D on the ISS is significantly more constrained than labs on Earth—access to mass, volume, power, and crew time are precious. To address this constraint, Space Tango works with researchers to offer the capabilities of a full lab condensed into a 10-cm CubeLab Module.

Following in the footsteps of other companies before them, an experiment in one of Space Tango's CubeLabs can be "plugged into" the ISS and either run automatically until it returns to Earth or be manually controlled from the ground. For Space Tango, microgravity is the next frontier in advancing scientific discovery and expanding the universe of R&D in space.

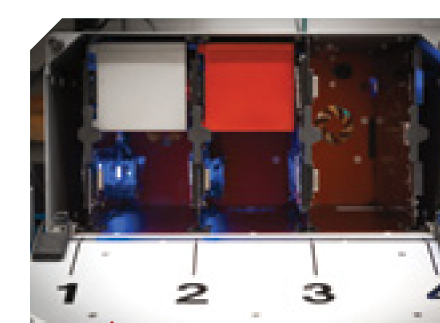
In February 2017, Space Tango's first customer payloads, including experiments from commercial and educational organizations, were transported to the ISS on SpaceX CRS-10. Because of the successes of these projects, a second facility was launched to the ISS on SpaceX CRS-12 in August, doubling the number of experiments Space Tango can support on a single mission. To date, Space Tango has housed 28 experiments on the ISS National Lab.

> ***"Every time humans have harnessed a new physics environment—be it microgravity or vacuum or electromagnetism—it has led to exponential growth in knowledge, benefits to humankind, and wealth creation, and this is part of that continuum," said Kris Kimel, co-founder and chairman of Space Tango. "We are now able, through technology and access to space, to really begin harnessing microgravity as a new physics environment."***

PROVIDING THE SPACE

Space Tango works with academic institutions, commercial for-profit companies, and philanthropic organizations to make research in microgravity accessible and affordable. Because many researchers do not have experience in spaceflight R&D, Space Tango works with customers to modify ground-based experiments to meet the demands of the space environment and make R&D objectives technically feasible. Space Tango's CubeLabs make experimenting in space more accessible and affordable to customers interested in harnessing the power of space to advance their R&D on Earth.

Researchers may be experts in their fields of study, but most are unaccustomed to the different challenges presented by working in microgravity. Procedures as simple as pouring liquids into a beaker must be altered to work on the ISS. Space Tango uses its team's expertise in spaceflight R&D to adjust experiments to microgravity and fit them within the CubeLab.



A TangoLab used by Space Tango on the ground to test the CubeLabs before flight

Space Tango

Gentry Barnett (left) and Twyman Clements (right) with CubeLabs
Space Tango

TangoLab-1 arrived on the ISS in August 2016 and is roughly a half-meter by half-meter (58-cm x 46-cm) platform that houses CubeLabs and provides power and communication links for experiments. TangoLab-1 is a permanent fixture on the ISS, but CubeLabs—and thus experiments—can be swapped out so that experiments can be repeated as is or modified in real time to meet the needs of the investigator.

Up to 21 CubeLab experiments can be run simultaneously. Each 10 cm x 10 cm x 10 cm CubeLab makes up a unit—known as a U—and can house a single experiment, whether it's from the life sciences, material sciences, or another field of study. Alternatively, an experiment can take up 2U, 4U, or even 6U, if needed. CubeLabs also contain the necessary attachments required for experiments, such as LED lights or imaging equipment.

Experiments within the CubeLabs are fully automated and designed to require minimal human intervention, which is a plus, as crew time is highly valuable. Real-time or near real-time data can be sent from the CubeLabs to customers on the ground, allowing them to stay up-to-date on their experiment's progress. Additionally, TangoLab-1 comes with several standard kits, including cell culturing as well as plant and bacterial growth kits.

TangoLab-1 is a general research platform and is not built for any specific use, making it highly customizable, said Twyman Clements, cofounder and CEO of Space Tango. "You can build a lot of the analytics and environmental controls into each individual CubeLab, which allows us to have a plant growth study next to a bacteria study," Clements said. "The TangoLab-1 facility stays on the ISS and really just provides power—a lot of the 'smarts' are inside the cube itself."

Aside from providing the hardware, Space Tango also guides researchers through the process of designing, integrating, and operating their experiments on the ISS—a multiple-step process. First, Space Tango does a preliminary analysis to better understand the goals and needs of the experiment. In the preliminary design phase, experimental operations are refined and the necessary technology is identified. Designs are then finalized, reviewed, and approved to match research objectives with engineering capabilities. Space Tango then assembles and reviews the payload to ensure it meets both the customer's needs and NASA's standards. Finally, the payload is launched and can be returned from the ISS.

LEARNING TO DANCE: SPACE TANGO'S BEGINNINGS

Space Tango's journey began in 2005, when Kimel was learning about CubeSats, or satellites similar in size to CubeLabs. After spending several summers at Stanford University learning about the engineering behind CubeSats, he and Clements (a graduate student at that time) saw the potential for CubeSat-like technology on the ISS—an idea that ultimately lead to the creation of Space Tango.

Space Tango is a commercial spin-off of Kentucky Space, a nonprofit with a Space Act Agreement with NASA to supply services to the ISS. Because of its relationship to Kentucky Space, Space Tango has access to an existing knowledge base regarding R&D on the ISS, which helped investors see the company's potential.

For Howie Diamond, managing director at California-based investment firm Ranch Ventures, Space Tango was an opportunity to contribute to the innovation happening through commercial research in space. According to Diamond, it was the combination of established know-how and the potential to provide novel insight into persisting questions that led him to invest in Space Tango.

> ***"The commercialization of microgravity research in general is really exciting to me," Diamond said. "It just feels like space as the final frontier can be this huge untapped resource and this huge opportunity for commercialization across so many sectors and industries, and I think Space Tango can be at the forefront of that."***

EXOMEDICINE

Although Space Tango can accommodate research and technology development in many different fields, Clements and Kimel have noticed that biomedical research in space is particularly popular and rapidly expanding. Much of this research aims to understand disease processes that are affected by space, using the microgravity environment of the ISS to better piece together disease pathways and mechanisms.

"Our primary focus has evolved to the point where 90 percent of our work is focused on biomedical research—something we call exomedicine, which we define as the research, development, and commercialization of medical solutions in space for applications on Earth," Kimel said.

RECENT TANGOLAB-1 EXPERIMENTS AT A GLANCE

MICROBIAL METHANE ASSOCIATED RESEARCH STRASBOURG NO. 1—*Airbus Defence and Space with International Space University and the University of Strasbourg*

This investigation seeks to examine how methanogens—methane-producing bacteria that play critical roles in several microbiomes—adapt to microgravity and alter their metabolic activity and growth. Methanogens contribute to microbiome health in the human digestive system, and this experiment may add to researchers' fundamental knowledge of this important microbe.

CONTRACTILE PROPERTIES OF SMOOTH MUSCLE IN MICROGRAVITY—*Craft Academy (a dual-credit high school) with Morehead State University*

This experiment is a science, technology, engineering, and mathematics (STEM) education payload that aims to study the mechanism behind involuntary cell contractions of aortic smooth muscle cells, helping researchers better understand and treat atherosclerosis (hardening and narrowing of the arteries).

ISSET EDUCATIONAL ENDEAVOR NO. 1—*The International Space School Educational Trust and King's College of London*

This group of STEM education projects is designed for learners of all ages. There are several types of projects, each of which aims to build core competencies in students by empowering them to design, develop, test, engineer, and operate a payload in space.

MEDICINAL PLANTS IN MICROGRAVITY—*University of Kentucky*

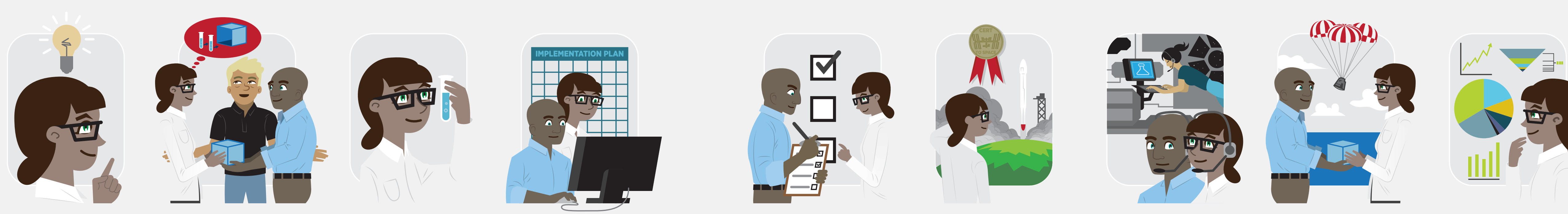
This investigation aims to establish a baseline genetic guideline for Valerian and Madagascar periwinkle plants, germinate the plants in microgravity, and grow multiple generations to determine if novel genes will be expressed. This study seeks to characterize compounds for use in chemotherapies, with the goal of reducing side effects.

LIFE CYCLE OF *ARABIDOPSIS THALIANA* IN MICROGRAVITY—*Magnitude.io*

*This STEM education experiment, designed for grades 6 to 8 and based on Next Generation Science Standards, seeks to demonstrate the life cycle of the model plant **Arabidopsis thaliana** in microgravity. While the plant grows on the ISS, classrooms on Earth will simultaneously grow their own plants for comparison.*

PHASE I: Preliminary experiment design
PHASE II: Preflight development
PHASE III: Execution

CASIS CONNECTS INVESTIGATORS WITH A SERVICE PROVIDER SUCH AS SPACE TANGO WHO HELPS TAKE THEM THROUGH THE PROCESS OF CONDUCTING RESEARCH ONBOARD THE ISS NATIONAL LAB.



1 Idea
2 Design requirements and objectives
3 Preliminary experiment design and preflight testing
4 Final design for spaceflight
5 Payload verification testing
6 Certification of flight readiness
7 Launch and in-orbit operations
8 Data return and payload recovery
9 Post-flight data analysis and application of results

Gentry Barnett, TangoLab program manager, preparing experiments to fly on the SpaceX CRS-10 mission

Space Tango

This concentration on biomedical research led to the development of the nonprofit think tank, the Exomedicine Institute. The purpose of the institute is to consider the “big questions” in biomedical research and how research in space can help tackle them, while leveraging resources from Kentucky Space and Space Tango. The microgravity environment of the ISS helps researchers better understand cell growth, gene expression, immunology, and other facets of biology in response to disease.

The Exomedicine Institute has already proposed several potential experiments, including culturing and sequencing human cancer cells and examining genetic variation in microbes such as yeast. Ultimately, the hope is to not only better understand the progression of disease but also develop new therapies and treatments for use on Earth, or perhaps one day even manufacture more effective therapeutic drugs in space.

NEXT STEPS: HELPING PEOPLE ON EARTH

A second TangoLab facility was launched to the ISS in August and has been installed, adding a few new capabilities and taking the number of experiments Space Tango can accommodate at a time from 21 to 42–dramatically expanding the number of customers that can conduct experiments on the ISS National Lab.

After their initial success, Space Tango intends to continue pushing the number and types of experiments conducted onboard the ISS. Diamond and his team are also working to support Space Tango in terms of marketing and communications, bringing more potential customers to Space Tango.

“We don’t even know what’s possible,” Diamond said. “We have our assumptions and our suppositions of what we feel would be the target customers for us. But, if we put it out there like a bat signal to the world, it’s going to be really exciting to see what comes back.”

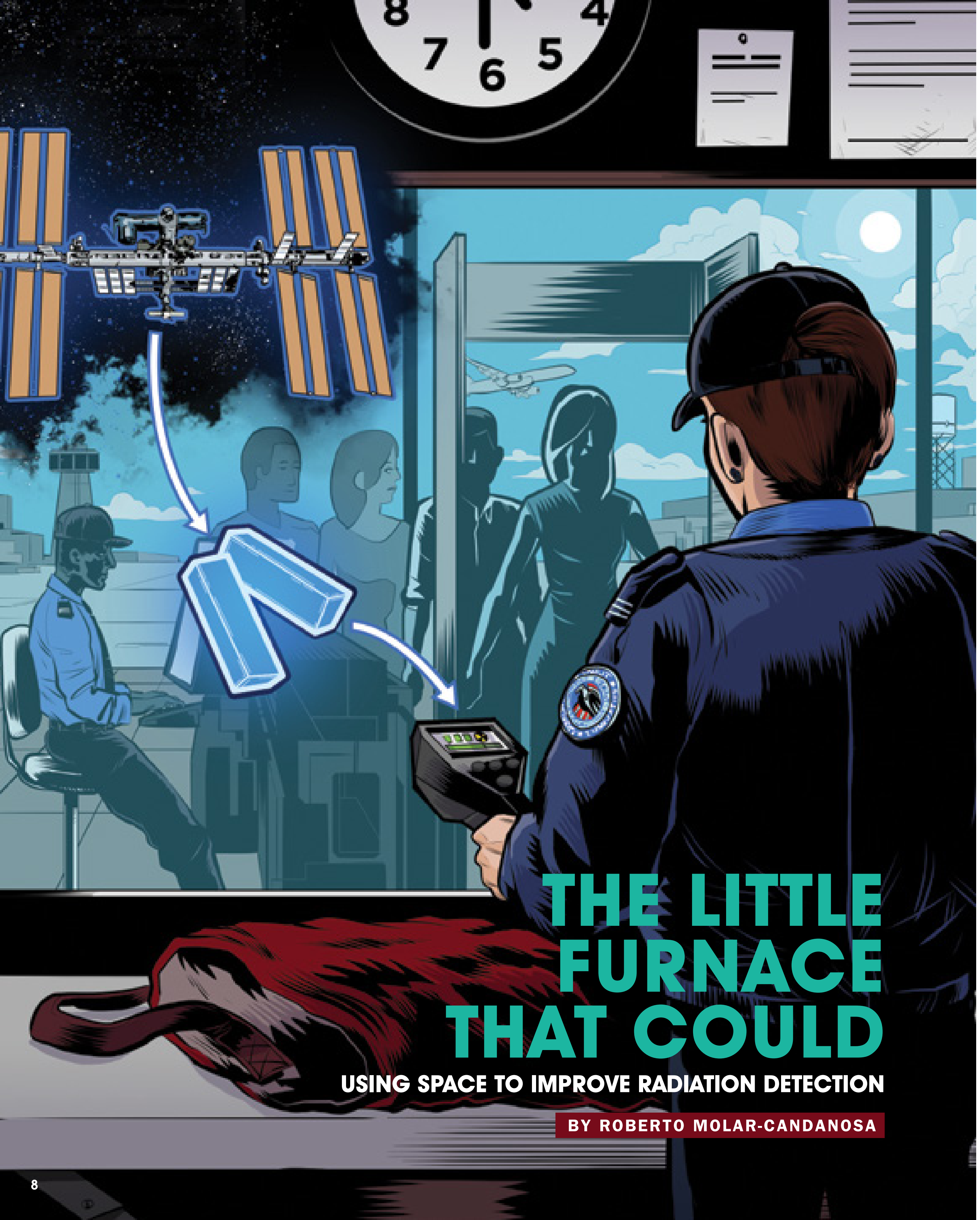
Many future projects are already in the works for Space Tango, focusing on pharmaceuticals, stem cells, analytical chemistry, and semiconductors, among other things. In addition to furthering research, particularly in biomedicine, Space Tango is also considering the potential of manufacturing in space and bringing finished products back to Earth.

Although Space Tango’s projects are highly diverse, there is one commonality among them: helping people on Earth.

> *“When people hear about using the space station, it’s all about going to Mars, which is certainly great, and I could talk about that forever, but our focus is using the ISS as a medium to create new products, better products—whether they be drugs or semiconductors or other materials,” Clements said. “This is not about us going to Mars; this is about us making life better on Earth.”* ■

The Space Tango and Craft Academy team at the SpaceX CRS-10 launch

Space Tango



THE LITTLE FURNACE THAT COULD

USING SPACE TO IMPROVE RADIATION DETECTION

BY ROBERTO MOLAR-CANDANOSA

Everything around you emits radiation—from the bananas in your kitchen, to cosmic rays from space, to the piece of paper (or screen) from which you are reading this sentence. Some of these types of radiation are so insignificant that they are harmless. But some can be dangerous. So, how can we better distinguish and detect different types of radiation?

One way is to improve the semiconductor and scintillator crystals used as radiation detectors. Two investigations that launched to the ISS National Lab in April are studying such crystals using the recently refurbished Solidification Using a Baffle in Sealed Ampoules (SUBSA) hardware. A high-temperature furnace roughly the size of a small microwave oven, SUBSA can be used to study how microgravity influences the synthesis of these crystals, which could ultimately enable improved functionality on Earth.

GROWING CRYSTALS ON EARTH

Electronic devices—including computers, medical imagers, and radiation detectors—function thanks to semiconductors: small and specially produced crystals used to conduct electrical signals. Smaller and more powerful semiconductors are the reason our pocket-sized cellphones are so smart these days.

Scintillator crystals used at the Jefferson National Accelerator Facility

Jefferson Lab

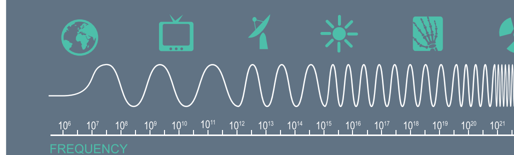
Conversely, scintillators are unique crystals that emit light when exposed to certain types of energy, much like glow-in-the-dark objects. They are mostly used in radiation detection devices for homeland security and defense applications, X-ray security cameras, and medical imaging devices.

To create both semiconductors and scintillators, scientists combine and melt various elements that crystalize after cooling down. The functionality of these crystals depends not only on their composition, but also on their purity and quality and the physical conditions they are exposed to during cooling.

Producing these high-quality crystals is not easy, and many difficulties in the production process can be blamed on gravity. Earth's gravity drives convection, the movement within and between fluids with different temperatures or densities, causing hot fluids to rise and cold or dense fluids to sink while transferring heat.

Aleksandar Ostrogorsky, Illinois Institute of Technology professor and principal investigator of one of the current SUBSA crystal growth projects, said that when crystals are grown on Earth using slow and precise solidification techniques, gravity-driven convection is a problem. It results in variable melt composition, which disrupts the radiation detection properties of the grown crystals.

> *"There's a continuing mixing in the melt when you grow crystals, as there is when you are boiling a pot of tea," Ostrogorsky said.*



RADIATION EVERYWHERE

Matter continuously emits electromagnetic radiation. Visible light and radio waves are examples of harmless radiation, whereas dangerous high-energy waves (such as X-rays and gamma rays) can come from certain gases, radioactive elements in nature, and even outer space. Moreover, in addition to electromagnetic radiation, hard-to-detect neutrons are emitted by uranium or plutonium, elements from which nuclear weapons are made.

These complex dynamics lead to crystals with problematic heterogeneous composition, cracks, bubbles, and other structural imperfections, which disrupt the performance of the crystal in downstream applications.

For example, to activate crystals with radiation detection capabilities, small quantities of a substance known as a dopant must be distributed uniformly throughout the crystal. On Earth, convection causes continuous and unpredictable movement as the melt crystallizes, disturbing dopant distribution.

For many years, scientists have thus aimed to achieve diffusion-controlled growth to grow crystals without the complexities caused by convection. That's where the SUBSA facility on the ISS National Lab could provide a competitive advantage. In space, buoyancy forces are virtually eliminated in the near-absence of gravity. This reduced motion allows for a more homogeneous distribution of dopants, fewer imperfections during crystallization, and ultimately, better crystals.

THE FIRST SUBSA EXPERIMENTS

In 2002, the SUBSA furnace was launched to space to study semiconductors made of indium antimonide. A specially designed transparent section of the SUBSA furnace allowed for observation and video-recording of the melting and crystallization processes onboard the ISS.

Tec-Masters, Inc./NASA

During Ostrogorsky's first SUBSA experiments in 2002, melting and directional solidification was observed for the first time under microgravity conditions. A data downlink from the video-enabled furnace on the ISS allowed Ostrogorsky to coordinate with NASA Astronaut Peggy Whitson to change temperatures, melt times, and other factors, observing how they affected crystallization. These experiments facilitated better understanding of the complex effects of convection in crystallization.

The 2002 successes laid the foundation for a new era of SUBSA utilization kicked off by Ostrogorsky and his former student, Alexei Churilov, who is now a senior scientist at Radiation Monitoring Devices, Inc. (RMD), in Watertown, Massachusetts (see *A New and Improved SUBSA Furnace*). In this round, Ostrogorsky is examining a different semiconductor material that is safe and affordable to produce, and Churilov is examining a scintillator crystal with the powerful ability to distinguish between various types of damaging radiation.

GROWING SEMICONDUCTOR CRYSTALS IN SPACE

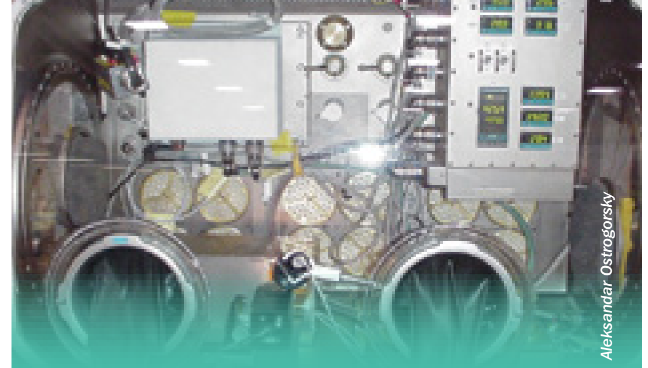
The new generation of SUBSA payloads seeks to meet growing technological demands of the U.S. Department of Homeland Security and the U.S. Department of Energy, both of which supported Ostrogorsky's research in the gap period between NASA-sponsored SUBSA experiments. Ostrogorsky's present SUBSA investigation on the ISS National Lab will test indium iodide, which is chemically similar to the indium antimonide samples he used in 2002.

> ***"Indium iodide is an overall promising detector for nuclear radiation," Ostrogorsky said, "and it is the only one I know that is completely benign, meaning it doesn't contain poisonous elements."***

Indium iodide can be prepared inexpensively and has a low melting point of 365°C. "That's a relatively easy job for the little SUBSA furnace," Ostrogorsky said. It is also simple to synthesize and reacts to gamma rays, making it suitable for radiation detection.

Ostrogorsky said that his current ISS National Lab experiment, launched on the Orbital ATK CRS-7 in April, will help determine the theoretical limit of the crystal's detection capabilities and other benchmark properties of semiconductors. The experiment is examining de-wetting, which prevents stress-induced imperfections, via separation of the melt from the crystal growth container—a process that has never been directly observed and that Ostrogorsky will watch thanks to the video-enabled SUBSA.

"If at the end this gives us a very good reference for high-quality materials, then we'll have a specific goal to continue this on Earth," Ostrogorsky said. "We could get a really good detector if we manage to control these properties."



Aleksandar Ostrogorsky

A NEW AND IMPROVED SUBSA FURNACE

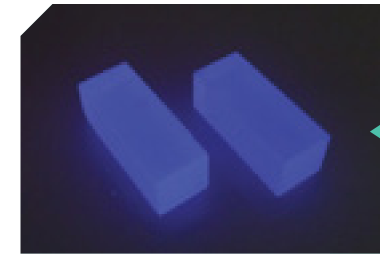
The SUBSA furnace launched in 2002 allowed scientists to heat samples to approximately 700°C and then precisely cool them down to allow for diffusion-controlled crystallization, all while streaming and recording video.

However, SUBSA's success in 2002 was not enough to overcome NASA funding limitations, and SUBSA was decommissioned shortly after the initial experiments. The hardware was flown back to Earth and sat in storage until 2015, when ISS National Lab customers demonstrated a growing demand for the capabilities of the SUBSA furnace. Through a mutually beneficial partnership, CASIS and NASA worked together to select a variety of payloads that would use the furnace, and NASA committed to refurbishing the hardware.

Upgrading the furnace took complex work to allow for a thermal containment system that could reach increased temperatures as high as 850°C. The upgrade also took care of "a little bit of wear and tear," said Scott Gilley, the SUBSA Payload Developer from Tec-Masters, Inc., who led the original hardware development in 2002 and the refurbishment in 2015.

SUBSA's software and thermal radiation shields were also updated, a larger range of container sizes can now be used, and a higher-definition camera was installed to observe and record the crystal growth process. Also, while SUBSA carries its legacy name, it no longer uses a baffle (a disc-shaped object that reduces fluid motion), because the 2002 experiments demonstrated that microgravity alone was capable of substantially reducing convection.

Hardware refurbishment is one way that NASA and CASIS are working together to maximize utilization of the ISS National Lab and leverage existing resources. Discussions regarding how best to leverage other hardware and facilities in the physical and life sciences are under way.



CLYC scintillator crystals under UV excitation

Radiation Monitoring Devices, Inc.

SYNTHESIZING SCINTILLATORS IN MICROGRAVITY

Although semiconductors are a powerful tool for identifying harmful gamma radiation, they cannot detect neutrons, an important type of radiation emitted from objects such as nuclear bombs. However, Cs_2LiYCl_6:Ce (also known as CLYC) scintillator crystals, another set of samples being tested inside the refurbished SUBSA furnace, are capable of detecting this critical signature of nuclear weapons.

Because neutrons do not normally interact with other materials, they are more difficult to detect. The ability to detect neutron radiation is the distinctive quality of CLYC scintillator crystals, said Churilov.

Developed by RMD with support from the U.S. Defense Threat Reduction Agency and Domestic Nuclear Detection Office, CLYC scintillator crystals can detect both gamma rays and neutrons. Furthermore, CLYC scintillators can differentiate between types of radiation. Such dual detection is useful for many applications. For example, CLYC scintillators could help minimize the number and types of detection devices needed for airport security personnel.

"Using one instrument with CLYC scintillators, you could distinguish between harmless sources of radiation versus something like cesium-137 for a dirty bomb," Churilov said. Current technology to detect neutrons is limited, so CLYC scintillator crystals could be game-changers in the field of radiation detection.

To move toward more widespread use of CLYC scintillator crystals for radiation detection devices, RMD is now focusing on scaling up production to grow crystals with larger diameters and fewer physical defects. "But when you scale up the size during crystal growth, defects are much more important," Churilov said. "Crystals crack more easily, they can grow bubbles in them, and so it's much more difficult."

Knowing how the CLYC scintillator mixture behaves and solidifies in microgravity will help Churilov and RMD determine the importance of certain aspects of their production process on Earth. The SUBSA experiments will enable RMD to observe whether convection limits the size and physical quality of CLYC scintillator crystals for improved radiation detection.

CLYC scintillator crystals

Radiation Monitoring Devices, Inc.

"When you eliminate convection, other subtle processes can be directly observed," Churilov said. "This will give us immediate guidance of how significant reducing convection in the melt is for our crystal growth."

LITTLE FURNACE, BIG BENEFITS

The SUBSA furnace is a relatively small facility, but the advancement in fundamental knowledge about the formation and purity of semiconductor and scintillator crystals may have dramatic impacts in the development of next-generation radiation detectors. Although manufacturing these materials in space may not yet be economically feasible, the knowledge gained by the SUBSA studies will accelerate progress in ground-based production.

> ***"The purpose of our microgravity experiment is not necessarily to grow better crystals in space," Churilov said. "Our ultimate goal is really to understand the formation of defects in these crystals and apply that to our production process back on Earth."***

However, in-orbit manufacturing of materials may not be as far off as one might think. Various companies are currently exploring the possibility of space-based platforms for producing consumer products or commercially important materials. The commercialization of low Earth orbit may include steps toward such next-generation space stations, and current payloads on the ISS National Lab include proof-of-concept initiatives in this realm. But for Ostrogorsky and Churilov, the advancement of knowledge is enough for now.

"Trying to think that someday we are going to have crystal production in space is too ambitious, too far away," Ostrogorsky said. "The idea is to do the experiments and get new knowledge so we can do some work on Earth." ■

PURE OF HEART:

How Microgravity is Improving Cardiac Cell Quality

BY EMILY TOMLIN

It is old wisdom that life is a journey and not a destination. But when your destination is space, it might seem difficult to find excitement in the mere act of preparing for flight. Surprisingly, however, many researchers make exciting and novel discoveries during their preflight experiments—and these findings not only pave the way for greater success in flight but also immediately contribute to scientific knowledge on Earth.

A recent illustration of preflight science discovery can be seen in the work of Chunhui Xu, associate professor in the Emory University Department of Pediatrics. While preparing for a future flight experiment, Xu generated results in the fields of translational biology and regenerative medicine that could advance our ability to model heart defects, improve precision medicine, and even cure diseases.

Xu's journey toward flight began in late 2013 when she was awarded a grant for a ground validation study in response to a CASIS Request For Proposals titled "The Impact of Microgravity on Fundamental Stem Cell Properties." Four years later, Xu has authored six publications detailing results related to her simulated microgravity and stem cell research, and her team is now preparing for a follow-on flight project to take their research to the next, and much higher-altitude, level of discovery.

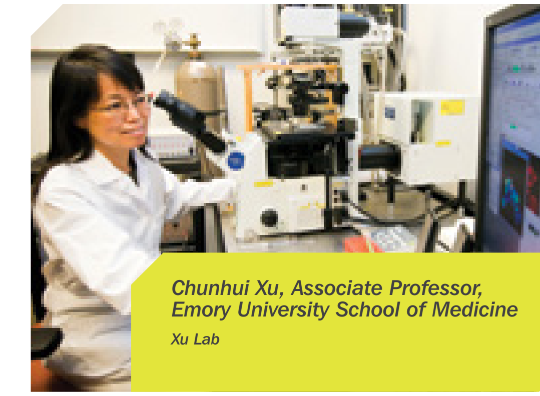
THE COMPLEXITY OF STEM CELLS IN MICROGRAVITY

Biological experiments have been conducted in space for more than 50 years—beginning with model organisms, expanding to include humans, and now encompassing all manner of cells and creatures, great and small. However, most of what is known about stem cell biology in microgravity is from ground analogs operated on Earth that simulate some aspects of a free-fall environment.

Moreover, results have been mixed. Although microgravity clearly alters gene expression of cells in culture and induces the aggregation of cells into tissue-like structures, stem cells appear to have cell-type-specific responses to microgravity. For example, some embryonic stem cells have shown increased growth and proliferation (associated with maintenance of their undifferentiated states), but precursors to liver and fat cells have shown increased rates of differentiation.

From a scientific perspective, both responses are interesting because they may reveal critical information about underlying molecular mechanisms of stem cell function. But it does leave some questions regarding what to expect from a stem cell experiment sent to space—hence the rationale for performing additional ground simulations.

"Ground-based research prior to flight is critical for every project," said Michael Roberts, deputy chief scientist for CASIS, "but some experiments are more critical than others. Analog validation helps us understand expected outcomes before moving to flight, improving the likelihood of scientific success and the likelihood of identifying and measuring the root cause." It is an added benefit, he noted, that many projects can inform and advance their field of research from these experiments alone.



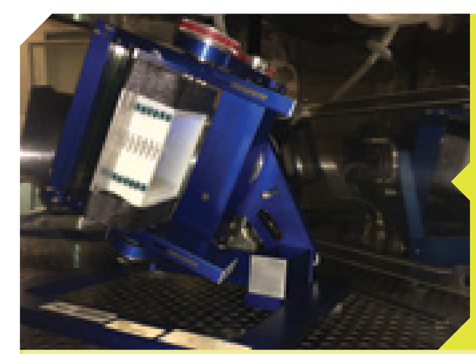
Chunhui Xu, Associate Professor, Emory University School of Medicine
Xu Lab

THE PROBLEM WITH HEART CELLS

Research in the Xu lab focuses on progenitor cells—cells that are partially differentiated (i.e., more specialized than a stem cell) but can still differentiate into multiple cell types. Specifically, the team is studying cardiac progenitors and their differentiation into cardiomyocytes, cells of the specialized muscle tissue of the heart.

"The problem in the field of cardiac medicine is that the heart has billions of cells, and any injury or defect can lead to serious illness," said Rajneesh Jha, a research associate at Emory University who worked on the Xu project as a postdoctoral fellow. "The bad cells need to be replaced, but cardiac cells have limited proliferative capacity."

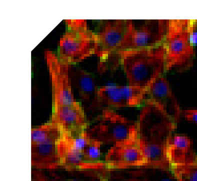
In other words, cardiac cells can only regenerate, or reproduce, a certain amount. Moreover, although cardiomyocytes are a promising cell source for regenerative medicine, disease modeling, and drug discovery, practical use requires that the cells be enriched (isolated as a pure population) and mature (fully developed). Current methods for producing cells of such quality fall short, typically growing and differentiating cells in 2D environments that generate immature cardiomyocytes within mixed populations.



Random positioning machine used to culture cells under simulated microgravity
Xu Lab

TAKING A LOAD OFF

There are several methods that can be used to simulate microgravity and test for 3D cultures. Two well-established methods involve use of a random positioning machine or a rotating wall vessel (developed by NASA). Such devices mimic true microgravity by providing a lack of sedimentation and improved 3D aggregation. Xu's experiments primarily used the random positioning machine, which rotates on multiple axes at varied speeds and angles, functionally removing the gravity vector by continuously shifting the orientation of cells. However, true removal of gravity is not achieved, and the effects of fluid movement on cells in spaceflight experiments are dramatically reduced compared with only modest reductions in simulators.



Microscopic image of cardiomyocytes derived from human induced pluripotent stem cells
Xu Lab

SUCCESS IN SIMULATION

Previous studies have established that producing cardiac cells in 3D liquid-batch cultures (such as a rotating or reciprocal motion shake flask) has an improved yield over 2D cultures (such as a petri dish) in their production of cardiomyocytes. Building on this logic, the Xu lab set out to examine whether their cells might have an even more robust yield if they combined a 3D culture with simulated microgravity.

Interestingly, they found that short exposure to simulated microgravity increased both survival and yield of the cardiomyocytes; specifically, three days of exposure was sufficient for maximum yield. Xu's team published their findings from this experiment, describing their success in producing highly enriched cardiomyocytes (99% purity) with expected functional properties—in other words, the cells appeared mature. Moreover, the cardiomyocytes were produced at up to a four-fold higher yield than in standard 3D cultures (and at an eight-fold higher yield than in 2D cultures).

Rajneesh Jha, Research Associate, Emory University School of Medicine
Xu Lab

> ***"We need mature cells for clinical applications and testing," said Jha, "and microgravity yields these mature cells more effectively than standard cell cultures."***

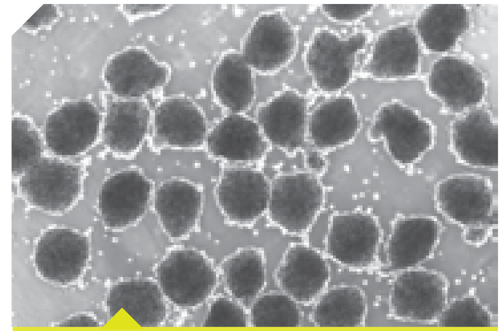
ECONOMIC AND COMMERCIAL APPLICATIONS

Beyond the obvious humanitarian benefit of improving cell characteristics for use in cardiac medicine, there is a commercial incentive to the success of Xu's research: Cardiomyocytes generated in the lab are for sale, and mature cells are in high demand for non-clinical use.

For example, mature cells can be used to develop organoids (micro-scale aggregates of cells that mimic the function of tissues or even whole organs). Organoid development is a blossoming industry in the realm of translational medicine because it offers an alternative to animal testing—they can be used to (1) study organ function and cell behavior in ways not before possible in standard cell cultures and (2) test the effectiveness and toxicity of potential therapeutics in ways more relevant to human biology because they are composed of human cells rather than those of non-human, model organisms. The Xu lab is experienced in such testing using early-stage "lab-on-a chip" technology (e.g., a microelectrode array chamber filled with organoids), on which high-throughput analyses can be performed.

"So many drugs pass safety testing in animals, but when they get to the clinic, they cause issues in humans," said Xu. "This could be, in part, because of electrophysiology specific to human cells." Thus, a pre-test in organoids could have both humanitarian and economic value by minimizing negative effects on patients in clinical trials and saving associated costs (each phase of a clinical trial typically costs millions of dollars). However, yield is again crucial to making this sort of test a reality.

> ***"Large numbers of cardiomyocytes need to be generated in a more efficient way than currently possible," said Xu. "When we combined simulated microgravity with 3D culturing techniques, we saw promising steps toward reaching that goal."***



Microscopic image of cardiac progenitor spheres generated by tissue engineering
Xu Lab

MAKING PERSONALIZED MEDICINE A REALITY

In addition to developing and testing treatments for damaged heart tissue, the Xu lab also uses cardiomyocytes to model the effects of congenital (present from birth) heart defects. To do this, the researchers collect skin cells from patients, manipulate those cells to acquire certain stem-cell-like features, and then re-differentiate them into cardiomyocytes for lab-on-a-chip studies. This allows the researchers to be certain that the genetic background of the test samples is identical to the patient.

The team uses the patient-specific chip to study disease characteristics and drug responses. The goal of such work is a future paradigm in which doctors could prescribe certain drugs that the chip shows will be most effective (and least toxic) to an individual, based on their unique genetic background. These studies are at the heart of personalized medicine, and the concept of treating heart defects or damage using such an approach is not as far removed from clinical reality as one might think.

THE BIGGER PICTURE

Heart disease is the leading cause of death in the U.S. and costs an estimated **$207 billion** each year in healthcare services, medications, and missed work. Accelerated drug testing, personalized medicine, stem cell therapies, and discovery science to open new solution pathways all hold promise to lessen the devastating effects of this common condition.

In fact, the Xu team recently worked with Peter Fischbach at Children's Healthcare of Atlanta to study patients with a genetic disorder that causes stress-induced arrhythmias (irregular heartbeat patterns). Arrhythmias caused by this genetic disorder are called catecholaminergic polymorphic ventricular tachycardia (CPVT). As described earlier, Xu's team collected patient cells, induced re-differentiation into cardiomyocytes, and analyzed the drug responses of the personalized organoids.

"In the clinical setting, we saw some children that did not respond to the commonly used beta-blockers, but they did respond to other specific drugs," said Xu. "We saw the same phenomena in a dish. Our results mirrored the clinical data." Beta-blockers are the first-line therapy to prevent arrhythmias in patients with CPVT; however, for unknown reasons, such therapy is unsuccessful in about 25% of patients. Xu's results, published in 2016, show proof of principle that their team's approach to personalized testing could potentially be used in these populations.

TAKING THE NEXT STEP

"The innovations in the Xu lab hold great promise for delivering more effective therapeutics in the future," said Roberts, "and microgravity is having a profound effect on their research."

The Xu team is excitedly preparing for their flight project, which will send cardiac progenitors derived from human skin cells into space and evaluate how microgravity affects their proliferative capacity. Simulated microgravity has allowed the team to make great strides in this area, according to Xu, and she hopes to uncover additional information by sending the cells to space.

Stem cells hold enormous potential for both curing disease (through replacement of damaged tissues) and advancing translational biology (through the growth of organs and tissues as disease analogs). "Dr. Xu's project has the potential to fill both applications," said Roberts. "A lot has been learned about her system from devices that simulate some aspects of microgravity, but true microgravity onboard the ISS National Lab may have advantages above and beyond these ground-based successes." ■

ADDITIONAL RESULTS

According to Xu, an additional exciting outcome of her simulated microgravity studies involved the upregulation of heat shock proteins in their samples. Heat shock proteins are a type of protein involved in stress response, and they are present in all living things. Though their name implies activation by heat stress, heat shock proteins actually respond to high or low temperatures as well as to a drop in vital nutrients such as oxygen and sugar. Although heat shock proteins have been implicated as having a role in cancer and other diseases, their activation in this case may actually be of benefit.

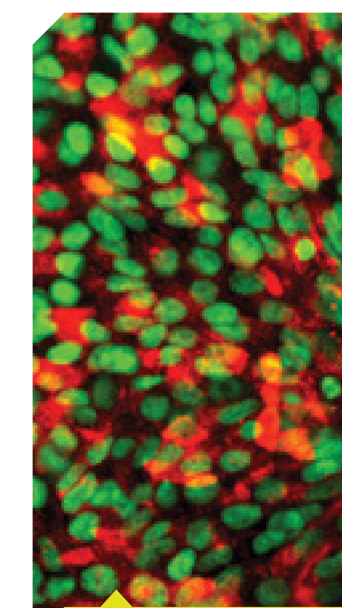
"We already know heat shock can improve survival, which may be part of why microgravity leads to increased viability," said Xu. "But heat shock cells are also more resistant to cell death, and they survive better when transplanted into animal models, so the microgravity upregulation of these proteins is very exciting."

The team is currently working on generating strategies to recapitulate this effect without microgravity.

OPPORTUNITIES FOR REGENERATIVE MEDICINE IN SPACE

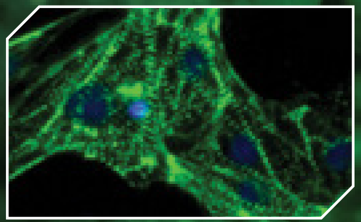
Xu's project is one of several cardiac stem cell projects in the ISS National Lab portfolio, and it complements a growing suite of bioscience projects geared toward tissue engineering, lab-on-a-chip technologies, and regenerative medicine in general. Many of these projects are powered through innovative public-private partnerships, including CASIS collaborations with government funding agencies. For example, in 2017, CASIS awarded five new projects in response to a research solicitation funded by the National Center for Advancing Translational Sciences (NCATS), part of the National Institutes of Health (NIH).

Another collaborative opportunity, this time in partnership with the National Science Foundation, is currently open and seeking proposals in transformative tissue engineering. This includes cellular engineering, tissue engineering, and modeling of physiological or pathophysiological systems in topic areas that include, but are not limited to: scaffolds and matrices, cell-cell and cell-matrix interactions, stem cell engineering and reprogramming, cellular immunotherapies, cellular biomanufacturing, system integration between biological components, and electromechanical assemblies. For more information on this opportunity, see the ad on pg. 16.



Microscopic image of human induced pluripotent stem cells
Xu Lab

CURRENT FUNDING OPPORTUNITY:



Tissue Engineering Research Onboard the International Space Station

Sponsored by the National Science Foundation

CASIS and the National Science Foundation are sponsoring a funding opportunity to support enhancements in the fields of transformative tissue engineering via space-based R&D. This is the third in a series of collaborations with the National Science Foundation to explore research concepts on the ISS National Lab.

UP TO $1.8M WILL BE AWARDED FOR MULTIPLE FLIGHT PROJECTS!

Prior to submitting a full proposal to NSF, all interested parties must submit a Preliminary Feasibility Review form to CASIS. CASIS strongly encourages interested parties to submit the review form no later than January 5, 2018.

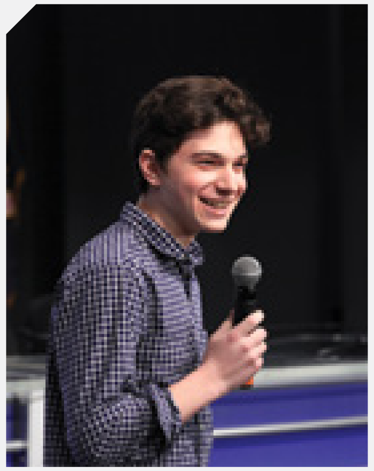
Proposal Submission Window: Jan 30, 2018 - Feb 12, 2018

Please see NSF 18-514 for full solicitation details.

A High Schooler's Guide to Space Science

BY AUSTIN JORDAN

Studying the effects of spaceflight on astronaut health is an enormous challenge for even the most eminent scientists at NASA. This research not only is critical to extending human presence beyond low Earth orbit but also has many practical health applications on Earth. To address questions related to human health in space and on Earth, NASA is collaborating with researchers across the country—including 16-year-old high school student Julian Rubinfien.



Julian Rubinfien, 2016 winner of the Genes in Space competition
NASA

Rubinfien, a bright high-schooler from New York with a penchant for microbiology, never imagined that he would be working with NASA scientists, meeting astronauts, and launching his experiment to space. However, through the Genes in Space student research competition, founded by Boeing and miniPCR and supported by CASIS, Rubinfien found himself in the lab with veteran researchers analyzing telomeres, the protective caps found on the tips of chromosomes.

Spaceflight induces many changes within the human body, including structural changes to the DNA inside our cells. Although it is natural for telomeres to shorten over time as a person ages, stresses such as those experienced during prolonged spaceflight can lead to abnormal regulation of telomere length. This abnormal regulation has been implicated in a variety of diseases including cardiovascular disease and some cancers.

A miniPCR™ machine, which is used to amplify DNA onboard the ISS
miniPCR

Understanding how spaceflight affects telomere length helps scientists elucidate causes of disease on Earth, but it is also important for the safety of astronauts on long-duration spaceflight missions to the Moon, Mars, and beyond. Rubinfien's experiment aims to successfully amplify telomeric DNA in space, a necessary step in creating an assay capable of measuring changes in telomere length during spaceflight.

"Unlike previous assays, this one should be capable of assessing changes in telomere length completely in orbit, without having to send materials back and forth from Earth," Rubinfien said. "Telomeres are of interest to NASA for their connections to cellular aging and senescence-related diseases that astronauts may develop during spaceflight."

Rubinfien was the 2016 winner of the Genes in Space competition, and his experiment launched to the ISS on Orbital ATK CRS-7 in April. Astronaut Jack Fisher, who carried out Rubinfien's experiment onboard the ISS, congratulated Rubinfien from orbit and thanked him for contributing to the incredible science being done on the space station to benefit humanity.

The opportunity to conduct research in space has significantly affected Rubinfien's career aspirations. He dreams of flying in space and eventually setting foot on Mars. Although no matter which career path he takes, Rubinfien pledges to continue to contribute to American space exploration in meaningful ways.

SPOT LIGHT

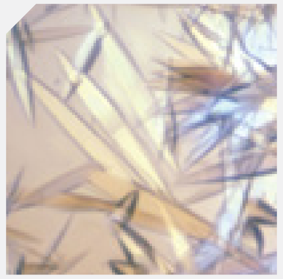
Microgravity Molecular Crystal Growth

BY AMELIA WILLIAMSON SMITH

For more than 30 years, scientists have used microgravity—onboard the Russian Space Station Mir, the Space Shuttle, and the ISS—to improve molecular crystal growth research. To scientists, crystals are solid materials with atoms arranged in a rigid geometrical structure. Crystals grown in microgravity are often larger and have a more rigid or ordered structure than those grown on Earth. The enhanced quality of microgravity-grown crystals from space leads to better images of the structures back on Earth. Scientists hypothesize that these observed benefits are the result of a slower, more uniform movement of molecules into a crystalline lattice in microgravity.

Crystal growth research in space has the potential to vastly improve life on Earth through numerous applications. Crystallization of organic molecules can lead to improvements in drug development, formulation, manufacturing, and storage. It can also help improve agriculture through better design of solutions that protect crops and enhance growth. Inorganic molecular crystallization can lead to advances in metal manufacturing and in electronics such as computers and smart phones. It can also help improve radiation detection capabilities for medical imaging and security devices.

The space station provides a valuable platform for molecular crystal growth, and several companies are already taking advantage of the microgravity environment onboard the ISS National Lab to advance their research and development (R&D). To enhance the commercialization potential of a platform in low Earth orbit for crystallization research, CASIS is committed to establishing an ISS National Lab Microgravity Molecular Crystal Growth (MMCG) Program.



Protein crystals grown in microgravity
Merck

The MMCG Program aims to make it easier and more economical to utilize the ISS National Lab for crystallization research and is specifically designed to meet the needs of commercial upstream R&D. The program provides streamlined access to the ISS National Lab through dedicated launches, repeat flight opportunities, and cost-effective set pricing.

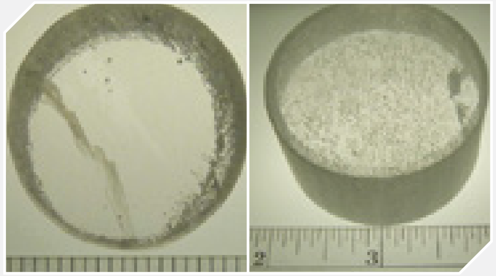
Through expanded use and validation of commercial-off-the-shelf hardware and access to vetted service providers with expertise in microgravity investigation design, the program aims to ease the transition from ground-based crystallography to spaceflight and minimize risk while increasing the probability of success. The goal is to provide a rapid return of samples to the research pathway by flying and returning samples within three months from the time of molecule selection.

To help investigators identify optimal molecules that could benefit from growth in microgravity, CASIS has developed criteria for informed molecule selection. These criteria are based on past spaceflight R&D experience and in-depth feedback gained from a CASIS technical interface meeting of protein crystallography experts and experienced hardware developers.

As part of the MMCG Program, CASIS is working toward establishing multi-year, multi-flight collaborations with commercial entities, other government agencies, and research foundations, and has already begun negotiating several such collaborations.

"Scientists have historically used microgravity to improve crystallization techniques toward advances in drug development and manufacturing," said Marc Giulianotti, CASIS senior associate program scientist. "We are excited to continue to advance the understanding of these improvements and facilitate increased access to the ISS National Lab through our MMCG Program."

For more information on the MMCG Program, go to www.spacestationresearch.com/research-library/reports/mmcg.



Defects in CLYC scintillator crystals synthesized on the ground
Radiation Monitoring Devices, Inc.

SPOT LIGHT

MUSES Gives Users a Unique View of Earth

BY ANNE WAINSCOTT-SARGENT

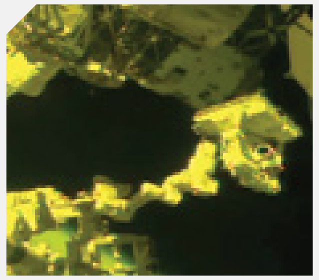
Soon it will be possible to zoom in on Earth from the ISS to determine the best sites to grow food crops or to quickly find areas hardest hit by natural disasters, as the first commercially operated Earth-sensing platform on the ISS is now fully operational. The Multiple User System for Earth Sensing (MUSES) platform, which launched to the ISS in June, enables a host of Earth-observation applications, including disaster response, maritime domain awareness, food security and agricultural production monitoring, and atmospheric investigations.

MUSES in the SpaceX Dragon trunk, awaiting removal
Teledyne Brown Engineering

Built and operated by Teledyne Brown Engineering through a cooperative agreement with NASA, the MUSES platform features four payload slots with a 50-degree range of motion that can dynamically point to any area on Earth. This pointing capability means users do not have to wait for the ISS to fly over a specific location, which significantly improves revisit times. MUSES accommodates up to four instruments simultaneously, and each instrument can be installed and removed by ISS robotic arm operators on the ground.

MUSES will offer companies a commercial platform for Earth observation and an engineering testbed for experiments and technology demonstrations, lowering the risk traditionally associated with sending new sensors or payloads into space via satellite launch. For low Earth orbit missions, MUSES is also a cost-effective alternative to small satellites, said Jack Ickes, vice president of Geospatial Solutions at Teledyne Brown Engineering.

"Being able to return your payload to either analyze what went wrong or to upgrade and improve capabilities over time preserves your investment," Ickes said. "We're also working with NASA to streamline the required payload verification process, with the goal to get from contract to orbit in less than nine months."



MUSES being installed on external logistics carrier (ELC4) by robotic arm
Teledyne Brown Engineering

MUSES is ideal for a multitude of Earth observation applications, from assessing weather patterns and climate change to driving better decision-making for companies and governments. For example, shipping companies could collect real-time data to predict when to send their fleets out to sea during a hurricane to minimize risk to crews and vessels. City planners could integrate geospatial information with weather patterns to predict where tornadoes may increase in frequency or strength to inform building construction codes to maximize safety. Platform instruments could detect and monitor flooding and coastal erosion, water pollution, red tides, and landslides. MUSES also will be a critical tool in disaster response.

MUSES reached full operating capacity in September, and its first instrument will be deployed during the first quarter of 2018, with additional payloads to follow. MUSES' first instrument, the DESIS-30 hyperspectral imager from the German Aerospace Center (DLR) will monitor water quality and ecosystems in coastal zones and oceans.

Hyperspectral images enabled through MUSES will allow DLR to gather vegetation and water classification data from nearly the whole planet, instead of relying on ground-based studies that can only monitor small areas. Such analyses provide a wealth of actionable information, for example, allowing farmers to determine whether crops are ready for harvest or whether they are in decline. Hyperspectral data from the DESIS-30 instrument will be sold commercially through Teledyne's Amazon cloud-based data catalog.

Teledyne sees MUSES as an innovative platform that opens a new portal for digital imaging solutions. The ability of MUSES to collect and integrate Earth observation data from multiple sources enables better intelligence from space and more informed decision-making on Earth.

SPOT LIGHT

Innovation Beyond Boundaries

BY AMY ELKAVICH

The 2017 ISS Research and Development Conference brought together a record-breaking number of scientists, engineers, entrepreneurs, commercial developers, and investors—many of them new to space—who are interested in using the ISS and its unique research capabilities.

Kate Rubins

Several featured attendees spoke to the more than 1,000 conference participants about cutting-edge science and space exploration. Elon Musk, known for his companies SpaceX, Tesla, and the Boring Company, outlined his plans to increase the number of reusable rocket components, his hopes for interesting new destinations for the first SpaceX manned craft, and his thoughts on artificial intelligence. Kate Rubins, NASA astronaut and molecular biologist, talked about the extraordinary science conducted during her first spaceflight (completed in 2016 on Expedition 48/49) and discussed ISS opportunities available to current and future users. Robert Bigelow of Bigelow Aerospace, used the ISSR&D conference platform to talk about his vision for the future, the construction of a commercial stand-alone space station (the B330), and the importance of lunar exploration.

Additionally, technical paper sessions provided researchers with opportunities to share their latest findings with their peers. Session discussions covered biomedical research, ISS technology and facilities, new education platforms and initiatives, commercial opportunities on the ISS, and other diverse topics.

The ISS National Lab also announced several new collaborations with widely recognized companies and foundations: Target Corporation and the Michael J. Fox Foundation are embracing space as an arena for solving big challenges (cotton sustainability and Parkinson's disease treatment, respectively). In another nontraditional collaboration, ISS National Lab service provider, Techshot, Inc., announced an initiative with Tupperware Brands Corp. to improve the design of containers used to grow plants on the ISS.

Robert Bigelow

Elon Musk and Kirk Shireman, ISS Program Manager at NASA

This year's conference confirms that low Earth orbit is a destination within reach for research and innovation that can accelerate exploration in space and discovery on Earth, and next year's conference will continue to offer unique opportunities for collaboration on space-based R&D to users across the commercial, government, academia, and private research communities.

SAVE THE DATE FOR ISSR&D 2018:

July 23–26, 2018, in San Francisco, California.

SPOT LIGHT

ISS U.S. NATIONAL LABORATORY

News & Notes FROM THE ISS NATIONAL LAB

A composite image of seven frames showing the ISS as it transited the Sun during the partial solar eclipse in August. NASA

SOLAR ECLIPSE ENGAGEMENT

For the solar eclipse in August, CASIS traveled to Idaho Falls, Idaho—a point in the path of totality—to promote the ISS National Lab and science, technology, engineering, and math education. NASA Astronaut Alvin Drew and Story Time from Space author Jeffrey Bennet (who wrote “Max Goes to the Space Station”) spoke at the education events, and the CASIS Space Station Explorers team engaged with students, educators, and the public as they distributed eclipse glasses. CASIS and the NASA ISS Program Science Office also held a Destination Station event at the South Carolina Research Authority in Charleston—another point in the path of totality. The ISS team spoke at multiple public engagements about the science behind the eclipse and met with local researchers and companies to discuss the unique research capabilities of the ISS National Lab.

Star Wars™ Mission Patch

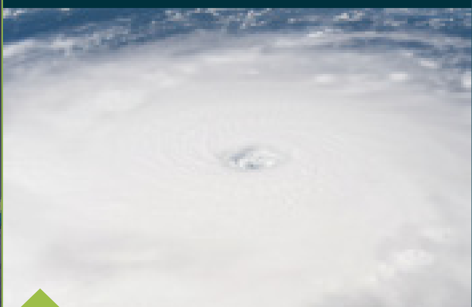
STAR WARS™ MISSION PATCH

In September, CASIS unveiled its latest mission patch representing all ISS National Lab payloads in 2017. The new mission patch was designed by Lucasfilm and features characters from the *Star Wars*™ franchise. Lucasfilm also recently announced a 10-episode “Science and Star Wars” web series designed in collaboration with IBM. An episode on spaceships released earlier this month prominently featured the ISS and two former crew members, highlighting facilities and research on station.

Hurricane Harvey NASA

NEW SCIENCE LAUNCHED

The SpaceX CRS-12 mission, which launched to the ISS in August, delivered more than 20 ISS National Lab payloads. Key payloads include research on novel antibacterial compounds, new approaches to treating high blood pressure, and stem cells to treat disease. Also included was a payload from the Michael J. Fox Foundation investigating a key protein that may serve as a new target for the treatment of Parkinson’s disease. Orbital ATK CRS-8 launched earlier this month carrying a dozen ISS National Lab payloads. Key payloads include bacteria and plant investigations, remote sensing research, student experiments, and payloads aimed at demonstrating new technologies. Thus far in 2017, the ISS National Lab has sponsored more than 100 separate experiments on station. The upcoming SpaceX CRS-13 mission, slated to launch no earlier than December, will bring additional payloads to the ISS from a wide variety of scientific disciplines.



Hurricane Irma NASA

HURRICANES FROM SPACE

ISS crew members captured unbelievable images of Hurricanes Harvey and Irma from space and were able to track the massive storms as they made landfall. The images from low Earth orbit were breathtaking, but frightening for all the damage sustained by those below. Our thoughts are with hurricane victims as they continue to recover from the impact of this year’s devastating storms.

> *Staff at both the Houston and Florida CASIS offices were affected by the hurricanes, which impacted the* ***Upward*** *production schedule, requiring a late publication of this issue. This will be the final issue of Volume 2, with the first issue of Volume 3 planned for after the New Year.*