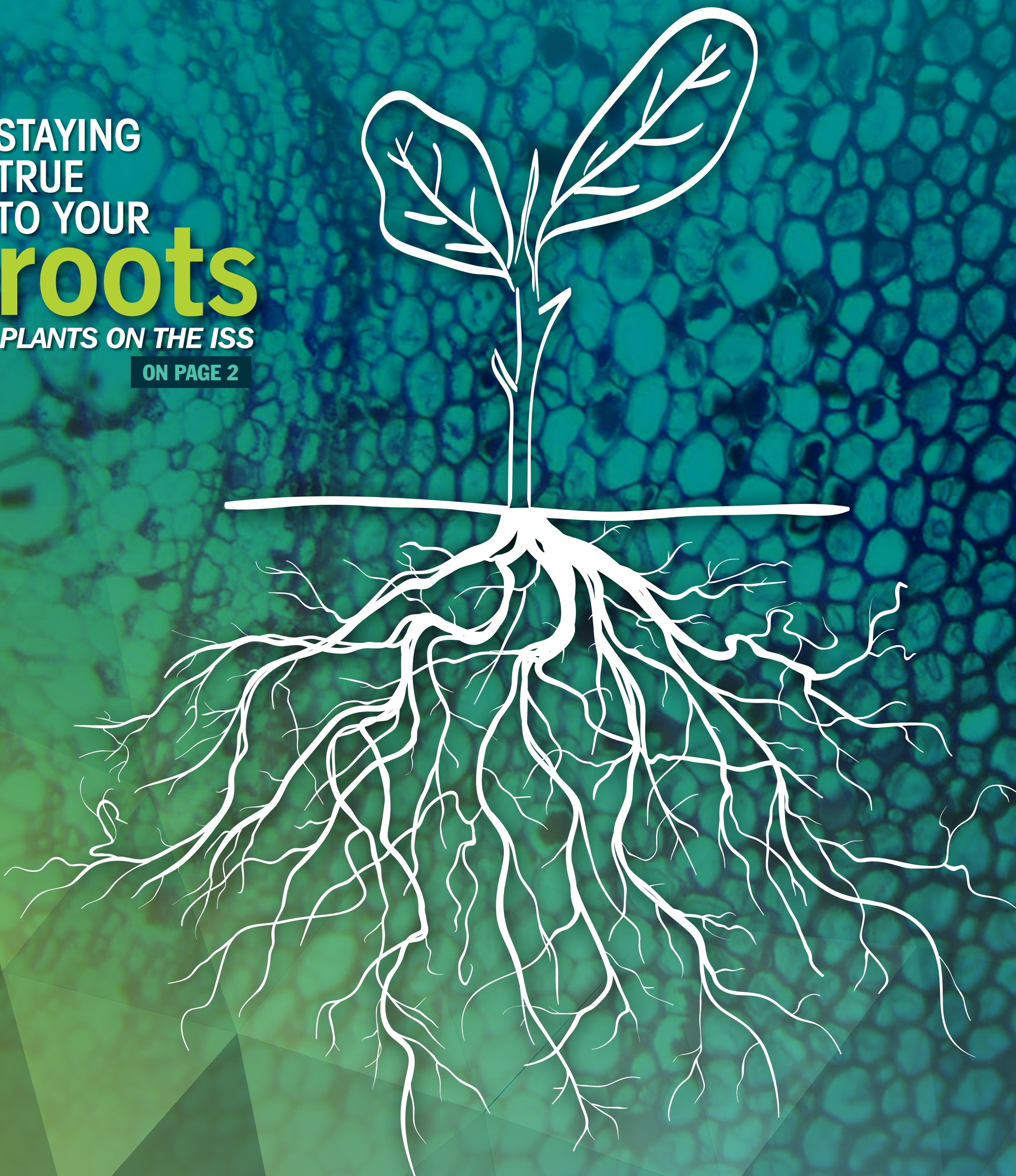
UPWARD

MAGAZINE OF THE ISS NATIONAL LAB • FEBRUARY 2016

STAYING TRUE TO YOUR roots

PLANTS ON THE ISS

ON PAGE 2



VOLUME 1 ISSUE 1

RODENT ROCKET RESEARCH

THE CONUNDRUM OF BIG DATA PROCESSING

THE FLIGHT OF THE TIN WHISKERS

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TABLE OF CONTENTS

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THE VIEW FROM THE CUPOLA

BY MICHAEL ROBERTS, CASIS DEPUTY CHIEF SCIENTIST

Michael Roberts is Deputy Chief Scientist of CASIS, where he works to solicit, select, and enable flight projects for the ISS National Lab. Prior to joining CASIS, he was a flight investigator on various NASA experiments and worked as a microbial ecologist, molecular biologist, and group lead in the NASA Advanced Life Support program at the Kennedy Space Center.

Welcome to the inaugural issue of *Upward*, the quarterly magazine of the International Space Station (ISS) U.S. National Laboratory. *Upward* is published by the Center for the Advancement of Science in Space (CASIS) as part of our mission to manage and enable access to the ISS National Lab. This is our communal forum to highlight research and education for the national lab on the station. Although managing a national laboratory in low Earth orbit is not an easy task, it is inspiring to be even a small part of the enterprise to bring tomorrow home to Earth by promoting research and technology development in space. Therefore, for us, "upward" is not merely a direction pointing to a new destination over the next horizon but rather a sense of perspective and purpose to reach beyond our grasp for better things yet to come.

Like all national labs, the ISS National Lab is a research facility that offers professional researchers, student investigators, innovators, and entrepreneurs unique and unparalleled opportunity for discovery using rare and precious tools to foster scientific return. Unlike any other national lab, however, the ISS National Lab is a mobile laboratory operating in an environment off of Earth for the benefit of life on Earth. The space station provides a microgravity environment and space exposure facility for researchers to conduct experiments in biotechnology/technology, health and medicine, Earth and space science, life sciences, physical sciences, remote sensing, and a myriad of other fundamental and translational fields. It is a platform for near-boundless exploration in an environment where gravity does not hold sway and the future of living and operating in space is an everyday reality. The ISS is your gateway to space and beyond the boundaries of imagination.

In this issue, you will learn about a few of the research activities on the ISS National Lab and events supported by CASIS back on Earth to engage and grow the community of space explorers and innovators who will build near-Earth space into a new marketplace of ideas, enterprise, and commerce. In an article by Amelia Smith, you will read how plants in space negotiate the absence of gravity to give direction to roots and shoots, and in turn, inform us about the mysteries of plant life on Earth. Marc Giulianotti describes the significant and surprising medical advances for the treatment of human disease made possible by creating habitats that allow mice and rats to live in space on station so that scientists can monitor the dramatic effects of microgravity on bones and muscles and the efficacy of front-line drugs designed to prevent musculoskeletal diseases like osteoporosis. And discovery is by no means limited to the lab and events inside of the station. Emily Tomlin contributes an article on the utilization of the station as an Earth observation platform with powers unlike any traditional Earth-orbiting satellites.

We invite you to read along and learn more about a few of the many exciting and challenging adventures in science, engineering, and education that await you in space. Neil deGrasse Tyson observed that "We went to the Moon and discovered Earth." I believe that we went to space to build an international space station and discovered humanity. Join us and accelerate the pace of your discovery to 27,600 km/h (17,100 mph). Join us in longing for the endless immensity (and boundless potential) of space. *Upward!* ■

University of Florida plant molecular biologists Robert Ferl (left) and Anna-Lisa Paul (right) in the University of Florida Space Plants Lab

STAYING TRUE TO YOUR ROOTS

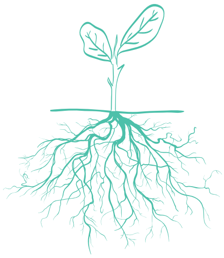
PLANTS ON THE ISS

BY AMELIA WILLIAMSON SMITH

Earth and its inhabitants have changed over time. One constant, though, has been gravity. Plants on Earth evolved in gravity, and gravity has long been known to play a key role in plant development. However, experiments conducted in the functional absence of gravity onboard the ISS have yielded results that challenge underlying assumptions regarding the role of gravity in root development.

The ISS National Lab provides a unique platform in which researchers can study fundamental plant development processes without the masking effect of gravity. An understanding of plant structure and behavior from spaceflight experiments translates directly to understanding how these processes work on the ground, said Anna-Lisa Paul, CASIS investigator at the University of Florida.

"Taking gravity out of the equation gives us insight into the inherent mechanisms of how plants work," Paul said. "And the better you understand that, the better equipped you are to design experiments on Earth to build better crops and expand productivity—in addition to being able to take plants with us when we leave Earth's orbit for extended missions or colonies on Mars."



UNDERSTANDING GRAVITY'S ROLE

On Earth, the plant hormone auxin is involved in orienting plant roots to grow in the direction of the pull of gravity. Auxin flows down the centermost cells of the root toward the root tip and then back up through the outer layer of root cells. This flow pattern is referred to as the "reverse fountain" model. Scientists had assumed that gravity played a role in establishing this flow.

Thus, in the functional absence of gravity onboard the ISS, one would expect a disruption in the flow and, instead, a diffuse distribution of auxin in the root tip. To test this hypothesis, Paul and co-investigator Robert Ferl, also a researcher at the University of Florida, recently conducted two experiments onboard the ISS—CARA and APEX03-2.

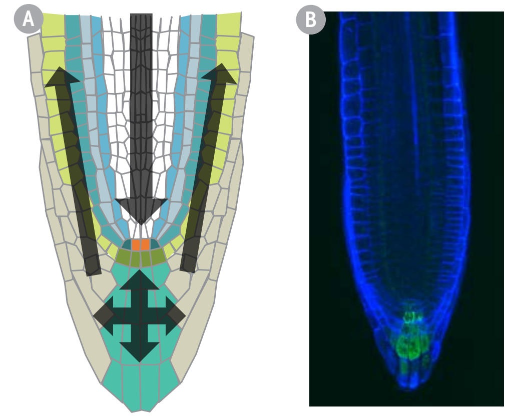
The results of these experiments demonstrated that the flow and distribution of auxin in the gravity-sensing portion of the root is actually not dependent on gravity. Instead, the pattern of auxin flow is a fundamental mechanism of root growth inherent in plants. These results were published in the Nature Partner Journal *npj Microgravity* in January 2016.

TAKING PLANT RESEARCH INTO SPACE

The CARA experiment (Characterizing Arabidopsis Root Attractions) was funded by CASIS and flown to the ISS in 2014, and the APEX03-2 experiment (Advanced Plant EXperiments) was funded by NASA Space Biology and flown to the ISS in 2015. In both experiments, Paul and Ferl examined green fluorescent protein-reporter gene expression in the plant *Arabidopsis thaliana* (a model organism for plant biology research) to compare the distribution of auxin in the root tips of plants grown on the ISS versus ground controls.

For each experiment, the spaceflight plants were placed in flight hardware to enable their growth in space, and the ground control plants were placed in a controlled environment chamber at NASA's Kennedy Space Center. For CARA, square petri plates with seedlings were attached to an interior wall of the ISS and received diffuse ambient light. For APEX03-2, the plates were placed inside Veggie, a climate-controlled locker on the ISS, with LED lights directly above the plates. Some of the plates in each experiment were wrapped with black cloth to block out all light.

> ***"Repetition is the key to real science success," Ferl said. "For APEX03-2, we used plants similar to ones used in CARA, but we also advanced the science by using plants of different ages and genotypes. This let us be sure that what we observed happens on more than a single trip to space."***



(A) Reverse fountain model of auxin flow in a root.

*(B) **Arabidopsis thaliana** root tip showing the location of gene expression associated with auxin signaling (green). Images collected with a Leica TSC-SP5 confocal microscope. Anna-Lisa Paul and Robert Ferl, University of Florida.*

Paul and Ferl used two methods to examine the distribution of auxin in the root tips. While the plants were onboard the ISS, Paul and Ferl worked with technicians at NASA's Glenn Research Center (GRC) in Ohio to use the Light Microscopy Module (LMM) on the ISS to image the live plants in real time. Once the plants returned from flight, Paul and Ferl examined the preserved plants in their laboratory using confocal microscopy.

To image the plants with the LMM on the space station, an ISS crewmember would take a survey photo of each plate and insert the plate into the LMM. Using the survey photo as a guide, Paul and Ferl worked with GRC technicians to navigate the LMM to look at regions of interest. "It was an interesting challenge to conduct that kind of experiment," Paul said. "You want to sit at the microscope and move the controls with your own hands, but instead you have to send computer scripts to the microscope up on the space station."

LMM

The LMM on the ISS features a modified Leica RXA microscope capable of using most standard Leica objectives. The LMM is configured to operate automatically and can also be controlled by the ISS crew or remotely from the ground. The LMM is capable of high-resolution black and white microscopy using bright field, epifluorescent, and fluorescent techniques.

GROWING TOWARD GRAVITY

If you rotate a vertically growing plant by 90 degrees, the roots will turn back down and continue to grow down toward gravity. This is because when the plant is turned, a chain reaction causes the auxin to redistribute from the root tip and accumulate on the side of the root facing downward. This triggers growth on the opposite side of the root, making the root tip curve back down.

CHALLENGING ASSUMPTIONS

In analyzing the results from CARA and APEX03-2, Paul and Ferl found that all of the plants grown on the ISS—regardless of light source, growth habitat, age, or genotype—had the same pattern of auxin distribution in the root tip as plants on Earth. Although the functional absence of gravity and the different light sources did affect root growth, the flow of auxin in root tips remained the same.

These results show that although auxin is a key messenger in determining a plant's response to gravity, gravity does not play a role in establishing the distribution of auxin in root tips, as scientists had assumed. Thus, the "reverse fountain" flow of auxin in root tips is neither reverse nor a fountain, because gravity is not involved.

Rather, the flow of auxin is an inherent developmental feature of root growth. Other messengers may also be involved in regulating a plant's responses to gravity.

"When you can take your experiment to a place where you no longer have to worry about the influence of gravity, it allows you to see many things you would not have been able to see before," Paul said. "We found that the native structures or signals in a plant—even when there are no directional cues—still enable the root to grow away from where it is planted, and you would not be able to see that on the background of a gravity environment."

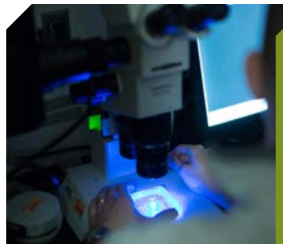
Interestingly, a fluorescent reporter gene used in CARA that targets another hormone, cytokinin, did exhibit different patterns of distribution in the root tips of plants grown on the ISS versus ground controls. Future experiments will further explore the effect of gravity on cytokinin signaling and related root growth.

ENABLING DISCOVERY

Access to the microgravity environment of the ISS National Lab gives researchers the opportunity to make discoveries that are not possible on Earth. CASIS and NASA work closely together with science investigators to enable access to the ISS National Lab and to make sure experiments such as CARA and APEX03-2 are successful, said Trent Smith, NASA Project Manager for Veggie, the plant-growth facility that housed APEX03-2.

> ***"The point of the space station is that it's really out there on the frontier," Smith said. "Frontiers are rich in discovery, and being on the frontier gives us the ability to be surprised and to advance knowledge."***

Increased access to the ISS National Lab also allows researchers to run series of experiments, much like they do in their laboratories on the ground, Paul said. "This has opened the door for us to ask increasingly more complex and interesting questions that have an impact not only on growing plants in space, but also on our fundamental understanding of how plants respond to any novel environment." ■



CONFOCAL MICROSCOPY

Confocal microscopy uses a laser to make high-resolution images of a specimen at multiple focal planes (or depth). The images are then assembled to reconstruct the 3-D structure of the specimen. Images can be taken as deep into the specimen as the light can penetrate. Future planned capabilities for the LMM on the ISS include confocal microscopy.

RODENT ROCKET RESEARCH

BIOMEDICAL DISCOVERY IN SPACE

BY MARC GIULIANOTTI

Rodents have been traveling to space since the 1950s, helping to pave the way for humans to safely venture off our planet. Since these early voyages of discovery to determine whether animals could survive spaceflight, mice and rats have continued to play an important role in space research. Rodents provide critical insight into not only the effects of spaceflight that impact astronaut health but also effects that mimic human disease on Earth, including those targeting the musculoskeletal and cardiovascular systems, immune function, wound healing, and metabolism.

Rodents flew on 27 U.S. space shuttle missions, and thanks to the work of scientists and engineers at NASA's Ames Research Center, rodents now have a new role in space research onboard the ISS National Lab. Previous shuttle missions housed rodents in microgravity for about 10 days. The new Rodent Research Hardware System is designed to allow rodents to spend up to 180 days in space, greatly improving our ability to use this powerful animal model to study the effects of spaceflight on human health.

MODELING HUMAN DISEASE

Rodents are surrogates for studying human disease because they share many similarities to humans in terms of anatomy, physiology, and genetics. Rodents and humans share virtually the same set of genes, and there is great similarity in genetic sequence and protein function.

Due to the similar genomes but much shorter lifespan of rodents—typically around two years—mice and rats experience many of the same diseases and effects of aging as humans, but on a vastly accelerated timescale, said Ruth Globus, ISS rodent research project scientist and co-director of the Bone and Signaling Lab at Ames.

> ***"Rodents are similar to humans in that as they age, they undergo detrimental changes such as bone mineral loss and muscle wasting," Globus said. "However, because rodents age much more quickly than humans, studies that would take years to conduct in humans can be done in weeks using rodents."***

This accelerated path to results is even further amplified by spaceflight, which induces rapid physiological changes in humans and animals, including accelerated bone loss and muscle wasting. By housing rodents onboard the ISS, experiments can be designed to better understand the mechanisms of these adverse effects and potentially develop solutions. The results from rodent studies on the ISS could not only enable longer space missions for humans in the future but also translate into new targets for the diagnosis, treatment, and prevention of human disease on Earth.

VALIDATING THE RODENT RESEARCH FACILITY

Rodent Research-1 (RR-1), which launched in September 2014, was the inaugural mission to validate the new ISS Rodent Research Facility. The facility includes modules for transporting rodents to and from the ISS as well as units to handle and house the rodents with ample food, water, and environmental control during the mission (see *The Rodent Research System* below).

The RR-1 mission delivered 20 mice to the ISS—10 as part of NASA-sponsored research and 10 supporting a commercial CASIS-sponsored investigation. The mission also delivered key hardware components to the ISS, including the Rodent Research Hardware System and the bone densitometer, a dual-energy x-ray device designed by Techshot, Inc.

The bone densitometer, an enhanced form of X-ray technology, has for the first time allowed in-orbit measurements of bone loss, soft-tissue density, lean/fat muscle mass, and total animal mass of live mice. A new addition to spaceflight research, the bone densitometer has worked very well onboard the ISS, enabling investigators to successfully monitor the effects of microgravity on rodent bone and muscle, said Rich Boling, Techshot vice president of corporate advancement.

THE RODENT RESEARCH SYSTEM

1

TRANSPORTER UNIT

The Rodent Research Hardware System consists of three main components: the Transporter Unit, the Animal Access Unit, and the Habitat Unit. The Transporter Unit houses rodents on their voyage from Earth to the ISS. The unit can house 20 mice or 12 rats for up to 10 days and contains all the necessary consumables for the rodents.

2

ANIMAL ACCESS UNIT

Once the rodents arrive at the ISS, the Animal Access Unit is utilized to transfer the rodents to their long-term housing unit, the Habitat Unit. The Animal Access Unit allows crew members to insert their hands into the unit through a glove interface and transfer the rodents from one container to another (e.g., to the bone densitometer) to conduct experiments.

3

HABITAT UNIT

Each individual Habitat Unit can house 10 mice or 6 rats for up to 90 days, supplying the rodents with food, water, fresh air, and lighting systems that simulate day and night conditions. The units contain infrared and visible-light cameras as well as other sensors that allow constant monitoring.

"The scans from the control studies performed onboard the ISS match perfectly with the ground-based studies," Boling said. "This means that researchers now have access to the same bone densitometer equipment onboard the ISS that they do in their ground-based labs."

Additionally, data obtained from the bone densitometer is downlinked from the ISS to researchers on the ground, providing data in near real time.

STUDYING RODENTS IN SPACE

While the primary goal of RR-1 was to validate the performance of the Rodent Research Facility, the translational research experiments performed in this inaugural mission also sought to elucidate microgravity's effects on organisms at a molecular and organ-system level.

For example, tissue samples from the 10 mice flown for the NASA-sponsored study were collected and analyzed for markers of gene expression and tissue responses as well as protein content. These analyses both validated crew procedures for future spaceflight research and provided investigators with detailed information on the biological effects of long-term spaceflight on healthy mice.

Moreover, RR-1 included research designed by investigators at the Novartis Institute of Biomedical Research, a major pharmaceutical company and CASIS commercial partner. The Novartis experiment included five wild-type ("normal") mice and five transgenic ("knock-out") mice that lack a specific gene, MuRF1, reported to trigger muscle wasting by degrading muscle protein. By comparing the effect of microgravity on the two sets of mice, the Novartis team hopes to reveal novel molecular targets for treating skeletal muscle atrophy, a debilitating condition associated with aging and many systemic diseases (e.g., diabetes, cancer, and renal failure).

A NEW PLATFORM FOR INNOVATION AND TRANSLATIONAL BIOMEDICAL RESEARCH

Robust success of the RR-1 mission paved the way for the Rodent Research-2 (RR-2) mission, which included an expanded investigation by the Novartis group. RR-2 built on the results from RR-1 by assessing changes in mouse hind-limb muscles, including skeletal muscle mass and fiber size. Mice in RR-2 were also exposed to spaceflight for varying periods of time—ranging from 2 to 8 weeks—to determine the progression of muscle wasting over time in the mice.

The ultimate goal of these Novartis rodent research studies is to aid in the development of new therapeutics to prevent or ameliorate the devastating effects of muscle wasting diseases. CASIS continues to facilitate such use of the Rodent Research Facility for research aimed at truly improving human health on Earth. Future Rodent Research missions 3, 4, and 5 (see *Upcoming Rodent Research Missions* below) are all currently slated to take on this grand challenge.

MAKING AN IMPACT

The ability to collect and analyze spaceflight data on individual mice by repeated measures of their bones and muscles accelerates the pace of medical discovery. Such research provides insight into the effectiveness of therapeutics designed to delay medical conditions such as osteoporosis (loss of bone density) and sarcopenia (loss of muscle mass and strength).

The ISS National Lab is thus a critical platform for research that may improve the quality of life for those of us here on Earth—and the new ISS Rodent Research Facility is a huge step toward augmenting our ability to realize that potential.

Both CASIS and NASA are reaching out to the scientific community to identify disease areas that could benefit from rodent research in a microgravity environment, said Janet Beegle, project manager at NASA's Ames Research Center. This may result in not only new planned missions but also tissue- and data-sharing collaborations (see *Tissue Sharing and the GeneLab Campaign* to the right).

"We want to inform the experts in these disease areas about the capabilities onboard the ISS National Lab," Beegle said. "We then want to work with them to design and implement research missions that will have a significant impact on human health." ■

UPCOMING RODENT RESEARCH MISSIONS

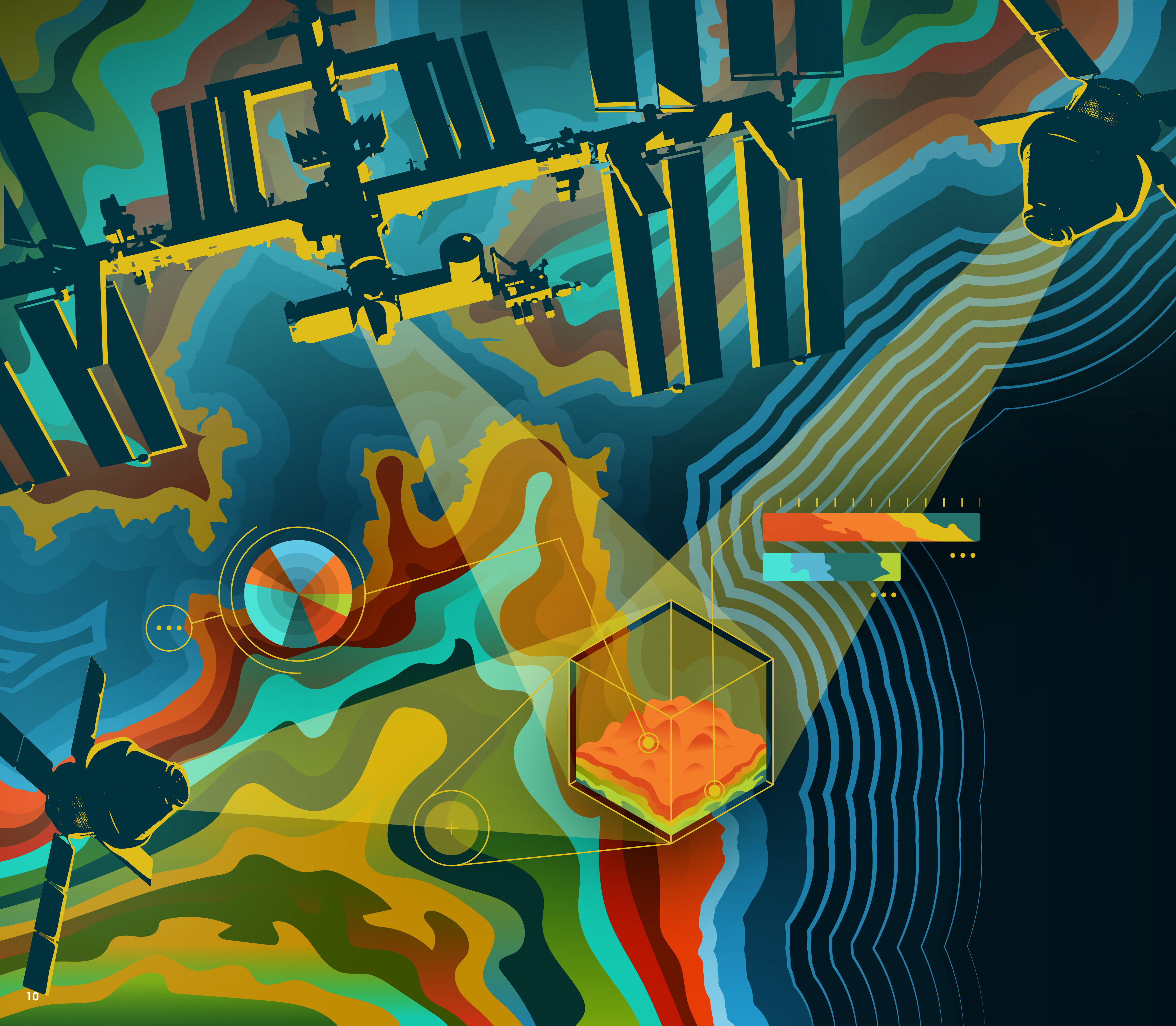
RR-3	**When:** Scheduled for SpaceX-8 (estimated launch early 2016) **Who:** Eli Lilly & Company, a major pharmaceutical company and CASIS commercial partner **Aim:** Utilize microgravity-induced muscle wasting to determine the impact of an antimyostatin antibody on rodent muscles. **Impact:** No Earth-based mouse models currently exist to study muscle wasting associated with whole-body immobilization, such as being bed-ridden. On the ISS, researchers are able to study predictable muscle atrophy in an otherwise healthy animal.
RR-4	**When:** Scheduled for SpaceX-10 (estimated launch late 2016) **Who:** Indiana University School of Medicine researchers Rasha Hammamieh and Melissa Kacena (supported by the U.S. Department of Defense) **Aim:** Validate bone regeneration studies in spaceflight by evaluating whether new therapies for fracture healing and bone regeneration are more effective than current options. **Impact:** This work aims to improve clinical outcomes for bone healing in injuries resulting from trauma, surgery, or infection. Positive results would increase the breadth of rodent research on the ISS National Lab.
RR-5	**When:** Scheduled for SpaceX-12 (estimated launch 2017) **Who:** University of California Los Angeles researcher Chia Soo **Aim:** Utilize microgravity-induced bone loss to test a novel osteoporosis therapeutic based on the protein NELL-1. **Impact:** Unlike most current therapies for osteoporosis that work by preventing bone loss, this novel treatment also promotes bone formation—potentially combating disease effects on two fronts. Critically, this mission will mark the first attempt by NASA to return live rodents to Earth from the ISS National Lab using the NASA Rodent Research Facility.

TISSUE SHARING AND THE GENELAB CAMPAIGN

GeneLab is a NASA initiative to create a centralized bioinformatics system that consists of a sample repository and a database for depositing, accessing, analyzing, and modeling datasets from model organisms exposed to the microgravity environment. GeneLab is being designed to integrate with existing databases containing results from Earth-based studies, and it will facilitate sharing of unique life science data obtained in spaceflight for comparison against carefully matched ground controls.

As the open-access, online searchable data repository for data from select rodent research missions and associated tissue sharing initiatives, GeneLab will benefit basic and translational research as the primary gateway to integrated genomics, transcriptomics, proteomics, and metabolomics data for health research comparing disease models in space to those on Earth.

genelab.nasa.gov/data



Constellations, Clouds, & the Conundrum of Big Data Processing

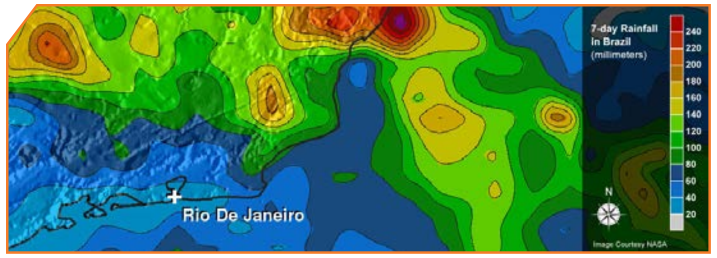
BY EMILY TOMLIN

For millennia, humans have looked up to the sky to find constellations of stars, wondering what mysteries they hold. Today, we live in a world where constellations of satellites look down on us, hoping to unravel mysteries as well—by capturing highly complex images of Earth.

In the commercial remote sensing market, the imaging of Earth from space has experienced a technical tsunami, giving rise to a population explosion of smaller but far more capable satellites with new sensing and communication capabilities. In the near future, constellations of nano-, micro-, and other small-sats will swarm low Earth orbit like drones filling the skies on Earth.

Despite the tiny size their names imply, these small satellites produce “big” data, the technical term for data sets so vast and complex that highly complex processing algorithms are required to analyze and interpret the meaning behind them. The images these satellites produce of Earth are not simple visible-light photographs—they are multi- and hyper-spectral images bursting with data. Thus, in parallel to this satellite baby boom is an ever-growing need for evolution in data processing.

Toward this end, HySpeed Computing recently launched a new online web application that provides remote sensing data analysis in the cloud: The Hyperspectral Imager for the Coastal Ocean (HICO) Image Processing System (IPS). Developed in part through ISS National Lab funding and support, HICO IPS provides an answer to today’s data processing challenges by efficiently delivering the power of image analysis to a global user community.



THE POWER OF EARTH IMAGING FROM SPACE

Imaging of Earth from space has existed for decades. However, the ISS is in a unique orbit and has its own particular advantages, different from that of traditional Earth-viewing satellites.

The most difficult images to process—whether taken from the ISS or from traditional satellites—are those of coastal zones, where typical analyses that are effective for land-only or water-only images fall short. HICO, though now retired from use on the ISS, was the first space-borne imaging spectrometer designed to study these difficult coastal areas.

There is a strong international community interested in ocean color sensing, said HICO Project Scientist Curtiss Davis, and coastal regions are a particularly complex challenge for this community. "The more wavelengths we use for imaging and the higher spatial resolution we can achieve, the more complete understanding we can gain," said Davis.

HICO was a pathfinder for hyperspectral imaging of these optically complex coastal waters. However, HICO still posed unique image analysis challenges, and improvements to algorithms were essential for processing data from HICO. Moreover, developments in satellite technology are also driving a need for timely solutions to these data processing hurdles.

THE RISE OF THE GEOSPATIAL APPLICATION MARKET

In addition to the complexities of coastal imaging data, the remote sensing field is at a transition point in history. Earth imaging used to be performed by only government satellites or very expensive commercial satellites. Now that getting to space is easier and less costly, the diversity and availability of data are expanding exponentially—via ISS imaging platforms, the booming new industry of small satellite constellations, and even drone technology.

ABOUT HICO SPONSORSHIP:

For its first three years in orbit, HICO was sponsored by the Office of Naval Research as an Innovative Naval Prototype. Support for the final two years was provided by the NASA ISS Program, and commercial applications for HICO data (e.g., HICO IPS) are sponsored by CASIS. HICO collected more than 10,000 images of Earth during its five years of operations (September 2009 – September 2014).

In the old way of doing things, only experts in the field performed the capture and analysis of Earth images from space. A specialist would specifically develop context-dependent and dataset-specific algorithms for a certain set of images, as needed.

"In essence, only those of us with the right computers and the right tools could do it," said Davis. "We needed a way to readily provide the results—to make HICO data much more widely used and to keep up with the vast amount of spectral info we can now collect."

Today, advances in satellite technology mean that big data is making its way into the hands of the larger community. To prepare for the wealth of information that is coming with planned sensors on the ISS and beyond, rapid innovation in computing technology is paramount.

> ***"It's the democratization of low Earth orbit," said HySpeed Computing President James Goodman. "We now have the ability to access a volume and variety of data that was never before available."***

However, the power of data generation continues to outpace processing capabilities. This opened the door for a business opportunity—the creation of new applications to perform these processing tasks.

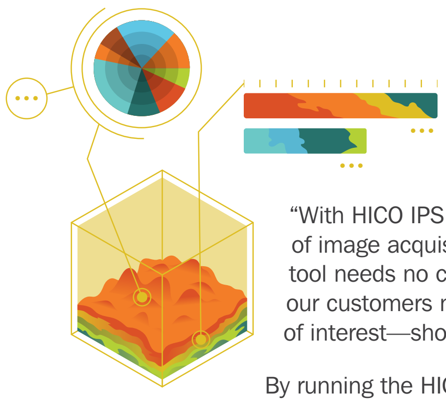
HICO IPS AS A PROOF OF CONCEPT

HICO IPS is a trailblazer for what can be done through a next-generation image processing application. As an online image analysis tool, it is a prototype for how the geospatial application market can tackle big data and provide accessibility to the global community.

"HICO IPS runs complex algorithms in a web application," said Goodman. "With this 'computing in the cloud' approach, it's possible to make data analysis available to everyone." Individual algorithms can be plugged into such applications in a modular fashion based on customer needs—where both the algorithms and derived products can be bought and sold in this emerging market.

As a web application, HICO IPS combines commercial and open-source software layers into an enterprise system that runs in the cloud, generating results on-demand per the user's request. This type of online image processing was practically unheard of five years ago, but now the market is exploding—and HICO IPS serves as a demo to the remote sensing community.

"When we show HICO IPS to our customers, they immediately see the value of accessing data through a web application," said Amanda O'Connor, business development manager at Harris Corporation. These customers are users of coastal remote sensing data—a diverse group ranging from commercial fisheries to public health organizations concerned with tourism.



"With HICO IPS, users need no prior knowledge of image acquisition or processing, and the tool needs no calibration," said O'Connor. "All our customers need is to say 'this is my area of interest—show me something about it.'"

By running the HICO IPS plug-in algorithms on a collection of example HICO imagery, one can evaluate various aspects of water quality in different coastal regions. Through this image analysis, customers can readily see how such information could be used to decide on prime fishing locations, for example, or the potential need for a swim advisory.

> ***"Remote sensing data allows decision-making in a real-time and meaningful way—but only if you can quickly interpret the data," said O'Connor. "With the HICO IPS application, even users without any industry expertise can still get meaningful answers quickly. It's a very simple interface."***

THE FUTURE OF CLOUD COMPUTING

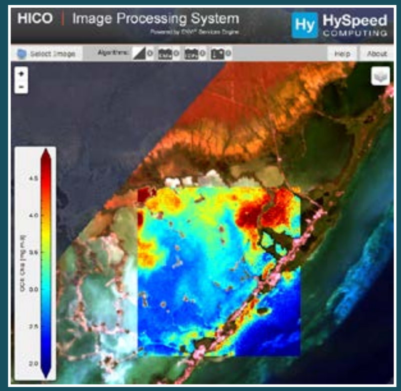
HICO is no longer producing real-time images, but the HICO IPS framework is applicable to other remote sensing instruments, including future imagers on the ISS as well as on other satellite and airborne platforms.

"Based on the positive user feedback we've received, we can re-use this architecture to access and catalogue details from other systems," said O'Connor. "The bigger question Dr. Goodman was asking was 'how can I make this data useable for everyday people?' And HICO IPS is a success in that. It's bringing science to the lay person who may not even know how to ask the questions."

Goodman says he envisions a remote sensing future where the line between local and cloud computing becomes obscured, where scientific achievements and innovations are readily shared through a distributed processing network, and where image-derived information is rapidly distributed through web applications. "The CASIS-sponsored HICO IPS project and resulting web application represents an important contribution toward realizing this goal," he said.

"HICO IPS bridges the gap between the theoretical science mission of the ISS and something people can consume and use," added O'Connor. "As a taxpayer, that makes me happy. This application is bringing return on investment to the public who helped finance the space station. That really underscores the relevancy of the ISS as a National Lab."

Hy HySpeed COMPUTING



The finished prototype HICO Image Processing System is available at:

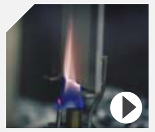
hyspeedgeo.com/HICO

Orbital ATK Returns to Flight with ISS National Lab Payloads

SPOT LIGHT

BY PATRICK O'NEILL

After a one-year hiatus, the Orbital ATK Cygnus cargo vehicle was launched from Kennedy Space Center in December, carrying supplies and experiments to the ISS National Laboratory. Payloads on this mission include an investigation to test flame-retardant textiles, a validation test for satellite technology, and a new facility to support life sciences research on the ISS.



Milliken & Company, one of the world's largest materials and physical sciences companies, is conducting a vertical burn investigation to evaluate flame-retardant textiles on the ISS. By examining how the textiles burn in the functional absence of gravity, researchers can better understand phenomena that occur during burning. The results could aid in developing better textile materials and designs in protective clothing for firefighters, military personnel, and anyone who may come into contact with fire-related hazards.

"We use unique insights, deep science, and meaningful design to deliver innovations that do good for the world and for our customers," said Jeff Strahan, research and development manager at Milliken & Co.

The small innovative company NovaWurks, Inc. is using the ISS as a platform to test its newly developed Hyper-Integrated Satellite (HISat), which provides complete satellite functionality in a nanosatellite-scale package. This project is testing technology for in-orbit assembly and deployment of the HISat system from the ISS. If the validation is successful, this technology could substantially reduce the costs of satellite system development for space-based R&D.

The new Space Automated Bio-product Lab (SABL) developed by BioServe Space Technologies is a locker-sized facility for life sciences research on the ISS. SABL maintains environmental control and can be automated to collect data using various sensors and high-definition video. It can also be operated by the ISS crew or remotely controlled from the ground. Data and video can be downlinked to the ground for real-time analysis by investigators anywhere in the world.

This Orbital ATK launch represented the first successful commercial resupply services launch to the ISS since the spring of 2015. For this launch, the Cygnus vehicle was placed on top of United Launch Alliance's Atlas V rocket—something that had never previously been done for an ISS resupply mission. ■

For more on Orbital ATK payloads, visit: **ark3.iss-casis.org**

ISS Virtual Tour: Experience the Wonder of the Space Station

SPOT LIGHT

BY AMELIA WILLIAMSON SMITH

Visitors to the Kennedy Space Center Visitor Complex (KSC VC) can now experience the wonder and excitement of the ISS by embarking on a breathtaking interactive tour of the space station. The ISS virtual tour, co-developed by CASIS and NASA, launched in July 2015 and debuted at KSC VC in December.

Built in 6K resolution, the ISS virtual tour covers the entire habitable area of the ISS inside and out in extraordinary detail. After examining the exterior of the ISS with the beautiful backdrop of the Earth below, visitors can go inside the space station.

As visitors "walk" through each module, they can explore "hotspots" that contain information about the hardware and facilities on the ISS. The tour also includes videos of astronauts talking about what it is like to live and work in space, and visitors can learn about current experiments onboard the ISS. The tour includes 15 scenes, more than 150 hotspots, upwards of 50 videos, and 250 images and other media.

Visitors interact with the ISS virtual tour through a mobile 55-inch touch-screen display with stereo surround sound. The ISS virtual tour is a one-of-a-kind educational tool for a wide range of large-scale audiences, making it perfect for KSC VC, which has a yearly attendance of more than one million people.

Three ISS virtual tour units are currently on display in high-traffic areas of KSC VC, and a fourth unit is being used as a traveling school exhibit for educational outreach, said Darlene Koenig, vice president of new business development at KSC.

"The ISS virtual tour is a vital new experience for our public education programs to tell the story and the 'why' of the ISS to the participating public who visit KSC VC," Koenig said.

Additional ISS virtual tour displays at other venues, such as museums, schools, trade shows, retail locations, and other public places, are planned for the future. This amazing new tool will allow people of all ages to explore the ISS in a way never before possible. ■

SPOT LIGHT

The Flight of the Tin Whiskers BY AUSTIN JORDAN

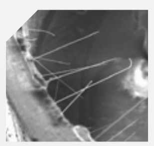
Disappointment billowed in the air, higher than the plumes of white smoke that burst over the Cape Canaveral skies on that clear June afternoon. A sinking feeling resided in the pits of stomachs, as the world watched the SpaceX Falcon 9 rocket explode a few minutes after lift-off. This feeling, "oh no not again," was compounded for a team of student scientists who had experienced this unwelcome feeling just eight months prior as they witnessed the first loss of their ISS-bound research project, "Tin Whiskers," in the Orb-3 mishap in October 2014.

But, as the smoke cleared and the journey to return to flight commenced, this determined team was inspired by the same spirit that has fueled our space program for generations—that discovery is not defined by our failures, challenges, or losses but rather by our resilience.

Lindbergh (far left) and Garvey (center), with collaborator Gabriel Voigt, discuss their research at an Orb-3 science briefing in October 2014.

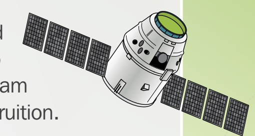
"Science is a process of failures, re-groupings, and discoveries," said Rachel Lindbergh, student scientist on the Tin Whiskers team. "These setbacks were devastating in the moment, but my team saw each mishap as an opportunity to improve our experiment. We'll cherish the end result all the more after conquering what we have faced."

Lindbergh and Joseph Garvey, co-principal investigators for Tin Whiskers, are involved in the Student Spaceflight Experiments Program (SSEP), a program created and managed by the National Center for Earth and Space Science Education. The Tin Whiskers team was selected from an SSEP competition led by Palmetto Scholars Academy in North Charleston, South Carolina, in which hundreds of pre-college students designed and proposed microgravity experiments.



The science of Tin Whiskers involves studying tiny crystalline structures that form around tin-plated metals commonly used in electronic components. The formation of these tiny structures, whose growth may be enhanced during spaceflight, is problematic for electronic equipment and can trigger malfunction within devices ranging from small electronic parts to satellites.

Lindbergh and Garvey have spent the last two years working to send their project to the ISS to test the hypothesis that spaceflight promotes tin whisker growth. The Tin Whiskers team hopes their research will expand on current understanding of how spaceflight affects electronic devices—in hopes of ultimately improving manufacturing processes for electrical components used in spaceflight and aviation.



After months of ardent work and collaboration, Tin Whiskers is slated to launch again on SpaceX-8, and the team is excited to see their project come to fruition.

"Being involved in this experiment opened my eyes to the true collaborative nature of science and to all the mysteries left undiscovered," Lindbergh said. "The possibilities for discovery are immense, and it is inspiring to know that my generation's future scientists and researchers will soon be contributing."

SSEP is a comprehensive science, technology, engineering, and mathematics program that provides students with the opportunity to conduct authentic spaceflight research. The program is enabled, in part, through contributions from CASIS and a strategic partnership with flight-experiment service provider, NanoRacks, LLC.

SPOT LIGHT

Rickie Fowler: Winning with Space-Inspired Golf Technology

BY PATRICK O'NEILL

When most people think of golf equipment, they do not normally associate it with space. However, Rickie Fowler, PGA superstar and COBRA PUMA Golf (CPG) brand ambassador, unveiled a new driver in late 2015 that has something that no other brand can tout—space is in it.

In 2014, CPG partnered with CASIS to send a variety of materials science investigations to the ISS to understand plating characteristics of metals in a microgravity environment. The purpose was to see whether the metals could be used to manufacture a more durable and efficient product line. CPG is currently evaluating the results from these initial investigations and hopes the findings will inform future product lines.

Through its partnership with CASIS, CPG learned of space-tested metal threads developed to combat the intense torque generated during a rocket launch. This torque is similar to the torque involved in hitting a golf ball with a driver. CPG incorporated these space-tested metal threads in its new KING LTD Driver, which Rickie Fowler is using during his 2016 PGA season. The driver is the first commercial product to feature the CASIS "Space Is In It" seal.

If you ask the 25 million Americans who play golf about the importance of advanced technology in golf equipment and the extent to which it impacts the game—innovation matters. Golfing manufacturers are constantly striving to develop drivers and clubs that are more durable and that can hit the ball farther and straighter. By utilizing space technology, CPG believes their "Space Is In It" driver has unique technological benefits that set it apart from drivers of other brands.

CPG's "Space Is In It" driver recently made its debut in the winner's circle. Using the driver in one of his first tournaments of 2016, Rickie Fowler won the Abu Dhabi HSBC Championship over an elite field of golf's biggest stars. This just goes to show that microgravity on the ISS National Lab has the ability to impact everything from drug development for human health all the way to improving your game on the golf course.

News & Notes

FROM THE ISS NATIONAL LAB

CALL FOR PAPERS RECAP

Earlier this month marked the close of the initial call for papers for the CASIS and National Science Foundation (NSF) joint solicitation focused on fluid dynamics research on the ISS. NSF is contributing $1.8 million in grant funding for the solicitation, making this the largest partnership for CASIS to date.

ON THE ROAD

CASIS attended the AAAS Annual Meeting earlier this month in Washington, D.C., and hopes to catch you in April at the National Space Symposium in Colorado Springs and the USA Science and Engineering Festival in Washington, D.C.

ISS RESUPPLY MISSIONS

Orbital ATK and SpaceX both currently plan to launch ISS resupply missions this spring. Key payloads include a new 3-D printer (the Additive Manufacturing Facility) and a new "wet lab" facility that will assist researchers with cell culture and molecular biology investigations. Pharmaceutical company Eli Lilly & Co. will also be sending up payloads for protein crystal growth and rodent research investigations aimed at drug discovery.