ISS

U.S. NATIONAL LABORATORY

ACCELERATING SCIENCE. ELEVATING IMPACT.

2018 ANNUAL REPORT

ISS
U.S. NATIONAL LABORATORY

MISSION

To foster scientific discovery and technological innovation in space, expand U.S. leadership in commercial space, and inspire the next generation.

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BOARD OF DIRECTORS

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ABOUT

About the International Space Station (ISS) U.S. National Laboratory:
In 2005, Congress designated the U.S. portion of the ISS as the nation's newest national laboratory to maximize its use for improving quality of life on Earth, promoting collaboration among diverse users, and advancing science, technology, engineering, and mathematics (STEM) education. This unique laboratory environment is now available for use by non-NASA U.S. government agencies, academic institutions, and the private sector, providing these customers access to a permanent microgravity setting, a powerful vantage point in low Earth orbit, and the extreme and varied environments of space.


NASA

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LETTER FROM THE PRESIDENT

I joined the ISS National Lab as president and chief executive officer in late summer, a newcomer to the space industry but with decades of experience in leading national science initiatives. As our nation's only orbiting laboratory, the ISS has become both a proof of concept for the value of sustained research initiatives in low Earth orbit (LEO) and a pathfinder for the future space economy. The robust, albeit currently small, economy built over the past six years by the ISS National Lab demonstrates that the commercialization and economic development of space is not limited to the satellite market—and we are providing the operational and cooperative infrastructure to drive this broad market expansion by building demand, enabling supply, and facilitating investment.

Demand

Since the transition of the ISS National Lab to nonprofit management in 2011, 185 new-to-space users in the areas of life sciences, physical sciences, technology development, and remote sensing have been awarded the opportunity to conduct investigations onboard the ISS National Lab. In total, 241 projects have been directly sourced by the ISS National Lab (135 of which represent commercial users), and dozens of other projects sourced by commercial partners and education programs have also been added to the ISS National Lab manifest. More than 70% of the payloads flown in fiscal year 2018 (FY18) had significant private-sector involvement, and more than 50% of newly selected projects added to the queue will require no ISS National Lab grant funding to complete their flight projects.

Supply

Since 2012, the ISS National Lab has engaged and supported business opportunities for a diverse community of Implementation Partners, the service providers that help researchers translate terrestrial project concepts into flight-ready payloads. This community has now grown to 45 members, eight of whom now manage commercially operated facilities onboard the ISS National Lab—up from only one in 2012. Fourteen such commercial facilities now operate on the ISS National Lab, with one additional facility that was recently installed on the ISS through the European Space Agency. Of the more than $5 million in ISS National Lab grant funding awarded in FY18, more than 70% went directly to these partners and not the end user.

Investment

In support of the growing LEO economy, the ISS National Lab has been able to leverage its $15 million per year in ISS research funds over the past five years to attract more than $150 million in non-NASA, third-party funding in support of individual ISS National Lab research and technology initiatives. This external funding originates from non-NASA government agencies such as the National Institutes of Health and the National Science Foundation, venture capitalists, private-sector companies such as Boeing and Target Corporation, end users themselves, and other investors. More than $19 million in funding in FY18 alone came from large-scale, multi-project programs funded by third-party sponsors. Additionally, the ISS National Lab investor network (organizations that have expressed specific interest in funding space ventures) nearly doubled in FY18 and now consists of more than 118 members that have contributed approximately $1.6 million in funding over the past three years.

Perhaps most critically, I believe this market is scalable, and the ISS National Lab has the institutional knowledge to do so based on direct experience working with the current users, service providers, sponsor organizations, investors, and diverse stakeholders.

Education

We also know how to capitalize on the power of space for improving science literacy in tomorrow's leaders, who will catalyze innovation and success in this future space market. More than 2 million educators, students, and parents were reached through ISS National Lab educational initiatives in FY18—yet education programs represent less than 4% of the total ISS National Lab grant funding allocated over the past five years. Smart partnerships with experienced organizations enable maximum reach for educational content related to the ISS National Lab.

In 2019 and beyond, I look forward to leading the ISS National Lab as we strengthen and diversify our partnerships and mature our research programs to enable further economic development and commercialization of the LEO platform market. We will focus on programs with high-impact potential to enable specific sectors, including areas that address larger challenges with terrestrial implications and potential future manufacturing capabilities such as advanced materials and tissue engineering. We will continue to lower barriers to entry and seek new approaches to overcome remaining barriers in the areas of time to flight, technology modernization, and continuity of research initiatives. Most importantly, we will continue to share our lessons learned and successes with the space community, our stakeholders, and the public as we persist in pioneering the best practices for community interaction and ISS platform utilization in this growing market.

Please read on for details about ISS National Lab progress and successes from FY18.

Sincerely,
Joseph Vockley, Ph.D.

ISS
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NASA

THE ISS NATIONAL LAB R&D PORTFOLIO

ADVANCING KNOWLEDGE AND FOSTERING ECONOMIC DEVELOPMENT IN SPACE

AT A GLANCE

- More than $150 million in external, non-NASA funds are now invested in ISS National Lab research following robust growth in FY18.
- The ISS National Lab selected 50 new projects and programs across diverse R&D areas, making FY18 the strongest year to date for portfolio growth.
- ISS National Lab education content reached more than 2 million people.
- Three granted patents complemented 17 new peer-reviewed publications.
- Multiple in-orbit firsts included technical demonstrations in supercomputing and in-orbit manufacturing.

Fiscal year 2018 (FY18) was a record-breaking year for portfolio expansion and private-sector utilization of the ISS National Lab. Third-party funding for spaceflight research and development (R&D) continued to rise, allowing us to leverage ISS National Lab resources for maximum user success—which this year ranged from patents to first-ever technical demonstrations in orbit. Finally, using less than 4% of ISS National Lab grant funds to date, the Space Station Explorers educational consortium has reached more than 3 million people, 2 million in FY18 alone. Below is a snapshot of portfolio activity and success, with additional details found throughout this report.

Private-sector R&D represented more than 70% of the 74 payloads delivered to the ISS National Lab in FY18, including two new commercially operated facilities (see page 9). In addition, 50 newly selected projects and programs joined our portfolio in FY18, the most growth to date in a single year. Finally, new ISS National Lab contractual relationships with future potential platform owners and aerospace companies (see page 12) were yet another step toward enabling a transition from the ISS to commercial LEO platforms.

More than $150 million in external, non-NASA funding currently supports the full ISS National Lab portfolio—a 50% increase in FY18. Multiyear programs sponsored in partnership with the National Institutes of Health (NIH), the National Science Foundation (NSF), and Boeing (see pages 14–15) are a critical part of this funding stream and support new R&D investigations across multiple disciplines, including fields such as regenerative medicine and advanced materials that promise tangible impact on quality of life.

More than $19 million in third-party funding was committed through these Sponsored Programs in FY18 alone, nearly equal to all previous years combined. Additionally, the ISS National Lab investor network nearly doubled in membership within FY18, growing to 118 members at year end and driving numerous capital introductions.

ISS National Lab educational initiatives reached more than 2 million students, parents, and educators in FY18—nearly double all previous years combined—and the Space Station Ambassador program now consists of more than 500 members, offering educators an opportunity to partner in support of the ISS National Lab portfolio. The Guardians of the Galaxy Space Station Challenge with Marvel Entertainment—a nationwide spaceflight research competition—awarded two student investigations, and the ISS National Lab was featured in Lucasfilm's web series "Science and Star Wars," designed in collaboration with IBM to engage the public on the science associated with the Star Wars universe.

FY18 SUCCESS STORIES

For details on these and other successes, see pages 16-17.

One year of operations for Hewlett Packard Enterprise's Spaceborne Computer, the first long-term demonstration onboard the ISS of supercomputing capabilities from a commercial off-the-shelf computer system.

Testing of the first-ever system for production of the optical fiber ZBLAN onboard the ISS by Made In Space, to demonstrate the feasibility of in-orbit manufacturing.

Ultra-high-definition video imagery of Earth released to millions of Apple TV users.

Educational content aired during National Geographic's "One Strange Rock," watched by 81 million viewers.

FAST FACTS ON FY18

$19M+ IN THIRD-PARTY FUNDING
through Sponsored Programs (see pages 14-15)

~50% OF NEW PROJECTS & PROGRAMS
required no ISS National Lab funding

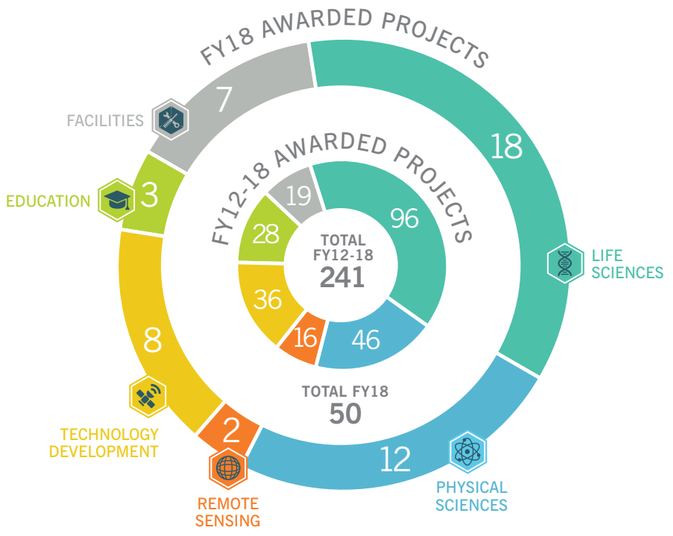
70% OF PROJECTS DELIVERED
to the ISS National Lab had significant private-sector involvement

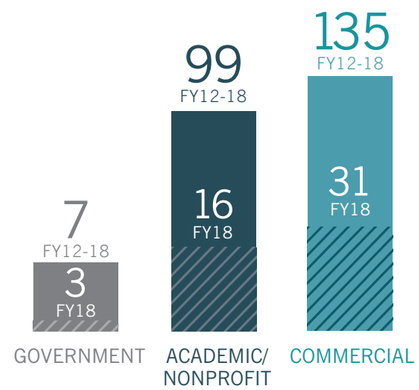
2M+ PEOPLE REACHED
by ISS National Lab education content

3 PATENTS GRANTED (see page 16)

17 JOURNAL ARTICLES PUBLISHED (see pages 22–25)

PROJECTS AND PROGRAMS SELECTED BY THE ISS NATIONAL LAB*





**These graphs represent projects and programs that were directly selected by the ISS National Lab managing entity or through ISS National Lab Sponsored Programs. They do not include projects managed by commercial service providers and education partner programs that may have been newly manifested for flight to the ISS National Lab in FY18.*

FAST FACTS ON THE PORTFOLIO TO DATE (FY12–18)

$150M+ IN EXTERNAL, NON-NASA FUNDING
supports the portfolio

$40M+ IN GRANT FUNDING
awarded

25% OF PORTFOLIO
originated from Sponsored Programs

50% OF GRANT FUNDING
goes directly to service providers (70%+ in FY18)

118 MEMBERS
of the ISS National Lab investor network

3.75% OF GRANT FUNDING
supports a growing education portfolio

3M+ PEOPLE
reached by education initiatives

500+ MEMBERS
of the Space Station Ambassador program for educators

IN-ORBIT ACTIVITIES ONBOARD THE ISS NATIONAL LAB

SUPPORTING GROWTH OF PRIVATE-SECTOR PARTICIPATION IN SPACE-BASED R&D

AT A GLANCE

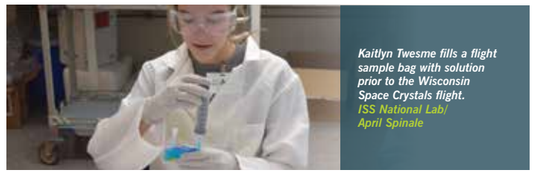
- In FY18, 74 payloads delivered to the ISS National Lab carried multiple projects and investigations across diverse sectors.
- More than 70% of launched payloads represented investigations from the private-sector and included projects from Fortune 500 companies, innovative startups, and leading media organizations.
- Two new commercially operated facilities were installed on the ISS National Lab.

The ISS National Lab strives to maximize utilization and science return, generating value and positive impact for the U.S. taxpayer. Private-sector utilization of the ISS National Lab was robust in FY18, representing 70% of payloads and including expansion of commercially operated facilities, illustrating demand and supply within the developing LEO economy. In-orbit commercial facility managers provide users with operational capabilities, experience, and engineering expertise to address unique research needs and are pioneering best practices for the future LEO marketplace.

DIVERSE PAYLOADS DEMONSTRATE INTEREST FROM A BROAD USER BASE

Five FY18 launch vehicles delivered 74 payloads to the ISS National Lab, many of which contained multiple projects. Below are selected highlights.

- **Fortune Global 500 company Budweiser** (Anheuser-Busch InBev) is studying the germination of barley to improve sustainable crop production here on Earth. Read more at issnl.us/ar1802.
- **National Geographic** installed a camera on the ISS to film educational content for their 10-episode television series "One Strange Rock," which was the network's fourth most watched series globally with 81 million viewers. View the series at: issnl.us/ar1803.
- **Spire Global** deployed the NanoRacks-LEMUR-2 satellites, part of a remote-sensing satellite constellation capable of providing global ship tracking and weather monitoring for the approximately 90% of global trade that is shipped by sea. Read more at issnl.us/ar1804.
- **Angiex**, a startup company awarded in collaboration with Boeing through the MassChallenge program (see pages 14–15), is evaluating a novel cancer therapy that targets tumor vascularization. Read more at issnl.us/ar1805.
- Researchers at the **University of California, Santa Barbara** seek to improve ocean-based oil and gas exploration, leading to commercial and environmental benefits. Read more at issnl.us/ar1806.



Kaitlyn Twesme fills a flight sample bag with solution prior to the Wisconsin Space Crystals flight. ISS National Lab/ April Spinale

European Space Agency astronaut Alex Gerst makes observations of the Domesticating Algae for Sustainable Production of Feedstocks in Space investigation. NASA

> *"Alpha Space's core business is commercial testing services on the exterior of the ISS, and our commercial implementation partnership with the ISS National Lab is crucial to our success. This partnership provides tangible benefits, especially help in finding customers and in ensuring that we have the ISS resources that we need to provide the services that we sell. The ISS National Lab is the ultimate resource for conducting scientific research and technology development in space."*
>
> —MARK GITTLEMAN, ALPHA SPACE

- Researchers at the **University of Florida** are studying algae in space toward possible bioproduction of new pharmaceuticals and health-related products. Read more at issnl.us/ar1807.
- The **University of Wisconsin–Madison** sponsored student crystal growth experiments on the ISS as part of an educational competition to promote science literacy. Read more at issnl.us/ar1808 and issnl.us/ar1809.

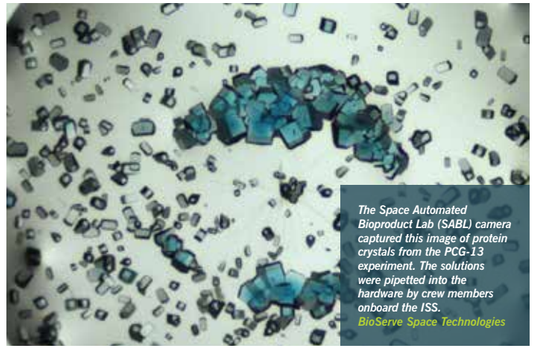
For a full listing of the ISS National Lab portfolio, including flight status of projects delivered this year, see issnl.us/ar1810.

EXPANDED FACILITY OPTIONS SUPPLY THE GROWING R&D USER BASE

14
COMMERCIALLY OPERATED FACILITIES
are onboard the ISS National Lab, managed by 8 companies.

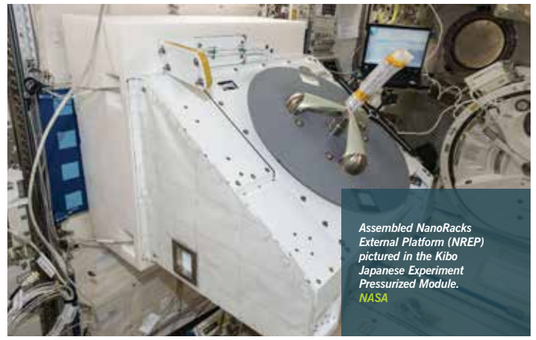
In-orbit commercial facility managers provide users with lab equipment, operational experience, and engineering support to address user research needs. The ISS National Lab now has 14 commercially operated laboratory facilities managed by eight companies, including two newly installed facilities in FY18 and one new facility manager:

- **The Multi-use Variable-gravity Platform (MVP)** operated by Techshot, Inc. is a centrifuge that can control temperature within experiment modules to support in-orbit control experiments by providing artificial gravity. The MVP is designed to collect and share data in near real-time from experiments in many fields, including those studying cells, protein crystals, and small model organisms such as fruit flies. For more information, see issnl.us/ar1811 and issnl.us/ar1812.
- **The Materials ISS Experiment Flight Facility (MISSE-FF),** developed by **new facility manager Alpha Space Test and Research Alliance, LLC** under a Cooperative Agreement with NASA, is a materials-science and component-testing platform on the outside of the ISS, providing data collection capabilities for passive and active material samples as well as other experiments requiring exposure to the extreme environment of space. For more information, see issnl.us/ar1813 and issnl.us/ar1814.



The Space Automated Bioproduct Lab (SABL) camera captured this image of protein crystals from the PCG-13 experiment. The solutions were pipetted into the hardware by crew members onboard the ISS. BioServe Space Technologies

> *"I believe that NASA and its Commercial Space Utilization Program, and the ISS National Lab, are succeeding at increasing demand for low Earth orbit commercial services. And Techshot is providing many of the picks and shovels that researchers are using in this 21st century gold rush in space."*
>
> —JOHN C. VELLINGER, TECHSHOT (TO THE NATIONAL SPACE COUNCIL AT THE WHITE HOUSE, MAY 18, 2018)



Assembled NanoRacks External Platform (NREP) pictured in the Kibo Japanese Experiment Pressurized Module. NASA

Other FY18 ISS National Lab commercial facility updates include:

- The Multi-User System for Earth Sensing (MUSES) from Teledyne Brown Engineering installed its first instrument, the DLR (German Space Agency) Earth Sensing Spectrometer (DESIS). The MUSES platform coupled with DESIS will assist in the advancement of Earth imaging, mapping, disaster recovery, and agricultural assessments.
- The NanoRacks External Platform (NREP) initiated the commercial platform's third customer mission.
- NanoRacks announced that Thales Alenia Space was selected as the latest partner in its commercial airlock program (joining Boeing and ATA Engineering). The first privately funded commercial airlock, "Bishop," is scheduled to become operational in 2020 and will increase capabilities in both R&D and ISS operations.

45
IMPLEMENTATION PARTNERS
provide commercial services to ISS National Lab users.

Additionally, dozens of innovative commercial Implementation Partners support the growing demand for space-based research by providing support services on the ground (see page 21), playing a critical role in the success of the ISS National Lab R&D community.

Collectively, these projects, programs, and service providers contribute to growth of the LEO economy by translating use of the ISS National Lab into downstream value to benefit life on Earth. In addition to the anecdotes and advancements discussed above, quantitative assessments of value (based on self-reported data from our investigators and review by external subject matter experts) indicate potential future incremental revenue from the ISS National Lab portfolio will exceed $900 million from estimated addressable markets totaling more than $100 billion.

DESIS image of Huntsville, Alabama, produced within 48 hours of installation onboard the MUSES platform. DLR and Teledyne Brown Engineering

ACCELERATING ACCESS

OPTIMIZING INFRASTRUCTURE FOR SUCCESS OF THE LEO COMMUNITY—NOW AND FOR THE FUTURE

AT A GLANCE

- The ISS National Lab community involves researchers, service providers, sponsors and investors, and experienced education partners.
- Multiple events and new digital tools in FY18 enhanced communication among and feedback from these diverse groups.
- Iterative feedback is improving the tools and processes that support an evolving landscape of LEO activity.

The ISS National Lab is a public-private partnership that leverages investment and unique space access to facilitate growth of the LEO economy. Many organizations within the spaceflight R&D ecosystem—such as service providers, investors, and the research community—depend on ISS National Lab functions and tools for their activities and growth, so it is important to refine these tools to foster community success. In FY18, these refinements included innovating solutions for digital community interaction and continuing to streamline the timeliness of project selection and development.

SHOWCASING OPPORTUNITIES FOR ISS NATIONAL LAB COMMERCIAL SERVICE PROVIDERS

As access to LEO and the ISS has increased, new private-sector service providers and facility operators have emerged to support the needs of diverse spaceflight R&D users. In January 2012, we began formalizing partnerships with these businesses and are continuing to improve how we facilitate the matching of ISS National Lab users with these service providers, also called Implementation Partners.

70%
OF ISS NATIONAL LAB GRANT FUNDING
went directly to businesses providing support services to lab users in FY18. These services are essential to implementing R&D projects onboard the ISS.

An online portal for ISS National Lab Implementation Partners was created this year and hosts information about potential users and their spaceflight R&D project needs, allowing providers to ask questions, submit quotes and proposals, and work together with users. This interactive platform allows for feedback at regular intervals and will continue to evolve to provide additional value to the LEO ecosystem.

Providers also had the opportunity to attend two ISS National Lab Implementation Partner workshops, hosted to encourage dialogue and feedback about how we connect users with providers and how we can better enable provider business development activities in the marketplace. Workshop sessions focused on the ISS National Lab Resource Utilization Planning System and professional development in sales and marketing.

A panel of investors discuss the opportunities and challenges within the global space economy at the 2018 ISSR&D Conference.
ISS National Lab/ Mauricio Hoyos

INCREASING CAPITAL FLOW

Execution of complex R&D projects can be capital intensive. Traditionally, government funding has dominated LEO R&D investment; however, we have seen improved potential in recent years to engage additional resources. To increase the probability for commercially successful R&D in LEO, we partner with sponsor organizations and accelerator programs, while also expanding our reach in the corporate and accredited investor community to potentially infuse new capital into this growing ecosystem. During FY18, the ISS National Lab investor network nearly doubled in membership, expanding to 118 participants.

> *"The ISS National Laboratory is a necessary pathfinder, along with private companies and investor groups, for the transition of the ISS toward a commercial platform ecosystem. The National Laboratory, along with others, will allow demand and supply to grow toward a sustainable U.S. commercial in-orbit platform(s) market. After a successful transition, we believe there remains a need for a National Laboratory capability as a part of a larger healthy ecosystem in low Earth orbit."*
>
> —ERIC STALLMER, COMMERCIAL SPACEFLIGHT FEDERATION

$150M+
IN EXTERNAL, NON-NASA MONEY
supports the ISS National Lab portfolio—committed over the past 5 years and representing more than double our seed funding from NASA during that time.

Now in its third year, we held the ISS National Lab start-up pitch event "Space Investment 2018" in conjunction with the ISS Research and Development (ISSR&D) Conference in San Francisco in July. The well-attended event brought together venture capitalists and corporate investors with innovators and entrepreneurs. Presentations focused on multifaceted investment opportunities in the rapidly expanding satellite sector as well as space-based biotechnology, materials science, and technology development areas.

We also launched a new online Investment Portal during the ISSR&D Conference. The Investment Portal is a free tool to facilitate dialogue between entrepreneurs and investors focused on commercial opportunities that emerge in the NewSpace and ISS ecosystems. By the end of FY18, the portal included 15 investment opportunities and had resulted in multiple capital introductions.

STREAMLINING INTERNAL PROCESSES TO FAST-TRACK SCIENCE


The Orbital ATK Antares rocket, with the Cygnus spacecraft onboard, launches from Pad-0A, Monday, May 21, 2018 at NASA's Wallops Flight Facility in Virginia.
NASA/Aubrey Gemignani

The time it takes ISS National Lab projects to transition from concept to award continues to shorten, adding innovative new users more rapidly to a growing portfolio. Having an efficient, repeatable, and documented proposal development, evaluation, and selection process establishes expectations with customers, improves stewardship of funding, and allows the ISS National Lab to more efficiently manage an increasing number of projects. Since 2016, the time it takes for a project to progress from concept to award has decreased by 50%.

Additionally, to better streamline use of specific resources, the ISS National Lab Resource Utilization Planning System (RUPS) enables optimal use of flight, increment, and facility allocation. RUPS continues to improve in its function to compare the capability of each resource during a given timeframe against the total resources required by the projects planned during that time—and we continue to refine how we use this information to guide business development efforts toward acquiring projects that fill utilization gaps. Using RUPS, we can adjust our business development targets in real time as research requirements mature, facility options evolve, and the payload manifest grows.

SPACE STATION EXPLORERS CONSORTIUM CONTINUES COLLABORATION

Space Station Explorers partner DreamUp interacts with attendees in the Space Station Explorers exhibit at the 2018 USA Science and Engineering Festival.
ISS National Lab

A range of educational outreach activities are supported and promoted through Space Station Explorers, a consortium of organizations that make science, technology, engineering, and mathematics (STEM) learning exciting through programs and products related to the ISS National Lab.

2M+
PEOPLE WERE REACHED THROUGH SPACE STATION EXPLORERS IN FY18—
almost double the reach from the last 5 years of ISS National Lab STEM outreach combined.

A record number of participants attended the 2018 Space Station Explorers Annual Meeting to discuss topics including program integration, marketing, and fundraising. The event builds cohesion among consortium members, helping shape the future of ISS National Lab education initiatives. Near-term actions included working groups to build cross-program partnerships and scale visibility, new collaborative proposals by program teams, and a new agreement with NSF to promote educational uses of the ISS.

> *"The ISS National Lab cultivates success for students around the country in a number of ways. They help to amplify student voices via their magazine **Upward**, their website and blog, pre-launch visitor activities, and via participation in contests, particularly those with sponsors such as Marvel. Events such as the Space Station Explorers yearly meeting are also important opportunities for those supporting students alongside the ISS National Lab to meet, collaborate, and improve."*
>
> —CARIE LEMACK, DREAMUP

POWER IN PARTNERSHIP

MATURING PROGRAMS AND RELATIONSHIPS FOR MAXIMUM BENEFIT

AT A GLANCE

- Increased external R&D investment enabled the ISS National Lab to scale demonstrated programs for maximum benefit.
- New partnerships with key players in the next era of LEO development helped support today's R&D while carving a path toward the future.
- New and ongoing education-focused partnerships strengthened reach within underserved STEM communities and groups.

The ISS National Lab supports R&D with benefit to life on Earth, as well as private-sector activities that support this R&D, to return value to the nation and strengthen the foundation for the growing LEO marketplace. In FY18, continued growth in collaborative efforts helped expand ISS National Lab R&D activities, attract new users, increase external R&D investment, and better reach underserved youth.

> *"The ISS National Lab provides a much needed and appreciated service to enable new entities besides the 'big players' to participate in ISS research opportunities."*
>
> —HANS-JUERGEN ZACHRAU, AIRBUS DS SPACE SYSTEMS, INC.

REPEAT SPONSORED PROGRAMS NURTURE A ROBUST PORTFOLIO

More than $19 million in external, non-NASA funding was committed in support of FY18 projects selected as part of Sponsored Programs—research competitions funded by a third party. This amount of Sponsored Program funding is nearly equal to all previous years combined. For FY18, these third parties included NIH, NSF, and Boeing—all previous program sponsors returning to support additional R&D.

- Four new research opportunities with NIH and NSF accounted for most of the FY18-committed funding and built on several years of ISS National Lab collaborations with these prominent research organizations.
- Boeing's support funded both the education-focused Genes in Space program and entrepreneurial R&D in partnership with the MassChallenge program, one of the leading startup accelerators. Both programs are multiyear and growing.

For a full list of FY18 research competitions and Sponsored Programs, including details about the innovations and R&D objectives they support, see pages 14–15.

Representatives from the ISS National Lab and Boeing pose for a photo with the MicroQuin team, winners of the MassChallenge Technology in Space competition. MassChallenge

NEW PARTNERSHIPS LOOK TO THE FUTURE OF LEO

Ken Shields (left), of the ISS National Lab, and Akos Hegyi (right), of Airbus DS, participate in a panel discussing commercial services in low Earth orbit at the 2018 ISSR&D Conference. ISS National Lab/ Mauricio Hoyos

Developing relationships with future potential platform owners and aerospace companies is the first step toward enabling a transition from the ISS to commercial LEO platforms. In FY18, we formalized contracts with several such companies to support new-to-space R&D activities, startup companies, and other businesses that depend on the longevity and reliability of space access and infrastructure at low cost, including:

- **Airbus DS North America** and **Bigelow Space Operations** (a division of Bigelow Aerospace), two key companies in the aerospace industry that plan to expand the capabilities of the ISS National Lab, ensuring that users derive maximum benefit.
- **ProXopS** and **SEOPS**, two companies whose plans, respectively, involve providing a multipurpose research platform and installing a cargo-vehicle-based small satellite deployment system.

INVESTING IN THE NEXT GENERATION OF EXPLORERS

In FY18, promoting STEM literacy in underserved communities and supporting engagement of young women in STEM topics and careers were notable in various education-focused partnership activities:

- **Story Time From Space** offers a combination of science, literacy, and entertainment through a library of free video recordings of astronauts on the ISS reading children's books and performing related science demonstrations.
- **DreamUp**, which has supported space-themed educational programming for almost 10 years, released a new set of educational kits that bring real ISS research into the classroom in a way that is authentic yet affordable.
- **Quest Institute**, which supports hands-on student experiments inspired by the ISS National Lab, specifically funded underserved schools this year, nearly doubling the number of schools in their program.
- **SciGirls in Space**, produced by Twin Cities PBS, will feature space-themed episodes including profiles of female scientists who have flown ISS experiments. The Emmy-award-winning television series is the most widely accessed female-focused STEM program in the nation, reaching more than 14 million girls (grades 3–8), educators, and families.
- **Alliance For Girls** signed a memorandum of understanding with us to formalize plans for mutual support through co-branding, outreach, and educational programming. Based in San Francisco, this is the largest alliance of girls' organizations in the country, reaching more than 300,000 underrepresented girls through member agencies.
- **Girl Scouts of Central Indiana** is the newest Scouts group to partner with us and has plans to create an ISS-themed merit badge in collaboration with pharmaceutical company and repeat ISS National Lab user Eli Lilly & Company.

178K+
ONLINE VIEWINGS OF STORY TIME FROM SPACE
occurred in just the last three months of FY18—many in classroom settings that reached dozens of students with each viewing.

500+
MEMBERS
are part of the ISS National Lab Space Station Ambassador program.

Additionally, the Space Station Ambassador program offers educators an opportunity to partner in support of ISS National Lab activities, serving as an advocate, conducting workshops and seminars, and developing educational content. For more information on the Space Station Ambassador program, visit issnl.us/ar1816.

NASA astronaut Serena Auñón-Chancellor floats in the cupola during a Story Time From Space reading on the space station. Story Time From Space

> *"We have seen students get more engaged with STEM and school in general as a result of all of the programs available through Space Station Explorers partners. The ability for students to be recognized through awards and speaking opportunities at conferences, highlighting their experiments, gives them the motivation and recognition that makes all of our programs stand out."*
>
> —DANNY KIM, QUEST INSTITUTE

10+
NEW ISS NATIONAL LAB EDUCATION-FOCUSED PARTNERSHIPS
were formed in FY18.

A Quest for Space student poses with his research poster at Kennedy Space Center during the SpaceX CRS-14 launch. ISS National Lab/ Nathan Adams

RESEARCH COMPETITIONS

TACKLING BIG QUESTIONS TO SOLVE REAL-WORLD PROBLEMS

AT A GLANCE

- Two 2017 competitions, one in collaboration with Target Corporation, announced awardees.
- Ten new ISS National Lab research competitions were released in 2018, most supported by funding from program-level sponsors.
- Programs sponsored by NIH and NSF provide powerful multiyear research opportunities that fuel innovation, new-customer entry, and national prominence.

Formal calls for research proposals in specific R&D focus areas complement traditional business development and outreach to build a diverse user base. All of these competitions involve either sponsorship funding from a non-NASA third party or non-monetary, in-kind collaborations with partner organizations. For more information on ISS National Lab research competitions, see issnl.us/ar1817.

PREVIOUSLY RELEASED COMPETITIONS AWARDED IN FY18

- **ISS Cotton Sustainability Challenge,** *sponsored by Target Corporation (up to $1M)*
  Cotton is a natural plant fiber and an important raw material for the production of textiles and clothing, but its cultivation requires sustainable access to limited natural resources such as water. This challenge awarded several projects across multiple sectors that will leverage the ISS National Lab to generate ideas for improving the utilization of ground-based natural resources for sustainable cotton production. This was the first ISS National Lab Sponsored Program fully funded by a private-sector company. Read more at issnl.us/ar1818.
- **FY18 Technology in Space Prize,** *co-sponsored by Boeing ($500K total) in association with MassChallenge Boston*
  Each year, the ISS National Lab and Boeing support a prize for startups associated with MassChallenge. This year's awards provided funding to three companies (Cellino Biotech, Guardion Technologies, and MakerHealth) to conduct research on the ISS National Lab. Read more at issnl.us/ar1819.

> *"The ISS National Lab unlocked the scientific potential of our technology and helped launch us to the next level in our company's growth."*
>
> —BRIAN HESS, LAUNCHPAD MEDICAL, LLC (TECHNOLOGY IN SPACE PRIZE AWARDEE)

COMPETITIONS RELEASED AND AWARDED WITHIN FY18

- **Microphysiological Systems Program for Translational Research in Space (also known as "Chips in Space"),** *sponsored by NIH (up to $12M)*
  NIH's National Center for Advancing Translational Sciences (NCATS) and National Institute of Biomedical Imaging and Bioengineering (NIBIB) collaborated to support an ISS National Lab funding opportunity focused on human physiology and disease. Data from this research—which will feature tissue chips—will help develop and advance technologies to improve human health. This opportunity is part of a four-year collaboration through which NIH will provide funding for space-based research investigations to benefit life on Earth. It is a reissue of an FY16 opportunity that resulted in five awarded projects.
- **Tissue Engineering on ISS to Benefit Life on Earth,** *sponsored by NSF (up to $1.8M)*
  This opportunity supports use of the ISS National Lab for enhancements in the field of transformative tissue engineering, within the scope of the NSF Engineering of Biomedical Systems Program. This includes cellular engineering, tissue engineering, and modeling of physiological systems. This is one of four collaborations with NSF since 2016 to fund ISS National Lab R&D.

Chips In Space Mission Patch
ISS National Lab/NCATS

BEHIND THE SCIENCE

RECENT ADVANCES IN BIOENGINEERING have enabled the manufacture of systems using human cells on chips to represent functional units of an organ. In parallel, developments in stem cell technology allow cultivation of tissue from humans with specific disease conditions. Advancing this research on the ISS National Lab promises to accelerate the discovery of molecular mechanisms that underlie a range of common human disorders and to improve understanding of drug targets and treatments in an environment that better mimics 3D tissue structures within the body. Such tissue chip research was supported by two competitions in FY18.

> *"The NIH Chips in Space collaboration will allow us to better understand disease processes in a way we never could before and improve human health by deploying tissue-chip technology on the ISS National Lab."*
>
> —DANILO A. TAGLE, NCATS

- **Fluid Dynamics and Particulate and Multiphase Processes Research on the ISS to Benefit Life on Earth,** *sponsored by NSF (up to $2M)*
  This opportunity supports use of the ISS National Lab for R&D in fluid dynamics and particulate and multiphase processes. The absence of phenomena such as thermal convection, sedimentation, and buoyancy in microgravity contribute to changes in fluid behavior in space, revealing fundamental properties of how fluids function and enabling design of advanced materials, electronics, nanotechnologies, and other consumer and healthcare products. This is our second collaboration with NSF dedicated to funding fluid dynamics in space, and one of four NSF collaborations.
- **Request for Proposals Utilizing the MISSE Platform for Materials Science Research in Space,** *issued in collaboration with Alpha Space Test and Research Alliance (non-monetary)*
  The MISSE-FF platform supports commercial and academic investigations in the field of materials science. Launched this year, the facility provides an in-orbit platform deployed externally on the ISS, enabling access to temperature variation, atomic oxygen, and enhanced radiation exposure, among other factors, without requiring extravehicular activity (for more information, see page 9). This research opportunity sought projects that will use the extreme conditions of space for development and testing of new materials, components, and systems with Earth-based applications.

The AlphaSpace MISSE-FF (Materials ISS Experiment Flight Facility) is prepared to be installed to its external location on the ISS.
NASA

- **Several education-focused research competitions:**
  - *Genes in Space, sponsored by Boeing ($250K) in collaboration with miniPCR, Math for America, and New England Biolabs. For more information see page 25.*
  - *Space Crystal Prize, in collaboration with The University of Wisconsin–Madison (non-monetary). For more information see page 8.*
  - *Guardians of the Galaxy Space Station Challenge, in collaboration with Marvel Entertainment, Space Tango, and NanoRacks (non-monetary). For more information see page 29 and issnl.us/ar1820.*

Students and parents involved in the Wisconsin Crystal Growing competition take a group photo at the SpaceX CRS-14 launch.
ISS National Lab/ Nathan Adams

COMPETITIONS RELEASED THIS YEAR, WITH AWARDS EXPECTED IN FY19

- **FY19 Technology in Space Prize,** *co-sponsored by Boeing ($500K total) in association with MassChallenge Boston (non-monetary)*
  For the sixth year in a row, the ISS National Lab is supporting a "Technology in Space" prize associated with MassChallenge. For the fifth year in a row, Boeing will be a co-sponsor. To date, MassChallenge alumni have raised more than $3 billion in funding and created more than 80,000 jobs. As MassChallenge's flagship location, MassChallenge Boston has accelerated more than 1,000 startups from across the country.
- **Request for Proposals for Rodent Research Reference Mission-1,** *issued in collaboration Taconic Biosciences (rodent supplier, non-monetary) and BioServe Space Technologies (biospecimen administration, non-monetary)*
  This opportunity will support investigators seeking to access biological specimens from the first ISS National Lab Rodent Research Reference Mission. On SpaceX CRS-16, 40 mice of two different age groups were launched to the ISS. Awardees from this opportunity will evaluate ground-control and spaceflight biospecimens from animal models of human disease to improve patient care on Earth for diseases and aging effects involving bone and muscle. For more information on the benefits of rodent research in space, see page 22.
- **2018 Microgravity Molecular Crystal Growth Utilization Solicitation,** *issued in collaboration with multiple service providers (non-monetary)*
  Microgravity has been used for more than 30 years to improve outcomes of crystal analyses, and the ISS National Lab continues to support such efforts through the Microgravity Molecular Crystal Growth Program. This solicitation provides the opportunity for researchers to propose new ideas for approaches to be tested in the space environment in the context of known crystallization behavior in ground studies. For more information about crystal growth in space, see page 25.

An Emulate, Inc. tissue chip photographed in the hand of an astronaut in a space suit. NASA

SUCCESS STORIES

FY18 ACHIEVEMENTS DEMONSTRATE THE VALUE OF THE ISS FOR INNOVATION

AT A GLANCE

- Three granted patents are related to ISS National Lab research by Procter & Gamble and Fiber Optics Manufacturing in Space, providing compelling evidence of the value of spaceflight R&D.
- Peer-reviewed publications showcased knowledge advancement across myriad fields, including work by student scientists.
- Success stories from Hewlett Packard Enterprise, Apple, and others complemented notable in-orbit firsts from ISS National Lab service providers and users.

Progress and success of users and laboratory facility service providers showcased the value of the ISS National Lab in FY18. Three patents directly tied to ISS National Lab R&D were granted, demonstrating the innovation achieved by companies using the orbiting laboratory. These successes are accompanied by several other published patent applications and peer-reviewed journal articles that indicated the value of the ISS National Lab via public dissemination of results to scientific peers. Additionally, anecdotal success stories and in-orbit "firsts" continued to highlight diverse value and impact from the ISS National Lab.

PATENT APPLICATIONS DEMONSTRATED PROGRESS TOWARD PRODUCT DEVELOPMENT

In February, three patent applications were published related to ISS National Lab research performed by Procter & Gamble (P&G)—two of which were granted in September. Spaceflight has been a part of the P&G research portfolio for almost a decade, with experiments studying complex fluid systems under time scales not possible on Earth. The patents describe proposed improvements related to consumer-product functional characteristics and shelf life.

An additional patent granted in June relates to production of the optical fiber ZBLAN on the ISS by Fiber Optics Manufacturing in Space. ZBLAN may exceed the performance of other fibers in common use across many sectors—including use in medical devices, sensors for the defense industry, and telecommunications—and the patent describes operational methods for future commercial microgravity ZBLAN production systems. In-orbit manufacturing may reduce defects that can form within ZBLAN fibers, which would increase functionality and value of the product.

PEER-REVIEWED PUBLICATIONS LEND CREDIBILITY AND PRESTIGE TO THE ISS NATIONAL LAB

In FY18, 17 published academic journal articles detailed results related to ISS National Lab investigations in the fields of biomedical research and particle physics, including a student-authored publication. For a detailed list of FY18 academic literature describing ISS National Lab projects and results, see pages 22–25, and for a full citation list of all publications related to the ISS National Lab, see Appendix I or issnl.us/ar1832.

Additionally, *Stem Cells and Development*, a globally recognized premier source of clinical, basic, and translational research on stem cells and their potential therapeutic applications, published a special space issue in FY18, highlighting work from ISS National Lab researchers: issnl.us/ar1822.

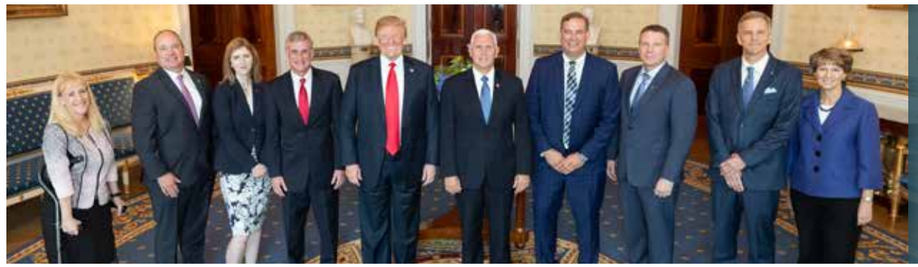
BEHIND THE SCIENCE

CONVECTION AND OTHER GRAVITY-DEPENDENT PHENOMENA are reduced or absent in microgravity, which enables highly accurate, repeatable, and measurable processes for materials science initiatives in upstream R&D and in-orbit production.

For more information on these projects, see the following resources.

- *Upward* article "The ISS & Household Products: How P&G is Using Space to Improve Customer Experience": issnl.us/ar1821
- *Upward* article "Exotic Glass Fibers From Space: The Race to Manufacture ZBLAN": issnl.us/ar1850

2015 Genes In Space winner Anna-Sophia Boguraev presents her experiment during the SpaceX CRS-8 prelaunch briefing in April 2016.
NASA



Techshot President and CEO John C. Vellinger (fourth from right) with President Donald Trump, Vice President Mike Pence, and members of the National Space Council.
Official White House Photo by Shealah Craighead

SUCCESS STORIES DEMONSTRATED THE VALUE OF THE ISS NATIONAL LAB

Individual R&D and private-sector achievements in FY18 highlight the range of ISS National Lab accomplishments.

NanoRacks-Remove Debris Satellite launch view taken by Expedition 56 crew.
NASA

- **NanoRacks** successfully deployed its largest microsatellite to date during the first deployment using the Kaber Microsatellite Deployer, a program that allows for deployment of a larger class of satellites (up to 100 kilograms) from the ISS. NanoRacks then broke the size record again during its third major microsatellite deployment: issnl.us/ar1825.
- **The Made In Space fiber optic puller system** was successfully activated for the first time onboard the space station, representing the first ISS National Lab project designed to demonstrate the commercial merit of manufacturing optical fiber in space: issnl.us/ar1826.
- **Apple TV** previewed new aerial images of Earth taken by astronauts on the ISS National Lab during a Worldwide Developers Conference keynote. On September 17, these images were made available to millions of Apple TV users as part of the release of tvOS 12: issnl.us/ar1827.
- **Zaiput Flow Technologies** validated the company's proprietary gravity-independent liquid-liquid separation technology, the first of its kind, onboard the ISS National Lab. Instead of relying on liquid sedimentation to separate liquids, Zaiput's system relies on surface tension and provides efficient continuous flow extraction, which is critical for chemical synthesis and could lead to significant advances in drug development and production: issnl.us/ar1828.

> *"Apple, in collaboration with the ISS National Lab, now offers aerial screensavers on Apple TV shot from the ISS by astronauts. These video screensavers allow our customers worldwide to enjoy stunning scenes of Earth in beautiful 4K HDR. Huge thanks to the ISS National Lab for all their help in taking this project from concept to reality."*
>
> —BERNADETTE SIMPAO, APPLE

> *"The ISS National Lab represents a unique innovation platform that provides an opportunity to think about science in a whole new way and serves as a gateway to future commercial applications in low Earth orbit. In addition to supporting research, we are pleased to provide solutions for the supply chain that will further facilitate space station utilization."*
>
> —TWYMAN CLEMENTS, SPACE TANGO

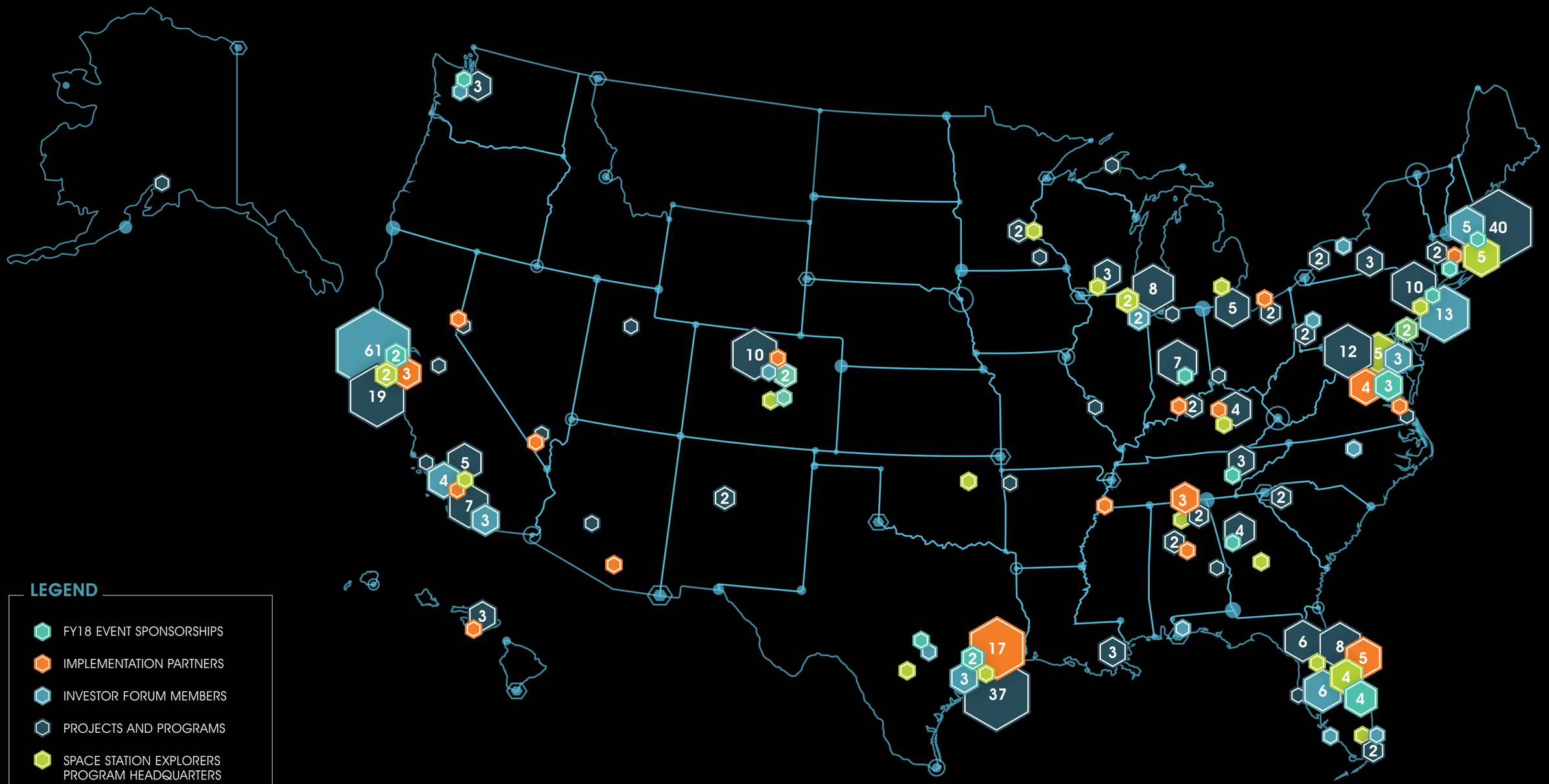
- **The Spaceborne Computer,** developed by Hewlett Packard Enterprise (HPE), completed one year of successful operations. This first long-term demonstration onboard the ISS of supercomputing capabilities from a commercial off-the-shelf computer system, achieving more than 1 trillion calculations per second, is demonstrating the ability of HPE's innovative software-hardening process to protect the computer's hardware from the harsh conditions of space: issnl.us/ar1829.
- **Bryce Hilliard,** a seventh-grade student scientist and participant in the Space Station Explorers Tomatosphere™ program, founded Space Dreamers, a nonprofit whose mission is to bring space science to students across the U.S. by creating kiosks for use in public areas in schools. The kiosks will incorporate information about ISS education programs and provide a live view of Earth from the ISS: issnl.us/ar1830.
- **Twyman Clements,** co-founder and CEO of Space Tango, was named one of the Top 100 "Most Creative People in Business 2018" by Fast Company, a business media brand with an editorial focus on innovation in technology, leadership, and design. Space Tango is an in-orbit facility manager and the Implementation Partner for several ISS National Lab R&D activities and education partner programs: issnl.us/ar1831.

Space Tango CEO Twyman Clements works with the TangoLab in preparation for SpaceX CRS-12.
ISS National Lab/ Nathan Adams

ISS NATIONAL LAB ON THE MAP

A SNAPSHOT OF FY18 ACTIVITIES

The ISS National Lab engages partners, users, and investors across the country to support diverse initiatives, from R&D projects to educational programs to new collaborative funding opportunities. We are empowered by this growing community to pursue multiple inroads to generate value to life on Earth from ISS utilization. Here is a snapshot of our FY18 key activities and the current network of participants in the ISS National Lab mission. For more details on these events and organizations, see pages 20–21.



LEGEND

- FY18 EVENT SPONSORSHIPS
- IMPLEMENTATION PARTNERS
- INVESTOR FORUM MEMBERS
- PROJECTS AND PROGRAMS
- SPACE STATION EXPLORERS PROGRAM HEADQUARTERS

ISS NATIONAL LAB ON THE MAP

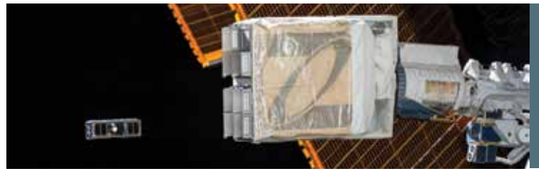
CONTINUED

THE SPACE STATION EXPLORERS CONSORTIUM

PROGRAM	PARTNER	LOCATION
Amateur Radio on the International Space Station (ARISS)	AMSAT	Kensington, MD
DreamUp	DreamUp	Washington, DC
ExoLab	Magnitude.io	Berkeley, CA
Genes in Space	Amplyus	Cambridge, MA
Guardians of the Galaxy	Marvel Custom Solutions	New York, NY
	Space Tango, Inc.	Lexington, KY
	DreamUp	Washington, DC
Growing Beyond Earth	Fairchild Tropical Botanic Garden	Coral Gables, FL
Higher Orbits	Higher Orbits	Leesburg, FL
ISS Above	Image BEAM, Inc.	Monrovia, CA
National Geographic	Cengage Learning	Evanston, IL
Orion's Quest	Orion's Quest	Canton, MI
Quest for Space	Quest Institute for Quality Education	San Jose, CA
Sally Ride ISS (Earth Knowledge Acquired by Middle school students) EarthKAM	United States Space & Rocket Center	Huntsville, AL
SciGirls	Twin Cities Public Broadcasting Station (PBS)	St. Paul, MN
Space Crystals	University of Wisconsin – Madison	Madison, WI
Space Station Academy	Virtual High School Collaborative	Maynard, MA
Storytime from Space	T2 Science & Math Education Consultants	League City, TX
Student Spaceflight Experiments Program	National Center for Earth and Space Science Education (NCESSE) Tides Center	Capitol Heights, MD
Tomatosphere	First the Seed Foundation	Alexandria, VA
Windows on Earth	TERC	Cambridge, MA
Zero Robotics	Massachusetts Institute of Technology (MIT)	Cambridge, MA
ISS Virtual Tour	Kennedy Space Center Visitor Complex	Kennedy Space Center, FL
	Astronauts Memorial Foundation	Kennedy Space Center, FL
	Crista McAuliffe Center	Framingham, MA
	Colorado Consortium for Earth and Space Science Education	Colorado Springs, CO
	Scobee Education Center at San Antonio College	San Antonio. TX
	Museum of Aviation	Robins Air Force Base, GA
	Tulsa Air & Space Museum	Tulsa, OK
National Design Challenge	National Design Challenge	Chicago, IL
Space Station Ambassador Program	ISS National Lab	Melbourne, FL
Space Station Explorers Live	ISS National Lab	Melbourne, FL

For more information on educational program activities in FY18, see page 13.

Space Automated Bioproduct Laboratory (SABL) incubator used onboard the International Space Station to conduct cell culture and other biological experiments.
NASA

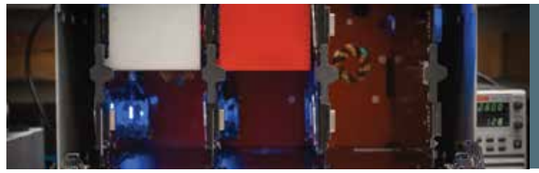


NanoRacks CubeSat Deployer shortly after successful deployment of CubeSats during Expedition 51.
NASA

IN-ORBIT COMMERCIAL FACILITY MANAGERS

COMMERCIAL FACILITY MANAGER	IN-ORBIT FACILITY
Alpha Space	▪ Materials ISS Experiment Flight Facility (MISSE-FF)*
BioServe Space Technologies	▪ Space Automated Bioproduct Lab (SABL)
Made In Space	▪ Additive Manufacturing Facility
NanoRacks, LLC	▪ NanoRacks Internal Platform (NanoLabs) ▪ NanoRacks CubeSat Deployer ▪ NanoRacks External Platform (NREP) ▪ NanoRacks PlateReader
Space Tango	▪ TangoLab-1 ▪ TangoLab-2
STaARS	▪ Space Technology and Advanced Research System
Techshot	▪ Bone Densitometer ▪ Advanced Space Experiment Processor (ADSEP) ▪ Multi-use Variable-gravity Platform (MVP)*
Teledyne Brown Engineering	▪ Multi-User System for Earth Sensing (MUSES)

**New in FY18*



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

Techshot's Multi-use Variable-gravity Platform (MVP).
Techshot Inc.

ISS NATIONAL LAB IMPLEMENTATION PARTNERS

▪ *In-orbit commercial facility managers*

- AECOM, Kennedy Space Center, FL
- AIRBUS DS Space Systems, Inc., Webster, TX
- Alpha Space, Houston, TX
- Astrotech Space Operations, Titusville, FL
- Bigelow Space Operations, Inc., North Las Vegas, NV
- Bionetics Corporation, Yorktown, VA
- BioServe Space Technologies, Boulder, CO
- Boeing Space Operations Company, Kennedy Space Center, FL
- Business Integra Technology Solutions (BI Tech), Houston, TX
- CSS-Dynamac, Fairfax, VA
- Emerald City Initiatives, Inc., Huntsville, AL
- FedEx Space Services, Memphis, TN
- HNu Photonics, LLC, Wailuku, HI
- Intuitive Machines, Houston, TX
- Iron Ring Technologies, LLC, Houston, TX
- Jacobs XPrSS, Houston, TX
- KBRwyle, Houston, TX
- LaMont Aerospace, Houston, TX
- Leidos Innovations Corporation, Reston, VA
- M&B Engineering, League City, TX
- Made In Space, Moffett Field, CA
- MDA Corporation, Houston, TX
- MEI Technologies, Houston, TX
- Micro Aerospace Solutions, Melbourne, FL
- NanoRacks, LLC, Houston, TX
- Oceaneering Space Systems, Houston, TX
- Paragon Space Development Corporation, Tuscon, AZ
- ProXopS, LLC, Houston, TX
- Raven Aerospace Technology, Inc., Houston, TX
- SEOPS, LLC, Houston, TX
- Sierra Nevada Corporation, Sparks, NV
- SpacePharma, Palo Alto, CA
- Space Systems Research Corporation, Alexandria, VA
- Space Tango, Inc., Lexington, KY
- Space Technology and Advanced Research Systems, Inc., (STaARS), Houston, TX
- Techshot, Greenville, IN
- Tec-Masters, Inc., Huntsville, AL
- Teledyne Brown Engineering, Huntsville, AL
- Thales Alenia Space (TAS) | ALTEC, Melbourne, FL
- The Aerospace Corporation, Los Angeles, CA
- ThinkSpace, Mountain View, CA
- UTC Aerospace Systems, Windsor Locks, CT
- Vencore, Chantilly, VA
- ZIN Technologies, Cleveland, OH
- UAB Engineering, Birmingham, AL

PUBLICATIONS

PEER-REVIEWED JOURNAL ARTICLES SHARE SCIENTIFIC ACHIEVEMENTS

AT A GLANCE

- Five of 17 new papers detailed rodent research, spaceflight studies that aid the study of molecular underpinnings to human disease on Earth.
- Four papers detailed remote sensing research that looks outward into space and may reveal fundamental aspects about our universe and its origins.
- Three papers detailed findings about cardiac stem cells, which behave differently in microgravity and may yield results critical for regenerative medicine.
- Additional R&D in protein crystal growth, nanotechnology, microbiology, and DNA sequencing also resulted in FY18 publications.

To date, 127 publications derive from ISS National Lab activities, 17 of which were published in FY18. Areas of study span from biomedical research to theoretical physics, and brief descriptions of the article findings are listed below. For detailed descriptions of the FY18-published papers and all ISS National Lab journal articles, see issnl.us/ar1832.

BEHIND THE SCIENCE

RESEARCH USING MODEL ORGANISMS SUCH AS RODENTS provides insight into not only effects of spaceflight on astronaut health but also effects that mimic human disease on Earth, such as bone loss, muscle wasting, heart disease, immune dysfunction, and other conditions. Five FY18 papers discuss rodent research.

To learn more about rodents in space, see the following resources.

- *Upward* article "Rodent Rocket Research: Biomedical Discovery in Space": issnl.us/ar1833
- *Upward* article "Building Bones: Testing a New Osteoporosis Therapy With Mice in Microgravity": issnl.us/ar1834
- Seeker's video on animal models in space: issnl.us/ar1835

Unveiling "Musica Universalis" of the Cell: A Brief History of Biological 12-Hour Rhythms.

Zhu B, Dacso CC, O'Malley BW.
J Endocr Soc. 2018; 2(7):727–752.

This article proposes a model in which mammalian cellular homeostasis and overall health rely on both the circadian (24-hour) clock and a 12-hour clock.

Development of a Step-Down for Altering Male C57BL/6 Mouse Housing Density and Hierarchical Structure: Preparations for Spaceflight Studies.

Scofield DC, Rytlewski JD, Childress P, et al.
Life Sci Space Res. 2018; 17:44–50.

This study explores optimal housing for male mice on the ISS and is part of a broader line of research on bone healing in microgravity.

Nfatc1 is a Functional Transcriptional Factor Mediating Nell-1-Induced Runx3 Upregulation in Chondrocytes.

Li C, Zheng Z, Zhang X, et al.
Int J Mol Sci. 2018; 19(1): E168.

This paper examines the role of T-cells in mediating molecular mechanisms that are essential to differentiation, maturation, and regeneration of cartilage cells.

Cohousing Male Mice With and Without Segmental Bone Defects.

Rytlewski JD, Childress PJ, Scofield DC, et al.
Comp Med. 2018; 68(2):131–138.

As part of a larger study on bone defects in microgravity, this study demonstrates that male mice with preflight surgical procedures and control mice can be cohoused under certain conditions.

Forces Associated With Launch Into Space do not Impact Bone Fracture Healing.

Childress P, Brinker A, Gong CS, et al.
Life Sci Space Res. 2018; 16: 52–62.

This paper demonstrates that mice that have sustained segmental bone defects can tolerate launch conditions, and the associated forces and vibrations did not impact the rate of healing.

NASA astronaut Barry "Butch" Wilmore setting up the Rodent Research-1 hardware in the Microgravity Science Glovebox onboard the International Space Station.
NASA

Close-up view of the Alpha Magnetic Spectrometer-02 (AMS-02) taken during an Expedition 50 spacewalk.
NASA

BEHIND THE SCIENCE

THE ALPHA MAGNETIC SPECTROMETER-02 (AMS-02) PROJECT is an international collaboration searching for evidence of dark matter and primordial antimatter to better understand the origin and composition of our universe. It has measured more than 100 billion particles since its launch in 2011, and four FY18 papers detail findings from AMS-02 data analysis.

Learn more about AMS-02 and other ISS National Lab projects looking outward into space in the Upward article "On the Frontier of Space: Looking Outward to Better Understand the Universe Around Us": issnl.us/ar1836.

Observation of Complex Time Structures in the Cosmic-Ray Electron and Positron Fluxes With the Alpha Magnetic Spectrometer on the International Space Station.

Aguilar M, Ali Cavasonza L, Ambrosi G, et al.
Phys Rev Lett. 2018; 121(5):051102.

This article analyzes the influence of solar activity and changes in the solar magnetic field on cosmic electron and proton intensities in LEO. Measuring these effects is important for understanding the overall stability of interstellar cosmic rays.

Precision Measurement of Cosmic-Ray Nitrogen and its Primary and Secondary Components With the Alpha Magnetic Spectrometer on the International Space Station.

Aguilar M, Cavasonza LA, Alpat B, et al.
Phys Rev Lett. 2018; 121(5):051103.

This article for the first time describes precision measurements of nitrogen nuclei in cosmic rays that distinguish between nuclei produced by stars and those created by heavier ions colliding as they travel through the galaxy.

Observation of Fine Time Structures in the Cosmic Proton and Helium Fluxes With the Alpha Magnetic Spectrometer on the International Space Station.

Aguilar M, Ali Cavasonza L, Alpat B, et al.
Phys Rev Lett. 2018; 121(5):051101.

This article analyzes the influence of solar activity on cosmic proton and helium intensities in LEO.

Observation of New Properties of Secondary Cosmic Rays Lithium, Beryllium, and Boron by the Alpha Magnetic Spectrometer on the International Space Station.

Aguilar M, Ali Cavasonza L, Ambrosi G, et al.
Phys Rev Lett. 2018; 120(2):021101.

This article describes measurements of secondary cosmic rays produced by heavy ions that collide while traveling through the galaxy and compares experimental results with theoretical predictions.

PUBLICATIONS
CONTINUED

Mary Kearns-Jonker, of Loma Linda University, receives the 2018 International Space Station Compelling Results Award in Biology and Medicine. Her research team published two of the below papers.
ISS National Lab/ Mauricio Hoyos

BEHIND THE SCIENCE

TISSUE-SPECIFIC STEM CELLS are a promising cell source for regenerative medicine, disease modeling, and drug discovery. Microgravity induces changes in these cells that help scientists understand more about how they behave and how to manipulate them for biomedical use, and three FY18 papers detail findings from stem cell studies relevant to cardiac cell function.

To learn more about cardiac stem cell research in microgravity, see the following resources.

- ISS National Lab blog post on Mary Kearns-Jonker, author of two FY18 papers and winner of the 2018 ISS Compelling Results Award in Biology and Medicine: issnl.us/ar1837
- *Upward* article "Pure of Heart: How Microgravity is Improving Cardiac Cell Quality": issnl.us/ar1838

Simulated Microgravity Impairs Cardiac Autonomic Neurogenesis From Neural Crest Cells.

Hatzistergos KE, Jiang Z, Valasaki K, et al.
Stem Cells Dev. 2018; 27(12): 819–830.

This study shows that microgravity negatively impacts progenitor cells that form the autonomic nervous system, an impairment that may ultimately lead to cardiac dysfunction.

Spaceflight Activates Protein Kinase C Alpha Signaling and Modifies the Developmental Stage of Human Neonatal Cardiovascular Progenitor Cells.

Baio J, Martinez AF, Bailey L, et al.
Stem Cells Dev. 2018; 27(12): 805–818.

This study investigates cardiac progenitor cells and found that microgravity caused cells to express genes associated with earlier stages of cardiovascular development.

Cardiovascular Progenitor Cells Cultured Aboard the International Space Station Exhibit Altered Developmental and Functional Properties.

Baio J, Martinez AF, Silva I, et al.
NPJ Microgravity. 2018; 4(1):13.

This paper characterizes changes in genetic expression of cardiovascular progenitor cells grown on the ISS and indicates that spaceflight enhances regenerative capabilities, a significant finding for improving the efficacy of cell-based therapies.

NASA astronaut Peggy Whitson, Expedition 50 Flight Engineer, works on a stem cell experiment inside the Microgravity Science Glovebox inside the U.S. Destiny laboratory module.
NASA

BEHIND THE SCIENCE

HIGH-QUALITY CRYSTALS of organic molecules, such as proteins, can lead to improvements in drug development, formulation, manufacturing, and long-term storage. Space-grown crystals are often larger and more well-ordered than crystals grown on Earth, and two FY18 papers discuss protein crystal growth related to ISS National Lab projects.

To learn more about space-based protein crystal growth, see the following resources.

- *Upward* article "Reshaping Drug Delivery Millions of Crystals at a Time": issnl.us/ar1839
- ISS National Lab technical report on Microgravity Molecular Crystal Growth: issnl.us/ar1840

The Structure of iPLA(2)βReveals Dimeric Active Sites and Suggests Mechanisms of Regulation and Localization.

Malley KR, Koroleva O, Miller I, et al. *Nat Commun. 2018;* 9(1):765.

This paper presents a novel crystal structure of calcium-independent phospholipase, which is genetically related to Parkinson's disease and other neurodegenerative conditions.

Direct Visualization of Critical Hydrogen Atoms in a Pyridoxal 5βPhosphate Enzyme.

Dajnowicz S, Johnston RC, Parks JM, et al. *Nat Commun. 2017;* 8(1):955.

This paper presents the structure of an enzyme dependent on pyridoxal 5'-phosphate, the active form of vitamin B6.

BEHIND THE SCIENCE

ADDITIONAL PUBLICATIONS IN BIOMEDICAL RESEARCH round out a diverse year for publications.

For additional information on the projects and research areas behind these publications, see the sidebar to the right and the following resources.

- Video of Alessandro Grattoni at the ISS National Lab 2018 Public Board Meeting: issnl.us/ar1841
- *Upward* article "Pushing Research to New Heights: Innovative Research at the ISS R&D Conference": issnl.us/ar1842
- *Upward* article "Microbes in Microgravity: Analyzing Gene Expression to Better Understand Bacteria in Space": issnl.us/ar1843

Anna-Sophia Boguraev discusses her research during a special stage presentation by the ISS National Lab at the 2018 USA Science and Engineering Festival.
ISS National Lab

Unexpected Behaviors in Molecular Transport Through Size-Controlled Nanochannels Down to the Ultra-Nanoscale.

Bruno G, Di Trani N, Hood RL, et al.
Nat Commun. 2018; 9:1682.

This paper examines molecular transport in a nanofluidic platform, which has applications in desalination, fuel cells, and drug delivery.

Successful Amplification of DNA Aboard the International Space Station.

Boguraev, A.-S., Christensen, H. C., Bonneau, A. R., et al.
NPJ Microgravity. 2017; 3:26.

This study outlines the use of polymerase chain reaction onboard the ISS to amplify DNA and detect genetic alterations.

Spaceflight Modifies *Escherichia coli* Gene Expression in Response to Antibiotic Exposure and Reveals Role of Oxidative Stress.

Aunins TR, Erickson KE, Prasad N, et al.
Front Microbiol. 2018; 9:310.

To better understand how to combat antimicrobial resistance, this experiment investigated the cause of increased antibiotic resistance that *E. coli* displays in microgravity and discovered that upregulation of stress response genes is a contributing factor.

GENES IN SPACE STUDENT SCIENTIST PUBLISHES FINDINGS

One FY18 article detailed student research resulting from the inaugural Genes in Space competition—an investigation that validated a new miniPCR system for use in space and successfully used the system to detect epigenetic changes in zebrafish embryos.

For more information on this project, see the following resources.

- *Upward* article "Launching a Dream: Exploring DNA in Space": issnl.us/ar1823
- Behind the Paper (from *Nature Microgravity*) "Genes (and PCR) in Space!": issnl.us/ar1824

"Since I was four years old, I watched rockets launch and all of the science being done in space, and I always wanted to be a part of it. Then suddenly, I was part of it—I was standing there with a rocket launching three miles away going to the ISS, and it had my experiment on it!"
—ANNA-SOPHIA BOGURAEV, STUDENT SCIENTIST

Additional Genes in Space Success Stories

- Student researcher Elizabeth Reizis showed that the T-cell Receptor Excision Circles (TERC) assay works as it should in the space environment, which may help study microgravity's effects on immune cells.
- Student researcher Sophia Chen demonstrated space-based use of a technique to measure several different microsatellites (segments of repeated DNA sequence) in a single assay, which may help study genetic changes linked to spaceflight radiation exposure.

R&D PROGRESS AND OBJECTIVES

HARNESSING THE POWER OF SPACE TO ADDRESS GLOBAL CHALLENGES

AT A GLANCE

- Fifty newly selected projects and programs were added to the ISS National Lab portfolio, more than half of which required no ISS National Lab funding.
- An expanding subset of projects and activities in tissue engineering and regenerative medicine promise to advance biomedical discovery and improve quality of life.
- Growing activities in fluid physics and materials science drove collaboration and in-orbit breakthroughs.
- Sustainability and crystal growth continue to be priority R&D areas that are likely to have tangible impact on our planet and its inhabitants.

Newly selected projects in FY18 showcase the diversity of the ISS National Lab portfolio and promise tangible return to the U.S. public. Additionally, specific research themes emerged as prominent focus areas in our FY18 portfolio and activities, addressing larger challenges with real-world implications and potential future manufacturing capabilities: regenerative medicine improves human health and longevity, and advanced materials drive technology innovation and influence how we communicate and how we construct the built environment around us.

NASA astronaut Randy Bresnik works with the The Effect of Microgravity on Stem Cell Mediated Recellularization (Lung Tissue) investigation in the Microgravity Sciences Glovebox. NASA

PORTFOLIO DIVERSIFICATION

Fifty newly selected projects and programs in FY18 involve collaborations with academic institutions, Fortune 500 companies, startups, nonprofits, and non-NASA government agencies, with many projects individually or sponsorship-funded. For example, fully funded FY18 additions to the ISS National Lab portfolio include:

50%
OF NEW PROJECTS IN FY18
required no ISS National Lab funding.

- **IBM** (artificial intelligence)
- **Lockheed Martin** (radiation shielding)
- **MIT** (satellite technology)
- **Nickelodeon** (fluid physics)
- **University of California, Santa Barbara** (soil science)

Additional projects from the Colgate-Palmolive Company, Princeton University, Sanofi Pasteur, and the National Cancer Institute are also well-known additions to the growing portfolio. For the full list of FY18 new projects and programs, see Appendix I or issnl.us/ar1810.

REGENERATIVE MEDICINE

R&D onboard the ISS in the broad field of regenerative medicine spans from cell-based studies to organoid growth and 3D printing of human tissues. We released our first research solicitation in regenerative medicine in 2013, focused on stem cell R&D, and have since flown 12 related payloads and expanded our portfolio to include tissue chips, a biofabrication facility, and other investigations—35 projects currently served by eight members of our service provider community.

One payload delivered in FY18 is a MassChallenge-funded project (see pages 14–15) from LaunchPad Medical, which used tissue culture on the ISS National Lab to test an injectable biomaterial, Tetranite™, that can glue bones together following a fracture and then naturally dissolve. This glue may both speed new bone growth and reduce recovery time and pain for the 50% of women and 25% of men over 50 who experience fractures.

BEHIND THE SCIENCE

TISSUE ENGINEERING has many applications but often includes culturing tissues resembling those in the body to:

1. Model human disease,
2. Allow higher-accuracy drug testing, or
3. Advance research in organ growth, toward addressing the shortage of organs for transplantation.

"NSF values our collaboration with the ISS National Lab, which empowers U.S. researchers to make important science and engineering discoveries in the microgravity environment. With these new experiments in space, NSF grantees will help us answer fundamental questions about tissue growth and engineering that cannot be studied on Earth and can help improve lives."
—DAWN TILBURY, NSF

BEHIND THE SCIENCE

THE BEHAVIOR OF MATERIALS IN THEIR FLUID STATE affects the properties of the solid material (e.g., metal alloys and semiconductors used in electronic circuits, optical fibers, and solar cells). In the absence of gravity, fluid behavior is altered and enables the development of advanced materials and better manufacturing processes on Earth. Exposure to the extreme conditions of space also makes the ISS National Lab an ideal platform for accelerated testing of material durability.

Other recent examples of ISS National Lab activities in regenerative medicine include multiyear programs funded by NIH and NSF, totaling $26 million in grant commitments and including several competitions issued this year (see pages 14–15). Newly selected NSF-sponsored projects in FY18 will focus on advancing progress toward liver organ bioengineering and use of tissue-engineered muscle to study disease. Three of the FY18 peer-reviewed publications related to ISS National Lab R&D also detail results in regenerative medicine (see page 24), bringing the total publication count for this focus area to 18.

ADVANCED MATERIALS

The ISS National Lab released its first solicitation in materials testing in 2012 and has since issued several solicitations related to materials science, three in collaboration with NSF. These programs expand our user base involved in upstream R&D as well as in-orbit manufacturing and commercially operated facilities.

New advanced materials activities in FY18 include installation of a commercially operated external materials exposure facility (see page 9), activation of a system to manufacture ZBLAN optical fibers in space (see page 17), and award of a new 3D printing technology education program from Harris Corporation. Within the ISS National Lab portfolio, 28 projects in collaboration with eight service providers relate to advanced materials R&D, and nine of these projects have flown to the ISS.

Additionally, the ISS National Lab co-sponsored an advanced materials workshop with NSF in FY18 focused on how microgravity and extreme environmental conditions enable LEO-based R&D that is impractical or impossible on Earth. Our workshops bring together experts in space-based R&D with thought leaders in key research areas to identify how the most pressing knowledge gaps in the field intersect with the demonstrated value of the ISS to build a roadmap for viable LEO-based programs.

CONTINUED FOCUS ON SUSTAINABILITY AND THERAPEUTICS

The ISS National Lab provides an ideal platform to evaluate technologies for improvements in ecosystem monitoring, manufacturing, and agriculture as potential solutions for a healthier planet. Sustainability bridges all of the science verticals we support, and related projects comprise approximately 13% of our portfolio. For more information, see issnl.us/ar1844.

FY18 activities related to sustainability included a workshop held at the 2018 ISSR&D Conference in San Francisco that focused on water sustainability and how the ISS can help raise awareness and reveal new solutions. Additionally, the Orbital Sidekick ISS Hyperspectral Earth Imaging System was launched to the ISS for a variety of applications related to sustainability and environmental monitoring, and the projects awarded from Target's ISS Cotton Sustainability Challenge (see page 14) included:

- **The University of Wisconsin–Madison** will examine how cotton plants respond to the stress of microgravity.
- **Upstream Tech** will use Earth imaging to enable automated monitoring and analysis of cotton agriculture.

Continued progress in R&D related to spaceflight crystal growth also refined strategy and set the stage for further advancement. In July, we held a Microgravity Molecular Crystal Growth (MMCG) workshop at the Hauptman-Woodward Medical Research Institute in Buffalo, New York, to gather input on the ISS National Lab MMCG Program from experts across the field of crystallography. The objectives of the workshop were to discuss progress made toward the goals outlined in the 2015 Protein Crystal Growth workshop, identify steps to accomplish remaining tasks, present new opportunities, and formulate future goals for the MMCG Program.

For a full member list for the ISS National Lab Science & Technology Advisory Panel (STAP), which helps guide strategic direction in these and other areas in collaboration with ISS National Lab staff and the Board of Directors Science Committee, see Appendix I.

Andrew Rush (second from right), president and CEO of Made In Space, receives the 2018 International Space Station Innovation Award in Physical Sciences and Materials Development. ISS National Lab/Mauricio Hoyos

BEHIND THE SCIENCE

ISS NATIONAL LAB–SPONSORED ORGANIC CRYSTAL GROWTH INVESTIGATIONS began launching to the ISS in 2014, and many have yielded high-quality crystals for analysis. Most projects focus on structural determination for drug design, but others aim to improve drug formulation, manufacturing, and storage. For example, scientists from Merck & Co. performed an ISS National Lab experiment to grow millions of highly ordered, uniform crystalline particles of the therapeutic monoclonal antibody Keytruda, Merck's anti-cancer immunotherapy drug. Results from this research could lead to a better method of delivery to patients. For more information, see issnl.us/ar1839.

ENGAGING THE NATION

DEPTH AND BREADTH OF OUTREACH, EVENTS, AND DIGITAL STRATEGY BROADEN OUR NETWORK

AT A GLANCE

- Approximately 1,000 people attended keynotes, technical sessions, workshops, and STEM showcases during the 2018 ISSR&D Conference.
- Strategic event sponsorship and participation reached new audiences, recognized key spaceflight R&D players, and resulted in new users.
- ISS National Lab web traffic increased by 42% over last year, with an 11% increase in time spent per viewer, indicating increased engagement and interest.
- Nontraditional partnerships with Lucasfilm, Marvel Entertainment, and Seeker allowed ISS National Lab content and activities to reach millions of new viewers.

Showcasing the diversity of ISS National Lab activities and success requires equally diverse approaches to engagement and outreach. The map on pages 16–17 includes a snapshot of all activities in FY18, and below are key highlights from events, digital media outreach, and high-visibility partner activities that helped us reach millions of people with ISS National Lab content this year.

Merck researcher Paul Reichert (right) receives an ISS National Lab Space Research Pioneer Award at the 2018 BIO International Convention for his work with protein crystals in space dating back to the space shuttle era. ISS National Lab

2018 ISSR&D CONFERENCE IN SAN FRANCISCO

The annual ISSR&D Conference drew nearly 1,000 participants and included dynamic keynote speakers, plenary presentations, technical sessions, new user workshops, an investor session, and other activities.

- Transformative science leaders explored the future of medical research in space during a panel discussion covering promising research areas, emerging technologies, and current results from ISS research. See issnl.us/ar1845 for recordings of this panel and other events.
- Subject matter expert workshops brought together thought leaders from outside the space industry with space researchers, service providers, and potential ISS National Lab users (see page 27).
- STEM Day at the conference highlighted Space Station Explorers consortium resources and activities of interest to students, parents, and educators. Students sponsored through programs such as the Space Crystal Prize and Genes in Space competitions spoke about their experiences conducting space-based research. A focal point of the day was a live video downlink with crew members onboard the ISS and student presenters.

The 2018 ISS Research and Development Conference took place in San Francisco July 23–26. ISS National Lab/ Mauricio Hoyos

ADDITIONAL EVENTS

Throughout FY18, the ISS National Lab provided opportunities for customers, the public, educators, and students to learn more about activities both on the ISS and on the ground to advance innovation. Event highlights from FY18 included:

- **Public Board Meeting**
  In January, the Board of Directors and executive leadership held the annual ISS National Lab Public Board Meeting. The event was available via live-stream and provided stakeholders, media, and interested members of the space community with an overview of recent successes and future opportunities, illustrating the tangible progress made toward full utilization of the ISS. For more information, see issnl.us/ar1846.
- **BIO International Convention**
  This annual convention that attracts leaders from around the world in the biotechnology and pharmaceutical industries had an attendance of more than 16,000 people from 74 countries. At the convention, we hosted a panel featuring representatives from biotech companies that are leveraging the research capabilities of the ISS National Lab. Since 2012, we have met with multiple researchers and companies at this event, resulting in partnerships such as a project with 490 BioTech (cancer drug research) and an agreement with current commercial service provider and future in-orbit facility operator HNu Photonics.

RECOGNIZING EARLY LEADERS IN SPACE-BASED COMMERCIAL R&D

We presented four "Pioneer Awards" at this year's BIO International Convention to Eli Lilly & Company, Merck & Co., Novartis, and Amgen. These and many other companies are raising awareness of ISS National Lab activities that are returning critical value back to the nation through their cutting-edge research in space.

- **Destination Station**
  Yearly, we team up with NASA to visit multiple U.S. cities as part of Destination Station, a free event through which the public engages with astronauts and scientists. This event also provides an opportunity for us to collaboratively engage with NASA and science thought leaders from well-known companies and organizations. Examples from FY18 include PepsiCo, the Centers for Disease Control and Prevention, Coca Cola, and two organizations that have recently been selected for ISS National Lab projects: IBM Watson and the Colgate-Palmolive Company.
- **USA Science and Engineering Festival**
  The 2018 USA Science and Engineering Festival, the nation's largest science festival, provided our Space Station Explorers consortium with a highly visible public engagement forum. We hosted a stage show and organized an informative panel in collaboration with Nickelodeon (hosted by Alex Hook, the star of Nickelodeon's hit TV show "I Am Frankie") to feature ISS National Lab student scientists.

ELI LILLY & CO., DELTA FAUCET COMPANY, AND TARGET CORP.

are example ISS National Lab partnerships that stemmed from Destination Station events.

Festival goers pose for a picture with Nickelodeon star Alex Hook (back center) in the Space Station Explorers exhibit at the 2018 USA Science and Engineering Festival. ISS National Lab

DEEPENING ENGAGEMENT THROUGH DIGITAL CHANNELS

Increased viewership of ISS National Lab content is critical for informing and engaging new users, partners, and investors. The ISS National Lab digital presence, anchored by our website and social media channels, is designed to raise awareness about research opportunities and activities on the ISS National Lab, highlighting the value of the lab and the success of its users. Through new collaborations, third-party content based on ISS National Lab activities is providing additional amplification of original content via new platforms, and we are reaching new audiences through various digital channels.

To take full advantage of this growth, we have deepened our content strategy to include daily postings on our ISS360 blog (see issnl.us/ar1847), which highlights research being conducted on the ISS National Lab and drives viewers to more in-depth information on ISS National Lab opportunities. This strategy directly contributed to a 42% increase in traffic to the ISS National Lab website this year from various acquisition channels including organic search, direct traffic, social media, and referral traffic (e.g., third-party websites aside from search engines). Alongside this sustained increase in web traffic, there was an 11% increase in the average time spent on the website, which directly correlates to the content strategy focused on owned digital channels.

AMPLIFYING COMMUNICATION OF SPACE STATION RESEARCH

Former NASA astronaut Cady Coleman makes a guest appearance on Lucasfilm's web series "Science and Star Wars" to discuss research and technology on the ISS National Lab. Lucasfilm

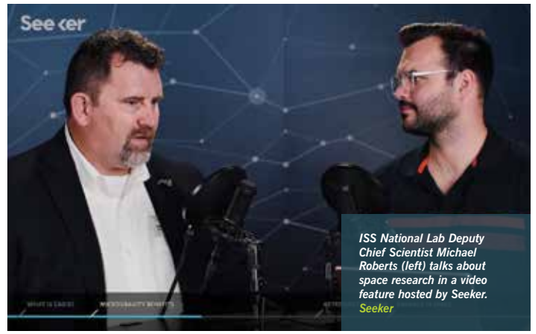
Our FY18 partnerships span from powerful media companies to influential STEM organizations that expand and diversify the ISS National Lab community:

- Following our collaboration with **Lucasfilm** on the 2017 ISS National Lab mission patch, the ISS National Lab was featured in Lucasfilm's web series "Science and Star Wars," designed in collaboration with IBM to engage the public on the science associated with the Star Wars universe.

THE GUARDIANS OF THE GALAXY SPACE STATION CHALLENGE

was developed following Marvel's previous collaboration on the 2016 ISS National Lab mission patch and was complemented by a "Science of Marvel" web series that garnered hundreds of thousands of views.

- Together with **Marvel Entertainment**, we announced and awarded the Guardians of the Galaxy Space Station Challenge—a nationwide spaceflight research competition for students. Two winning investigations focused on studying aeroponic farming and analyzing the effectiveness of a dental glue launched to the ISS in December 2018.
- Popular science content publisher **Seeker** is working with us to highlight research conducted on the ISS National Lab through its new digital channel, Seeker Universe, which launched in May 2018. Multiple videos highlighting ISS National Lab facilities and research investigations have reached millions of viewers through Seeker's many social media platforms. In addition, Seeker is featuring our content on their website, podcasts, and other channels to connect their subscribers with the excitement of ISS National Lab R&D.



ISS National Lab Deputy Chief Scientist Michael Roberts (left) talks about space research in a video feature hosted by Seeker. Seeker

FY18 FINANCIALS

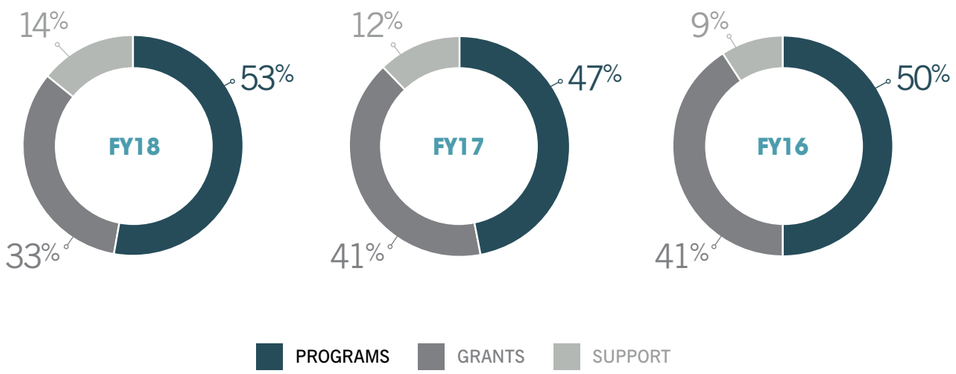
UNAUDITED SUMMARY STATEMENT OF FINANCIAL POSITION AS OF SEPTEMBER 30:

	2018	2017	2016
Total assets	$3,417,124	$2,073,619	$2,086,293
Total liabilities	$618,764	$415,846	$390,828
Total net assets	$2,798,360	$1,657,773	$1,695,465
Total liabilities and net assets	**$3,417,124**	**$2,073,619**	**$2,086,293**

UNAUDITED SUMMARY STATEMENT OF ACTIVITIES FOR YEARS ENDED SEPTEMBER 30:

	2018	2017	2016
Total revenues and other support	$19,444,100	$17,738,180	$16,377,431
Total operating expenses	$18,303,511	$17,775,872	$16,623,131
Change in net assets	$1,140,589	$(37,692)	$(245,700)
Net assets, beginning of the year	$1,657,771	$1,695,465	$1,941,165
Net assets, end of the year	**$2,798,360**	**$1,657,773**	**$1,695,465**

EXPENSES (%)



CORE VALUES

PASSION FOR THE MISSION

We are inspired and driven by the International Space Station and the incredible opportunity ahead of us. We understand and are humbled by what others have sacrificed to build the ISS. We embrace the role that we play in shaping the future of space research by maximizing the impact of this incredible laboratory.

CUSTOMER FOCUSED

We are committed to our customers and understand that each and every one of us contributes to the user experience. As the conduits to the space station, we aim to do everything in our power to improve the customer journey and focus on our customer's objectives.

TEAMWORK

We believe in the power of inclusion—that there is greater strength in working together to solve complex problems. We collaborate and build networks, harnessing the best ideas from inside and outside the organization. We treat our coworkers, partners, customers, and vendors with respect and appreciation.

PROFESSIONALISM

We convey professionalism in all that we do. We communicate openly and transparently and use appropriate channels. We recognize that each employee is an ambassador of the ISS National Laboratory and contributor to the ISS brand.

STEWARDSHIP

We recognize the great responsibility that we have to maximize the use of the ISS to benefit life on Earth. We demonstrate good stewardship of our resources and put the mission above all else when making business decisions. We are accountable for our actions and expect our users, partners, and vendors to share in these values.

COMMITTED TO EXCELLENCE

We take pride in our work and aspire to be the best we can be. We adhere to the highest standards of our professions and adopt best practices. We embrace new ideas and explore innovative ways of working.

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