FY17 Q1 REPORT

Quarterly Report for the Period October 1 – December 31, 2016

CENTER FOR THE ADVANCEMENT OF SCIENCE IN SPACE (CASIS)

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EXECUTIVE SUMMARY

The first quarter (Q1) of fiscal year 2017 (FY17) saw steady momentum for the International Space Station (ISS) U.S. National Laboratory; building off the successes of last year with increased investments in ISS research among federal agencies, forging new partnerships, and the return to flight of OrbitalATK's Cygnus spacecraft delivering new research to station.

One of the hallmarks of Q1 was the announcement of a new joint solicitation to study combustion science on the ISS National Lab, sponsored by CASIS and the National Science Foundation (NSF). NSF has committed up to $1.8 million in funding to support research projects selected from this opportunity. This is the second joint solicitation between CASIS and NSF, and the relationship has been a definitive sign of the ISS National Lab's utility to address research objectives within top federal programs. There continues to be a strong commercial presence in low Earth orbit (LEO), with more than half of CASIS projects awarded in Q1 involving commercial entities. Commercialization has also extended to the station's infrastructure, with four new commercially operated facilities awarded in Q1 that will expand ISS research capabilities.

KEY HIGHLIGHTS FROM Q1 FY17:

- **New Research Delivered:** OrbitalATK's Cygnus spacecraft successfully returned to flight in October, and Japan's automated space freighter HTV-6 took flight in December, collectively delivering eight payloads to the ISS National Lab, including a number of SmallSats developed by NanoRacks.
- **Projects Selected for Flight:** Sixteen projects were awarded, including ten from commercial entities, four from returning ISS National lab users, six from new users awarded through research opportunities in partnership with sponsor organizations, and one from the Michael J. Fox Foundation. This is a positive indication of the value of the spaceflight R&D platform to the current and expanding ISS National Lab user community.
- **Strengthening Government Partnerships:** The National Institutes of Health (NIH), CASIS, and NASA coordinated a live video downlink with NASA Astronaut Kate Rubins and NIH Director Dr. Francis Collins to discuss current life sciences research on ISS National Lab. The event was broadcast worldwide via NASA TV and NASA's Facebook page.
- **Fortifying Key Ecosystems:** The ISS National Lab is ramping up strategic outreach by establishing a permanent presence in Silicon Valley, California, a region ripe with innovation and currently home to nearly 50% of the CASIS investor network and more than 10% of the CASIS-awarded R&D portfolio.
- **ISS National Lab Research Yields Important Results:** Four scientific papers were published based on flight results from ISS National Lab research—three from CASIS-sponsored investigations and one from the Alpha Magnetic Spectrometer investigation.

Finally, in Q1, CASIS released its FY16 annual report that chronicled the progress of the ISS National Lab during a productive year and highlighted the evolution of this amazing research platform under five years of CASIS management. The report is available in its new online format at: ar2016.iss-casis.org.

ISS NATIONAL LAB PORTFOLIO

MAXIMIZE UTILIZATION AND DEMONSTRATE MEASURABLE IMPACT

NEWLY SELECTED PROJECTS

Life Sciences

Eight life sciences projects were awarded in Q1—four from commercial entities and four from academic institutions. Two of the projects resulted from an ISS National Lab joint Sponsored Program with the Boeing Company (as part of the MassChallenge business accelerator competition)—one project aiming to crystallize a medically relevant protein complex, and one testing a model system for evaluating the toxicity of novel cancer drugs that target blood vessels. Both of these projects involved investigators who are new to space. This is the fourth year the ISS National Lab has partnered with MassChallenge, the world's largest startup accelerator to support early-stage entrepreneurs with non-dilutive seed funding, and the third year it has partnered with Boeing for this competition. The repeated financial commitment from Boeing to support ISS National Lab flight projects demonstrates success in expanding the ISS community by leveraging external funding—in this case, to identify nontraditional flight projects through innovative start-up company ideas.

Additionally, two of the life sciences investigations were among three projects awarded in Q1 that resulted from an ISS National Lab joint Sponsored Program with the University of Florida. One of the life science projects aims to understand the molecular mechanisms behind vascular cell damage that results in cardiovascular disease, and the other project seeks to engineer microalgae for growth in microgravity that rapidly add biomass and produce high-value compounds. Both of these projects also involved investigators who are new to space. The University of Florida contributed $238,000 to the Sponsored Program, which was open to all University of Florida faculty, and CASIS provided matching funds for implementation costs. The partnerships and external financial support that comprise Sponsored Programs such as this one promote awareness of the value of the ISS research platform and augment the accessibility of this platform to the R&D community.

Of the remaining four life sciences projects awarded in Q1, one supports a new ISS National Lab facility that will enable a broad range of life sciences experiments onboard the ISS. A second investigation will validate and help calibrate another new life sciences research facility on the ISS. The last two projects involve macromolecular crystallization experiments to study medically relevant proteins. One of the crystallization experiments is funded by the Michael J. Fox Foundation (MJFF), the largest non-profit funder of Parkinson's disease research in the world. An existing ISS National Lab Principal Investigator made introductions between CASIS and MJFF during FY16, and this introduction resulted in an awarded program proposal and the prospect of a continued relationship with MJFF. The leucine-rich repeat kinase 2 (LRRK2) protein crystallization project was awarded in Q1, and the MJFF team is currently conducting ground studies in preparation for flight during the first half of 2017. In addition to this initial research project, CASIS and MJRR are continuing discussions on other potential ISS projects that will help to achieve the goal of ending Parkinson's disease in our lifetime.

Physical Sciences

Two projects in the area of physical sciences were awarded in Q1—both from new-to-space investigators. One project, aimed at developing a protein-based retinal prosthetic to restore vision to those blinded by retinal degenerative diseases, resulted from the ISS National Lab joint Sponsored Program with Boeing (as part of the MassChallenge business

accelerator competition, discussed above). The other project, which resulted from the ISS National Lab joint Sponsored Program with the University of Florida (also described above), seeks to conduct electrodeposition, a process for applying materials to any electrically conductive surface, in microgravity to reduce imperfections and improve manufacturing processes on the ground for materials with industrial and medical applications.

Technology Development

In Q1, four projects were awarded in the area of technology development—all from commercial entities. One project aims to test the long-term operation of a commercial off-the-shelf high performance computer in the harsh environment of space. The remaining three projects support facilities onboard the ISS National Lab—one project will accelerate the engineering design of a new automated tissue printing system (or bioprinter), another supports the development of a second TangoLab-1 general research platform (doubling Space Tango's current CubeLab capacity to meet customer demand), and a third supports the development of an external platform for materials science and component testing—the Materials ISS Experiment Flight Facility (MISSE-FF). A series of MISSE experiments funded by NASA and other government agencies have flown on previous missions using earlier iterations of the platform, but the new facility will provide a commercially available platform with expanded services for the remaining lifetime of the ISS.

Education

Two projects were awarded in the area of education in Q1. One project, from a commercial entity, seeks to collect 360° imagery of the internal area of the ISS for education and commercial applications. The other project, from an academic institution, provides an opportunity for the winning student team from the 2017 Wisconsin Crystal Growing Competition to grow their crystals onboard the ISS National Lab to test their optimized conditions for Earth-based crystallization against microgravity-based crystallization.

For more information on all newly awarded projects, see the table beginning on page 16.

OPERATIONAL UPDATE

The launch of the Orbital ATK CRS-5 (OA-5) commercial resupply mission in Q1 marks the third Orbital ATK mission following its vehicle loss in October 2014, and a return to flight from the MARS Spaceport at Wallops Island, VA. Some of the key ISS National Lab payloads onboard OA-5 include the following:

- **Controlled Dynamics Locker** for Microgravity Experiments is a programmable isolation mount platform located inside an ExPRESS locker. This platform insert for existing ISS hardware will provide research payloads with a controlled dynamic acceleration environment; in other words, a technology that will actively dampen fluctuations/disturbances in the microgravity environment that occur onboard spacecraft. PI: Scott Green, Controlled Dynamics, Inc., Huntington Beach, CA. Payload Developer: Controlled Dynamics, Inc.
- **NanoRacks External Cygnus CubeSat Deployer** is a small satellite deployment system that is designed to release CubeSats from the Cygnus module after the vehicle departs from the ISS. Mounted on the outside of Cygnus, the CubeSats may be deployed at an altitude determined by NanoRacks and their launch partners. The OA-5 mission marked a historic milestone of the first CubeSats being deployed at 500 km, an orbit higher than that of the ISS. Payload Developer: NanoRacks, LLC.

- **LEMUR-2 Satellites**, which are part of a remote sensing satellite constellation that provides close to real-time weather monitoring and tracking of oceangoing ships. The satellites in this investigation are deployed from both the NanoRacks CubeSat Deployer on the ISS and the NanoRacks External Cygnus Deployer, demonstrating the technology at a range of altitude bands. PI: Jenny Barna, Spire Global, Inc., San Francisco, CA. Payload Developer: NanoRacks, LLC.

The Q1 launch of Japan's H-II Transfer Vehicle, or HTV-6, was the sixth flight of the automated, unmanned resupply vehicle developed by the Japan Aerospace Exploration Agency (JAXA) to deliver cargo to the ISS. Some of the key ISS National Lab payloads onboard HTV-6 include the following:

- **Dependable Multiprocessing (DM) Payload Processor,** which is a new type of computer architecture that uses several commercially available processors working together to increase computing speed and reduce computing errors in a space environment. Hosted on the NanoRacks External Platform (NREP), this investigation demonstrates that DM technology can work in the radiation environment of space, enabling its use on future space missions. PI: John Samson, Honeywell, Clearwater, FL. Payload Developer: NanoRacks, LLC.
- **LEMUR-2 satellites,** which are part of a remote sensing satellite constellation that provides close to real-time weather monitoring and tracking of oceangoing ships. The satellites in this investigation are deployed from both the NanoRacks CubeSat Deployer on the ISS and the NanoRacks External Cygnus Deployer, demonstrating the technology at a range of altitude bands. PI: Jenny Barna, Spire Global, Inc., San Francisco, CA. Payload Developer: NanoRacks, LLC.
- **On-Demand Sample Return Capability–Small Payload Quick Return (TechEdSat-5)** is the proposed Small Payload Quick Return (SPQR) project that provides the capability of returning small payloads from the ISS in a temperature and pressure controlled environment. TechEdSat-5 is the fifth development step in the series and will further develop the tension-based drag device (an 'Exo-Brake') and demonstrate frequent uplink/downlink control capability. Payload Developer: NanoRacks, LLC.
- **DreamUP-NanoRacks-CUBERIDER-1** is a modular sensor payload that allows classrooms to upload and run code that is capable of running tests and collecting data on the ISS. PI: Sebastian Chaoui, Cuberider, Drummoyne, Australia. Payload Developer: NanoRacks, LLC.
- **DreamUP-NanoRacks-Radiation Tolerant Computer Mission on the ISS (RTcMISS),** which tests new computer technology on the ISS to help improve the state-of-the-art space computing system. PI: Brock LaMeres, Montana State University, Bozeman, MT. Payload Developer: NanoRacks, LLC.

The ISS National Lab now supports commercially operated user facilities from five companies, a significant expansion from only one in 2012. In a shift from traditional government-operated spaceflight research, these innovative companies are primarily commercially funded and have the responsibility of planning and managing the in-orbit operations for their facilities. For the research community, this means increased opportunities for business-to-business engagement, lower cost of research, rapid experiment iteration, and less reliance on legacy government processes. In Q1, CASIS awarded four new facilities that will expand these commercial services on the ISS National Lab in the coming years. For more information on all newly awarded projects (including facilities), see the table beginning on page 16.

PROJECT STATUS

In Q1, four research papers resulting from ISS National Lab investigations were published, formally announcing spaceflight findings. Peer-reviewed journal articles and other research publications are a critical means for the scientific community to disseminate research findings, and such publications often lend merit and prestige to initiatives—and to the ISS National Lab by association, bringing visibility and credibility to this powerful research platform.

Below are details on the three CASIS-sponsored research publications released in Q1. The landmark findings and incremental progress showcased in these publications illustrate continued traction toward the ultimate goals of health care advancement, technology innovation, and other achievements that will improve overall knowledge and quality of life for humankind. Moreover, a strong publication base often precedes commercial investment in a particular sector.

Life Sciences

An article published in the journal *PLoS ONE* by BioServe Space Technologies researcher Luis Zea at the University of Colorado, Boulder describes results that corroborate for the first time the altered extracellular environment model of microbial growth in microgravity. This model postulates that behavioral changes in bacteria in space are due to microgravity-induced changes in the environment around the cells. Bacterial experiments have been done in low Earth orbit since the 1960s and have documented that bacteria grown in space behave differently than bacteria grown on Earth. For example, some bacterial strains exhibit enhanced growth, increased ability to cause disease, and reduced susceptibility to antibiotics in space. For decades, scientists have hypothesized that these behavioral changes are due to the lack of gravity-driven forces and flows altering the environment around the cells; however, the altered extracellular environment model had not been confirmed empirically or computationally. By studying at the molecular level the responses of the bacteria grown on the ISS versus ground samples, Zea and his team were able to identify changes in gene expression that correlate with what one would expect to see if the model were correct. According to the model, the lack of gravity-driven forces leads to reduced transportation of nutrients to cells and waste products away from cells. This, in turn, leads to reduced availability of nutrients (glucose) for absorption and a buildup of waste-product (acetic acid) around the cells. In the bacteria grown in space, Zea and his team found gene expression profiles associated with starvation (due to reduced glucose uptake) and acidic response (from waste-product buildup around the cell). These results provide new insights that inform research aimed at uncovering novel molecular targets against drug-resistant bacteria and developing new antibiotics and vaccines.

An article published in the journal *Acta Crystallographa Section F: Structural Biology Communications* by California Institute of Technology researcher Pamela Bjorkman describes results from ISS and ground crystallization experiments of MW1, an antibody that binds to the mutated huntingtin protein in people with Huntington's disease. Huntington's disease (HD) is an inherited disease that causes the breakdown of nerve cells in the brain. Although some medications can help manage the debilitating symptoms of HD, there are no treatments to prevent or reverse the physical, mental, and behavioral decline associated with the disease. HD is found in people that have a specific change to the huntingtin protein, an essential protein in the body. In people with HD, one end of the huntingtin protein has an expanded sequence of glutamine amino acids (called a polyglutamine expansion) caused by repeats in the gene that codes for the protein. While it is unclear what exactly this expansion does and how it may lead to HD symptoms, scientists have found that there are several antibodies, such as MW1, that bind to this polyglutamine expansion of huntingtin. The crystallization of the MW1 antibody allows researchers to use X-ray diffraction to gain critical information about the structure and potential binding sites of the molecule (for example, the binding of MW1 to the huntingtin protein).

Understanding the binding interaction between MW1 and huntingtin may allow researchers to develop diagnostic tools to monitor the regression of abnormal huntingtin proteins in patients enrolled in clinical trials for the treatment of HD. By utilizing the microgravity environment of the ISS, Bjorkman and her team were able to obtain MW1 crystals with improved quality that were 20% larger than the matching controls grown on Earth.

Technology Development

An article published in the journal *Nanoscale* by Houston Methodist Research Institute researcher Alessandro Grattoni describes a novel method for the development of a tunable, ultra-low power implantable drug delivery device. The ability to remotely control and modulate the dosage of medications through the use of implantable devices will have a significant benefit to modern medicine. Many chronic conditions require long-term therapeutics that are often administered orally or by injections. When administered in these ways, there is an initial burst of concentrated drug in the patient's blood, followed by a decrease, which is a far from ideal way to maintain a therapeutic dose of a drug for an extended period of time. To overcome this limitation, Dr. Grattoni and his team are working to develop an implantable device that can deliver a steady and metered dose of the drug through diffusion, without the need for a pump or even power (a major limitation associated with other implantable devices). The device's nanochannel system consists of membranes with very small channels—roughly two to three times the size of the drug molecule to be delivered. The drug is contained in a reservoir that can be easily refilled by an injection through the patient's skin. The release of the drug can be adjusted by applying an electrical field across the nanochannels in a way that interrupts and then reactivates the release. In working to design the device, Grattoni and his team needed to understand how molecules of different size, shape, and charge diffuse across the nanochannels. To do this, they needed to explore in microgravity how fluids behave in confined spaces. It is not possible to directly observe individual molecules diffusing across nanoscale channels; however, in microgravity, a surrogate model represented by fluorescent microparticles in microchannels can, in specific circumstances, be highly representative of smaller molecules in nanochannels.

For details on these Q1-published articles and their expected Earth benefits, see the Contributions to Scientific Knowledge table on page 15.

Remote Sensing

Another article was published in *Physical Review Letters* in December reporting the most recent discoveries from the fifth year of operations in space of the Alpha Magnetic Spectrometer (AMS-02), a state-of-the-art particle physics detector constructed and operated on the ISS National Lab by an international team composed of 60 institutes from 16 countries and organized under US Department of Energy (DOE) sponsorship. For the first time ever, the AMS team describes the precise measurement of the boron to carbon nuclei flux ratio in cosmic rays. This latest report is another in a series of important publications in Physical Review Letters from the AMS and its mission to probe the foundations of modern physics by measuring long term variation in cosmic ray flux over a wide energy range of particles ranging from protons to iron nuclei. The data reported here comprised measurements from 2.3 million boron nuclei and 8.3 million carbon nuclei detected by AMS.

Life Sciences

In addition to publications, ISS National Lab investigators also experienced success in the commercial realm: Food and Drug Administration (FDA) approval of a commercial product to detect medically significant changes in intracranial

pressure (ICP), or pressure inside the skull. ICP is a key physiological metric used to help physicians diagnose numerous neurological conditions, including traumatic brain injury (TBI). Unfortunately, the current gold standard for measuring ICP requires a neurosurgeon to drill a hole into the patient's skull to surgically implant a sensor—a highly invasive procedure that is usually limited to patients receiving treatment in intensive care units. Due to high costs per patient and the risk of infections associated with the method, 40% and 66% of severe TBI patients in US and Europe, respectively, do not receive the recommended ICP monitoring suggested by the Brain Trauma Foundation. Neural Analytics, a biomedical startup working on translational research originally conducted at the University of California, Los Angeles, developed technology that uses a patented algorithm to correlate changes in cerebral blood flow velocity with changes in ICP using non-invasive ultrasound technology. Neural Analytics received seed funding from CASIS as part of the MassChallenge Accelerator Program, to support technical development of a framework to capture subtle variations in cerebral blood flow and extend its application to a number of neurological conditions, including a new relationship with NASA to examine its utility for assessing ICP in ISS crew members. These technological improvements helped lay the foundation for a highly portable ultrasound device to help in detection of ICP and TBI—and in November 2016, the FDA approved the company's first commercial product based on this R&D, the Lucid System. TBI affects approximately 2.5 million people in the U.S. every year, and mild forms of TBI or concussion affect an estimated 4 million people in the U.S. annually. Neural Analytics' non-invasive approach represents a major improvement to the current gold standard that requires implantation of sensors in the brain, a method that is usually declined by many patients. Patients receiving proper diagnosis and monitoring of TBI will lead to earlier therapeutic intervention and improved health for the patient.

For more information on this product, see the Commercial Impact—Products or Services Created table on page 16.

STIMULATING AND CULTIVATING DEMAND FOR ISS AND BEYOND

EXPAND THE ISS NATIONAL LAB NETWORK AND DRIVE COMMERCIAL UTILIZATION

OPEN AND UPCOMING OPPORTUNITIES

New NSF Funding Opportunity: Combustion Science

In Q1, CASIS released a joint solicitation with the National Science Foundation (NSF) to support investigations on the ISS National Lab in the fields of fundamental combustion science and thermal transport. NSF is committing up to $1.8 million in grant funding toward the suite of ISS National Lab flight projects that will be selected in response to this solicitation.

The long-duration microgravity environment provided by the ISS National Lab has unique benefits for the study of combustion and thermal transport phenomena. Many processes such as thermal convection, sedimentation, and buoyancy are absent in microgravity, and elimination of these variables allows phenomena of interest to be studied without gravitational interference. The results from such studies could have applications in industries including consumer products, electronics, manufacturing, medical devices and pharmaceuticals, oil and gas, and clean energy. To be eligible for award through this competition, proposals must demonstrate a tangible benefit to improving life on Earth through advancement of fundamental science and engineering knowledge.

This is the second joint solicitation between NSF and CASIS; the first focused on the field of fluid dynamics, and the resulting awarded projects were announced last quarter. For more information about this current funding opportunity,

view the full proposal solicitation via the NSF Division of Chemical, Bioengineering, Environmental, and Transport Systems. It is anticipated that these CASIS-NSF joint solicitations will continue yearly, with the topic rotating among various areas of physical science.

Potential Future Opportunity: Microbiome Research

In conjunction with the American Society of Gravitational and Space Research (ASGSR) annual meeting in Q1, CASIS hosted a workshop on the microbiome/immunome and associated diseases. More than 40 attendees representing industry, academia, government, and private research organizations participated in presentations and discussions on microbiome and virome research in microgravity. The workshop presentations and recommendations are available online at http://www.iss-casis.org/Workshops/Microbiome.aspx.

CASIS intends to further define the exploration of microbiome/immunome research in model organisms, humans, and ecosystems on the ISS National Lab. This workshop identified resources (flight/ground) and equipment required to support research in microgravity with consideration for science, technology, engineering, and mathematics (STEM) education and collaborative funding opportunities. Ultimately, this workshop will lead to an ISS National Lab initiative on microbiome/immunome research in microgravity that provides a platform for accelerating research by academic, commercial, and government institutions seeking to improve life on Earth. A program manager from the Defense Advanced Research Projects Agency - Biological Technologies Office (DARPA-BTO) who attended the microbiome workshop will visit the NASA Kennedy Space Center in late February to discuss possible collaborations for Sponsored Program research on the ISS National Lab.

STRATEGIC AREAS OF FOCUS

Industry Outreach

In Q1, the ISS National Lab made substantial progress in establishing a permanent presence in the Silicon Valley area of California, an innovation ecosystem for technology and R&D with access to significant investment capital. CASIS is setting up an office in this region that will support both permanent and rotating staff. In Q1, CASIS held 14 high-level meetings with key Silicon Valley stakeholders, including Fortune 500 companies, industry leaders in the materials science and information systems sectors, and top academic research institutions, as well as a variety of investment firms and venture capitalists. These meetings focused on generating ideas for ISS National Lab flight projects, STEM education programs, and Sponsored Programs (competitions for ISS National Lab R&D opportunities funded by a partner organization).

These activities complement the existing ISS National Lab presence in California, which (prior to Q1) included four implementation partners, approximately 10 yearly industry events, and 20 organizations with ISS National Lab projects. Additionally, 17 of the 40 investors in the CASIS investor network have a presence in Silicon Valley/San Francisco. Development of the CASIS investor network is ongoing, and introductions between ISS National Lab investigators and members of the network are taking place.

The ISS National Lab also continued strategic outreach to key targets in Q1 through participation in several conferences and trade association events throughout the U.S., including the MassChallenge Awards Ceremony, Industrial Research Institute fall meeting, SpaceCom, World Stem Cell Summit, Dreamforce, and the AAS Space Based Environmental Intelligence meeting. For more information

on these and other Q1 events, see the Events and Conferences Table on page 27.

LEO Commercialization

Focus Area: Protein Crystal Growth

As part of ongoing efforts to develop a Macromolecular Crystallization Program in microgravity, CASIS released a solicitation in Q4FY16 for proposals to provide support services—including laboratory, integration, and hardware support—for researchers interested in conducting crystallization experiments onboard the ISS National Lab. The CASIS Request for Proposals - Support Services for the Macromolecular Crystallization Program was finalized in Q1FY17 with the selection of five preferred partners. The preferred partners were notified, and subcontracts will be completed in Q2. Once the subcontracts are complete, new investigators will have access to hardware and services at pre-negotiated rates, streamlining the proposal development and contracting phase of projects. This will provide a platform for discovery to users across many communities—commercial, other government agencies, academia, and private research—while also supporting future LEO commercialization efforts.

It has been shown that many crystals grown in microgravity are larger and more detailed than those grown on Earth, yielding structures that are more accurate and provide greater insight into protein function. This allows better structure-based drug designs while also informing improved strategies for drug manufacturing—with the end goal of more effective and affordable pharmaceuticals. A first step in developing a program for repetitive, low-cost crystallization in microgravity is engaging existing partners and potential new partners intent on providing hardware and services capable of enhancing crystallization opportunities onboard the ISS National Lab for the duration of the program.

Focus Area: Organ Bioengineering

The Vascular Tissue Challenge Roadmapping Workshop, organized by the New Organ Alliance, brought together more than 100 attendees from a variety of government agencies, academic institutions, and industry organizations to discuss state-of-the-art technology in thick-tissue vascularization and 3D tissue engineering, toward ending the organ shortage benefiting from these technologies. The workshop was sponsored by NanoRacks, TechShot, and Space Pharma in partnership with CASIS, the National Science Foundation, the NASA Centennial Challenges Program, Duke University Cardiovascular Research Center, the Organ Preservation Alliance, and the Methuselah Foundation. CASIS participated in the opening remarks and a panel discussion in support of ISS National Lab activities related to advancing the field of organ bioengineering.

- Biomedical engineering on Earth is capable of producing tissues and organs that may one day resolve a growing shortage of organs for donation. Already, miniature versions of these artificial organs are extremely helpful for testing of new potential drugs. However, a substantial limitation on the effectiveness of tissue engineering approaches for pharmaceutical testing or disease modeling—let alone human organ transplant—is the challenge of establishing a blood vessel system within these in vitro tissues (i.e., vascularization).
- NASA's Vascular Tissue Challenge is a $500,000 prize to be divided among three teams who successfully create human vascularized organ tissue greater than 1cm in an in vitro environment—while maintaining metabolic functionality similar to their in vivo native cells throughout a 30-calendar day survival period. For more information on the Challenge, visit: https://www.neworgan.org/vtc-prize.php.
- CASIS has partnered with the New Organ Alliance and the Methuselah Foundation to provide an "Innovations in Space" Award associated with the Challenge that will cover launch costs and $200,000 in hardware costs to send one team's tissue experiment to the ISS, toward advancements in healthcare and biomedical research on Earth.

Building Sustainability

As the nonprofit manager of a U.S. National Laboratory, CASIS monitors the impact of its research grants by tracking grantee in-kind support and cost sharing. This helps to evaluate the degree to which projects advance more rapidly than would be possible solely from CASIS funding. Nearly $5 million in non-CASIS, non-NASA funding is projected to support the projects awarded in Q1. Such financial contributions from ISS National Lab users and sponsor organizations augment CASIS seed funding, toward maximum project impact and growing financial sustainability of spaceflight R&D.

PARTNERSHIPS AND COLLABORATIONS

Applications Received for NIH-NCATS Funding Opportunity

CASIS and the National Center for Advancing Translational Sciences (NCATS), part of the National Institutes of Health (NIH), in Q4FY16 released a Funding Opportunity Announcement (FOA) to solicit applications through the NCATS Tissue Chip for Drug Screening program. This announcement is part of a four-year collaboration through which NCATS will provide up to $12 million in funding to use tissue chip technology (also known as microphysiological systems or "organs-on-chips") onboard the ISS National Lab for translational research to benefit human health on Earth. This NIH FOA closed during Q1FY17, and NCATS will begin their Scientific Merit Review of all received proposals during the next fiscal quarter, with funding announcements anticipated by Q4. More information can be found at http://casistissuechip.blogspot.com/, and a copy of the FOA is available at http://grants.nih.gov/grants/guide/rfa-files/RFA-TR-16-019.html.

Continued Progress in Collaboration with NSF

Following a successful joint solicitation between CASIS and NSF in 2016 in fluid dynamics, where five investigators were awarded a total of $1.5M for their ISS flight projects, CASIS and NSF have teamed up again this year to offer up to $1.8M in research funding towards ISS flight projects in the field of combustion and thermal transport. This opportunity is further discussed on page 9. It is anticipated that these CASIS-NSF joint solicitations will continue yearly, with the topic rotating among various areas of physical science.

OUTREACH AND EDUCATION

PROMOTE THE VALUE OF THE ISS AS A LEADING ENVIRONMENT FOR R&D AND STEM EDUCATION

INCREASING AWARENESS AND POSITIVE PERCEPTION

The launch of the Orbital ATK CRS-5 (OA-5) resupply mission in Q1 generated high visibility for the ISS National Lab. A CASIS representative participated in the OA-5 prelaunch briefing broadcast on NASA TV, which highlighted several enabling technologies (mentioned previously on page 5) that will enhance the research capabilities on the ISS National Lab. The briefing is available here: https://youtu.be/fvIT10SLPQU. Because of the successful launch, there were also several stories published that referenced the ISS National Lab research that launched on OA-5 (see: http://www.space.com/34352-fire-experiments-launch-to-space-station.html).

Also in Q1, NASA Astronaut Kate Rubins participated in a live video downlink from the space station with National Institutes of Health (NIH) Director Dr. Francis Collins (available at https://youtu.be/QYaYMo2XrAY). This downlink, broadcast on NASA's International Space Station Facebook page and NASA TV, provided a major spotlight for space science among the broader research community. Rubins and Collins discussed the scientific milestone of sequencing DNA in space for the first time, which Rubins executed in August 2016, and highlighted the ISS National Lab-sponsored heart cells experiment led by researchers from Stanford University's Cardiovascular Institute. The downlink also highlighted recent other government agency investments in microgravity research, including CASIS partnerships with the National Center for Advancing Translational Sciences (NCATS) and the National Science Foundation (NSF).

Astronaut Kate Rubins' work with the heart cells experiment continues to fascinate the scientific community, the public, and the media. In December, Rubins participated via Skype in a keynote address at the 2016 World Stem Cell Summit along with members of the research team from Stanford University Cardiovascular Institute to discuss this important experiment. The keynote address resulted in a published news story on Science Magazine's website (see: http://www.sciencemag.org/news/2016/12/why-are-scientists-shooting-stem-cells-space).

STEM INITIATIVES

Through the Space Station Explorers community, the ISS National Lab continues to make significant investments in STEM education outreach. In Q1, CASIS launched the Space Station Explorers Ambassador program, with more than 120 educators volunteering to promote ISS-related educational content in their classrooms. This program seeks highly engaged educators that are looking to leverage ISS-related content to spark student interest in STEM subjects and topics. The program will supply teachers with content, enrichment opportunities, and resources throughout the year to deepen engagement with students across the country.

CASIS continued its sponsorship of Brevard Space Week. This week-long program, coordinated by Brevard Schools Foundation and Kennedy Space Center, brings more than 6,000 sixth-graders from across Brevard County on a field trip to the Center to learn about the important research being conducted on the ISS and in other NASA missions.

The CASIS Education team also participated in the 2016 World Stem Cell Summit's inaugural Public Day, which featured a series of free presentations from scientists and subject matter experts. The Education team presented an overview of the Space Station Explorers community and available resources to the students, after-school specialists, and parents in attendance.

Q1 FY17 METRICS

SECURE STRATEGIC FLIGHT PROJECTS: Generate stimulated significant, impactful, and measurable demand from customers willing to cover their costs and therefore recognize the value of the ISS as an innovation platform.

	Q1 FY17	Q2 FY17	Q3 FY17	Q4 FY17	FY17 TOTAL TO DATE	TARGETS FY17
ISS National Lab payloads manifested	18				**18**	**100**
ISS National Lab payloads delivered	8				**8**	**100**
Solicitations / Competitions	1				**1**	**4**
Project proposals generated	31				**31**	**100**
Projects awarded	16				**16**	**40**
ISS National Lab return customers	4				**4**	**20**
ISS National Lab new customers	12				**12**	**20**
Total Value of CASIS Grants Awarded*	$1,986,869				**$1,986,869**	**$5,000,000**
CASIS seed funding toward total project cost	29.44%				**29.44%**	**20%**
Peer-reviewed scientific journal publications	4				**4**	**As they occur**
Products or services created/enhanced	1				**1**	**As they occur**

*Grants include awards to both projects and programs

SECURE INDEPENDENT FUNDING: Leverage external funding through Sponsored Programs to support ISS National Lab projects.

	Q1 FY17	Q2 FY17	Q3 FY17	Q4 FY17	FY17 TOTAL TO DATE	TARGETS FY17
Sponsored Program/external funding for grants	$1,800,000				**$1,800,000**	**$5,000,000**

BUILD REACH IN STEM: Create STEM programs, educational partnerships, and educational outreach initiatives using ISS National Lab-related content.

	Q1 FY17	Q2 FY17	Q3 FY17	Q4 FY17	FY17 TOTAL TO DATE	TARGETS FY17
STEM programs (active)	12				**12**	**15**
Number of students, educators, and other participants engaged in STEM initiatives	62,820				**62,820**	**500,000**
Total value of CASIS STEM grants awarded**	$205,656				**$205,656**	**$402,000**

** Total STEM grants awarded included in the Total Value of CASIS Grants Awarded figure above

INCREASE AWARENESS: Build positive perception of the ISS National Lab within key audience communities.

	Q1 FY17	Q2 FY17	Q3 FY17	Q4 FY17	FY17 TOTAL TO DATE	TARGETS FY17
Outreach events						
Conferences and industry event sponsorships	7				**7**	**12**
Speaking engagements	29				**29**	**68**
Subject matter expert workshops	1				**1**	**4**
Total media impact						
Thought leadership publications (white papers, trade articles, etc.)	0				**0**	**5**
News mentions (clips, blogs)	616				**616**	**5,000**
*Twitter followers^*	103,426				**103,426**	**114,000**
Website visitors	22,358				**22,358**	**129,000**
Social media engagement (Facebook, Twitter, and Instagram)	150,842				**150,842**	**180,000**

^ Cumulative

ISS UTILIZATION: CASIS to use 50% of U.S. allocation onboard the ISS.

INCREMENT	UPMASS (KG)	DOWNMASS (KG)	CREWTIME (HRS)			
	ACTUALS	ACTUALS	ALLOCATION*	ACTUALS^	RESERVE	USAGE**
Inc 37/38 (Sep 2013-Mar 2014)	334.7	7.9	427	78.42	-	18%
Inc 39/40 (Mar 2014-Sep 2014)	389.1	197.8	386	70.75	-	18%
Inc 41/42 (Sep 2014-Mar 2015)	716	705.5	346	130.29	-	38%
Inc 43/44 (Mar 2015-Sep 2015)*	538.3	165.93	229	223.33	-	98%
Inc 45/46 (Sept 2015-Mar 2016)	384.6	0	293	125.75	-	43%
Inc 47/48 (Mar 2016-Sept 2016)	760.9	313.54	356	314.25	-	88%
Inc 49/50 (Sept 2016-Mar 2017)	***463.61***	***0***	***312***	***245.86***	***123.1***	***79%***
Inc 51/52 (Mar 2017-Sept 2017)	***1673.8***	***595.13***	***338***	***475.78***	***85.78***	***141%***

* "Allocation" is defined as the baselined number of crew time hours allocated by NASA at increment minus 3 months to the ISS National Lab for prioritized utilization to directly support in-orbit ISS NL payload utilization operations.

^ "Actuals" are defined as the definite and verified number of crew time hours that were utilized to support in-orbit ISS NL payload utilization operations. This data is collected reported and verified by NASA after the actual in-orbit operations have been completed.

** "Usage" is defined as the percentage of ISS National Lab allocated crew time hours that were actually utilized during a given increment pair.

CONTRIBUTIONS TO SCIENTIFIC KNOWLEDGE – RESULTS PUBLISHED

Title: A Molecular Genetic Basis Explaining Altered Bacterial Behavior in Space. **Principal Investigators:** Dr. David Klaus and Dr. Luis Zea **Institution:** University of Colorado, Boulder **Location:** Boulder, CO **Resulted From:** CASIS-awarded Proposal "Using the International Space Station to Evaluate Antibiotic Efficacy and Resistance" **Citation:** Zea L, Prasad N, Levy SE, Stodieck L, Jones A, Shrestha S, et al. (2016) A Molecular Genetic Basis Explaining Altered Bacterial Behavior in Space. *PLoS ONE* 11(11): e0164359.	**Description:** The results presented in this paper corroborate for the first time the altered extracellular environment model, which has been hypothesized for decades. Bacteria grown in space behave differently than bacteria grown on the ground—for example, some strains of bacteria exhibit enhanced growth, increased virulence, and reduced susceptibility to antibiotics in space. The altered extracellular environment model postulates that microgravity alters the immediate environment around bacterial cells, leading to the observed changes in behavior in space. For this study, gene expression data from space-grown bacteria were compared with that of ground controls. The gene expression data from the space-grown samples was found to correlate with changes in gene expression that one would expect if the altered extracellular environment model were correct, providing strong support for the model. **Earth Benefit:** An understanding of changes in bacterial behavior in space can help scientists better protect astronauts from infection during future long-duration spaceflight missions. In addition, understanding how changes in the extracellular environment affect bacterial behavior also sheds light on the mechanisms of bacterial behavior in people on Earth. Furthermore, elucidation of the mechanisms by which the altered extracellular environment in space triggers behavioral changes in microorganisms and our own cells informs research aimed at uncovering novel molecular targets against drug-resistant bacteria and developing new antibiotics and vaccines.
Title: Anti-PolyQ Antibodies Recognize a Short PolyQ Stretch in Both Normal and Mutant Huntingtin Exon 1 **Principal Investigator:** Dr. Pamela Bjorkman **Institution:** California Institute of Technology **Location:** Pasadena, CA **Resulted From:** An award in response to a CASIS solicitation promoting protein crystal growth on the ISS **Citation:** Owens GE, New DM, Olvera AI, Manzella JA, Macon BL, Dunn JC, Cooper DA, Rouleau RL, Connor DS, Bjorkman PJ. *Acta Crystallogr F Struct Biol Commun.* 2016 Oct 1;72(Pt 10):762-771.	**Description:** This paper discusses results from crystallization experiments performed on the ISS and matching ground-based experiments utilizing an antibody, MW1, for the polyQ terminal of huningtin—a mutation found in people with Huntington's disease. Understanding the structural interactions between MW1 and the mutant huningtin protein could ultimately lead to novel methods to monitor mutant huntingtin in patients undergoing clinical trials to treat Huntington's disease. Bjorkman and her team demonstrate that, on average, the MW1 crystals grown in microgravity were 20% larger and had improved quality (i.e., decreased mosaicity and diffraction resolution) compared with the control crystals grown on Earth. However, interestingly, the highest-quality crystal overall was formed on Earth after return from microgravity. **Earth Benefit:** Understanding the binding interaction between MW1 and the huntingtin protein could lead to novel treatment approaches for Huntington's disease, an inherited neurodegenerative disease for which there is no cure.

Title: The active modulation of drug release by an ionic field effect transistor for an ultra-low power implantable nanofluidic system. **Principal Investigator:** Dr. Alesandro Grattoni **Institution:** Houston Methodist Research Institute **Location:** Houston, TX **Resulted From:** A multi-year matching funding agreement with the Houston Methodist Research Institute **Citation:** Bruno G, Canavese G, Liu X, Filgueira CS, Sacco A, Demarchi D, Ferrari M, Grattoni A. *Nanoscale. 2016 Nov 10;8(44):18718-18725.*	**Description:** This paper describes a novel method of drug delivery focused on the development of a tunable, ultra-low power implantable medical device. Current state-of-the-art implantable drug delivery devices have certain limitations, mainly stemming from high energy consumption, which in turn requires large implantable batteries (restricting where the devices can be placed and requiring large surgical incisions). Utilizing electrofluidics, the new nanofluidic system described in the paper overcomes these limitations by providing an ultra-lower power drug delivery device. In working to develop the device, the research team utilized the light microscopy module onboard the ISS to understand how molecules of different size, shape, and charge diffuse across nanochannels. It is not possible to directly observe individual molecules diffusing across nanoscale channels; however, in microgravity, a surrogate model represented by fluorescent microparticles in microchannels can, in specific circumstances, be highly representative of smaller molecules in nanochannels. Data from the nanochannel diffusion experiments in microgravity were used in the development of the control algorithm for drug release by the prototype medical device described in the paper. **Earth Benefit:** These results aid in the development of next-generation, more reliable, smaller, and longer lasting drug delivery implants with ultra-low power consumption.

COMMERCIAL IMPACT – PRODUCTS OR SERVICES CREATED

Product: Lucid System (FDA approval) **Principal Investigator:** Dr. Robert Hamilton **Institution:** Neural Analytics **Location:** Los Angeles, CA **Resulted From:** A project awarded as part of the MassChallenge Accelerator Program	**Description:** The Lucid System, a highly portable ultrasound device to detect and evaluate signs of increased intracranial pressure, represents the first commercial product developed by biomedical startup Neural Analytics to receive FDA approval. The non-invasive approach of Lucid System represents a major improvement to the current gold standard for medical evaluation of traumatic brain injury (TBI), which requires implantation of sensors in the brain, a method that is usually declined by more than 40% of patients in the U.S. and Europe. Specifically, the technology uses a patented algorithm to correlate changes in cerebral blood flow velocity with changes in intracranial pressure using non-invasive ultrasound technology. **Earth Benefit:** The Lucid System will help physicians monitor the flow of blood and diagnose potentially health- or life-threatening brain disorders, including TBI, without the need for invasive tests. As a highly portable product, it can also help early detection of the more than 2.5 million people in the U.S. who suffer from TBI and concussion, which impact athletes, the military, and other personnel.

PROJECTS AWARDED IN Q1 FY17

Title: Endothelial Cells In Microgravity for Evaluation of Cancer Therapy Toxicity **Principal Investigator:** Dr. Shou-Ching Jaminet **Affiliation:** Angiex **Location:** Cambridge, MA	**Description:** This project seeks to evaluate the hypothesis that microgravity cultured endothelial cells represent a valid model system to test the effects of vascular-targeted cancer drugs on normal blood vessels. In order to grow, all solid tumors must generate new blood vessels. Angiex has created a novel cancer therapy that targets a protein involved in the proliferation of the cells called endothelial cells (ECs) that line the walls of blood vessels. However, the major challenge shared by all developers of vascular-targeted drugs is the lack of an in vitro model of resting normal endothelium to test drug toxicity. ECs cultured in microgravity may be the breakthrough model, as they appear to share many features of the *in vivo* resting endothelium, including a persistent state of reduced cell growth. If the hypothesis is validated, microgravity-cultured ECs would constitute an important model system for evaluating the action of any vascular-targeted drug. It would also potentially enable Angiex's novel drug to be designed for lower toxicity. **Earth Benefit:** Cancer is the second highest cause of death in the United States and is expected to surpass heart disease as the leading cause of death by 2030. Already, cancer is the leading cause of death in 22 states. Approximately 200 million people worldwide (16 million in the U.S.) are currently living with cancer, and 8.2 million people worldwide (589,000 in the U.S.) die from it each year. Angiex's novel therapy targets both the tumor vasculature and tumor cells. Because nearly all cancers require growth of a distinct vasculature to enable tumor growth, Angiex's drug may potentially treat more than 90% of all cancers.

Title: Microgravity Crystalization of Glycogen Synthase-Glycogenin Protein Complex **Principal Investigator:** Dr. David S. Chung **Affiliation:** Dover Lifesciences **Location:** Dover, MA	**Description:** This project aims to bring the experience of being in space onboard the ISS to millions of students through two STEM education experiences. The Virtual Astronaut Experience uses proprietary 3-D virtual reality models of the inside and outside of the ISS and Oculus Touch controllers to allow students to move through the ISS just like astronauts do, by physically grabbing onto holds and propelling their body through microgravity. The Classroom in 360° Experience will consist of recorded "talks and lessons" from astronauts on the ISS combined with a recording of students from a classroom. The students will have a chance to ask questions that the astronauts will answer in their filming. The astronaut and classroom portions will be seamlessly stitched together to produce an immersive 360° experience, featuring the simulation of students in a classroom interacting with astronauts on the ISS for the purposes of specific talks and lessons. **Earth Benefit:** Crystalization of proteins for structural determination is an important tool for drug discovery. Determination of the structure of glycogen synthase in complex with glycogenin could aid in the development of drugs that inhibit glycogen synthase, which could be used to treat obesity, rare genetic disorders, and cancer. There is currently a significant unmet need for drugs to treat these conditions. .
Title: Enhancement of Performance and Longevity of a Protein-Based Retinal Implant **Principal Investigator:** Dr. Nicole L. Wagner **Affiliation:** LambdaVision **Location:** Farmington, CT	**Description:** The goal of this project is to improve the quality and efficiency of the manufacturing process for a protein-based retinal prosthetic that aims to restore vision to the millions of people who are blinded by retinal degenerative diseases, particularly retinitis pigmentosa and age-related macular degeneration. The retinal implant consists of multiple layers of the light-activated protein, bacteriorhodopsin, and is generated utilizing an automated layer-by-layer approach using a polymer binder and an ion-permeable scaffold. Gravity interferes with the homogeneity and uniformity of the layers, and LambdaVision hypothesizes that preparing the multi-layer protein/polymer films in microgravity will be faster and will yield improvements in the homogeneity of the films, the degree of orientation of the protein, and the stability of the resulting multilayer system. **Earth Benefit:** The flexible, protein-based, ion-mediated retinal implant under development will restore vision to the millions of patients suffering from retinal degenerative diseases, particularly retinitis pigmentosa (RP) and age-related macular degeneration (AMD). These diseases damage the photoreceptor cells of the eye, causing a loss of independence for the individual and eventually leading to blindness. In addition to the physical and emotional burden of vision loss, the cost of vision problems in the U.S. is estimated to be $139 billion. To date, no cure exists for patients with RP or AMD, and there are only a limited number of treatments available. Thus, there is a significant unmet need for a therapy or prosthetic capable of restoring functional vision to these patients. The success of this project will allow a better understanding of gravity's effects on the manufacturing process of retinal implants, help accelerate time to market, and enable key decisions to deliver consistent manufacturing of high-quality films for commercialization of the retinal prosthetics.
Title: Crystallization of LRRK2 Under Microgravity Conditions **Principal Investigator:** Dr. Marco Baptista **Affiliation:** Michael J. Fox Foundation **Location:** New York, NY	**Description:** This project aims to utilize the microgravity environment onboard the ISS to optimize the crystallization of the human protein kinase Leucine-rich repeat kinase 2 (LRRK2). LRRK2 is a key signaling molecule in neurons and is closely associated with the development of Parkinson's disease, which affects approximately 5 million people worldwide. Despite a relatively straightforward chemical approach for making drugs that inhibit LRRK2, its complex biology and critical role in normal cellular function and disease remains largely unclear. Characterization of LRRK2's protein structure, identified through crystallization, will support efforts to develop the most selective and potent LRRK2 inhibitor with potential to treat the disease with minimal negative side effects. **Earth Benefit:** Approximately 5 million people worldwide are currently living with Parkinson's disease, and this number is estimated to double by the year 2040. Numerous patents and publications from academic, small biotech, and major pharmaceutical companies claim drug strategies for LRRK2. It is estimated that the potential commercial opportunity for a blockbuster therapeutic with a disease- modifying label in idiopathic Parkinson's disease is more than $2 billion per year.
Title: Influence of Microgravity on Neurogenesis **Principal Investigator:** Dr. Caitlin O'Connell-Rodwell **Affiliation:** HNu Photonics **Location:** Wailuku, HI	**Description:** This project will help accelerate the design, development, and validation of the BioChip SpaceLab (BCSL), a life sciences research facility that is expected to be installed on the ISS National Lab in 2017/2018. The validation experiment will measure how microgravity directly affects human neuroblastoma (a type of cancer that forms in nerve tissue) cell differentiation *in vitro* and will utilize live-cell imaging techniques in real-time on the ISS. This calibration will validate the functionality of the platform for support of this and other cell lines using similar experimental designs and will improve the success rate of future research projects that require BCSL and/or other platforms, including those supporting tissue-on-chip investigations. **Earth Benefit:** The BSCL research facility has the potential to discover novel drugs and treatments for prevalent diseases such as heart disease, Alzheimer's disease, immune system dysfunction, and cancer. For example, utilizing the BSCL research facility to harness microgravity's effect on neuron differentiation may provide a novel cell model to understand neurogenesis dysfunction in Alzheimer's disease, Parkinson's disease, or Huntington's disease and discover potential therapeutics.

Title: STaARS-1 Research Facility **Principal Investigator:** Dr. Heath Mills **Affiliation:** Space Technology and Advanced Research Systems, Inc. (STaARS) **Location:** Houston, TX	**Description:** This project will support Space Technology and Advanced Research Systems, Inc. (STaARS) in the final stages of the construction of the STaARS-1 Research Facility, a next-generation ISS research platform with the capacity to support research in physical sciences, advanced biotechnology, and life sciences. **Earth Benefit:** The STaARS-1 Research Facility is a multipurpose facility that will enable a broad range of experiments on the ISS. In the pharmaceutical market, STaARS-1 will facilitate novel drug discovery, drug compound production and virulence modeling. STaARS-1 will support biomedical therapeutic markets through drug delivery system development, regenerative tissue engineering (stem cell technologies), and biofilm formation prevention. Within the energy markets, STaARS-1 will support studies targeting novel biofuel production through enhanced quality and quantity of multiple compounds.
Title: Spaceborne Computer **Principal Investigator:** David Petersen **Affiliation:** Hewlett Packard Enterprise **Location:** Milpitas, CA	**Description:** This project will entail a year-long experiment on the ISS to test the operation of commercial off-the-shelf (COTS) high performance computer systems in the harsh environment of space. During high-radiation events, the research team will verify that the systems are able to continue to operate correctly by lowering their power and therefore speed. **Earth Benefit:** If successful, this technology demonstration could benefit spacecraft, satellite, and remote outpost computer systems as well as other terrestrial computer systems operating in harsh radiation environments.
Title: Spaceflight Effects on vascular endothelial and smooth muscle cell processes **Principal Investigator:** Dr. Josephine Allen **Affiliation:** University of Florida **Location:** Gainesville, FL	**Description:** The goal of this investigation is to elucidate the molecular mechanisms behind vascular cell damage, like those associated with cardiovascular disease on Earth, by exposing vascular cells to the microgravity environment onboard the ISS National Lab. Changes in the transcriptomics of vascular cells in space will be assessed, and flight samples will be compared with ground-based controls. The insights gained from this study will contribute to an improved understanding of the molecular mechanisms behind cardiovascular disease and have the potential to open new lines of research and/or treatment options. **Earth Benefit:** Cardiovascular disease (CVD) is the leading cause of death in the United States, with an estimated 86 million Americans currently affected by one or more types of CVD. CVD produces an immense economic burden on the U.S., with annual costs of $317 billion in 2011-2012. Data has shown a link between spaceflight and the incidence of CVD. Understanding the stress response of vascular cells to microgravity can provide insight into CVD and potentially shed light on new areas of research into diagnostics and therapeutics for heart disease.
Title: Domesticating algae for sustainable production of feedstocks in space **Principal Investigator:** Dr. Mark Settles **Affiliation:** University of Florida **Location:** Gainesville, FL	**Description:** This investigation seeks to engineer microalgae for growth in microgravity to understand the genetic basis of rapid biomass increase and high-value compound production. A long-term goal is to domesticate and engineer algae for optimal production of biomass feedstocks in space while consuming waste carbon dioxide. Although there is great promise in developing algae into a feedstock for chemical or food production, relatively few algae growth studies have been conducted in space. Algae can also produce high-value compounds that can be used to develop important refined products (such as health-related, pharmaceutical, and nutraceutical products). Abiotic stress from the growth environment can increase production of these high-value compounds in algae. Microgravity, which could be perceived as an abiotic stress, may induce the production of such compounds. **Earth Benefit:** For the successful commercialization of low Earth orbit, sustainable systems are needed to support human activities in space. One such need is the ability to use carbon dioxide waste from respiration to produce useful organic compounds. Toward this end, algae could be used to convert water, light, and carbon dioxide into biomass. Microgravity may also trigger the production of high-value compounds that could be used to produce important pharmaceutical and other health-related products. This investigation aims to be a first step toward developing algae that can help sustain both a low-Earth orbit space economy and future long-duration spaceflight missions. Additionally, advances in genome sequencing, genetics, and gene editing technologies allow humans to domesticate algae for maximal productivity of high-value compounds, and insights from this research could be exploited to improve the domestication of algae on the ground.
Title: An ISS Experiment on Electrodeposition **Principal Investigator:** Dr. Kirk Ziegler **Affiliation:** University of Florida **Location:** Gainesville, FL	**Description:** This project seeks to test electrochemical deposition onboard the ISS to determine if the absence of gravity reduces interfacial instability patterns produced during electrodeposition. Electrodeposition is a process by which an electric current is used to form thin metal features on conductive surfaces like electrodes. During this process, patterns of imperfections form that cause interfacial instability, which can either optimize or deteriorate an electrical current's flow through the electrode. This investigation seeks to utilize the microgravity environment on the ISS (which eliminates gravity-driven confounding factors such as convection) to control the electrodeposition processes so that controlled growth of ordered, high-aspect-ratio structures with fewer imperfections can be achieved. **Earth Benefit:** Results from this investigation can be applied to improve the manufacture of many systems on the ground, such as microfluidic reactors, microscale heat exchangers, sensors, and catalytic converters for use in both industrial (cell phones, computers, etc.) and medical (implantable devices) applications. The results from this investigation will provide the preliminary data needed to secure long-term and substantial external funding from NASA, DOE, and industry.

Title: Microgravity Crystal Growth for Improvement in Neutron Diffraction **Principal Investigator:** Dr. Timothy Mueser **Affiliation:** University of Toledo **Location:** Toledo, OH	**Description:** This investigation seeks to utilize the microgravity environment onboard the ISS National Lab to produce larger and higher quality crystals of three medically relevant proteins for neutron diffraction, with an aim to improve the structure determination of the proteins. The three proteins being crystallized are: Salmonella typhimurium tryptophan synthase (TS), cytosolic aspartate aminotransferase (AST), and a protein complex of a bacteriophage RNase H and single stranded DNA binding protein. Improved structure determination of these proteins could help control Salmonella contamination in the food industry, aid in the development of compounds to help monitor treatment progress in patients with heart or liver disease, and provide insight into how DNA repair could be optimized to prevent diseases caused by damage to DNA. **Earth Benefit:** This project aims to produce larger and higher quality crystals of the Salmonella typhimurium tryptophan synthase (TS) enzyme for improved structure determination to enable the development of novel approaches for the effective elimination of Salmonella contamination. Salmonella is a food-borne pathogen that primarily affects infants and young children. An estimated 94 million cases of Salmonellosis are reported globally each year (with 0.2% mortality). The AST enzyme in humans is a biomarker for myocardial infarction or liver disease. Thus, improved structure determination of the AST enzyme could provide insight into the development of compounds that can help monitor the clinical progress of patients receiving treatment for heart or liver disease. The RNase H protein complex mediates DNA repair. Determining the structure of the RNase H protein complex may provide insights into how the natural process of DNA repair can be optimized to help prevent diseases such as cancers that are, in part, due to DNA damage.
Title: MISSE Flight Facility **Principal Investigator:** LD Stevenson **Affiliation:** Alpha Space **Location:** Houston, TX	**Description:** This project supports the Materials ISS Experiment (MISSE)-Flight Facility (FF) platform developed by Alpha Space Test and Research Alliance (Alpha Space). MISSE-FF will provide a commercially-available materials science and component testing platform with an operational life through the end of the ISS. As an ISS National Lab payload, the platform will provide testing and data collection for both passive and active material samples, component testing in the extreme environment of low Earth orbit, and sample return to Earth for post-mission processing. The MISSE-FF program will be more flexible and will provide several additional services and data than the previous MISSE point-solution experiments. This will allow the testing of more samples and components than previous MISSE experiments. It will also allow the testing in four directions (ram, wake, zenith, and nadir (limited)) on the ISS at the same time. **Earth Benefit:** For all previous MISSE experiments, MISSE-1 through MISSE-8, NASA estimated a total cost of $77 million with an estimated value to the economy of nearly $2 billion over the course of 15 years. The MISSE-FF will allow for an accelerated testing environment for thousands of materials (such as polymers, coatings, and composites) and components (such as switches, sensors, and mirrors) for use in military and commercial products of the future. MISSE-FF testing will provide a platform for testing materials to further the U.S. space program and the mission to Mars by proving their performance in low Earth orbit before going deeper into space. Products such as solar cells can be improved through MISSE-FF testing, and then later used as power sources for remote areas on Earth.
Title: ISS Bioprinter Facility **Principal Investigator:** Dr. Eugene Boland **Affiliation:** Techshot, Inc. **Location:** Greenville, IN	**Description:** This project seeks to complete the Preliminary Design Review for a space-based, automated tissue and organ printing system. The system will be capable of culturing a defined heterogeneous cell population to bioprint tissues and organs that can then be implanted into patients. Once completed, this system will function as a bioprinter capable of personalized medical treatment for either Earth-based patients or astronauts on future duration spaceflight missions. Utilizing a bioprinter to print tissues and organs for transplantation is significantly less invasive than using organs from donors. **Earth Benefit:** The 3D printing of biomaterials is a large and rapidly growing field. According to a 2015 Industry Analytic Research Consulting analysis, the 3D printed materials market in healthcare exceeded $280 million and is estimated to grow over the next six years. This includes all aspects of medical materials, including metals, plastics, ceramics, biomaterials, cells, tissues and organ substitutes. Advances in tissue engineering for 3D bioprinting are gaining importance, and the tissues generated by bioprinting will become available for transplantation in the near future. However, high costs and technical hurdles will hinder the market growth. As a target therapy, development of cardiac repair or replacement tissues in low Earth orbit may provide a cost competitive solution. Techshot has begun investing in this business opportunity, which it believes can improve outcomes for patients.
Title: TangoLab-1.1 **Principal Investigator:** Twyman Clements **Affiliation:** Space Tango, Inc. **Location:** Lexington, KY	**Description:** This project supports the installation of a second TangoLab-1 facility on the ISS. TangoLab-1 is a general research platform on the ISS that enables a broad range of research that utilizes the unique environment of low Earth orbit. The first TangoLab-1 facility will remain on the ISS to double Space Tango's CubeLab capacity to meet customer demand. This second platform, TangoLab-1.1, will have upgrades to the airflow and heat rejection systems to enable larger heat load experiments but will remain the same as TangoLab-1 in terms of ISS interfaces. Both facilities will be fully compatible with one another for operational flexibility. **Earth Benefit:** Since the installation of TangoLab-1 on the ISS in September 2016, there has been significant customer demand to utilize the facility—current demand is more than five times the capacity of the TangoLab-1 facility. The addition of TangoLab-1.1 doubles SpaceTango's CubeLab capacity and enables a larger customer base to utilize the facility, further supporting the commercialization of low Earth orbit. The addition of TangoLab-1.1 will also allow quicker return of payloads to the ground on ISS resupply missions.

Title: Street View Imagery Collect on ISS **Principal Investigator:** Anna Kaputsa **Affiliation:** ThinkSpace **Location:** Mountain View, CA	**Description:** This project seeks to collect full 360° imagery of the internal area of the ISS. The end product will have significant STEM (science, technology, engineering, and mathematics) education applications as well as an extensive global reach through Google Street View and Google Earth. The project will use existing in-orbit resources to create this commercial product, requiring no additional hardware items to be launched. **Earth Benefit:** The significance of the project is the outreach it will achieve. The end product will have significant STEM education applications as well as an extensive global reach. Google Street View is one of the top-10 most used Google products, and has imaged more than 75 countries. Google plans to introduce the ISS imagery as part of the GeoEDU teachers outreach effort, where Google hosts annual teachers summits around the world to educate teachers and policy makers on Google's Geo resources that can be incorporated as part of school curriculum. In addition to student outreach, ISS panoramic imagery will be available to everyone that can access Google Street View and Google Earth.
Title: Crystal Growth STEM 2017 **Principal Investigator:** Ilia Guzei **Affiliation:** University of Wisconsin, Madison **Location:** Madison, WI	**Description:** This project provides an opportunity for the winning team of students from the 2017 Wisconsin Crystal Growing Competition to grow their crystals onboard the ISS National Lab to test their optimized conditions for Earth-based crystallization against microgravity-based crystallization. Students from the winning team will work with the Wisconsin Molecular Structure Laboratory and the CASIS Space Station Explorers team to translate their optimum growth conditions into an experiment to be conducted on the ISS. **Earth Benefit:** In this education project, students learn about crystallization techniques and the importance of microgravity for these studies. The students will work to adapt Earth-based experimental procedures to flight-capable projects, compare data from crystals grown on the ISS to ones grown on the ground, communicate their results through various social media outlets, and contribute to a publication in *Upward*—the quarterly publication of the ISS National Lab.

Q1 FY17 PROJECT PIPELINE

VALIDATION STUDIES AND GROUND TESTING

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	CITY	STATE
ARISS (Amateur Radio from ISS)	Frank Bauer	AMSAT (Radio Amateur Satellite Corporation)	Kensington	MD
3D Neural Microphysiological System	Dr. Michael Moore	AxoSim Technologies	New Orleans	PA
BCM-Dept. of Molecular & Cellular Biology OMICS	Dr. Clifford Dacso	Baylor College of Medicine	Houston	TX
Longitudinal Assessment of Intracranial Pressure During Prolonged Spaceflight	Dr. Clifford Dacso	Baylor College of Medicine	Houston	TX
Optimizing Jammable Granular Assemblies in a Microgravity Environment	Jason Hill	Benevolent Technologies for Health	Cambridge	MA
Commercial space-borne hyperspectral harmful algal bloom (HAB) products	Dr. Ruhul Amin	BioOptoSense, LLC	Metairie	LA
NDC-4: Space Station STEM Challenge	Matthew Weaver	Collins Middle School	Salem	MA
Spacecraft-on-a-Chip Experiment Platform	Dr. Mason Peck	Cornell University	Ithaca	NY
Generation of Cardiomyocytes from Human iPS Cell-derived Cardiac Progenitors	Dr. Chunhui Xu	Emory University	Atlanta	GA
Testing TiSi2 Nanonet Based Lithium Ion Batteries for Safety in Outer Space	Emily Fannon	EnerLeap	Newton	MA
Architecture to Transfer Remote Sensing Algorithms from Research to Operations	Dr. James Goodman	HySpeed Computing, LLC	Miami	FL
Rodent Research-4 Validation Study	Dr. Rasha Hammamieh and Dr. Melissa Kacena	Indiana University Research	Indianapolis	IN
Improving Astronaut Performance of National Lab Research Tasks	Dr. Jayfus Doswell	Juxtopia, LLC	Baltimore	MD
Interrogating the Unfolded Protein Response in Microgravity-Induced Osteoporosis and Sarcopenia	Dr. Imran N. Mungrue	Louisiana State University Health Science Center	New Orleans	LA
Viral infection dynamics and inhibition by the Vecoy nanotechnology	Dr. Drew Cawthon	Lovelace Respiratory Research Institute	Albuquerque	NM
Great Lakes Specific HICO Water Quality Algorithms	Dr. Robert Shuchman	Michigan Technological University	Houghton	MI

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	CITY	STATE
Impact of Increased Venous Pressure on Cerebral Blood Flow Velocity Morphology	Dr. Robert Hamilton	Neural Analytics	Los Angeles	CA
Orions Quest-Student Research on the ISS	Peter Lawrie	Orions Quest	Canton	MI
Microbead Fabrication using Rational Design Engineering	Dr. Brian Plouffe	Quad Technologies	Beverly	MA
Utilize ISS Energy Systems Data for Microgrid Design and Operation	Nicholas Kurlas	Raja Systems	Boston	MA
High Data Rate Polarization Modulated Laser Communication System	Dr. Eric Wiswell	Schafer Corporation	Huntsville	AL
Reducing signal interruption from cosmic ray background in neutron detectors	Dr. Andrew Inglis	Silverside Detectors	Boston	MA
Hyperspectral Mapping of Ironbearing Minerals	Dr. William H. Farrand	Space Science Institute	Boulder	CO
Examine Bone Tumor and Host Tissue Interactions Using Micro-Gravity Bioreactors	Dr. Carl Gregory	Texas A&M Health Science Center	College Station	TX
Remote controlled nanochannel implant for tunable drug delivery	Dr. Alessandro Grattoni	The Methodist Hospital Research Institute	Houston	TX
Combined evaluation of mouse musculoskeletal data	Dr. Virginia Ferguson	University of Colorado Boulder	Boulder	CO
Generation of Mesendoderm Stem Cell Progenitors in the ISS-National Laboratory	Dr. Robert Schwartz	University of Houston System	Houston	TX
Hyperspectral Remote Sensing of Terrestrial Ecosystem Carbon Fluxes	Fred Huemmrich	University of Maryland Baltimore County	Baltimore	MD
Effects of Simulated Microgravity on Cardiac Stem Cells	Dr. Joshua Hare	University of Miami	Miami	FL
3D Organotypic Culture System	Dr. Rocky S. Tuan	University of Pittsburgh	Pittsburg	PA
HICO Identification of Harmful Algal Blooms	Dr. Richard Becker	University of Toledo	Toledo	OH

PREFLIGHT

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	PLANNED LAUNCH VEHICLE	ESTIMATED LAUNCH DATE	CITY	STATE
MUSES Imaging Platform	Bill Corley	Teledyne Brown Engineering	SpX-11	2/1/17	Huntsville	AL
Systemic Therapy of NELL-1 for Osteoporosis (RR-5)	Dr. Chia Soo	UCLA	SpX-11	2/1/17	Los Angeles	CA
Development and Deployment of Charge Injection Device Imagers	Dr. Daniel Batcheldor	Florida Institute of Technology	SpX-10	2/14/17	Melbourne	FL
Growth Rate Dispersion as a Predictive Indicator for Biological Crystal Samples	Dr. Edward Snell	Hauptman Woodward Medical Research Institute, Inc.	SpX-10	2/14/17	Buffalo	NY
Application of Microgravity Expanded Stem Cells in Regenerative Medicine	Dr. Abba Zubair	Mayo Clinic	SpX-10	2/14/17	Rochester	MN
Nanobiosym- Galactic Grant	Dr. Anita Goel	Nanobiosym	SpX-10	2/14/17	Cambridge	MA
SSEP11 – Endeavor	Dr. Jeff Goldstein	NCESSE/Tides Center	SpX-10	2/14/17	Washington	D.C.
The Effect of Macromolecular Transport on Microgravity PCG	Dr. Lawrence DeLucas	University of Alabama at Birmingham	SpX-10	2/14/17	Birmingham	AL
SG100 Cloud Computing Payload	Trent Martin	Business Integra	OA-7	3/16/17	Houston	TX
NDC-2: Denver	Brian Thomas	Centaurus High School	OA-7	3/16/17	Lafayette	CO
Detached Melt and Vapor Growth of InI in SUBSA Hardware	Dr. Aleksandar Ostrogorsky	Illinois Institute of Technology	OA-7	3/16/17	Chicago	IL
Magnetic 3D Cell Culture for Biological Research in Microgravity+A56A37A37:A51	Dr. Glauco Souza	Nano3D Biosciences, Inc.	OA-7	3/16/17	Houston	TX
Efficacy & Metabolism of Azonafide Antibody-Drug Conjugates (ADCs)	Sourav Sinha	Oncolinx Pharmaceuticals, LLC	OA-7	3/16/17	Boston	MA

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	PLANNED LAUNCH VEHICLE	ESTIMATED LAUNCH DATE	CITY	STATE
Crystal Growth of Cs2LiYCl6:Ce Scintillators in Microgravity	Dr. Alexei Churilov	Radiation Monitoring Devices, Inc.	OA-7	3/16/17	Watertown	MA
Genes In Space-2	Julian Rubinfien	The Boeing Company (sponsor)	OA-7	3/16/17	New York	NY
NDC-2: Denver	Shanna Atzmiller	Bell Middle School	SpX-11	4/9/17	Golden	CO
NDC-3: Chicagoland Boy Scouts and Explorers	Norman McFarland	Boy Scouts of America	SpX-11	4/9/17	Palatine	IL
NDC-2: Denver	Joel Bertelsen	Chatfield Senior High School	SpX-11	4/9/17	Littleton	CO
Tomatosphere-2	Ann Jorss	First the Seed Foundation	SpX-11	4/9/17	Alexandria	VA
Functional Effects of Spaceflight on Cardiovascular Stem Cells	Dr. Mary Kearns-Jonker	Loma Linda University	SpX-11	4/9/17	Loma Linda	CA
Neutron crystallographic studies of human acetylcholinesterase for the design	Andrey Kovalevsky	Oak Ridge National Lab	SpX-11	4/9/17	Oak Ridge	TN
TangoLab-1.1	Twyman Clements	Space Tango, Inc.	SpX-11	4/9/17	Lexington	KY
Effect of Microgravity on Stem Cell Mediated Recellularization	Dr. Alessandro Grattoni	The Methodist Hospital Research Institute	SpX-11	4/9/17	Houston	TX
NDC-3: Chicagoland Boy Scouts and Explorers	Dr. Sandra Rogers	Boy Scouts of America	SpX-12	8/1/17	Whiting	IN
Electrolytic Gas Evolution Under Microgravity	Larry Alberts	Cam Med LLC	SpX-12	8/1/17	West Newton	MA
Eli Lilly – Lyophilization	Jeremy Hinds	Eli Lilly and Company	SpX-12	8/1/17	Indianapolis	IN
Assessing Osteoblast Response to Tetranite(TM)	Nikolaos Tapinos, MD, PhD	LaunchPad Medical	SpX-12	8/1/17	Boston	MA
Demonstration and Exploration of the Effects of Microgravity on Production of Fluoride-Based Optical Fibers for Science, Technology, Education and Commercialization on the International Space Station	Michael Snyder	Made In Space, Inc.	SpX-12	8/1/17	Moffett Field	CA
Crystallization of LRRK2 Under Microgravity Condition	Dr. Marco Baptista	Michael J. Fox Foundation	SpX-12	8/1/17	New York	NY
STaARS-1 Research Facility	Dr. Heath Mills	Space Technology and Advanced Research Systems Inc. (STaARS)	SpX-12	8/1/17	Houston	TX
Characterizing Arabidopsis Root Attractions (CARA) – grant extension request	Dr. Anna-Lisa Paul	University of Florida Board of Trustees	SpX-12	8/1/17	Gainesville	FL
Conversion of Adipogenic Mesenchymal Stem Cells into Mature Cardiac Myocytes in the ISS National Laboratory	Dr. Robert Schwartz	University of Houston	SpX-12	8/1/17	Houston	TX
Ultra-Portable Remote-Controlled Microfluidics Microscopy Microenvironment	Dan O'Connell	HNu Photonics	SpX-13	9/20/17	Wailuku	HI
Implantable Nanochannel System for the Controlled Delivery of Therapeutics for Muscle Atrophy (RR-6)	Dr. Alessandro Grattoni	The Methodist Hospital Resesarch Institute	SpX-13	9/20/17	Houston	TX
Capillary-Driven Microfluidics in Space	Dr. Luc Gervais	1Drop Diagnostics US Inc.	TBD	TBD	Boston	MA

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	PLANNED LAUNCH VEHICLE	ESTIMATED LAUNCH DATE	CITY	STATE
Comparative Real-Time Metabolic Activity Tracking for Improved Therapeutic Assessment Screening Panels	Dr. Gary Sayler	490 BioTech, Inc.	TBD	TBD	Knoxville	TN
Corrosion Inhibitor Exposed to the Extreme Environments in Space	Lauren Thompson Miller	A-76 Technologies, LLC	TBD	TBD	Houston	TX
SiC Microgravity Enhanced Electrical Performance (MEEP)	Rich Glover	ACME Advanced Materials	TBD	TBD	Albuquerque	NM
MISSE Flight Facility	LD Stevenson	Alpha Space	TBD	TBD	Houston	TX
Endothelial Cells In Microgravity for Evaluation of Cancer Therapy Toxicity	Dr. Shou-Ching Jaminet	Angiex	TBD	TBD	Cambridge	MA
The Universal Manufacture of Next Generation Electronics	Dr. Supriya Jaiswal	Astrileux Corporation	TBD	TBD	La Jolla	CA
Implantable Glucose Biosensors	Dr. Michail Kastellorizios	Biorasis, Inc.	TBD	TBD	Storrs/ Mansfield	CT
Cranial Bone Marrow Stem Cell Culture in Space	Dr. Yang (Ted) D. Teng	Brigham and Women's and Space Bio-Laboratories Co., Ltd	TBD	TBD	Boston	MA
Inertial Spreading and Imbibition of a Liquid Drop Through a Porous Surface	Dr. Michel Louge	Cornell University	TBD	TBD	Ithaca	NY
Unmasking Contact Line Mobility and Inertially-Spreading Drops	Dr. Paul Steen	Cornell University	TBD	TBD	Ithaca	NY
Space Development Acceleration Capability (SDAC)	Philip Bryden	Craig Technologies	TBD	TBD	Cape Canaveral	FL
Providing Spherical Video Tours of ISS	David Gump	Deep Space Industries	TBD	TBD	Moffett Field	CA
Droplet Formation Studies in Microgravity	Garry Marty	Delta Faucet	TBD	TBD	Indianapolis	IN
Rodent Research-Wound Healing	Dr. Rasha Hammamieh	Department of Defense and Indiana University Research	TBD	TBD	Fort Detrick	MD
DexMat CASIS CNT Cable Project	Dr. Alberto Goenaga	DexMat, Inc.	TBD	TBD	Houston	TX
Microgravity Crystalization of Glycogen Synthase-Glycogenin Protein Complex	Dr. David S. Chung	Dover Lifesciences	TBD	TBD	Dover	MA
Survivability of Variable Emissivity Devices for Thermal Control Applications	Dr. Hulya Demiryont	Eclipse Energy Systems, Inc.	TBD	TBD	St. Petersburg	FL
Fiber Optics Manufacturing in Space (FOMS)	Dr. Dmitry Starodubov	FOMS, Inc.	TBD	TBD	San Diego	CA
Spaceborne Computer	David Petersen	Hewlett Packard Enterprise	TBD	TBD	Milpitas	CA
Influence of Microgravity on Neurogenesis	Dr. Caitlin O'Connell-Rodwell	HNu Photonics	TBD	TBD	Wailuku	HI
Intuitive Machines-ISS Terrestrial Return Vehicle (TRV)	Steve Altemus	Intuitive Machines	TBD	TBD	Houston	TX
GRASP	Robert Carlson	JAMSS America, Inc.	TBD	TBD	Houston	TX
Enhancement of Performance and Longevity of a Protein-Based Retinal Implant	Dr. Nicole L. Wagner	LambdaVision	TBD	TBD	Farmington	CT
Development and validation of a microfluidic lab-on-a chip	Dr. Siobhan Malany	Micro-gRx, Inc.	TBD	TBD	Orlando	FL
Nemak Alloy Solidification Experiments	Dr. Glenn Byczynski	Nemak	TBD	TBD	Southfield	MI

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	PLANNED LAUNCH VEHICLE	ESTIMATED LAUNCH DATE	CITY	STATE
Map the Penetration Profile of a Contact-Free Transdermal Drug Delivery System	Dr. Robert Applegate	Novopyxis	TBD	TBD	Boston	MA
The Virtual Astronaut	Amaresh Kollipara	Oculus	TBD	TBD	Los Angeles	CA
Constrained Vapor Bubbles of Ideal Mixtures	Dr. Joel Plawsky	Rensselaer Polytechnic Institute	TBD	TBD	Troy	NY
Intraterrestrial Fungus Grown in Space (iFunGIS)	Dr. Heath Mills	Space Technology and Advanced Research Systems Inc. (STaARS)	TBD	TBD	San Antonio	TX
Intracellular Macromolecule Delivery and Cellular Biomechanics in Microgravity	Harrison Bralower	SQZ Biotechnologies	TBD	TBD	Somerville	MA
NDC-4: Space Station STEM Challenge	Benjamin Coleman	Talbot Middle School	TBD	TBD	Fall River	MA
ISS Bioprinter Facility	Dr. Eugene Boland	Techshot, Inc.	TBD	TBD	Greenville	IN
Street View Imagery Collect on ISS	Anna Kaputsa	ThinkSpace	TBD	TBD	Mountain View	CA
Investigation of the effects of microgravity on controlled release of antibiotics and curing mechanism of a novel wound dressing	Dr. Elaine Horn-Ranney	Tympanogen, LLC	TBD	TBD	Norfolk	VA
Quantifying Cohesive Sediment Dynamics for Advanced Environmental Modeling	Dr. Paolo Luzzatto-Fegiz	University of California, Santa Barbara	TBD	TBD	Santa Barbara	CA
Kinetics of nanoparticle self-assembly in directing fields	Dr. Eric Furst	University of Delaware	TBD	TBD	Newark	DE
Spaceflight Effects on vascular endothelial and smooth muscle cell processes	Dr. Josephine Allen	University of Florida	TBD	TBD	Gainesville	FL
Domesticating algae for sustainable production of feedstocks in space	Dr. Mark Settles	University of Florida	TBD	TBD	Gainesville	FL
An ISS Experiment on Electrodeposition	Dr. Kirk Ziegler	University of Florida	TBD	TBD	Gainesville	FL
Faraday Waves and Instability-Earth and Low G Experiments	Dr. Ranga Narayanan	University of Florida Board of Trustees	TBD	TBD	Gainesville	FL
Microgravity Crystal Growth for Improvement in Neutron Diffraction	Dr. Timothy Mueser	University of Toledo	TBD	TBD	Toledo	OH
Crystal Growth STEM 2017	Ilia Guzei	University of Wisconsin, Madison	TBD	TBD	Madison	WI
Space Based Optical Tracker	Dr. John Stryjewski	Vision Engineering Solutions	TBD	TBD	Orlando	FL
Zaiput Flow Technologies – Galactic Grant	Dr. Andrea Adamo	Zaiput Flow Technologies	TBD	TBD	Cambridge	MA
SPHERES Zero Robotics High School	Dr. Alvar Saenz Otero	Massachusetts Institute of Technology	yearly	yearly	Cambridge	MA
SPHERES Zero Robotics Middle School	Dr. Alvar Saenz Otero	Massachusetts Institute of Technology	yearly	yearly	Cambridge	MA

IN ORBIT

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	PLANNED LAUNCH VEHICLE	ESTIMATED LAUNCH DATE	CITY	STATE
Eli Lilly – Dissolution of Hard to Wet Solids	Dr. Richard Cope, Dr. Alison Campbell, and Dr. Kenneth Savin	Eli Lilly and Company	SpX-10	3/19/17	Indianapolis	IN
NIH-Osteo	Dr. Bruce Hammer	University of Minnesota	SpX-10	3/19/17	Minneapolis	MN
Controlled Dynamics Locker for Microgravity Experiments on ISS	Dr. Scott A. Green	Controlled Dynamics, Inc.	SpX-12	9/2/17	Huntington Beach	CA
Demonstration and TRL Raising of the Net Capture System on the ISS	Ron Dunklee	AIRBUS DS Space Systems, Inc.	N/A	N/A	Webster	TX
National Lab Project: AMS	Dr. Samuel Ting	Department of Energy; MIT	N/A	N/A	Cambridge	MA
National Lab Project: ISERV	Burgess Howell	Disaster Relief Charter; NASA Marshall Space Flight Center	N/A	N/A	Huntsville	AL
GLASS AIS Transponder Global AIS on Space Station	Robert Carlson	JAMSS America, Inc.	N/A	N/A	Houston	TX
Additive Manufacturing Operations Program	Michael Snyder	Made In Space, Inc.	N/A	N/A	Moffett Field	CA
NanoRacks External Platform	Michael Johnson	Nanoracks, LLC	N/A	N/A	Houston	TX
Zero-G Characterization & OnOrbit Assembly for Cellularized Satellite Tech	Talbot Jaeger	NovaWurks, Inc.	N/A	N/A	Los Alamitos	CA
Project Meteor	Michael Fortenberry	Southwest Research Institute	N/A	N/A	Boulder	CO
MultiLab: Research Server for the ISS	Twyman Clements	Space Tango, Inc.	N/A	N/A	Lexington	KY
Bone Densitometer	John Vellinger	Techshot, Inc.	N/A	N/A	Greenville	IN
Windows On Earth	Dan Barstow	TERC	N/A	N/A	Cambridge	MA
Tropical Cyclone Intensity Measurements from the ISS (CyMISS) – Season 3	Dr. Paul Joss	Visidyne, Inc.	N/A	N/A	Burlington	MA
Materials Testing – Earth Abundant Textured Thin Film Photovoltaics	Dr. Jud Ready	Georgia Institute of Technology	TBD	TBD	Atlanta	GA
Honeywell/Morehead-DM Payload Processor	Dr. Benjamin Malphrus	Honeywell/Morehead State University	TBD	TBD	Morehead	KY
Materials Testing – The Evaluation of Gumstix Modules in Low Earth Orbit	Dr. Kathleen Morse	Yosemite Space	TBD	TBD	Groveland	CA

POSTFLIGHT/COMPLETE

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	CITY	STATE
NDC-1: Pilot Program	Angela Glidewell	Awty International School	Houston	TX
NDC-1: Pilot Program	Jessika Smith	Awty International School	Houston	TX
Collaborative project-protein crystal growth to enable therapeutic discovery	Dr. Matt Clifton	Beryllium Discovery Corp.	Bedford	MA
Ants in Space	Stefanie Countryman	BioServe Space Technologies	Boulder	CO
Osteocyte response to mechanical forces	Dr. Paola Divieti Pajevic	Boston University	Boston	MA
PCG-Crystallization of Huntington Exon-1 Using Microgravity	Dr. Pamela Bjorkman	California Institute of Technology	Pasadena	CA

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	CITY	STATE
Cobra Puma Golf Microgravity Electrodeposition Experiment	Mike Yagley	Cobra Puma Golf	Carlsbad	CA
NDC-1: Pilot Program	Rev. Brian Reedy	Cristo Rey Jesuit College Preparatory of Houston	Houston	TX
NDC-1: Pilot Program	Greg Adragna	Cristo Rey Jesuit College Preparatory of Houston	Houston	TX
NDC-1: Pilot Program	Kathy Duquesnay	Duchesne Academy	Houston	TX
NDC-1: Pilot Program	Susan Knizner	Duchesne Academy	Houston	TX
HUNCH Extreme Science-3	David Schlichting	Eaglecrest High School	Centennial	CO
Eli Lilly-RR3 Myostatin	Dr. Rosamund Smith	Eli Lilly and Company	Indianapolis	IN
Eli Lilly PCG	Kristofer R. Gonzalez-DeWhitt and Michael Hickey	Eli Lilly and Company	Indianapolis	IN
Tomatosphere	Ann Jorss	First the Seed Foundation	Alexandria	VA
Exploiting on-orbit crystal properties for medical and economic targets	Dr. Edward Snell	Hauptman Woodward Medical Research Institute, Inc.	Buffalo	NY
Espresso Cup	Dr. Mark Weislogel	IRPI LLC	Wilsonville	OR
PCG – IPPase Crystal Growth in Microgravity	Dr. Joseph Ng	iXpressGenes, Inc.	Huntsville	AL
Molecules Produced in Microgravity from the Chernobyl Nuclear Accident	Dr. Kasthuri Venkateswaran	Jet Propulsion Laboratory/Caltech	Pasadena	CA
Kentucky Space/Exomedicine Lab – Flatworm	Dr. Mahendra Jain	Kentucky Space, LLC	Lexington	KY
Omega Hydrofuge Plant Growth Chamber – HUNCH Extreme Science – Lakewood	Matthew Brown	Lakewood High School	Lakewood	CO
Merck PCG-1	Dr. Paul Reichert	Merck Pharmaceuticals	Whitehouse Station	NJ
Merck PCG-2	Dr. Paul Reichert	Merck Pharmaceuticals	Whitehouse Station	NJ
Vertical Burn	Dr. Jeff Strahan	Milliken	Spartanburg	SC
Validation of WetLab-2 System for qRT-PCR capability on ISS	Julie Schonfeld	NASA ARC	Moffett Field	CA
SSEP5a – Falcon I	Dr. Jeff Goldstein	NCESSE/Tides Center	Washington	D.C.
SSEP5b – Falcon II	Dr. Jeff Goldstein	NCESSE/Tides Center	Washington	D.C.
SSEP6 – Orion	Dr. Jeff Goldstein	NCESSE/Tides Center	Washington	D.C.
SSEP7 – Charlie Brown	Dr. Jeff Goldstein	NCESSE/Tides Center	Washington	D.C.
SSEP8 – Yankee Clipper	Dr. Jeff Goldstein	NCESSE/Tides Center	Washington	D.C.
SSEP9 – Odyssey	Dr. Jeff Goldstein	NCESSE/Tides Center	Washington	D.C.
SSEP10 – Kitty Hawk	Dr. Jeff Goldstein	NCESSE/Tides Center	Washington	D.C.
T-Cell Activation in Aging-1	Dr. Millie Hughes-Fulford	Northern California Institute for Research and Education, Inc.	San Francisco	CA
T-Cell Activation in Aging-2	Dr. Millie Hughes-Fulford	Northern California Institute for Research and Education, Inc.	San Francisco	CA
Novartis Rodent Research-1	Dr. David Glass	Novartis Institute for Biomedical Research	Cambridge	MA
Novartis Rodent Research-2	Dr. David Glass	Novartis Institute for Biomedical Research	Cambridge	MA
Binary Colloidal Alloy Test – Low Gravity Phase Kinetics Platform	Dr. Matthew Lynch	Procter & Gamble, with Zin Technologies, Inc.	Cincinnati	OH
Collaborative project-protein crystal growth to enable therapeutic discovery	Dr. Cory Gerdts	Protein BioSolutions	Gaithersburg	MD

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	CITY	STATE
Synthetic Muscle: Resistance to Radiation	Dr. Lenore Rasmussen	Ras Labs	Hingham	MA
HUNCH Chlorella/Billings Central Catholic High	Dr. Florence Gold	Rocky Mountain College	Billings	MT
PCG - Crystallization of Medically Relevant Proteins Using Microgravity	Dr. Sergey Korolev	Saint Louis University	Saint Louis	MO
Effects of Microgravity on Stem Cell-Derived Heart Cells	Dr. Joseph Wu	Stanford University	San Francisco	CA
Mutualistic Plant/Microbe Interactions	Dr. Gary W. Stutte	SyNRGE, LLC	Titusville	FL
Story Time from Space – 1	Patricia Tribe	T2 Science and Math Education Consultants	League City	TX
Story Time from Space – 3	Patricia Tribe	T2 Science and Math Education Consultants	League City	TX
Story Time from Space – 2	Patricia Tribe	T2 Science and Math Education Consultants	League City	TX
Story Time from Space – 4	Patricia Tribe	T2 Science and Math Education Consultants	League City	TX
Genes In Space	Anna-Sophia Boguraev	The Boeing Company (sponsor)	Bedford	NY
Decoupling Diffusive Transport Phenomena in Microgravity	Dr. Alessandro Grattoni	The Methodist Hospital Research Institute	Houston	TX
PCG – Crystallization of Human Membrane Proteins in Microgravity	Dr. Stephen Aller	University of Alabama at Birmingham	Birmingham	AL
Antibiotic Effectiveness in Space-1 (AES-1)	Dr. David Klaus	University of Colorado Boulder	Boulder	CO
Molecular Biology of Plant Development (Petri Plants)	Dr. Anna-Lisa Paul	University of Florida	Gainesville	FL
Protein Crystal Growth for Determination of Enzyme Mechanisms	Dr. Constance Schall	University of Toledo	Toledo	OH
Drug Development and Human Biology: Use of Microgravity for Drug Development	Dr. Timothy Hammond	Veterans Administration Medical Center	Durham	NC
Cyclone Intensity Measurements from the International Space Station (CyMISS)	Dr. Paul Joss	Visidyne, Inc.	Burlington	MA

CONFERENCES AND EVENTS IN Q1 FY17

CONFERENCE AND INDUSTRY EVENT SPONSORSHIPS

EVENT	LOCATION	DATE	AUDIENCE	DESCRIPTION
Dreamforce 2016	San Francisco, CA	10/4/16-10/7/16	Salesforce users	CASIS exhibited at Dreamforce 2016, an annual user conference hosted by Salesforce.com that brings together thought leaders, industry pioneers, and thousands of technology professionals. CASIS demonstrated the capabilities of the ISS through its interactive 3D display, providing conference attendees with a hands-on experience for exploring and learning about the entire habitable area of the ISS.
Biomedical Engineering Society Annual Meeting	Minneapolis, MN	10/5/16-10/8/16	Biomedical researchers, engineers, and companies	CASIS exhibited at the annual meeting of the Biomedical Engineering Society, the world's leading society of nearly 3,000 professionals devoted to developing and using engineering and technology to advance human health and well-being. The CASIS team engaged with potential applicants for the National Center for Advancing Translational Sciences (NCATS)/CASIS sponsored program and discussed how the spaceflight environment provides the opportunity to accelerate technologies out of the laboratory.

EVENT	LOCATION	DATE	AUDIENCE	DESCRIPTION
American Society for Gravitational and Space Research (ASGSR) Annual Meeting	Cleveland, OH	10/26/16-10/29/16	Scientific community	CASIS exhibited and presented at the 32nd Annual Meeting of the American Society for Gravitational and Space Research (ASGSR), the largest gathering of global scientists with a common interest in how living organisms and physical systems respond to gravity. CASIS conducted plenary sessions focused on the ISS National Lab, current and planned research onboard the space station, and CASIS resources to support research in microgravity. Additionally, CASIS hosted 50 students in presentations and conversations to inspire interest in STEM disciplines.
Commercial Spaceflight Federation (CSF) Executive Leadership Forum	Washington, DC	10/27/16	Congressional staffers, NASA administrators, industry, FAA, and other D.C. stakeholders groups	CASIS participated in strategic discussions related to the future of human spaceflight during an executive leadership briefing hosted by the Commercial Spaceflight Federation (CSF), which was attended by nearly 40 members of congressional staff, NASA administration, industry, FAA, and other stakeholder groups. NASA Senior Economic Advisor Alexander MacDonald led an open discussion on future economic considerations for human spaceflight activities in low Earth orbit.
MassChallenge Boston Awards 2016	Boston, MA	11/2/16	Start-up companies, investors, and supporters	CASIS sponsored the MassChallenge Awards, the finale of the Boston startup accelerator program for promising entrepreneurs. In addition to the 128 finalists and their guests, CASIS connected with a community of entrepreneurs, investors, corporate executives, politicians, and philanthropists.
Space Commerce Conference and Exposition (SpaceCom)	Houston, TX	11/15/16-11/17/16	Aerospace professionals, business executives, and researchers	CASIS was a sponsor, presenter, and exhibitor at the Space Commerce Conference and Exposition (SpaceCom), a commercial industry event where business leaders, space services providers, and technologists from multiple aerospace sectors learned how to utilize new space technology and enable access to space-based assets. CASIS participated in six panels and talks focused on accessing the ISS and its capabilities, recent research projects conducted on the ISS, and how space research and technology has and will continue to benefit life on Earth.
World Stem Cell Summit	West Palm Beach, FL	12/6/16-12/9/16	Scientists, researchers, and academics specializing in stem cell and regenerative medicine research	CASIS was a co-organizing sponsor, presenter, and exhibitor at the World Stem Cell Summit, an interdisciplinary conference produced by the Genetics Policy Institute and the Regenerative Medicine Foundation. The summit convenes hundreds of stem cell science and regenerative medicine stakeholders, enabling CASIS to engage with key stakeholders in support of low Earth orbit (LEO) commercialization, organ bioengineering efforts related to stem cell research, organs-on-chips, and tissues-to-organs research.

SUBJECT MATTER EXPERT WORKSHOPS

EVENT	LOCATION	DATE	AUDIENCE	DESCRIPTION
Immunome/ Microbiome Workshop	Cleveland, OH	10/25/16	Researchers and scientists	CASIS continued its ongoing series of subject-matter-expert workshops with a one-day forum on "Omes and Omics: Exploring the Microbiome/ Immunome and Disease on the International Space Station U.S. National Lab." CASIS Deputy Chief Scientist Michael Roberts led nearly 40 researchers and scientists through discussions to identify and prioritize research questions and science requirements for a sustainable sponsored research program onboard the ISS National Lab.

ADDITIONAL CONFERENCE AND EVENT PARTICIPATION

EVENT	LOCATION	DATE	AUDIENCE	DESCRIPTION
Florida Afterschool Alliance (FASA) Conference	Orlando, FL	10/12/16-10/14/16	FASA informal education administrators	The CASIS team presented the Space Station Explorers portfolio and engaged students in hands-on activities.
Industrial Research Institute Member Summit	Chicago, IL	10/16/16-10/20/16	Industry leaders	A CASIS representative participated in the Industrial Research Institute Member Summit on "Digitalization and R&D Management" to learn how current industry leaders develop R&D and innovation portfolios.
Space Day at Divine Mercy Catholic Academy	Merritt Island, FL	10/20/16	Students, educators, and parents	A CASIS representative interacted with more than 160 elementary and middle school students during Space Day at Divine Mercy Catholic Academy. Students learned about the Space Station Explorers program and engaged in educational activities about communication on the ISS.

EVENT	LOCATION	DATE	AUDIENCE	DESCRIPTION
CASIS Academy Live	Cape Canaveral, FL	10/21/16	Students, graduate students, teachers, and guests	CASIS hosted 140 middle school students, educators, and guests in person and online. Principal Investigator Jeremy Hinds spoke to the students about the importance of freeze drying in space. He also participated in a NASA Digital Learning Network interview and conducted a public talk at the Kennedy Space Center Visitor Complex. In addition, 16 sites connected to the live stream from CA, FL, VA, MO, IL, IN, Korea, Germany, Peru, and Denmark.
Vascular Tissue Challenge Roadmapping Workshop	Mountain View, CA	11/9/16-11/10/16	Atendees from government agencies, academic institutions, and industry organizations	The workshop, organized by the New Organ Alliance, brought together more than 100 attendees to discuss state-of-the-art technology in thick-tissue vascularization and 3D tissue engineering, toward ending the organ shortage benefiting from these technologies. CASIS participated in the opening remarks and a panel discussion. The workshop was sponsored by NanoRacks, TechShot, and Space Pharma in partnership with CASIS, the National Science Foundation, the NASA Centennial Challenges Program, Duke University Cardiovascular Research Center, the Organ Preservation Alliance, and the Methuselah Foundation.
Florida Theater - Museum of Science and History	Jacksonville, FL	11/14/16	Students, educators, and the general public	CASIS exhibited and highlighted Space Station Explorers program resources during a special event, "An Evening with Neil deGrasse Tyson," hosted by the Florida Theatre and the Museum of Science and History.
Amateur Radio on the International Space Station (ARISS) Annual Conference	Houston, TX	11/15/16-11/17/16	ARISS team	A CASIS representative introduced the Space Station Explorers program to 100 individuals attending the Amateur Radio on the International Space Station (ARISS) Annual Conference. ARISS helps inspire students to pursue interests in science, technology, engineering, and mathematics by engaging them in the excitement of talking directly with crew members onboard the ISS.
IAA (International Academy of Astronautics)	Cape Canaveral, FL	11/18/16	Engineering and science professionals in aerospace, students, and industry leaders	A CASIS representative spoke to an audience of 50 young aerospace engineering professionals, science professionals, and students on achieving success in the changing environment of commercial space operations. CASIS also interacted with senior officers of the American Institute of Aeronautics and Astronautics and Space Coast industry leaders.
CASIS Academy Live	Cape Canaveral, FL	11/28/16	Students and educators	CASIS hosted 43 students and educators from Bayside Lakes High School. Special CASIS guest, Dr. Ken Savin from Eli Lilly and Company, discussed the pharmaceutical industry and his research on the ISS. He also conducted a live interview on the NASA Digital Learning Network and gave a public talk in the Journey to Mars Theater at the Kennedy Space Center Visitor Complex.
National Earth Science Teachers Association Share-a-Thon	Columbus, OH	12/1/16-12/3/16	K-12 educators	The CASIS team exhibited at the National Earth Science Teachers Association Share-a-Thon, which enables teachers to explore ideas, activities, and projects for Earth science education. CASIS introduced attendees to the Space Station Explorers program and other Earth science teaching resources.
Career Day at Southwest Middle School	Palm Bay, FL	12/2/16	Students	A CASIS representative introduced more than 125 middle school students to the Space Station Explorers program during Career Day at Southwest Middle School.
CASIS Academy Live	Cape Canaveral, FL	12/9/16	Students, educators, and guests	CASIS hosted 42 students and educators from Ft. Pierce High School where Dr. Deborah Gordon shared her work in ant research in microgravity. Dr. Gordon also interacted with students in a live interview as part of the NASA Digital Learning Network and conducted a public talk in the Astronaut Theater at the Kennedy Space Center Visitor Complex.

FINANCIALS

BUSINESS STATUS REPORT (UNAUDITED)

OCT 1 – DEC 31, 2016	ACTUAL Q1 2017	BUDGET Q1 2017	VARIANCE	ACTUAL YTD 2017	BUDGET YTD 2017	VARIANCE
Direct Labor	$1,460,687	$1,572,688	$(112,001)	$1,460,687	$1,572,688	$(112,001)[a]
Subcontracts	$209,824	$475,785	$(265,961)	$209,824	$475,785	$(265,961)[b]
Permanent Equipment > $5k	$8,974	$413,700	$(404,726)	$8,974	$9,000	$(26)
Office Supplies & Equipment	$60,403	$256,578	$(196,175)	$60,403	$73,174	$(12,771)
Travel	$232,767	$256,578	$(23,811)	$232,767	$256,578	$(23,811)
Grants	$429,360	$1,920,640	$(1,491,280)	$429,360	$1,920,640	$(1,491,280)[c]
Other Direct Expenses	$374,466	$376,094	$(1,628)	$374,466	$376,094	$(1,628)
Total	**$2,776,481**	**$5,272,063**	**$(2,495,582)**	**$2,776,481**	**$4,683,959**	**$(1,907,478)**

(a) Headcount Actual 42 vs. Budget of 45.
(b) Subcontracts were lower than budget for marketing, science, business development, and legal.
(c) Grant recipient milestone payments have shifted to later in FY17 due to flight delays.

BREAKOUT OF COOPERATIVE AGREEMENT FUNDING

	Q1 FY17	Q2 FY17	Q3 FY17	Q4 FY17
Direct	55.20%			
Indirect	19.50%			
Grants	15.30%			

BREAKOUT OF CASIS GRANTS

	Q1 FY16	Q2 FY16	Q3 FY16	Q4 FY16
Private/Commercial	$421,644			
Academic	($88,466)*			
Mission Based Costs	$96,181			

*Negative value due to returned funds from a previous grantee.

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