FY16 Q4 REPORT

Quarterly Report for the Period Jul 1 – Sep 30, 2016

CENTER FOR THE ADVANCEMENT OF SCIENCE IN SPACE (CASIS)

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EXECUTIVE SUMMARY

The final quarter of FY16 was characterized by meaningful progress for the International Space Station (ISS) U.S. National Laboratory through increased R&D, new research programs and partnerships, and improved commercial utilization. The CASIS team made significant strides in engaging new user segments, cultivating federal government agency participation in space research, and increasing awareness of station capabilities. In addition to a record number of ISS crew time hours devoted toward utilization payloads, this quarter was important for further development of the ISS as a first-class research platform. For the first time ever, DNA was successfully sequenced in microgravity as part of the Biomolecule Sequencer experiment performed by NASA astronaut and molecular biologist Kate Rubins. The new ability to sequence the DNA of living organisms in space is an exciting reminder of the scientific and medical possibilities of spaceflight R&D.

Marking a critical point in the history of CASIS partnerships with non-NASA government agencies, multiyear collaborations with both the National Science Foundation (NSF) and the National Institutes of Health (NIH) were announced in Q4, totaling more than $19 million in potential funding from these organizations for ISS National Lab R&D. Recognition of the exceptional value of the ISS National Lab by these prominent science organizations bolsters the importance of the CASIS mission and the value of space-based research aimed at improving the lives of people on Earth. By partnering with non-NASA government organizations engaged in leading-edge science, CASIS is able to leverage funding from outside sources to support innovative research onboard the ISS National Lab.

KEY HIGHLIGHTS FROM Q4 FY16 INCLUDE:

- **Increased R&D in orbit** – Expedition 47/48 set a record for crew hours dedicated to science research, averaging 44 hours per week. Additionally, there are now three commercial partners operating facilities on the ISS National Lab, with two new partners added in the past year alone and three more preparing for future operations. Finally, four academic journal articles were published in Q4 resulting from CASIS-sponsored projects.
- **New ISS National Lab science delivered and returned** – The successful launch and berthing of SpaceX CRS-9 saw 22 payloads reach the ISS, spanning a variety of science disciplines, including two commercial experiments from Eli Lilly, a new commercial facility from Space Tango, Inc., and several education payloads previously lost in two launch anomalies.
- **Commercial utilization** – CASIS awarded Facebook's Oculus for an innovative STEM project to engage students in advanced technologies and Delta Faucet to conduct applied fluids research onboard the ISS National Lab. Additionally, an agreement with Airbus lays the groundwork for a new external facility that will support more robust remote sensing, technology development, and materials research initiatives.
- **Connecting the space research community** – CASIS, NASA, and the American Aeronautical Society co-sponsored the 5th annual ISS Research and Development Conference, which represented the largest gathering of the ISS R&D user community to date, with more than 700 attendees.
- **Space Investment Network** – CASIS continues to attract leading venture capital and angel investors and has grown its network to 33 investors. To date, CASIS has facilitated more than 70 introductions between start-up companies and its investor network. CASIS plans to scale up both the network and number of introductions during FY 2017, with the goal of infusing more capital into the ISS National Lab and low Earth orbit user communities.

While the quarter was overwhelmingly positive, the ISS National Lab experienced a notable setback in terms of the transportation infrastructure with the unfortunate SpaceX Falcon 9 rocket explosion on Space Launch Complex 40 in September 2016. CASIS is working with the research community and its counterparts at NASA and industry to minimize the impact on future research in the pipeline.

Finally, CASIS released the third issue of *Upward*, the ISS National Lab's official quarterly magazine. The latest issue highlights several projects, including the science that global consumer goods giant Procter & Gamble conducted on the ISS in an effort to improve the shelf life of its products. The volume and diversity of activity in Q4 reflects the cumulative efforts of CASIS, NASA, other government agencies, and a growing cadre of commercial and academic institutions now actively involved in space research.

ISS NATIONAL LAB PORTFOLIO

ESTABLISH INNOVATION CYCLES AND UTILIZE THE ISS FOR DEVELOPING NEW CAPABILITIES

AWARDS AND OPPORTUNITIES

Life Sciences

In the life sciences area, the ISS National Lab announced two funding opportunities in Q4 and held multiple webinars associated with current and upcoming opportunities.

1. **Funding Opportunity and Webinar in collaboration with NIH:** CASIS and the National Center for Advancing Translational Sciences (NCATS), part of the National Institutes of Health (NIH), 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. In advance of this FOA release, CASIS and NCATS held an informational webinar that provided interested investigators an opportunity to learn more about the CASIS–NCATS partnership and to interact with personnel that have specific expertise in developing spaceflight experiments for the ISS. More than 120 people participated in the webinar, the slides and recording from which can be found at casistissuechip.blogspot.com.

   - Microphysiological systems research onboard the ISS National Lab takes advantage of the reduced fluid shear, microgravity environment that recapitulates 3-D cellular and tissue structures. Advancing this research in space could accelerate the discovery of molecular mechanisms that underlie a range of common human disorders on Earth, as well as improve understanding and testing of therapeutic targets and treatments.
   - This area of research is a high priority for CASIS, as evidenced by both this new NCATS partnership and an additional award announcement last quarter from a CASIS competition focused on organs-on-chips research. CASIS and NCATS hope to encourage investigators with expertise in materials science, microfabrication, microfluidics, universal media, stem cell technology, tissue engineering, and disease modeling to consider applying for this newest funding opportunity: grants.nih.gov/grants/guide/rfa-files/RFA-TR-16-019.html.

2. **Funding Opportunity and Webinar in the area of protein crystal growth:** Also in Q4, as part of ongoing efforts to develop a Macromolecular Crystallization Program, CASIS released a solicitation for proposals to provide support services—including laboratory, integration, and hardware support—for researchers interested in conducting crystallization experiments onboard the ISS National Lab. 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. In support of this solicitation, CASIS hosted a written question and answer period and held a webinar to answer questions in advance of the September 15 submission deadline. Selections will be made in Q1FY17, and it is anticipated that responses from this solicitation will inform and enhance ISS National Lab commercial initiatives in the field of protein crystal growth. The CASIS Macromolecular Crystallization Program 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.

3. **Webinar in the area of tissue engineering:** A third webinar in Q4 supported NASA's Vascular Tissue Challenge, a competition to produce technologies capable of creating viable, thick metabolic tissues that can be used to advance research on human physiology, fundamental space biology, and medicine both on the ISS National Lab and in terrestrial studies.

   - 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 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 1 cm in an in vitro environment—while maintaining metabolic functionality similar to their in vivo native cells throughout a 30-calendar day survival period. As of the conclusion of the webinar, the competition is officially open: www.neworgan.org/vtc-prize.php.
   - CASIS is providing 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.

Finally, three new life sciences projects were selected in Q4—two from commercial customers and one in collaboration with the Department of Defense (DoD) for a rodent project on wound healing. For more information on all newly awarded projects, see the table on page 18.

Physical Sciences

Q4 marked the official announcement of the awardees from the CASIS–National Science Foundation research competition to support fluid dynamics investigations on the ISS National Lab. This was the first Sponsored Program (research solicitation fully or partially funded by an outside organization) for CASIS in partnership with a non-NASA government agency—which laid the foundation for the currently open FOA with NCATS, discussed above. NSF is committing approximately $1.5 million in grant funding toward five ISS National Lab flight projects selected in response to the fluid dynamics solicitation. These projects will take advantage of the long-duration microgravity environment provided by the ISS National Lab and its unique benefits for the study of fluid dynamics.

The five awardees, from academic research institutions, will use the ISS National Lab to study topics in fluid dynamics ranging from vapor bubbles to droplet spreading. The unique high-quality and long-duration microgravity environment on the ISS National Lab has many benefits for the study of fluid dynamics processes and phenomena. Many processes that affect the behavior of fluids on Earth, such as thermal convection, sedimentation, hydrostatic pressure, and buoyancy, are absent in microgravity. The elimination of these variables allows physical phenomena of interest to be studied

without gravitational interference. These investigations, many of which have commercial support, will directly benefit a wide range of industries including microelectronics, avionics, pharmaceuticals, and agriculture.

In addition, a physical science project awarded in Q4 to Delta Faucet (seeking to improve the company's H_2Okinetic shower head technology through spaceflight research in applied fluid physics) demonstrated the continued progress of the ISS National Lab in attracting R&D from Fortune 500 companies and their subsidiaries.

For more information on all Q4-awarded projects, see the table beginning on page 18.

Remote Sensing

CASIS awarded a grant in Q4 to JAMSS America, Inc. (JAI) to develop a remote sensing, multi-user facility called the Global Receive Antenna and Signal Processor (GRASP), planned for launch to the ISS National Lab in early 2018. GRASP, a multi-mode radio frequency collection system, will serve as a natural extension to the GLASS payload (also from JAI, and discussed in the next section) that launched in Q4. For more information on this and other Q4-awarded projects, including their potential commercial and Earth benefits, see the table beginning on page 18.

Education

CASIS awarded two new education projects in Q4—both in collaboration with commercial companies. One is the second annual award as part of the Boeing Genes in Space national competition, which targets grades 7–12 and involved participation of approximately 380 students this year. Proposed projects revolved around an on-orbit hardware kit that can be used by educators or other investigators to perform ISS-based research. The hardware consists of a mini polymerase chain reaction thermal cycler to allow students to work with modern commercial off-the-shelf platforms onboard the ISS.

The second education project awarded in Q4 was to Facebook's Oculus, further expanding the inclusion of Fortune 500 companies and their subsidiaries the ISS National Lab education portfolio. The Oculus/Facebook project connects the new innovation of the virtual and augmented reality community with the ISS National Lab by offering students a unique learning experience through advanced technology. For project descriptions of these education projects and for more information on all newly awarded projects, see the Projects Awarded in Q4 FY16 table on page 18.

In additional research opportunities, a joint ISS National Lab research initiative between CASIS and the University of Florida (UF) was announced in August and is open to all UF faculty. Projects will be reviewed by UF and CASIS on the basis of scientific merit, future funding potential, operational feasibility, and value impact—and up to six experiments will be selected for award of a flight project onboard the ISS National Lab. The total UF funding committed to the program is up to $250,000, with CASIS committed to covering matching funds for implementation costs.

PROJECT STATUS

During ISS Launch Increment 47/48, which ended during Q4, a new record was set for crew time spent on utilization, with an average of 44 hours per week. This exciting trend in increasing use of the ISS research platform for R&D is punctuated also by the growth of commercial services providers facilitating research onboard the ISS National Lab, a community that has grown from one to six members since 2011 (three already in orbit and three currently advertising for upcoming services). The productivity of the ISS National Lab is closely linked to these companies, who are helping to make it easier and faster than ever before to utilize the ISS for R&D.

Furthermore, knowledge of this increased R&D on the ISS National Lab is penetrating the public sector through expanded media coverage—amplifying awareness of innovative and diverse ISS research. For example, research announcements related to the R&D onboard SpaceX CRS-9 (SpX-9), see below, led to more than 950 articles written about the ISS National Lab/CASIS during Q4 alone.

The SpaceX launch to the ISS on July 18 was the 9th of 12 SpaceX commercial resupply missions to the ISS under the Commercial Resupply Services (CRS) contract. The launch of SpX-9 also represented the second successful SpaceX flight since the SpaceX CRS-7 launch anomaly on June 28, 2015. SpX-9 delivered approximately 5,000 pounds of pressurized cargo, including research experiments, food, crew provisions, and exercise equipment, and it returned approximately 3,000 pounds of research, systems cargo, and waste back to Earth.

Some of the ISS National Lab payloads onboard SpX-9 include:

- **Effects of Microgravity on Stem Cell-Derived Heart Cells,** which aims to study how human cardiomyocytes (heart tissue) derived from induced pluripotent stem cells (hiPSC-CMs) contract, grow, and change in microgravity—and how those changes vary between subjects. Results may lead to a better understanding of the maturation and the cardiac aging process of hiPSC-CMs (which is now one of the bottlenecks for medical application of these cells)—with significance toward cardiovascular disease modeling, drug screening, and cell replacement therapy/regenerative medicine. *PI: Joseph Wu, Stanford University School of Medicine, Stanford, CA. Payload Developer: BioServe Space Technologies, Inc.*
- **Hard to Wet Surfaces,** which aims to study how certain materials used in the pharmaceutical industry dissolve in water while in microgravity. Results from this investigation, one of two from pharmaceutical giant Eli Lilly that launched on SpX-9, could help inform the design of tablets that dissolve in the body to deliver drugs—improving drug design for medicines used on Earth. *PI: Richard Cope, Eli Lilly and Company, Indianapolis, IN. Payload Developer: Zin Technologies, Inc.*
- **Space Tango MultiLab-1,** which will provide a standardized platform and open architecture for experimental modules, helping to shrink development cycle and cost. MultiLab presents opportunities to numerous investigators to explore new and potentially game-changing discoveries in areas such as human tissue regeneration, drug development, disease treatment, and energy or materials research. *PI: Twyman Clements, Payload Developer: Space Tango, Inc.*
- **Earth Abundant Textured Thin Film Photovoltaics,** which aims to study a new nanotechnology design for solar cells, using textured materials that are lighter weight and less costly to produce compared with previous designs. Materials placed on the outside of the ISS are exposed to much higher levels of solar radiation than those that reach Earth's surface, and exposure to these harsh conditions make the ISS an ideal platform for developing, testing, and optimizing new materials, including those for alternative energies. *PI: Jud Ready, Georgia Institute of Technology, Atlanta, GA. Payload Developer: NanoRacks, LLC.*
- **Fluorescent Polarization in Microgravity,** which will validate a commercial Plate Reader instrument that detects changes in light when molecules bind together—enabling researchers to measure the interactions of proteins with DNA or antibodies, as well as many other biomedical functions. *PI: Siobhan Malany, Micro-GRx and Sanford Burnham Medical Research Institute, Orlando, FL. Payload Developer: NanoRacks, LLC*.

In addition, some of the ISS National Lab payloads that returned to Earth on SpX-9 include:

- **Decoupling Diffusive Transport Phenomena in Microgravity,** which used microgravity to study the flow of molecules, providing a new understanding of particle flow at the nanoscale level. These results will be used to inform the design of

next-generation drug delivery devices—including the device to be used in the upcoming rodent research ISS mission from this PI, which is in collaboration with global pharmaceutical research giant Novartis. *PI: Alessandro Grattoni, Houston Methodist Research Institute, Houston, TX. Payload Developer: BioServe Space Technologies, Inc.*

- **Assessment of Myostatin Inhibition to Prevent Skeletal Muscle Atrophy and Weakness in Mice Exposed to Long-duration Spaceflight (Rodent Research-3–Eli Lilly),** which studied molecular and physical changes in the musculoskeletal system of rodents during spaceflight. Results will expand scientists' fundamental biomedical understanding of muscle atrophy and bone loss as well as provide new data related to an antibody that has been shown to have therapeutic potential in mice on Earth. Muscle function was measured with a grip-strength meter, and preliminary results show significant effects of the tested antibody on skeletal muscle function and mass under conditions of microgravity. *PI: Rosamund Smith, Eli Lilly and Company, Indianapolis, IN. Payload Developer: BioServe Space Technologies, Inc.*
- **Molecules Produced in Microgravity from the Chernobyl Nuclear Accident,** which screened fungal strains isolated from the Chernobyl nuclear power plant accident site to identify natural secreted products with biomedical or agricultural applications. Fungal products have been widely used in medicine and agriculture for centuries, and these unique fungal strains produce new agro- and pharma-related natural products on Earth. Thus testing the cells under stressful microgravity conditions may yield production of additional novel secondary metabolites. *PI: Kasthuri Venkateswaran, California Institute of Technology, Pasadena, CA. Payload Developer: Vencore, Inc.*

Education highlights from Q4 launches to the ISS National Lab

The CASIS National Design Challenge-1 re-flight projects were launched on SpX-9 and then returned to the ground to the respective Houston-based schools (Awty International School, Cristo Rey Jesuit College Preparatory of Houston, and Duchesne Academy). These education projects were sadly lost on two previous launch attempts (Orb-3 and SpX-7) that experienced catastrophic launch anomalies. Their completion marks a long-overdue but exciting success for the student scientists involved while also illustrating the realities of spaceflight research and its current challenges.

The Tomatosphere education project also launched on SpX-9, delivering 1.2 million tomato seeds to the ISS National Lab for exposure to microgravity. These seeds will be used in spring 2017 to support seed growth experiments in thousands of classrooms across the U.S. and Canada. This flight allows the sponsor organization, First the Seed Foundation, to double the number of students involved in the program (from the nearly 700,000 students who participated in 2016). Expansion of this successful program into the U.S. is in the early stages, and outreach across the country is occurring through the U.S. Department of Agriculture Farm to School programs and the American Seed Trade Association—as well as direct to teachers through conferences and meetings.

Life Sciences – Project Progress Update

In Q4, four academic research articles were published as a result of ISS National Lab sponsored R&D—all in the life sciences. Two of the peer-reviewed articles resulted from ground research performed by a researcher using simulated microgravity to improve the expansion (i.e., growth) of stem cells for use in the repair of damaged heart tissue in patients on Earth. Two additional peer-reviewed articles resulted from additional researchers conducting ground experiments in preparation for flight research on the ISS National Lab. One investigation focused on spinal cord injury in rats resulting from an aggressive cancer cell, and the other used a mouse model to better understand the role of a protein that regulates circadian rhythm in the maintenance of human health. The final article details results from a spaceflight experiment examining the protein responsible for Huntington's disease.

- An article published in the journal *Scientific Reports* by Emory University researcher Dr. Chunhui Xu describes a method using simulated microgravity to generate human heart cells from stem cells. Heart disease is the leading cause of death in the U.S. and costs an estimated $207 billion each year in healthcare services, medications, and missed work. Heart cells derived from stem cells could potentially be used as a therapy to treat damaged heart tissue and act as a biological pacemaker; however, large numbers of heart cells with high survivability would be needed. This is currently a barrier to medical applications for stem cells. In this study, Dr. Xu and her team describe a new method to produce highly pure and highly viable (able to survive) heart cells with various measurable functions associated with healthy heart tissue. They also found that growing the cells in simulated microgravity produced up to four times the number of heart cells grown in normal gravity. This method described by Dr. Xu and her team could help advance the timeline toward using stem cell–derived heart cells to treat damaged heart tissue in humans in the future. Moreover, it demonstrates the utility of microgravity for these types of studies and provides evidence to support future space-based endeavors in this field.
- A second article by Dr. Xu published in the journal *Disease Models & Mechanisms* describes a disease model to study the insufficient response to drug therapy that is observed in certain patients with a genetic disorder called catecholaminergic polymorphic ventricular tachycardia (CPVT). CPVT causes exercise-induced arrhythmias (irregular heartbeat patterns), which can cause the heart to stop beating. Drugs called beta-blockers are the standard treatment to prevent arrhythmias in patients with CPVT. However, for unknown reasons, beta-blocker therapy is unsuccessful in about 25% of patients with CPVT. In this study, Dr. Xu and her team showed how a specialized cell type could successfully be used to create an in vitro model of this condition, which will allow researchers to better study the molecular basis for insufficient beta-blocker responses patients with CPVT. If doctors can anticipate a patient's response to beta-blocker therapy based on a molecular signature, it would help to inform important decisions about the patient's treatment plan.
- An article published in the journal *Cell Transplantation* by Harvard Medical School researcher Dr. Yang Teng describes the results of growing cancer cells at a slightly higher temperature in preparation for transplanting the cells into rodents—as a model for spinal cord injury. Glioblastoma multiforme is the most aggressive kind of glioma (a type of cancer in the brain or spinal cord). Although gliomas that form in the spinal cord are far less common than those that form in the brain, the incidence of intramedullary spinal cord gliomas (ISCG) is rising. Additionally, the survival rate of ISCG is low due to poor response to conventional treatments, which include surgery, chemotherapy, and radiation. Thus, a robust disease model of ISCG is critical for researchers to gain a better understanding of the mechanisms behind this type of cancer and to develop more effective treatments. However, few studies have been done on ISCG, in part due to the low survivability of implanted tumor cells in the spinal cord of rodent models. Dr. Teng and his team found that for two types of cell lines, cells grown at slightly warmer temperatures grew faster than those grown at standard experimental temperatures. In fact, the tumor cells from one of the cell lines, after implantation into the spinal cord of female rats, grew more robustly in the rodent model than the cells cultured at standard temperatures. These findings demonstrate that the temperature at which tumor cells are grown plays a role in optimizing the cells for implantation into animal models, and the results of this study could help researchers more successfully model ISCG. Other factors, including gravitational factors, could also play a role.
- An article published in the *Journal of Biological Rhythms* by Baylor College of Medicine researcher Dr. Brian York and his team describes the importance of the protein Steroid Receptor Coactivator-2 (SRC-2) in maintaining circadian rhythm and metabolism. Circadian rhythm is the daily cycle of physiological processes that results from the syncing of an organism's internal clock to external cues in the environment, such as light, temperature, and food. Chronic disruption in circadian rhythm can have a serious negative impact on an organism's physiological processes and increases the risk of metabolic problems (such as obesity, high blood pressure, and high triglyceride levels), type 2 diabetes, cardiovascular disease, chronic liver disease, non-alcoholic fatty liver disease, cirrhosis of the liver, and liver cancer. This investigation

aimed to study the effects of SRC-2 on circadian-related behavior and metabolism, and the team found that mice lacking SRC-2 fail to adapt to the stress of chronic disruption in circadian rhythm. The results of this research could lead to advancements in therapies to treat several human diseases including those related to metabolic disorders, cardiovascular disease, and inflammation, which affect a vast majority of aging adults in the U.S. Using the results from these experiments, Dr. York and his colleagues are also now developing a flight project to explore the effects of SRC-2 on circadian-related behavior and metabolism of mice in space, where circadian rhythms are influenced by microgravity.

For more details on these publications, see the table on page 17.

BUSINESS DEVELOPMENT AND PARTNERSHIPS

EXPAND THE CASIS NETWORK, LEVERAGE FUNDING, AND DRIVE COMMERCIAL UTILIZATION

STRATEGIC AREAS OF FOCUS

As mentioned above, the continued focus of the ISS National Lab on commercial utilization is well illustrated by two Q4 project awards to Fortune 500 companies and their subsidiaries (Facebook's Oculus and Delta Faucet). Additional project and Sponsored Program proposals with Fortune 500 pharmaceutical, consumer product, and industrial companies are also in development.

LEO Commercialization

In a major development toward the support of low Earth orbit (LEO) commercialization, CASIS finalized a memorandum of understanding in Q4 with Airbus to identify customers for the future Bartolomeo external platform. Remote sensing (and specifically observation of Earth from space) is a major area of focus in the expansion of a sustainable commercial market in LEO. The purpose of this new agreement is to establish a mutually beneficial relationship between Airbus and CASIS to advance and afford institutions, researchers, and educators a unique opportunity to conduct scientific research, commercial technology development, and educational projects onboard the ISS National Lab. Specifically, the Bartolomeo platform, to be developed by an Airbus-led consortium, will expand and improve the capabilities of the ISS to support the U.S. research and technology development community.

In additional areas of focus for the support of LEO commercialization, webinars and research opportunities in the areas of protein crystal growth and tissue engineering, discussed above, also occurred in Q4. Moreover, several sessions and meetings at the ISS R&D Conference in July focused on these areas and on the additional focus area of on-orbit manufacturing. Finally, CASIS attended several conferences and meetings (detailed in the Events table beginning on page 27) in these priority research areas to continue to build awareness of ISS National Lab capabilities to advance commercial progress in these sectors.

As the ISS National Lab continues work to enable commercialization of LEO, there is also a heightened focus on communicating the value of the ISS through emphasis on the impactful results from spaceflight R&D, which mark progress on the path to that goal. Toward that end, in Q4, CASIS conducted a retrospective analysis of the ISS National Lab R&D portfolio to assess value and potential impact using a quantitative assessment framework designed with impartial third party subject matter input. This framework includes measures that enable discussion of how the current portfolio aligns with ISS National Lab strategic goals and resulting progress toward key objectives. For CASIS, the

overarching goal represented in this framework is to facilitate access to the ISS National Lab for science and technology development that benefits Earth and leads to the growth of a commercial market in LEO.

The portfolio analysis performed in Q4 included a panel of unpaid, unbiased subject matter experts who evaluated outcomes for a subset of CASIS-selected projects in multiple dimensions, including metrics in the economic, innovation, and social domains. Results from this assessment (currently in preparation) will inform future CASIS communication strategies regarding value and impact and also shape revisions to the ISS National Lab proposal selection process.

PARTNERSHIPS AND COLLABORATIONS

In addition to commercial market penetration through conference attendance and brainstorming sessions with key targeted companies, the ISS National Lab was also represented in partnership with NASA at several industry events in Q4—namely, three Destination Station Roadshows that involved formal Industry Days with key accounts (Fortune 500 companies and other strategic partners):

- In San Diego (integrated with the ISS R&D Conference), the ISS National Lab brought in nontraditional users for sessions on how to access the ISS National Lab, presenting to more than 100 potential new users and building awareness through the Destination Station Mobile Exhibit and press interviews.
- In Philadelphia, the ISS National Lab presented to more than 150 researchers and scientists as part of the GlaxoSmithKline (GSK) Industry Day, generating multiple potential project concepts. Additionally, through participation in the Franklin Institute/GSK STEM (Science, Technology, Engineering, and Mathematics) day, CASIS reached more than 1,000 children with ISS National Lab messaging.
- In Chicago, the ISS National Lab conducted three major industry day sessions with the United States Gypsum Corporation, the global independent safety science company UL, and McDonalds, generating multiple potential project ideas and initiating discussions regarding potential Sponsored Programs.

For more information on industry outreach and events involving ISS National Lab representation, see the Conferences and Events table on page 27.

With respect to development of collaborative efforts, a total of 33 investment partners are currently in the CASIS investor network and have agreed to receive investment opportunities from potential and current ISS users seeking funding. To date, 70 company–investor introductions have been made, including commercial space and non-space companies. An invite-only session held at the ISS R&D Conference facilitated such connections between space startups and investors. A panel of investors provided insight on what investors were interested in seeing from space startups, and then 11 commercial space startups pitched their business ideas to 14 investors. A total of 64 attendees, including NASA management, strategic partners, implementation partners, and CASIS staff attended the event. CASIS plans to hold similar events in the future.

Physical Sciences

In an exciting development in partnership with non-NASA government agencies, a memorandum of understanding between CASIS and NSF was signed in Q4, building on the research opportunity (Sponsored Program) described on page 5. Through this MOU, CASIS and the CBET (Chemical, Bioengineering, Environmental, and Transport Systems) Division of NSF, will develop yearly solicitations for research studies onboard the ISS. Following on the successful FY16 solicitation in the field of fluid dynamics (five awards totaling $1.5 million in grant funding from NSF), CASIS and NSF are planning to release a solicitation in FY17 that will focus on combustion and thermal transport. Topics in future

years will rotate among various areas of physical science that are relevant to NSF and ISS National Lab goals. Each solicitation is expected to provide approximately six awards and up to $1.8 million in NSF grant funding.

Based on the announcement in Q4 of ongoing Sponsored Programs with both NIH and NSF, this quarter truly marks a critical point in the history of CASIS partnerships with non-NASA government agencies. These prominent science organizations recognize the exceptional value of the ISS National Lab and are working hand-in-hand with CASIS to support research that utilizes our nation's unique orbiting laboratory for the benefit life on Earth. By partnering with non-NASA government organizations engaged in leading-edge science, CASIS is able to leverage funding from outside sources to support innovative research onboard the ISS National Lab. Partnerships such as these bolster the importance of the CASIS mission and the value of space-based research aimed at improving the lives of people on Earth.

Education

In Q4, a multiyear STEM education program proposal was awarded to Orion's Quest (OQ), an Internet-based education program for grades 5-12. The OQ program aims to challenge students to excel in math and science through active participation in research currently being conducted on the ISS, by featuring ISS National Lab projects and their investigators.

- Specifically, the OQ program supports the joint participation of students, educators, and researchers in experiments currently manifested on SpaceX CRS-9 and SpaceX CRS-10. OQ develops an educational component in support of the investigators' research and provides a standards-based curriculum that covers preflight preparation to postflight activities. During preflight preparation, students learn about NASA engineers, technicians, and administrators, and the role that each plays in the planning and tracking of the mission. For the mission phase, experiment support data is provided, and students take on the role of a Mission Specialist Astronaut. Students formulate their own hypothesis about microgravity's effect on the specimen (e.g., plants, seeds, or cells). With digital images, data, and video provided through the OQ website, students record measurements and observations. In the postflight phase, classroom findings are forwarded to the investigators for review and inclusion in databases (and publications), if appropriate.
- During its previous 12 years of operation in collaboration with NASA, the OQ program has reached approximately 20,000 students—about 3,000 this year alone. The program has progressively increased participation each year, including students in low socioeconomic settings in small towns and urban regions, with an emphasis on increasing the number of minorities and females who participate in the program. Through this new partnership, CASIS hopes to enable the OQ program to reach thousands of students nationwide through afterschool networks, Challenger Learning Centers, Boys and Girls Clubs of America, Boy Scouts, STEM Scouts, Girls Inc., and others.

CASIS established another new education partnership in Q4 with the Challenger Center located in Colorado Springs. This partnership will provide more than 500 underrepresented students with access to the Challenger Center and will provide professional development for more than 100 educators. Last quarter, CASIS launched a new education program called Space Station Explorers, which connects student communities to existing ISS National Lab education programs. Through the Challenger Center, CASIS Space Station Explorer educational content is expected to reach more than 10,000 students annually.

OUTREACH AND EDUCATION

PROMOTE THE VALUE OF THE ISS TO THE NATION AND ESTABLISH IT AS A LEADING ENVIRONMENT FOR STEM EDUCATION

INCREASING AWARENESS

In July, the ISS National Lab partnership between CASIS and NASA was showcased at the 5th annual International Space Station Research & Development Conference—the premier conference dedicated to ISS National Lab science and expanding R&D opportunities in low Earth orbit. The event, hosted by CASIS, NASA, and the American Astronautical Society, attracted new and veteran space researchers, commercial R&D executives, students, educators, and leaders, with more than 700 attendees present for the three day conference. Event highlights included luminary keynote presentations from Dr. Eric Topol (director of the Scripps Translational Science Institute and former chairman of cardiovascular medicine at Cleveland Clinic), Dr. Sanjay Gupta (chief medical correspondent for CNN), NASA Astronauts Scott and Mark Kelly (subjects of the highly publicized Twins Study), and Peter Diamandis (chairman of the XPrize Foundation). The theme of this year's conference, Your Catalyst for Discovery, was reflected throughout the event, as a variety of industries including virtual reality, investment groups and venture capitalist firms, and STEM education organizations were featured at the event in an effort to expand and diversify connections within the ISS user community.

Q4 also saw the national debut of the ARK4 mission patch. The patch, created in partnership with Marvel Custom Solutions Group, is intended to represent all science delivered to the ISS National Lab in the 2016 calendar year. The patch was unveiled at Comic-Con San Diego, and the announcement garnered national media coverage (including mentions in *The Verge, Wired,* and *The Washington Post*), which generated greater public awareness for the ISS National Lab.

The third issue of *Upward*, the ISS National Lab's official quarterly magazine was released in September and features an overview of the science that global consumer goods giant Procter & Gamble (P&G) conducted on the ISS. The issue previews the findings from P&G for the first time ever. Additionally, issue 3 of *Upward* discusses the molecular biology research made possible through the development of WetLab-2 and highlights a variety of other current and upcoming ISS National Lab projects. This quarterly magazine is a key strategic communications product for the ISS National Lab that is distributed to current and prospective researchers, stakeholders within the space research community, congressional stakeholders, and the ISS National Lab's online community. Find isse 3 of *Upward* at ww2.iss-casis.org/UpwardIssue3.

Additionally, in Q4, CASIS continued outreach and engagement with a number of commercial companies at various events including the American Institute of Aeronautics and Astronautics Small Sat Conference, the Space Grant Consortium, and an Eli Lilly patient advocacy summit.

STEM INITIATIVES

Zero Robotics, an ISS National Lab education program focused on teaching students the basics of coding and robotics, held its Middle School ISS Finals tournament in August at the Massachusetts Institute of Technology in Boston. The Synchronized Position Hold, Engage, Reorient, Experimental Satellites (SPHERES): Zero Robotics program provides an opportunity for middle school students to participate in a computer science learning activity using SPHERES satellites that are onboard the ISS. As part of a competition, students write algorithms for the SPHERES satellites to accomplish tasks relevant to future space missions. The algorithms are tested by the SPHERES team, and the best designs are

selected for the competition to operate the SPHERES satellites onboard the ISS. More than 70 teams, comprised of 700 students representing 13 states, participated in the Middle School ISS Finals, which was conducted onboard the ISS with the assistance of the Expedition 48 crew serving as referees. Teams matched their coding skills against one another in a head-to-head competition, as they programmed experimental satellites to perform a variety of commands. The event was livestreamed from the ISS.

In addition to supporting ISS National Lab education partners, CASIS continued its community outreach activities. For the second consecutive year, CASIS participated in the Kennedy Space Center Community Day held at the KSC Visitor Complex—a free event open to the general public that encourages hands-on interaction with science and educates the public on various missions and research that NASA and its partners are supporting. CASIS exhibited at the event and highlighted ISS National Lab educational opportunities that are available for students. The event drew more than 4,000 attendees.

Several ISS National Lab education initiatives were also mentioned in an article in *Air & Space Magazine* from September that focused on how students are using the ISS National Lab to engage in STEM. The article highlighted multiple ISS programs, including the Student Spaceflight Experiments Program, DreamUp, and EarthKAM, with a focus on the various partners that help make student research on the ISS possible.

Q4 FY16 METRICS

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

	Q1 FY16	Q2 FY16	Q3 FY16	Q4 FY16	FY16 TOTAL TO DATE	TARGETS FY16
Solicitations/Competitions	1	1	2	3	**7**	**5**
Project proposals generated	30	56	14	12	**112**	**100**
Projects awarded	7	11	4	12	**34**	**40**
Return customers: Projects awarded to previous CASIS customers pursuing a new opportunity	0	4	0	2	**6**	**10**
New customers: Projects awarded to principal investigators that have never flown	3	4	2	7	**16**	**20**
Customers who are new to CASIS but not to spaceflight R&D	4	3	2	3	**12**	**10**
Total value of CASIS grants awarded	$470,199	$2,647,327	$1,483,653	$ 729,954	**$5,331,133**	**$4,000,000**
CASIS seed funding toward total project cost+	22%	40.8%	58.9%	27.4%	**34.8%**[1]	**20%**
Flight projects manifested*	20	29	17	8	**74**	**70**
Flight projects delivered to the ISS National Lab*	12	9	15	22	**58**	**72**
Results published in scientific journals	4	1	1	4	**10**	**As they occur**
Products or services created	0	1	0	0	**1**	**As they occur**

* All National Lab Payloads. [1] This is not an average of the quarterly percentages, but an average across the total number of projects, which varies from quarter to quarter.

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

	Q1 FY16	Q2 FY16	Q3 FY16	Q4 FY16	FY16 TOTAL TO DATE	TARGETS FY16
Sponsored Program/external funding for grants	$1,500,000	$1,350,000	$250,000	$3,250,000	**$6,350,000**	**$3,000,000**

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

	Q1 FY16	Q2 FY16	Q3 FY16	Q4 FY16	FY16 TOTAL TO DATE	TARGETS FY16
Active STEM programs	12	12	14	14	**14**	**15**
Number of students, educators, and other participants engaged in STEM initiatives	29,717	35,200	113,192	149,968	**328,077**	**180,000**

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

	Q1 FY16	Q2 FY16	Q3 FY16	Q4 FY16	FY16 TOTAL TO DATE	TARGETS FY16
Outreach events						
Conferences and industry event sponsorships	4	4	5	3	**16**	**18**
Speaking opportunities	33	17	11	22	**82**	**95**
Subject matter expert workshops	3	0	0	0	**3**	**8**
Total media impact						
Thought leadership publications (white papers, trade articles, etc.)	1	0	0	0	**1**	**5**
News mentions (clips, blogs)	410	484	1095	1234	**3,223**	**5,000**
Twitter followers ^	82,001	85,145	89,734	94,500	**94,500**	**107,000**
Website visitors	22,768	28,158	33,157	37,016	**121,099**	**256,500**
YouTube views	132,810	77,888	261,934	161,701	**634,333**	**700,000**
Social media engagement (Facebook, Twitter, and Instagram)	16,193	90,799	60,761	127,649	**295,402**	**100,000**

^ Cumulative

YEAR-END NOTE REGARDING TARGET VERSUS ACTUAL METRICS VALUES:

During FY16, the strategic focus of the ISS National Lab to expand the research and technology portfolio shifted toward sustainable, multiyear, and/or multi-project sponsored research programs that secure extramural funding from commercial companies, other government agencies (e.g., DoD, NIH, NSF), and industry consortia. This transition in strategic focus resulted in a mismatch between some projected target metrics and actual FY16 totals:

- Fewer projects were awarded as priorities shifted away from individual projects to diversify and expand the portfolio and toward larger, multiyear or multi-institutional projects—this is also reflected in a lower number of awarded customers who are new to space or returning to the ISS National Lab for a second project.
- The total value of grants awarded reflects increased funding committed toward projects in strategic focus areas important to the enabling of LEO commercialization—specifically, a focused investment into tissue engineering projects in FY16. This strategic decision is also evidenced by the increased CASIS seed funding committed toward FY16-selected projects.
- Great success in leveraging extramural funding from other government agencies is evidenced by a substantially larger value for Sponsored Program funding secured versus target metrics.
- Fewer subject matter expert workshops were convened than projected because the strategic purpose of the workshops was primarily to generate research priorities for solicited research funded by CASIS, an approach that has become secondary to the pursuit of Sponsored Programs.
- The strategic transition also generated fewer thought leadership publications as the organization pivoted toward modification of the portfolio with additional emphasis on Sponsored Programs.

With respect to Education and Outreach metrics:

- A higher number of engaged students, teachers, and others in the education community resulted from success at a few key events—namely, the U.S. Science and Engineering Festival and Destination Imagination—as well as higher than expected participation in the ARISS program (Amateur Radio from the ISS) in FY16.
- Engagement numbers over the course of the year exceeded target measurements by approximately 195%, in large part due to increased presence through Twitter, Facebook, and Instagram. With fewer launches in the early portion of FY16, however, news mentions dipped below targeted expectations. In Q3 and Q4 respectively, news mentions returned to near-target expectations, with launches, partnerships, and conferences providing multiple opportunities to promote the ISS National Lab.
- In FY16, CASIS shifted to a new, more accurate method of calculating website visitors. Previously, this metric represented pageviews, which may yield a somewhat inflated snapshot of true visitor interactions. This metric now reflects the more meaningful tracking of “user sessions,” which accounts for the uniqueness of each visitor. While this is a more accurate representation of web traffic and visitor numbers, it does yield a somewhat lower value for the metric than was projected based on the old calculation methodology.

MAXIMIZING 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)	***1775.1***	***129.6***	***312***	***436.81***	***137.59***	***140%***
Inc 51/52 (Mar 2017-Sept 2017)	***735***	***576.99***	***338***	***215.49***	***39.5***	***64%***

Data through 9/13/2016

*Includes SpX-7 upmass/downmass

CONTRIBUTIONS TO SCIENTIFIC KNOWLEDGE – RESULTS PUBLISHED

Title: Simulated Microgravity and 3D Culture Enhance Induction, Viability, Proliferation and Differentiation of Cardiac Progenitors from Human Pluripotent Stem Cells **Citation:** Dr. Chunhui Xu **Institution:** Emory University **Resulted from:** CASIS RFP "The Impact of Microgravity on Fundamental Stem Cell Properties" issued in 2013	**Description:** This paper describes a method to generate cardiomyocytes (heart cells) from human pluripotent stem cells (hPSCs). The method involves differentiating hPSCs into cardiomyocytes by introducing growth factors and other inducers of cell proliferation and/or differentiation. The hPSCs were isolated in microwells, forcing them to aggregate into 3-D spheres. The spheres were then transferred to a cell culture plate and grown in simulated microgravity, where a random positioning machine continuously reoriented the gravity vector. Culturing the cells in simulated microgravity resulted in osteocytes with higher levels of contractility, maturity markers, and viability than cells cultured in standard gravity. In addition, the overall cardiomyocyte yield was up to four times higher when cultured in simulated microgravity. This comparison was also tested using human embryonic cell lines, which obtained similar results. **Earth Benefit:** Heart disease is the leading cause of death in the United States and costs an estimated $207 billion each year in healthcare services, medications, and missed work. Pre-clinical studies have shown that the therapeutic use of cardiomyocytes derived from hPSCs can prevent the progression of heart failure and can function as a biological pacemaker. A reliable and safe production method for these cells may advance the timeline toward clinical human application.
Title: A Human Pluripotent Stem Cell Model of Catecholaminergic Polymorphic Ventricular Tachycardia Recapitulates Patient-Specific Drug Responses **Principal Investigator:** Dr. Chunhui Xu **Institution:** Emory University **Resulted from:** CASIS RFP "The Impact of Microgravity on Fundamental Stem Cell Properties" issued in 2013	**Description:** This article describes a patient-specific disease model to study insufficient beta-blocker response observed in certain patients with a genetic disorder that causes stress-induced arrhythmias (irregular heartbeat patterns). Arrhythmias caused by this genetic disorder are called catecholaminergic polymorphic ventricular tachycardia (CPVT). The model was created using induced pluripotent stem cell-derived cardiomyocytes (iPSC-CMs) derived from a CPVT patient. Beta-blockers are the first-line pharmacological therapy to prevent arrhythmias in patients with CPVT; however, for unknown reasons, such therapy is unsuccessful in about 25% of patients. In this study, Dr. Xu and her team sought to determine whether the inadequate beta-blocker response could be observed in vitro using iPSC-CMs from CPVT patients in which beta-blocker therapy was unsuccessful. For the study, iPSCs were derived from such a patient and converted into cardiomyocytes (heart cells), thereby retaining any genetic mutation(s) that cause arrhythmias and preserving the disease phenotype. A stimulant was then administered to the cardiomyocytes, triggering in vitro arrhythmias. The cellular response to beta-blocker therapy and alternative drug therapies (in comparison with that of cardiomyocytes derived from non-CPVT control subjects) was evaluated. Results confirmed that iPSC-CMs can be used to recapitulate in vitro the insufficient beta-blocker response observed in certain patients with CPVT, thus validating this patient-specific disease model. In addition, the results suggest that cardiomyocyte-specific factors may be involved in beta-blocker therapy response in CPVT patients. **Earth Benefit:** CPVT is a life-threatening genetic disorder that causes stress-induced arrhythmias, which can lead to cardiac arrest. The first-line treatment for CPVT patients is beta-blocker therapy; however, for unknown reasons, it is unsuccessful in about 25% of patients. If clinicians could anticipate a CPVT patient's response to beta-blocker therapy based on a molecular signature, it would greatly aid in decision making about the patient's treatment plan. A patient-specific disease model, such as the one described in this article, could help researchers better understand the insufficient beta-blocker response observed in certain patients with CPVT and what factors could play a role in determining beta-blocker response.

Title: The Effects of Thermal Precondition on Oncogenic and Intraspinal Cord Growth Features of Human Glioma Cells **Principal Investigator:** Dr. Yang Teng **Institution:** Harvard Medical School **Resulted from:** Unsolicited proposal (PI Louis Yuge)	**Description:** This article describes the experimental results from utilizing mild thermal preconditioning before implantation of human glioblastoma cells into the spinal cord of rodent models. The incidence of intramedullary spinal cord gliomas (ISCG) is rising and more effective treatments are needed, thus a robust disease model is critical. However, few studies have been done on ISCG, in part, due to limited successful engraftment of tumor cells into the spinal cord of rodent models. Dr. Teng and his team hypothesized that mild thermal preconditioning (culturing the tumor cells at a slightly warmer temperature before implantation) may influence the survivability of the transplanted cells in rodents. To test this hypothesis, two different human glioblastoma cell lines were cultured at 37°C and 38.5°C. The investigators found that the cells cultured at 38.5°C grew slightly faster than those cultured at 37°C. Following culture, cells that demonstrated a greater response to the temperature difference were then implanted into the spinal cord of immunodeficient adult female rats at one of two locations. Results showed that the cells preconditioned at 38.5°C grew more robustly in both spinal cord locations than the cells cultured at 37°C. These findings demonstrate that culture temperature plays a role in tumor cell optimization for implantation into the spinal cord of rodent models, which could help researchers more successfully model ISCG. **Earth Benefit:** Glioblastoma multiforme is the most aggressive and highly resistant type of glioma in the central nervous system. Although primary gliomas in the spinal cord are less common than those in the brain, the incidence of ISCG is rising. Additionally, the survival rate of ISCG is low—less than 2 years with maximum intervention—due to poor response to conventional treatments. Thus, a robust model of ISCG is critical to achieving a better understanding of the mechanisms behind ISCG and to developing more effective treatments. An increasing mortality rate from glioblastomas is driving the treatment market toward nearly $1 billion by 2022.
Title: Genetic and Environmental Models of Circadian Disruption Link SRC-2 Function to Hepatic Pathology **Principal Investigator:** Drs. Bert O'Malley, Clifford Dacso, and Brian York **Institution:** Baylor College of Medicine **Resulted from:** A mulit-year partnership involving several preflight, omics-based projects	**Description:** This paper describes the importance of Steroid Receptor Coactivator-2 (SRC-2), a metabolic transcriptional coregulator, in the maintenance of metabolism and circadian rhythm, the daily cycle of physiological processes in organisms cued by external stimuli. Chronic circadian disruption can have a serious impact on physiological processes and increases the risk of metabolic dysfunction. In this study, Dr. York and his team examined the effects on metabolism and locomotive behavior in mice lacking SRC-2. The study builds on the team's previous work that found that mice lacking SRC-2 exhibit altered circadian behavior and an increased risk of metabolic dysfunction and liver cancer. This publication details the contribution of SRC-2 function to maintaining the coordinated balance of metabolism, circadian biology, and optimal sleep/wake work cycles. **Earth Benefit:** Chronic disruption of circadian rhythm has been shown to seriously impact physiological processes and increase the risk of metabolic dysfunction, accelerated aging, and cancer. The results of this study could help advance the development of therapeutics aimed at resolving circadian disruption and comorbidities such as metabolic syndrome, cardiovascular disease, and inflammation. As this collection of disease pathologies impacts an overwhelming majority of the U.S. adult population, research aimed at circumventing these health problems represents a potentially intangible long-term benefit to improve human health.

PROJECTS AWARDED IN Q4 FY16

Title: Tympanogen – Wound Healing **Principal Investigator:** Dr. Elaine Horn-Ranney **Affiliation:** Tympanogen, LLC **Location:** Norfolk, VA	**Description:** This project seeks to improve the process of antibiotic release from a novel patch that can treat military combat wounds and reduce the occurrence and severity of sepsis, or systemic inflammation. This novel patch contains a hydrogel with inherent antimicrobial properties that can promote healing of a wound while acting as a scaffold for regenerating tissue. Reduced fluid motion in microgravity will allow for more precise studies of this hydrogel behavior and its controlled release from the patch. **Earth Benefit:** Sepsis is a major economic and healthcare burden and is usually caused by exposure of an open wound to contaminated surfaces. It is one of the most expensive conditions treated in U.S. hospital stays, with an aggregate cost of more than $15 billion. In order to help reduce the occurrence and severity of sepsis, Tympanogen has developed an antibiotic-infused, non-surgical solution to treat open wounds. Moreover, infectious complications from combat-related injuries remain a critical issue in modern medicine, and novel therapeutics are necessary to improve outcomes for soldiers injured on the battlefield. There is currently no wound dressing that can sustain release of antibiotics or other agents directly to the wound site while simultaneously maintaining the structural integrity necessary for successful wound healing.
Title: GRASP **Principal Investigator:** Robert Carlson **Affiliation:** JAMSS America, Inc. **Location:** Houston, TX	**Description:** Global Receive Antenna and Signal Processor (GRASP) is an enabling technology facility that provides affordable recovery of terrestrial radio frequency (RF) data using the ISS. Remote RF data is vital to commercial entities, governmental entities, and the research community for reasons as diverse as tracking ships at sea, studying animal migrations, improving agricultural yields, and monitoring the health of assets and health of the environment. The GRASP facility consists of an internally-mounted signal processing unit and an externally-mounted nadir-pointing antenna array. A key feature of GRASP is that it can be simultaneously used by multiple users, each targeting unique frequencies of interest. The GRASP facility on the ISS will increase access to and use of terrestrial RF signal data, which is currently constricted due to limited access to and high cost associated with recovering terrestrial RF signals using satellites. **Earth Benefit:** The GRASP facility provides increased access to RF data recovered from space at a reduced cost. One application of GRASP is providing better tools to monitor and respond to illegal fishing and pollutant dumping in ocean waters. These illegal activities destroy ecosystems and contribute to more than $20 billion annually in economic losses. Other applications that may benefit from analysis of RF data collected by GRASP include the following: improved operational and environmental performance for commercial ships; environmental monitoring; wildlife tracking; remote asset monitoring and tracking; weather data collection; confirmation of post-launch CubeSat activation; agricultural monitoring for water conservation and sustainable application of fertilizers; spectrum studies to identify usage of given frequencies; and radio propagation studies to identify sources of interference.

Title: Intraterrestrial Fungus Grown in Space (iFunGIS) **Principal Investigator:** Dr. Heath Mills **Affiliation:** Space Technology and Advanced Research Systems, Inc. (STaARS) **Location:** San Antonio, TX	**Description:** This project has two objectives: Goal 1 seeks to validate a fast-track hardware capability for molecular biology projects; Goal 2 will determine at a molecular level the response of a deep subsurface fungus, Penicillium chrysogenum, to growth in microgravity. This fungal species produces a novel penicillin-like antibiotic natural product, giving the fungus high commercial value. Organisms respond to environmental changes by altering their metabolic processes in an effort to regulate internal biochemical conditions. Previous results have shown that organisms have different metabolic responses to microgravity, including alterations in growth rate and virulence. Thus, the aim of this project is to determine the metabolic impact of spaceflight on this novel fungal species. The production and effectiveness of the novel penicillin-like antibiotic produced by the fungus will also be characterized following exposure to microgravity. **Earth Benefit:** There is a pressing need for new antimicrobial therapeutics as antibiotic resistance and infection from community-acquired pathogens continue to rise worldwide. This project could potentially provide a successor to penicillin, an antibiotic that currently represents an 8% share of the more than $40 billion U.S. market.
Title: The Virtual Astronaut **Principal Investigator:** Amaresh Kollipara **Affiliation:** Oculus/Facebook **Location:** Los Angeles, CA	**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:** The Virtual Astronaut Experience and the Classroom in 360° Experience will be made available to educators at schools, science centers, and museums nationwide. Through Oculus' "VR for Good" and "VR Outreach" pilot programs, more than 100 schools across the country are expected to have access to these STEM experiences. As part of Oculus' Virtual Science Center Program, the STEM experiences will also be available through virtual reality kiosks at the California Science Center, which is visited by more than one million students each year. Oculus anticipates additional science centers will become involved in the near future. Additionally, the STEM experiences will be disseminated on Facebook, which has more than 1.65 billion monthly users.
Title: Wound Healing **Principal Investigator:** Dr. Rasha Hammamieh **Affiliation:** DoD **Location:** Fort Detrick, MD	**Description:** This project is part of a broader effort to understand the effects of spaceflight on tissue healing. Studies suggest that microgravity likely impairs the wound healing process, and microgravity has been shown to have negative effects on skin quality in astronauts. This project seeks to identify the molecular foundations of cutaneous (skin) wound healing that are vulnerable to spaceflight-induced stress, potentially revealing biologically relevant pathways for the next generation of wound healing therapies. Samples from mice will be collected over a time course of wound healing, both in spaceflight conditions and in ground controls. In addition, the team will attempt to identify surrogate biomarkers from the blood, which if validated in humans, could eventually provide clinically useful diagnostic markers for the state of skin wounds. This project will mark the first time a comprehensive systems biology approach has been used to understand the impact of spaceflight on wound healing. **Earth Benefit:** Roughly 2% of the U.S. population suffers from chronic non-healing wounds, with a conservative cost estimate for patient care exceeding $50 billion per year. This project seeks to utilize a comprehensive systems biology approach to reveal biologically relevant pathways for wound healing therapies. Ultimately, this could lead to a significant reduction in the health care cost associated with treating these patients and could provide a viable therapeutic for the more than 30% of the patient population that do not respond to current therapeutic options for chronic non-healing wounds.
Title: Droplet Formation Studies in Microgravity **Principal Investigator:** Garry Marty **Affiliation:** Delta Faucet **Location:** Indianapolis, IN	**Description:** This project seeks to evaluate the water droplet formation, water flow, and pressure of Delta Faucet's current H2Okinetic shower head technology versus the industry-standard use of jet nozzles. H2Okinetic technology allows better control of droplet size and increases the speed of the drops (fewer water drops are used, but the droplets are larger and are moving faster), which creates a feeling of increased pressure for the end user. The study will evaluate how best to control the output of water droplets to create a better performing shower device that provides an improved experience for the end user while also conserving water and energy. The full effects of gravity in the formation of water droplet size (with a standard jet nozzle or H2Okinetic technology) are unknown. By conducting research in microgravity, Delta Faucet seeks to gain a better understanding of the upper limit of what can be achieved with the H2Okinetic technology and determine if and how the technology can be improved. **Earth Benefit:** Delta Faucet seeks to gain a better understanding of water droplet formation from the company's H_2Okinetic shower head technology in order to further improve both end user experience and water conservation. Showering devices carry an average cost of $45.50, and the overall market for such devices is $676 million and continues to grow as more of the population turns from bathing to showering. Currently, Delta Faucet holds a 20% market share in shower faucets, and there is room for the company's technology to be further applied in this market. Continuing to improve H2Okinetic technology performance, end user experience, and affordability will drive additional sales and market share.

Title: Genes In Space-2 **Principal Investigator:** Julian Rubinfien **Affiliation:** The Boeing Company (sponsor) **Location:** Houston, TX	**Description:** This project aims to study genetic processes (specifically, telomere shortening in human organoids) that may lead to accelerated aging in space. This is a winning student experiment from the Genes in Space innovation challenge, which invites students to propose pioneering DNA amplification experiments using the unique environment of the ISS. **Earth Benefit:** Genes In Space is a national and international research competition for middle and high school students designed "to foster creativity, collaboration, and critical thinking among young innovators bridging the biological and physical sciences." The winning student experiment uses the tools of molecular biology to better understand how microgravity affects telomere length. Telomeres, the end caps on each of our chromosomes, typically shorten as we age. This shortening has been implicated in some human diseases associated with aging.
Title: Quantifying Cohesive Sediment Dynamics for Advanced Environmental Modeling **Principal Investigator:** Dr. Paolo Luzzatto-Fegiz **Affiliation:** University of California, Santa Barbara **Location:** Santa Barbara, CA	**Description:** This project is focused on the study of forces between particles that cluster together. The physical system studied consists of sediments of quartz and clay particles. By conducting the research on the ISS, it is possible to separate the forces acting on the particles over a short range (adhesive forces) versus those acting over a long range (cohesive forces). In microgravity, investigators can observe how particles cluster over long time scales without gravitational settling, which complicates measurements taken on Earth. The quartz/clay system is commonly found in a wide variety of environmental settings (such as rivers, lakes, and oceans) and plays an important role in technological efforts related to deep sea hydrocarbon drilling and carbon dioxide sequestration. **Earth Benefit:** This project will improve our fundamental understanding of physical interactions between soil and sediment particles. It has important applications on Earth for geologists and engineers who work in the Earth's surface sediments for environmental and geological monitoring, carbon cycle modeling, the sequestration and mobilization of contaminants, and deep-water hydrocarbon exploration. Oil companies spend millions of dollars per well to fund exploratory drilling operations to find even one good site. Results from this project may lead to better computation models that will allow oil companies to more precisely find deep sea sites for drilling productive oil wells.
Title: Inertial Spreading and Imbibition of a Liquid Drop Through a Porous Surface **Principal Investigator:** Dr. Michel Louge **Affiliation:** Cornell University **Location:** Ithaca, NY	**Description:** This project will utilize the microgravity environment on the ISS to improve understanding of imbibition, a process in which water is absorbed by solids. Measuring and observing this process is significantly easier to achieve on the ISS, due to the suppression of gravitational forces. **Earth Benefit:** The imbibition process is critically important not only for life on Earth, plant seeds imbibe water to germinate, but also for many engineering and industrial processes. For example, understanding how solids and liquids interact can lead to major improvements in flood control, estimated to cause $11 billion in damages annually, and medical advances in stopping bleeding. Other applications include wet granulation, a process used by pharmaceutical companies for drug manufacturing.
Title: Unmasking Contact Line Mobility and Inertially-Spreading Drops **Principal Investigator:** Dr. Paul Steen **Affiliation:** Cornell University **Location:** Ithaca, NY	**Description:** This project is focused on the study of the behavior of drops pinned on a vibrating surface. The investigators hope to develop a theory to predict conditions for how and when the drops oscillate, while conducting experiments to verify the theoretical model in microgravity conditions. Results from this work can potentially be applied to medical, agricultural, manufacturing, and other industrial processes. **Earth Benefit:** Results from this project have applications in medical, agricultural, industrial, and manufacturing processes. One industrial example is immersion lithography—an important technology in the manufacture of semiconductor chips that has enabled faster computer processors. Results from this project may also improve the process of inertial spreading, a fundamental process in immersion lithography, and reduce the number of defects seen on semiconductors manufactured today.
Title: Constrained Vapor Bubbles of Ideal Mixtures **Principal Investigator:** Dr. Joel Plawsky **Affiliation:** Rensselaer Polytechnic Institute **Location:** Troy, NY	**Description:** This project will examine gas/liquid interfaces of various organic mixtures used in heat pipes. Heat pipes are heat transfer devices that are used routinely for cooling a variety of electronic equipment, including laptop computers. Heat pipes use fluid to transfer heat. An essential feature of these devices is that the fluid undergoes a phase change from liquid to vapor. The detailed motion of the liquid and vapor, and the motion and dynamics of the interface between the two phases, can strongly affect the performance of heat pipes and similar systems. **Earth Benefit:** Results from this project will provide information that can be used to improve the efficiency of phase-change heat and mass transfer operations, which are critically important in many diverse fields such as energy conversion, distillation, microelectronics cooling, and coating processes. Substantial energy savings in energy transmission, manufacturing processes, and the operation of electromechanical devices can be obtained by improving the function of heat pipes and the transition from liquid to vapor.
Title: Kinetics of Nanoparticle Self-assembly in Directing Fields **Principal Investigator:** Dr. Eric Furst **Affiliation:** University of Delaware **Location:** Newark, DE	**Description:** The number of advanced materials manufactured by the assembly of colloidal particles is growing. Assembly can be controlled by applying external fields (such as a magnetic field) that affect the motion of the particles and their organization during assembly. Performing self-assembly research in microgravity is advantageous because on Earth, the particles sediment due to gravity with a sedimentation rate that increases as they form large and complicated structures. The colloidal particles examined in this project could serve as building blocks for advanced materials that control the propagation of sound and heat in electronics. **Earth Benefit:** Self-assembly is a phenomenon where the components of a system assemble themselves spontaneously via interactions to form a larger functional unit. The ability to assemble nanoparticles into an ordered, well-defined configuration in three-dimensional space is crucial to the development of advanced electronic devices. This work will form the foundation of an emerging effort in nanomanufacturing to realize cost-efficient and scalable functional nanomaterials for use in smaller electronic, mechanical, and electromechanical devices (i.e., nanotechnology).

Q4 FY16 PROJECT PIPELINE

GROUND PROJECTS

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	CITY	STATE
High Data Rate Polarization Modulated Laser Communication System	Dr. Eric Wiswell	Schafer Corporation	Huntsville	AL
Impact of Increased Venous Pressure on Cerebral Blood Flow Velocity Morphology	Dr. Robert Hamilton	Neural Analytics	Los Angeles	CA
Hyperspectral Mapping of Ironbearing Minerals	Dr. William H. Farrand	Space Science Institute	Boulder	CO
Combined evaluation of mouse musculoskeletal data	Dr. Virginia Ferguson	University of Colorado Boulder	Boulder	CO
Architecture to Transfer Remote Sensing Algorithms from Research to Operations	Dr. James Goodman	HySpeed Computing, LLC	Miami	FL
Effects of Simulated Microgravity on Cardiac Stem Cells	Dr. Joshua Hare	University of Miami	Miami	FL
Generation of Cardiomyocytes from Human iPS Cell-derived Cardiac Progenitors	Dr. Chunhui Xu	Emory University	Atlanta	GA
Rodent Research-4 Validation Study	Dr. Rasha Hammamieh and Dr. Melissa Kacena	Indiana University Research	Indianapolis	IN
Commercial space-borne hyperspectral harmful algal bloom (HAB) products	Dr. Ruhul Amin	BioOptoSense, LLC	Metairie	LA
Interrogating the Unfolded Protein Response in Microgravity-Induced Osteoporosis and Sarcopenia	Dr. Imran N. Mungrue	Louisiana State University Health Science Center	New Orleans	LA
Optimizing Jammable Granular Assemblies in a Microgravity Environment	Jason Hill	Benevolent Technologies for Health	Cambridge	MA
NDC-4: Space Station STEM Challenge	Matthew Weaver	Collins Middle School	Salem	MA
Testing TiSi2 Nanonet Based Lithium Ion Batteries for Safety in Outer Space	Emily Fannon	EnerLeap	Newton	MA
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
Reducing signal interruption from cosmic ray background in neutron detectors	Dr. Andrew Inglis	Silverside Detectors	Boston	MA
ARISS (Amateur Radio from ISS)	Frank Bauer	AMSAT (Radio Amateur Satellite Corporation)	Kensington	MD
Improving Astronaut Performance of National Lab Research Tasks	Dr. Jayfus Doswell	Juxtopia, LLC	Baltimore	MD
Hyperspectral Remote Sensing of Terrestrial Ecosystem Carbon Fluxes	Fred Huemmrich	University of Maryland Baltimore County	Baltimore	MD
Great Lakes Specific HICO Water Quality Algorithms	Dr. Robert Shuchman	Michigan Technological University	Houghton	MI
Orions Quest-Student Research on the ISS	Peter Lawrie	Orions Quest	Canton	MI
Viral infection dynamics and inhibition by the Vecoy nanotechnology	Dr. Drew Cawthon	Lovelace Respiratory Research Institute	Albuquerque	NM
Spacecraft-on-a-Chip Experiment Platform	Dr. Mason Peck	Cornell University	Ithaca	NY
HICO Identification of Harmful Algal Blooms	Dr. Richard Becker	University of Toledo	Toledo	OH
3D Neural Microphysiological System	Dr. Michael Moore	AxoSim Technologies	New Orleans	PA
3D Organotypic Culture System	Dr. Rocky S. Tuan	University of Pittsburgh	Pittsburg	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
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
Generation of Mesendoderm Stem Cell Progenitors in the ISS-National Laboratory	Dr. Robert Schwartz	University of Houston System	Houston	TX

IN PREFLIGHT DEVELOPMENT

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	LAUNCH VEHICLE	ESTIMATED LAUNCH DATE	CITY	STATE
Controlled Dynamics Locker for Microgravity Experiments on ISS	Dr. Scott A. Green	Controlled Dynamics, Inc.	OA-5	10/6/16	Huntington Beach	CA
NDC-2: Denver	Shanna Atzmiller	Bell Middle School	SpX-10	TBD - Jan 2017	Golden	CO
Rodent Research-4	Dr. Rasha Hammamieh	Department of Defense and Indiana University Research	SpX-10	TBD - Jan 2017	Fort Detrick	MD
Growth Rate Dispersion as a Predictive Indicator for Biological Crystal Samples	Dr. Edward Snell	Hauptman Woodward Medical Research Institute, Inc.	SpX-10	TBD - Jan 2017	Buffalo	NY
Application of Microgravity Expanded Stem Cells in Regenerative Medicine	Dr. Abba Zubair	Mayo Clinic	SpX-10	TBD - Jan 2017	Rochester	MN
Nanobiosym- Galactic Grant	Dr. Anita Goel	Nanobiosym	SpX-10	TBD - Jan 2017	Cambridge	MA
SSEP11 – Endeavor	Dr. Jeff Goldstein	NCESSE/Tides Center	SpX-10	TBD - Jan 2017	Washington, D.C.	
The Effect of Macromolecular Transport on Microgravity PCG	Dr. Lawrence DeLucas	University of Alabama at Birmingham	SpX-10	TBD - Jan 2017	Birmingham	AL
NDC-2: Denver	Brian Thomas	Centaurus High School	SpX-10	TBD - Jan 2017	Lafayette	CO
NDC-2: Denver	Joel Bertelsen	Chatfield Senior High School	SpX-10	TBD - Jan 2017	Littleton	CO
Honeywell/Morehead-DM Payload Processor	Dr. Benjamin Malphrus	Honeywell/Morehead State University	HTV-6	12/9/16	Morehead	KY
Development and Deployment of Charge Injection Device Imagers	Dr. Daniel Batcheldor	Florida Institute of Technology	HTV-6	12/9/16	Melbourne	FL
Corrosion Inhibitor Exposed to the Extreme Environments in Space	Lauren Thompson Miller	A-76 Technologies, LLC	OA-7	12/30/16	Houston	TX
SG100 Cloud Computing Payload	Trent Martin	Business Integra	OA-7	12/30/16	Houston	TX
Detached Melt and Vapor Growth of InI in SUBSA Hardware	Dr. Aleksandar Ostrogorsky	Illinois Institute of Technology	OA-7	12/30/16	Chicago	IL
Magnetic 3D Cell Culture for Biological Research in Microgravity+A56A37A37:A51	Dr. Glauco Souza	Nano3D Biosciences, Inc.	OA-7	12/30/16	Houston	TX
Efficacy & Metabolism of Azonafide Antibody-Drug Conjugates (ADCs)	Sourav Sinha	Oncolinx Pharmaceuticals, LLC	OA-7	12/30/16	Boston	MA
Crystal Growth of Cs2LiYCl6:Ce Scintillators in Microgravity	Dr. Alexei Churilov	Radiation Monitoring Devices, Inc.	OA-7	12/30/16	Watertown	MA
Genes In Space-2	Julian Rubinfien	The Boeing Company (sponsor)	OA-7	12/30/16	New York	NY
NDC-3: Chicagoland Boy Scouts and Explorers	Dr. Sandra Rogers	Boy Scouts of America	OA-7	12/30/16	Whiting	IN
NDC-4: Space Station STEM Challenge	Benjamin Coleman	Talbot Middle School	SpX-11	2/1/17	Fall River	MA
NDC-3: Chicagoland Boy Scouts and Explorers	Norman McFarland	Boy Scouts of America	SpX-11	2/1/17	Palatine	IL
Tomatosphere-2	Ann Jorss	First the Seed Foundation	SpX-11	2/1/17	Alexandria	VA
Functional Effects of Spaceflight on Cardiovascular Stem Cells	Dr. Mary Kearns-Jonker	Loma Linda University	SpX-11	2/1/17	Loma Linda	CA
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-11	2/1/17	Moffett Field	CA
Neutron crystallographic studies of human acetylcholinesterase for the design	Andrey Kovalevsky	Oak Ridge National Lab	SpX-11	2/1/17	Oak Ridge	TN

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	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
Eli Lilly – Lyophilization	Jeremy Hinds	Eli Lilly and Company	SpX-12	6/1/17	Indianapolis	IN
Characterizing Arabidopsis Root Attractions (CARA) – grant extension request	Dr. Anna-Lisa Paul	University of Florida Board of Trustees	SpX-12	6/1/17	Gainesville	FL
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
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
Capillary-Driven Microfluidics in Space	Dr. Luc Gervais	1Drop Diagnostics US Inc.	TBD	TBD	Boston	MA
Comparative Real-Time Metabolic Activity Tracking for Improved Therapeutic Assessment Screening Panels	Dr. Gary Sayler	490 BioTech, Inc.	TBD	TBD	Knoxville	TN
SiC Microgravity Enhanced Electrical Performance (MEEP)	Rich Glover	ACME Advanced Materials	TBD	TBD	Albuquerque	NM
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
Electrolytic Gas Evolution Under Microgravity	Larry Alberts	Cam Med LLC	TBD	TBD	West Newton	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
DexMat CASIS CNT Cable Project	Dr. Alberto Goenaga	DexMat, Inc.	TBD	TBD	Houston	TX
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
Ultra-Portable Remote-Controlled Microfluidics Microscopy Microenvironment	Dan O'Connell	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
Assessing Osteoblast Response to Tetranite(TM)	Dr. Nikolaos Tapinos	LaunchPad Medical	TBD	TBD	Boston	MA
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
Map the Penetration Profile of a Contact-Free Transdermal Drug Delivery System	Dr. Robert Applegate	Novopyxis	TBD	TBD	Boston	MA

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	LAUNCH VEHICLE	ESTIMATED LAUNCH DATE	CITY	STATE
Oculus & Facebook STEM Sponsored Program	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
Effect of Microgravity on Stem Cell Mediated Recellularization	Dr. Alessandro Grattoni	The Methodist Hospital Research Institute	TBD	TBD	Houston	TX
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
Faraday Waves and Instability-Earth and Low G Experiments	Dr. Ranga Narayanan	University of Florida Board of Trustees	TBD	TBD	Gainesville	FL
Conversion of Adipogenic Mesenchymal Stem Cells into Mature Cardiac Myocytes in the ISS National Laboratory	Dr. Robert Schwartz	University of Houston	TBD	TBD	Houston	TX
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
Rodent Research – Wound Healing	Dr. Rasha Hammamieh	Department of Defense and Indiana University Research	TBD	TBD	Fort Detrick	MD

CURRENTLY IN ORBIT

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	RETURN VEHICLE	RETURN 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	12/20/16	Indianapolis	IN
Materials Testing – Earth Abundant Textured Thin Film Photovoltaics	Dr. Jud Ready	Georgia Institute of Technology	TBD	TBD	Atlanta	GA
GLASS AIS Transponder Global AIS on Space Station	Robert Carlson	JAMSS America, Inc.	N/A	N/A	Houston	TX
MultiLab: Research Server for the ISS	Twyman Clements	Space Tango, Inc.	N/A	N/A	Lexington	KY
NIH-Osteo	Dr. Bruce Hammer	University of Minnesota	SpX-10	12/20/16	Minneapolis	MN
Materials Testing – The Evaluation of Gumstix Modules in Low Earth Orbit	Dr. Kathleen Morse	Yosemite Space	TBD	TBD	Groveland	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
Validation of WetLab-2 System for qRT-PCR capability on ISS	Julie Schonfeld	NASA ARC	N/A	N/A	Moffett Field	CA
Additive Manufacturing Operations Program	Michael Snyder	Made In Space, Inc.	N/A	N/A	Moffett Field	CA
Project Meteor	Michael Fortenberry	Southwest Research Institute	N/A	N/A	Boulder	CO
Zero-G Characterization & OnOrbit Assembly for Cellularized Satellite Tech	Talbot Jaeger	NovaWurks, Inc.	N/A	N/A	Los Alamitos	CA

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	RETURN VEHICLE	RETURN DATE	CITY	STATE
NanoRacks External Platform	Michael Johnson	Nanoracks, LLC	N/A	N/A	Houston	TX
Bone Densitometer	John Vellinger	Techshot, Inc.	N/A	N/A	Greenvillte	IN
National Lab Project: ISERV	Burgess Howell	Disaster Relief Charter; NASA Marshall Space Flight Center	N/A	N/A	Huntsville	AL
National Lab Project: AMS	Dr. Samuel Ting	Department of Energy; MIT	N/A	N/A	Cambridge	MA
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

IN POSTFLIGHT ANALYSIS/COMPLETED

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	CITY	STATE
NDC-1: Pilot Program	Greg Adragna	Cristo Rey Jesuit College Preparatory of Houston	Houston	TX
NDC-1: Pilot Program	Angela Glidewell	Awty International School	Houston	TX
NDC-1: Pilot Program	Jessika Smith	Awty International School	Houston	TX
NDC-1: Pilot Program	Rev. Brian Reedy	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
Tomatosphere	Ann Jorss	First the Seed Foundation	Alexandria	VA
Molecules Produced in Microgravity from the Chernobyl Nuclear Accident	Dr. Kasthuri Venkateswaran	Jet Propulsion Laboratory/Caltech	Pasadena	CA
SSEP10 – Kitty Hawk	Dr. Jeff Goldstein	NCESSE/Tides Center	Washington, D.C.	
Effects of Microgravity on Stem Cell-Derived Heart Cells	Dr. Joseph Wu	Stanford University	San Francisco	CA
Story Time from Space – 2	Patricia Tribe	T2 Science and Math Education Consultants	League City	TX
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
SSEP9 – Odyssey	Dr. Jeff Goldstein	NCESSE/Tides Center	Washington, D.C.	
HUNCH Chlorella/Billings Central Catholic High	Dr. Florence Gold	Rocky Mountain College	Billings	MT
Mutualistic Plant/Microbe Interactions	Dr. Gary W. Stutte	SyNRGE, LLC	Titusville	FL
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
Vertical Burn	Dr. Jeff Strahan	Milliken	Spartanburg	SC
Story Time from Space – 3	Patricia Tribe	T2 Science and Math Education Consultants	League City	TX
Cyclone Intensity Measurements from the International Space Station (CyMISS)	Dr. Paul Joss	Visidyne, Inc.	Burlington	MA
Osteocyte response to mechanical forces	Dr. Paola Divieti Pajevic	Boston University	Boston	MA
Espresso Cup	Dr. Mark Weislogel	IRPI LLC	Wilsonville	OR
Omega Hydrofuge Plant Growth Chamber – HUNCH Extreme Science – Lakewood	Matthew Brown	Lakewood High School	Lakewood	CO

PROJECT	PRINCIPAL INVESTIGATOR	AFFILIATION	CITY	STATE
Merck PCG-2	Dr. Paul Reichert	Merck Pharmaceuticals	Whitehouse Station	NJ
Novartis Rodent Research-2	Dr. David Glass	Novartis Institute for Biomedical Research	Cambridge	MA
Synthetic Muscle: Resistance to Radiation	Dr. Lenore Rasmussen	Ras Labs	Hingham	MA
Kentucky Space/Exomedicine Lab – Flatworm	Dr. Mahendra Jain	Kentucky Space, LLC	Lexington	KY
SSEP8 – Yankee Clipper	Dr. Jeff Goldstein	NCESSE/Tides Center	Washington, D.C.	
T-Cell Activation in Aging-2	Dr. Millie Hughes-Fulford	Northern California Institute for Research and Education, Inc.	San Francisco	CA
Collaborative project-protein crystal growth to enable therapeutic discovery	Dr. Matt Clifton	Beryllium Discovery Corp.	Bedford	MA
Cobra Puma Golf Microgravity Electrodeposition Experiment	Mike Yagley	Cobra Puma Golf	Carlsbad	CA
Novartis Rodent Research-1	Dr. David Glass	Novartis Institute for Biomedical Research	Cambridge	MA
Collaborative project-protein crystal growth to enable therapeutic discovery	Dr. Cory Gerdts	Protein BioSolutions	Gaithersburg	MD
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
SSEP7 – Charlie Brown	Dr. Jeff Goldstein	NCESSE/Tides Center	Washington, D.C.	
PCG-Crystallization of Huntington Exon-1 Using Microgravity	Dr. Pamela Bjorkman	California Institute of Technology	Pasadena	CA
Exploiting on-orbit crystal properties for medical and economic targets	Dr. Edward Snell	Hauptman Woodward Medical Research Institute, Inc.	Buffalo	NY
PCG – IPPase Crystal Growth in Microgravity	Dr. Joseph Ng	iXpressGenes, Inc.	Huntsville	AL
Merck PCG-1	Dr. Paul Reichert	Merck Pharmaceuticals	Whitehouse Station	NJ
T-Cell Activation in Aging-1	Dr. Millie Hughes-Fulford	Northern California Institute for Research and Education, Inc.	San Francisco	CA
PCG - Crystallization of Medically Relevant Proteins Using Microgravity	Dr. Sergey Korolev	Saint Louis University	Saint Louis	MO
PCG – Crystallization of Human Membrane Proteins in Microgravity	Dr. Stephen Aller	University of Alabama at Birmingham	Birmingham	AL
Molecular Biology of Plant Development (Petri Plants)	Dr. Anna-Lisa Paul	University of Florida	Gainesville	FL
Ants in Space	Stefanie Countryman	BioServe Space Technologies	Boulder	CO
SSEP5b – Falcon II	Dr. Jeff Goldstein	NCESSE/Tides Center	Washington, D.C.	
SSEP6 – Orion	Dr. Jeff Goldstein	NCESSE/Tides Center	Washington, D.C.	
Binary Colloidal Alloy Test – Low Gravity Phase Kinetics Platform	Dr. Matthew Lynch	Procter & Gamble, with Zin Technologies, Inc.	Cincinnati	OH
Story Time from Space – 1	Patricia Tribe	T2 Science and Math Education Consultants	League City	TX
Antibiotic Effectiveness in Space-1 (AES-1)	Dr. David Klaus	University of Colorado Boulder	Boulder	CO
SSEP5a – Falcon I	Dr. Jeff Goldstein	NCESSE/Tides Center	Washington, D.C.	

CONFERENCES AND EVENTS IN Q4 FY16

CONFERENCE AND INDUSTRY EVENT SPONSORSHIPS

EVENT	LOCATION	DATE	AUDIENCE	DESCRIPTION
International Space Station Research & Development Conference 2016	San Diego, CA	7/11/16-7/14/16	Scientists, commercial developers, entrepreneurs, investors, and partners	CASIS hosted the 5th Annual International Research and Development Conference with the American Astronautical Association and NASA, bringing together nearly 700 scientists, commercial developers, entrepreneurs, investors, and partners as well nearly 1,000 STEM education attendees (students, educators, and parents). The conference continues to grow a vibrant community of individuals and organizations focused on state-of-the-art research in microgravity, commercialization of low earth orbit, and the enabling technologies that support opportunities and new discoveries in space.
American Crystallographic Association Annual Meeting	Denver, CO	7/22/16-7/26/16	Scientists	CASIS exhibited and presented at the American Crystallographic Association Annual Meeting, an annual event where scientists from multiple research areas exchange cutting-edge ideas and techniques. The meeting hosts one of the largest assemblies of scientists involved in protein crystal growth and microgravity crystallization. CASIS presented the ISS National Lab capabilities, its unique and advantageous environment for crystallization studies, and how CASIS can help facilitate microgravity research.
Space Angels Network Expedition 16	San Francisco, CA	8/28/16-8/31/16	Researchers, commercial companies, and other governmental agencies	CASIS Executive Director Greg Johnson visited with 10 commercial companies during Expedition 16, hosted by Space Angels Network, a global network for angel investors offering insider access to the emerging private space industry and sophisticated investment opportunities across diverse market segments, with the expertise and network connections to cultivate returns on investment. The Expedition 16 event enabled Space Angel Network members seriously interested in investing in the space sector to experience cutting-edge space technology, go behind the scenes at the most exciting space startups, and meet astronauts, fellow Space Angels Network members, and prominent space industry leaders.

ADDITIONAL CONFERENCE AND EVENT PARTICIPATION

EVENT	LOCATION	DATE	AUDIENCE	DESCRIPTION
Organ-On-A-Chip World Congress 2016 & 3D-Culture	Boston, MA	7/7/16-7/8/16	Global key opinion leaders in biological and medical sciences	CASIS presented a poster session at the 2nd Annual Organ-on-a-Chip World Congress in its ongoing effort to promote tissue chip research onboard the ISS National Lab. CASIS networked extensively with key opinion leaders in the field to discuss the ISS research platform for experiments in the biological and medical sciences.
Destination Station	Philadelphia, PA and Chicago, IL	8/12/16-8/18/16	Fortune 500 companies, government agencies, and area students	CASIS coordinated a five-day Destination Station event in Philadelphia and Chicago. CASIS and NASA hosted innovation days with Fortune 500 companies from various industries to promote microgravity research. The teams also held a STEM day with the Franklin Institute with participation from Chicago Mayor Rahm Emanuel.
Space Technology and Investment Forum	San Francisco, CA	8/16/16-8/17/16	Space industry CEOs and founders of new space startups, venture capitalists, angel investors, and aerospace researchers	CASIS Executive Director Greg Johnson joined Debra Facktor Lepore, vice president and general manager for strategic operations with Ball Aerospace, to deliver a luncheon keynote at the Space Technology and Investment Forum. This investment conference from the Space Foundation joins together top venture capitalists and angel investors with space industry experts who explain the technical, legal, and business issues critical to market analysis and risk assessment.
AIAA Small Satellite Conference	Logan, UT	8/8/16-8/12/16	Small satellite companies, including bus providers and component manufacturers	CASIS presented at the 30th Annual Small Satellite Conference hosted by the American Institute of Aeronautics and Astronautics and Utah State University. In its presentation, CASIS discussed how the ISS can meet the needs of the Earth observation and technology development communities. Members of the CASIS team met individually with commercial aerospace companies throughout the conference to explore potential flight project ideas and concepts.
Challenger Center National Conference	Framingham, MA	8/11/2016	Industry executives, educators, scientists, engineers and partners	CASIS Executive Director Greg Johnson participated in a panel discussion titled "STEM Education Through the Lens of Space Exploration" at the Challenger Center National Conference. More than 100 U.S. attendees gathered for the proceedings for idea sharing, new programming discussions, and professional development. CASIS conducted education to convey its resources for stimulating interested in STEM education.

EVENT	LOCATION	DATE	AUDIENCE	DESCRIPTION
Zero Robotics Middle School Finals	Cambridge, MA	8/12/2016	Educators and students	CASIS sponsored and the Middle School Zero Robotics Finals, which were held at the Massachusetts Institute of Technology and broadcast live to satellite locations throughout the U.S., including Kennedy Space Center, and Russia. CASIS Executive Director Greg Johnson was a speaker at the event, where 70 middle school teams (including one from Russia) and 700 students competed to get their state's or country's computer programming code to the SPHERES on the ISS.
IRI Fall Multi-Networks Meeting	Milwaukee, WI	9/12/16-9/14/16	Senior leaders from commercial R&D companies and federal laboratories	A CASIS representative attended the Industrial Research Institute Fall Multi-Networks Meeting and was a panelist discussing industrial collaboration with national and federal labs. CASIS also participated in Innovation Leadership Network and External Technology Network sessions to learn how current industry leaders develop R&D and innovation portfolios.
AIAA Space Commercialization Executive Summit	Long Beach, CA	9/13/16	Senior executives, influencers, and stakeholders involved in the commercial space sector	CASIS Executive Director Greg Johnson participated in the inaugural Space Commercialization Executive Summit produced by the American Institute of Aeronautics and Astronautics (AIAA) and Aviation Week Network. The event brought together industry, space commerce, R&D, academia, and government communities to positively contribute to the space industry and foster an evolving and growing space economy.
Kennedy Space Center Community Day	Cape Canaveral, FL	9/17/16	Public	At this free event that is open to the public, CASIS featured the ISS virtual tour, quantum levitation demonstration, and Space Station Explorers website—reaching approximately 4,300 students, teachers, and parents.
Bay Area Science & Innovation Consortium	Menlo Park, CA	9/28/16	Leaders of major research universities and institutions, national laboratories, and commercial entities	CASIS Executive Director Greg Johnson addressed the Bay Area Science & Innovation Consortium board of directors, representing SRI International, Dolby Labs, IBM, Seimens, Oracle, the University of California, Lawrence Livermore National Laboratory, and Lawrence Berkeley National Laboratory.
NCATS/DARPA Tissue Chip Consortium Meeting	Arlington, VA	9/29/16-9/30/16	Researchers with NCATS/DARPA	CASIS attended the joint National Center for Advancing Translational Sciences (NCATS) and Defense Advanced Research Projects Agency (DARPA) Tissue Chip Consortium Meeting. CASIS Chief Deputy Scientist Michael Roberts presented a new collaboration between CASIS and NCATS to promote human physiology research on the ISS. The presentation and a poster session provided details for submitting applications for tissue chip systems translational research in space.
CASIS Academy Live	Cape Canaveral, FL	9/30/16	Students, teachers, graduate students, and guests	CASIS Academy Live hosted 40 attendees in discussions of scientific research, including a presentation on “Plants in Space” by Dr. Anna-Lisa Paul. The event also included a live interview with Rachel Powers from DLN Network TV Livestream and a NASA education session on living in space.

FINANCIALS

BUSINESS STATUS REPORT (UNAUDITED)

JUL 1 – SEP 30, 2016	ACTUAL Q4 2016	BUDGET Q4 2016	VARIANCE	ACTUAL YTD 2016	BUDGET YTD 2016	VARIANCE
Direct Labor	$1,379,699	$1,760,492	($380,793)	$5,319,931	$6,593,061	($1,273,131)[a]
Subcontracts	$247,105	$565,825	($318,720)	$1,410,222	$2,477,455	($1,067,233)[b]
Permanent Equipment > $5k	$11,158	$13,000	($1,842)	$45,573	$117,700	($72,127)
Office Supplies & Equipment	$71,880	$66,283	$5,597	$222,871	$273,764	($50,893)
Travel	$221,410	$289,863	($68,453)	$931,661	$1,108,738	$(177,077)[c]
Grants	$3,045,819	$4,466,421	($1,420,602)	$6,818,908	$10,499,284	($3,680,376)[d]
Other Direct Expenses	$453,335	$403,067	$50,268	$1,714,226	$2,019,318	($305,092)[e]
Total	**$5,430,406**	**$7,564,951**	**($2,134,545)**	**$16,463,302**	**$23,089,320**	**($6,626,018)**

(a) Budgeted headcount was 49; actual was 41.
(b) Subcontracts were lower than budgeted for legal, fundraising, and several expert consultants.
(c) Travel costs are lower because of lower than budgeted headcount.
(d) Several Grant recipient milestones have shifted to FY17. The entire uncosted carryover going into FY17 (which includes carryover funds from prior fiscal years) has been committed via contract grants to be paid out between FY17 and FY18.
(e) Advertising campaign budgeted was not executed because of a change in strategy.

BREAKOUT OF COOPERATIVE AGREEMENT FUNDING

	Q1 FY16	Q2 FY16	Q3 FY16	Q4 FY16
Direct	43%	54%	59%	34.4%
Indirect	13%	15%	15%	10.2%
Grants	44%	31%	26%	55.4%

BREAKOUT OF CASIS GRANTS

	Q1 FY16	Q2 FY16	Q3 FY16	Q4 FY16
Private/Commercial	$1,258,897	$595,288	$534,151	$2,189,069
Academic	$477,861	$312,572	$348,842	$744,140
Mission Based Costs	$61,538	$94,026	$89,914	$112,609

CENTER FOR THE ADVANCEMENT
OF SCIENCE IN SPACE (CASIS)
6905 N. Wickham Road, Suite 500
Melbourne, FL 32940
888.641.7797
www.iss-casis.org