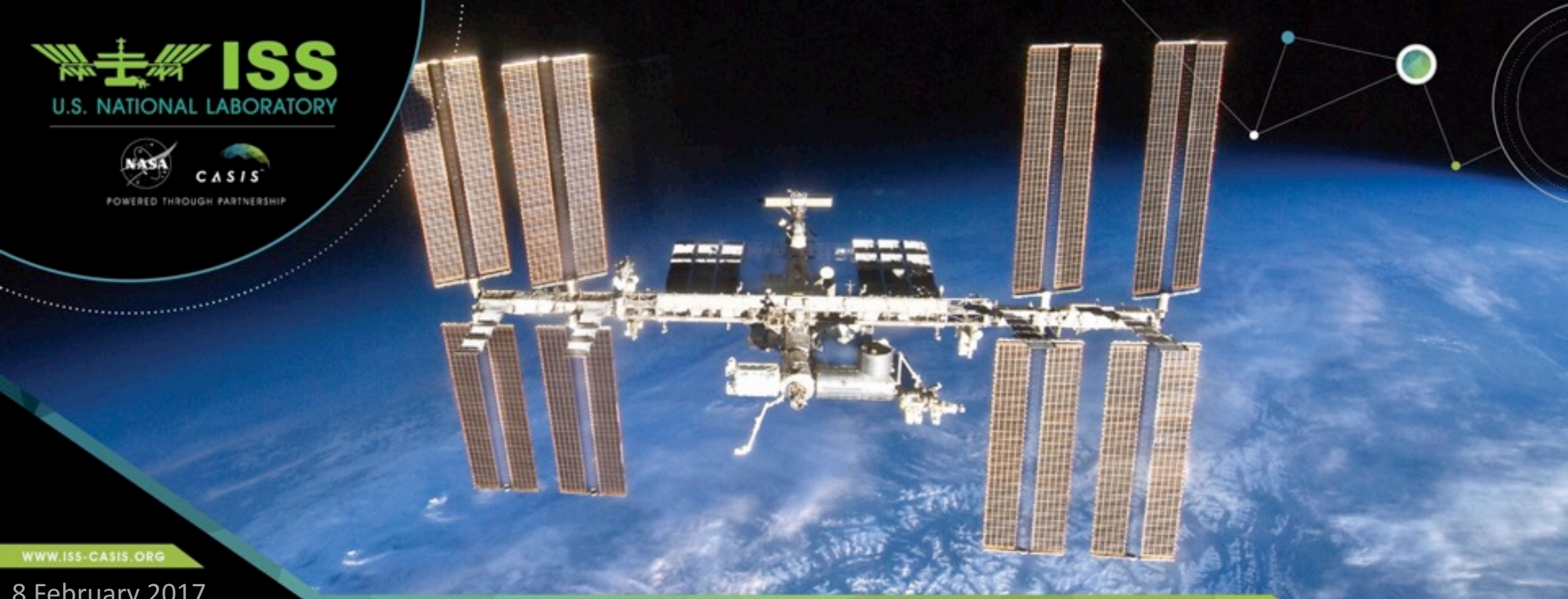


ISS U.S. NATIONAL LABORATORY

NASA CASIS

POWERED THROUGH PARTNERSHIP

WWW.ISS-CASIS.ORG

8 February 2017

COMMITTEE ON A MIDTERM ASSESSMENT OF IMPLEMENTATION OF THE DECADAL SURVEY ON LIFE AND PHYSICAL SCIENCES RESEARCH AT NASA

CASIS ROLE IN MICROGRAVITY RESEARCH ON THE ISS NATIONAL LAB

Cindy Martin Brennan, Strategic Communications Manager

Michael Roberts PhD, Deputy Chief Scientist

OUTLINE

- History and Policy Development for the ISS National Lab
- ISS National Lab Relationship to the Decadal
- ISS National Lab Research Portfolio
- ISS National Lab Portfolio Management
- Q&A

ISS U.S. National Lab: An Historical Perspective

In 2004, NASA dissolved the Office of Biological and Physical Science Research (OBPR) program. The OBPR was the nation's microgravity R&D program and a primary user of the ISS for non-exploration discovery-based projects.

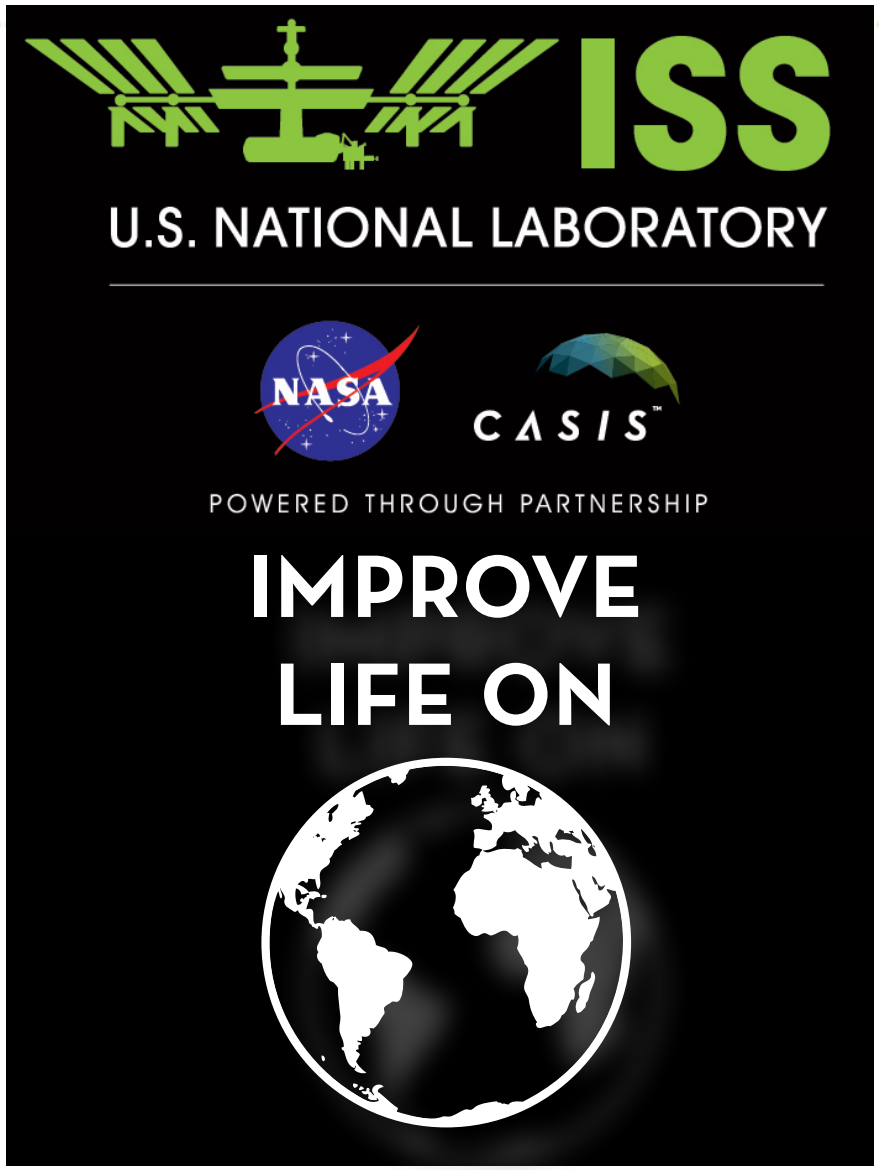
In response, Congress passed the NASA Authorization Act of 2005.

- designated the U.S. segment of the ISS as a National Laboratory for use by the U.S. public and private sector;
- directed NASA to allocate at least 15 percent of the funds budgeted for ISS research to ground-based, free-flyer, and ISS life and microgravity research that was not directly related to supporting the human exploration program;
- directed ISS to be used for a diverse range of microgravity research including fundamental, applied and commercial research.

In 2010, Congress directed NASA to engage in a cooperative agreement with a not-for-profit entity to manage the ISS National Lab. The non-profit should consider recommendations of the National Academies Decadal Survey on Biological and Physical Sciences in Space in establishing research priorities and in developing proposed enhancements of research capacity and opportunities for the ISS National Laboratory

- Through a competitive process, the Center for the Advancement of Science in Space (CASIS) was selected in late 2011;
- Between 2010 and 2015, a series of bipartisan legislation was passed to ensure continuation of support and utilization of the ISS through 2024, including support for exploration, development of commercial capabilities, and international cooperation.

THE COOPERATIVE AGREEMENT



1.2 CASIS Purpose

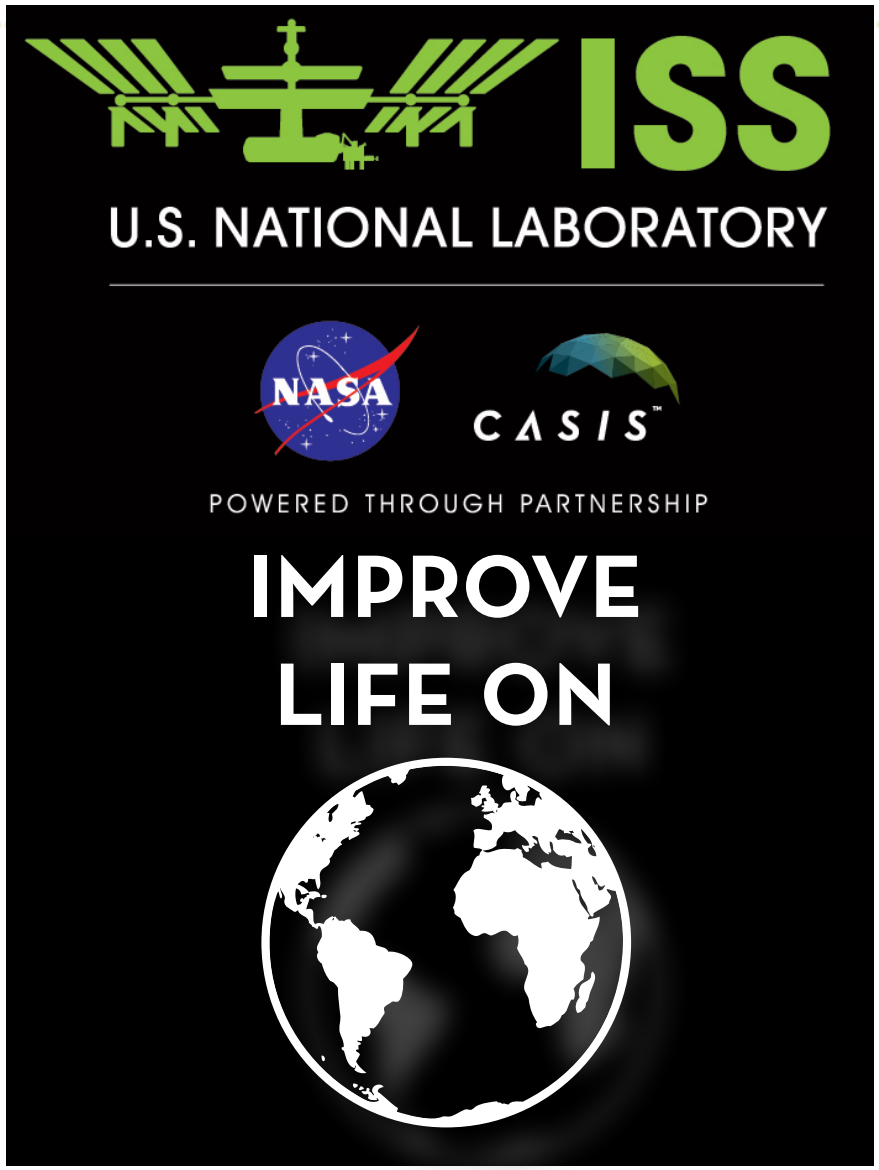
1.2.1 CASIS Mission

CASIS will be responsible for maximizing the value of the ISS to the nation by developing and managing a diversified R&D portfolio based on U.S. national needs for basic and applied research and by using the ISS as a venue for Science, Technology, Engineering and Mathematics (STEM) educational activities.

1.2.2 CASIS Goals

- Stimulate, develop and manage the U.S. national uses of the ISS by other U.S. government agencies, academic institutions and private firms.
- Develop tools and techniques to communicate the value of uses of the ISS National Laboratory ("ISS NL") and increase the return on the U.S. investment in the ISS.

THE COOPERATIVE AGREEMENT



2.1 CASIS Responsibilities

2.1.1 Stimulate Interest and Use of the ISS National Laboratory
CASIS will stimulate interest in and use of the ISS NL as a platform for basic and applied research for other U.S. government agencies, academic institutions, and private firms.

2.1.2 Develop the ISS National Laboratory
CASIS will determine the research objectives that provide the most value to the nation across the breadth of research disciplines and across the range of basic to applied research.

2.1.3 Manage the ISS National Laboratory
CASIS will prioritize the entire NL research portfolio of technology demonstrations, basic, and applied research using a fair, transparent, and impartial selection process that maximizes value of the ISS investment made by the Nation.

ISS U.S. National Lab: THE BASICS

NASA provides

- basic financial assistance - $15M per year
- Transportation to/from station
- Payload integration
- Not less than 50% of the US research capacity to ISS National Laboratory managed experiments

While NASA's ISS activities are focused on exploration, technology development, and living and working in space, the ISS National Lab provides a pathway for disruptive, non-exploration research and development (R&D) , commercial activities, and STEM activities

CASIS provides (as part of 50% allocation)

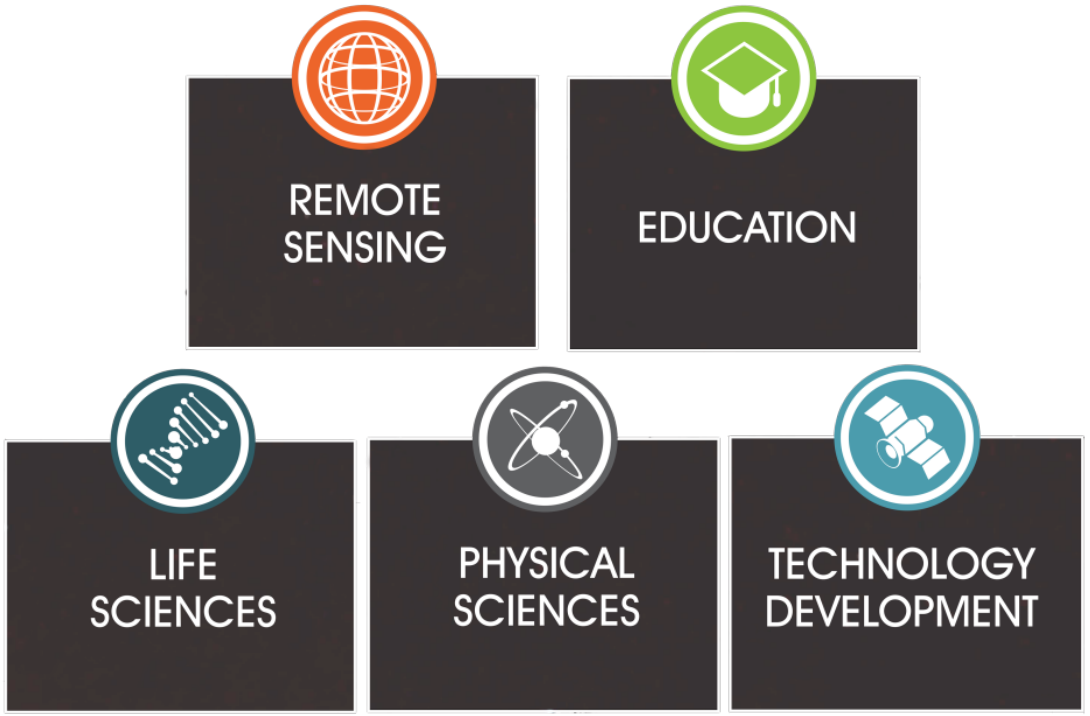
- Selection and implementation of scientific and education activities (non-exploration)
- Development and implementation of flight support requirements for ISS-NL projects,
- Non-traditional partnerships, cost-sharing agreements, and other arrangements that help offset federal costs of the ISS-National Laboratory.

ISS NL SCIENCE PORTFOLIO

ISS NATIONAL LAB PORTFOLIO

The ISS U.S. National Lab provides opportunity for research and discovery targeted to a definitive impact on Earth

The opportunities are wide-ranging:



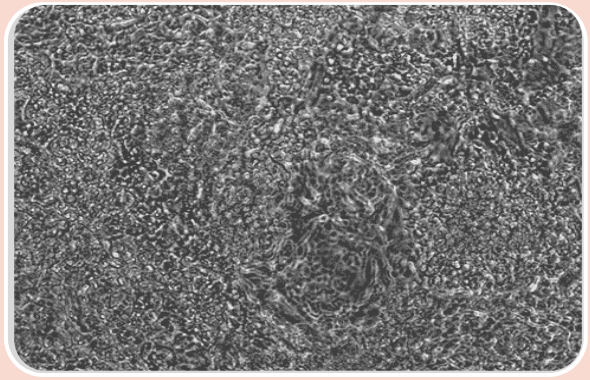
U.S. NATIONAL LABORATORY

POWERED THROUGH PARTNERSHIP

IMPROVE LIFE ON

ISS NATIONAL LAB: EXPANDING THE FRONTIERS OF SCIENCE

ISS U.S. NATIONAL LABORATORY



Accelerating U.S. Innovation and Commercial Leadership in Low Earth Orbit and Beyond

Pursuing Groundbreaking Science, Technology & Innovation for the Nation

Captivating, Empowering, and Launching the Next Generation of Discovery through STEM Opportunities

ISS NATIONAL LAB: FY2016 ANNUAL REPORT

Available online at http://ar2016.iss-casis.org/

Science Payloads Delivered to the ISS National Lab in FY16

Orbital ATK *Cygnus* CRS OA-4 **LAUNCH: 6 December 2015**

- Milliken & Company - Vertical Burn
- Novawurks, Inc -Zero-G & OnOrbit Assembly for Cellularized Satellite Technology
- BioServe-SABL (Space Automated Bioproducts Lab 1 AND 2)

Orbital ATK *Cygnus* CRS OA-6 **LAUNCH: 23 March 2016**

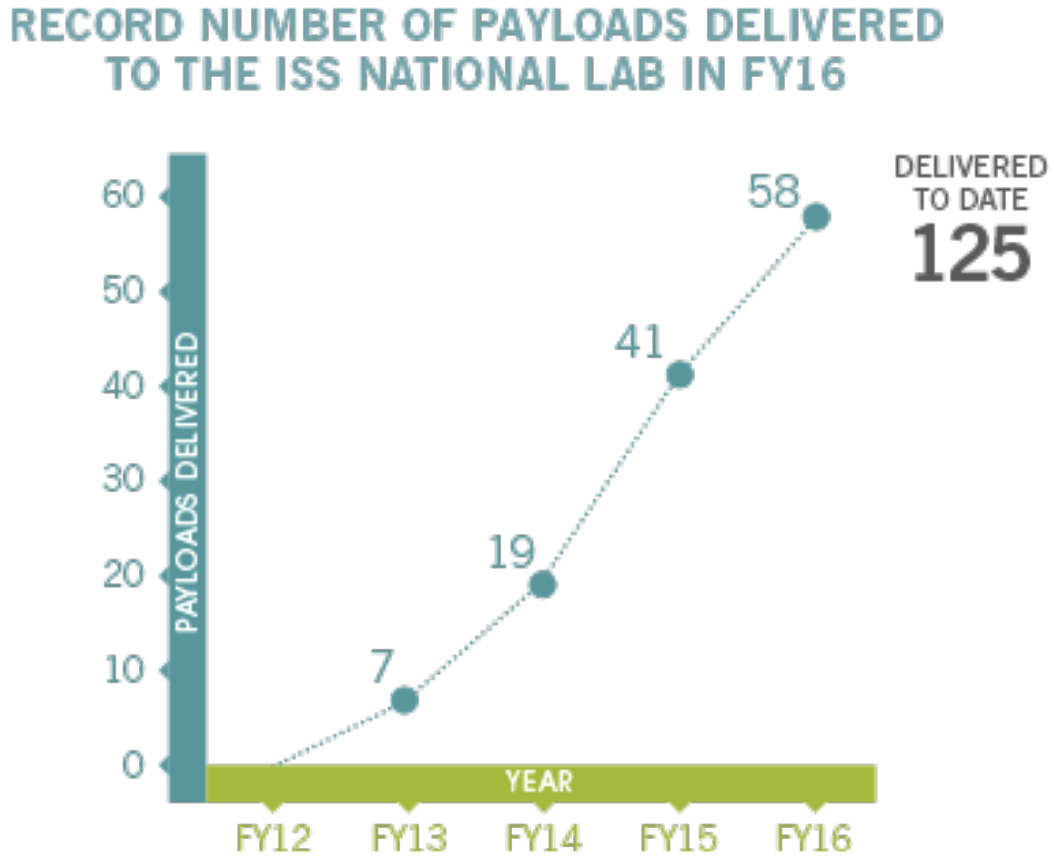
- Made In Space-Additive Manufacturing Facility
- Project Meteor

Space-X *Dragon* CRS-8 **LAUNCH: 8 April 2016**

- Grattoni (HMRI)-Microchannel Diffusion
- Eli Lilly-Protein Crystal Growth
- Eli Lilly-Rodent Research-3 (RR-3) Myostatin
- Wetlab-2
- Genes in Space

Space-X *Dragon* CRS-9 **LAUNCH: 18 July 2016**

- Eli Lilly-Dissolution of Hard-to-Wet-Solids
- Ready (Ga Tech)-Earth Abundant Textured Thin Film Photovoltaics
- Wu (Stanford)-Effects of Microgravity on Stem Cell-Derived Heart Cells
- Global AIS on Space Station
- Venkateswaran (JPL)-Beneficial compounds produced by fungi in µg
- Pajevic (BU)- NIH-Osteo
- NanoRacks Plate Reader-2



Commercial Launches to the ISS National Lab in FY16 and FY17

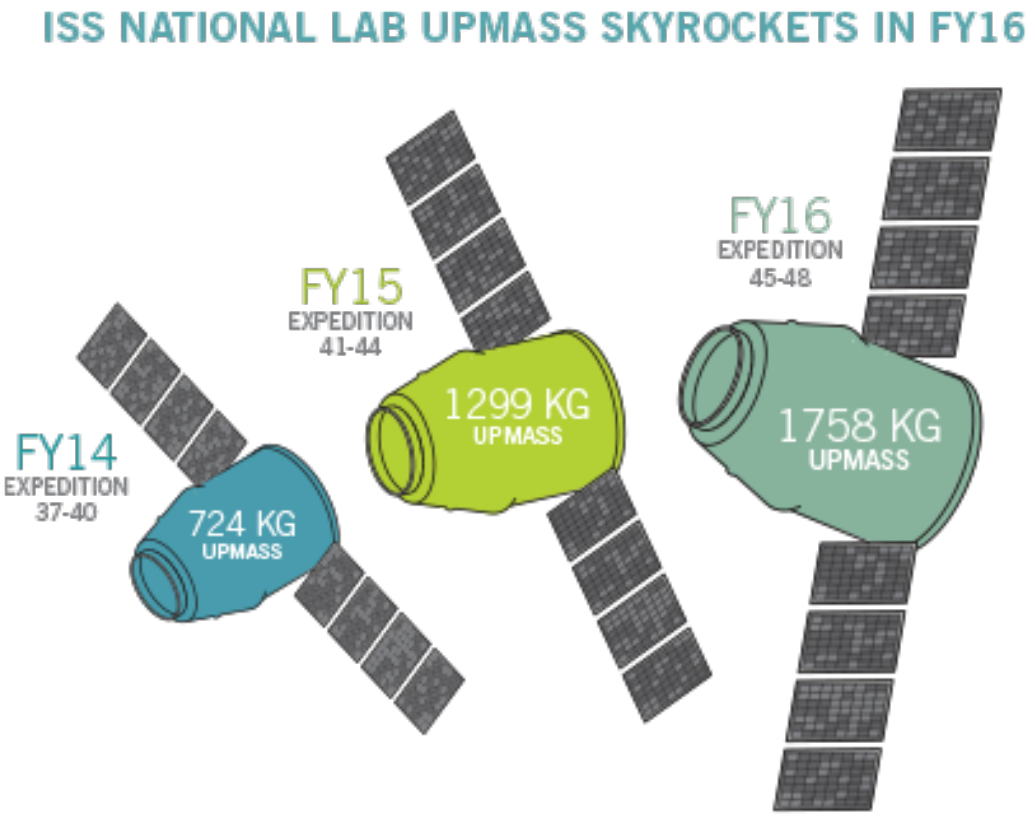
FY16

1. Orbital ATK *Cygnus* CRS OA-4 — LAUNCH: 6 December 2015
2. Orbital ATK *Cygnus* CRS OA-6 — LAUNCH: 23 March 2016
3. Space-X *Dragon* CRS-8 — LAUNCH: 8 April 2016
4. Space-X *Dragon* CRS-9 — LAUNCH: 18 July 2016

FY17

1. Orbital ATK *Cygnus* CRS OA-5 — LAUNCH: 16 October 2016
2. JAXA HTV-6 — LAUNCH: 9 December 2016
3. Space-X *Dragon* CRS-10 — LAUNCH: NET 14 February 2017
4. Orbital ATK *Cygnus* CRS OA-7 — LAUNCH: NET 16 March 2017
5. Space-X *Dragon* CRS-11 — LAUNCH: NET 9 April 2017
6. Space-X *Dragon* CRS-12 — LAUNCH: NET 1 August 2017
7. Orbital ATK *Cygnus* CRS OA-8 — LAUNCH: NET 1 October 2017

NET – No Earlier Than (launch date is uncertain)



ISS National Lab new firsts

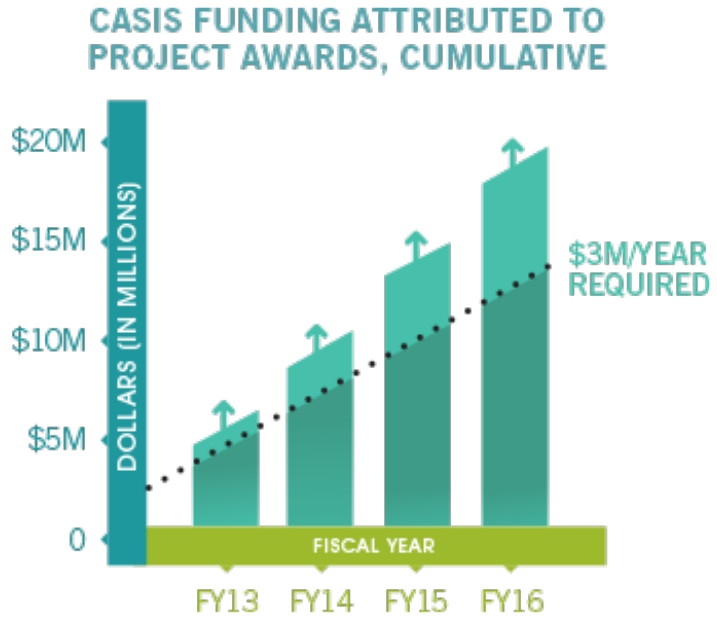
This unprecedented view shows SpaceX's *Dragon* cargo ship (SpX CRS-8) at left, Orbital ATK's *Cygnus* ship (CRS OA-6) at center, and Russia's *Progress* cargo ship at far right after the Dragon's docking on April 10, 2016. It's the first time two private U.S. cargo ships have been together at the station.

Also aboard the *Dragon*, packed inside its unpressurized trunk section, is BEAM — the Bigelow Expandable Activity Module —an experimental inflatable space habitat that will be attached to the aft port of the Harmony node.

Image courtesy of NASA TV.

ISS NATIONAL LAB: FY16 ENGAGEMENT & INVESTMENT

- **CASIS allocated $5.3M in seed funding toward projects that attracted more than $15M matching funding**
- **National Institutes of Health (NIH) and National Science Foundation (NSF) –** $19 million in potential multi-year funding programs announced in Q4
- **49 investors in an investor network that continues to grow**

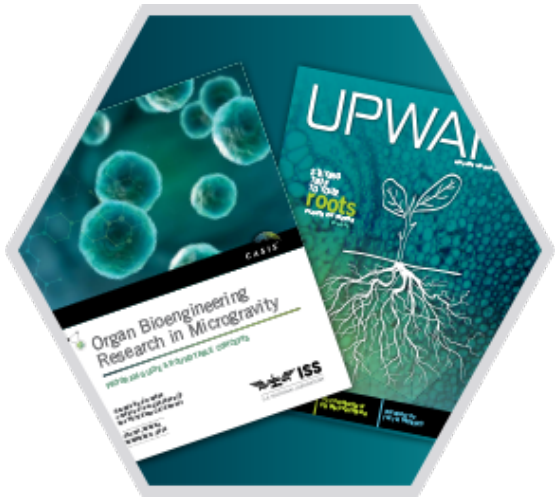


PURSUING GROUNDBREAKING SCIENCE

ISS U.S. NATIONAL LABORATORY

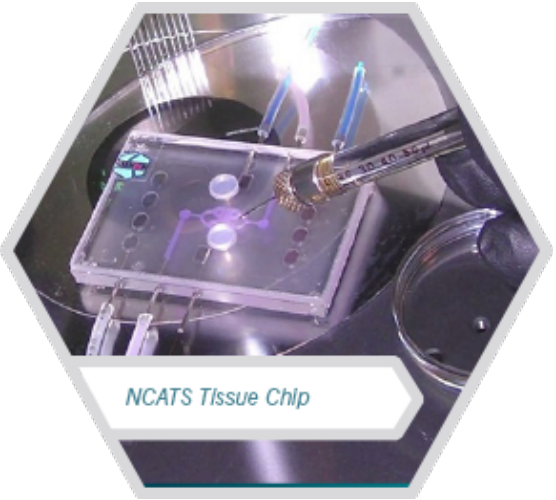
Research Payload Highlights:

- 58 Payloads delivered
- Eli Lilly – Innovation in Rodent Research; Drug Development
- First projects onboard the NanoRacks External Platform
- Diverse projects include: Milliken, Airbus, JAMMS America, SyNRGE
- National Lab research has resulted in 89 peer-reviewed publications since 2005

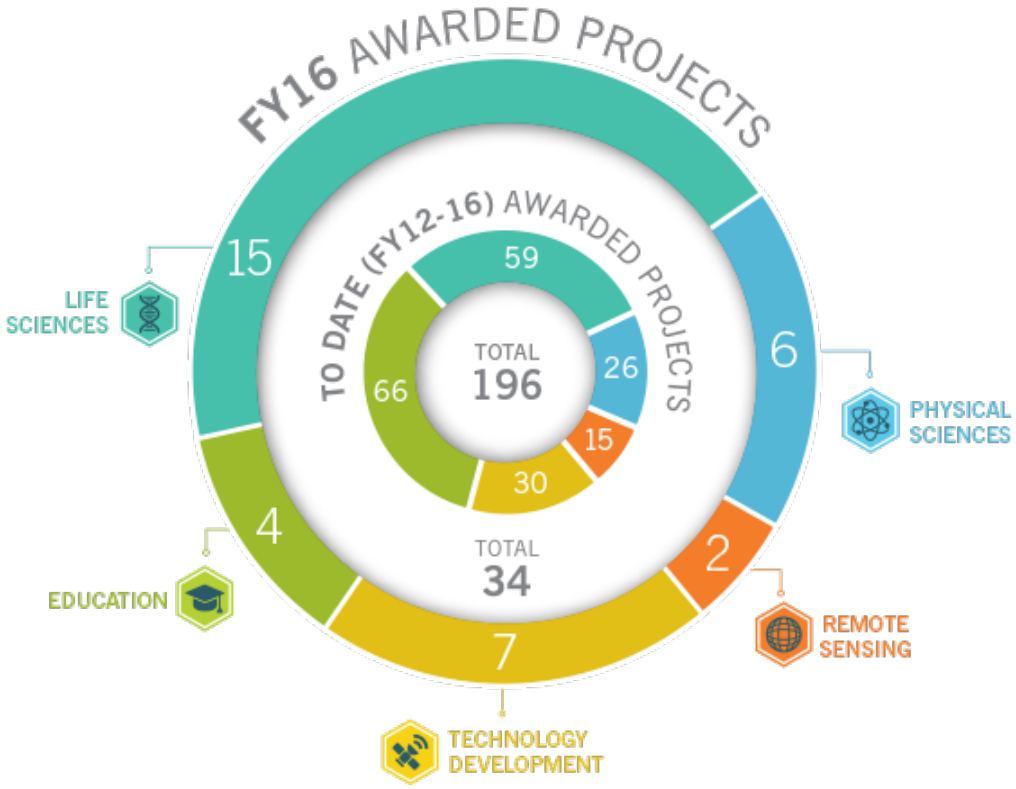


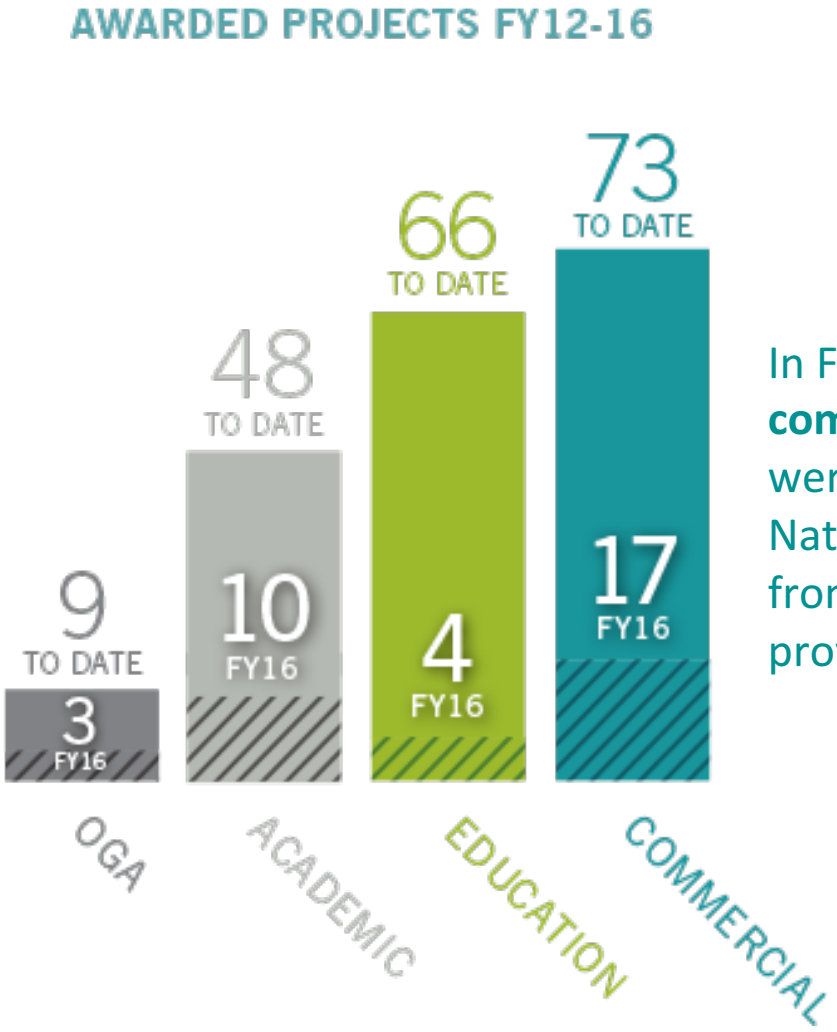

Additive Manufacturing Facility


Microgravity Protein Crystal Growth Workshop


NCATS Tissue Chip

MAXIMIZING SCIENCE RETURN





In FY16, **29 additional commercial payloads** were added to the ISS National Lab manifest from commercial service providers

CASIS VERTICALS & SPONSORED PROGRAMS PORTFOLIO

ISS U.S. NATIONAL LABORATORY

Life Sciences

ACCELERATED DISEASE MODELS: MUSCLE / BONE / IMMUNE & WOUND HEALING

Lilly
NOVARTIS
ONCOLINX

DRUG DELIVERY SYSTEMS

Lilly
HOUSTON Methodist LEADING MEDICINE

DIAGNOSTICS ON CHIP TECHNOLOGIES

NANOBIOSYM Where little things make a big difference
CAMMED
Zaiput Flow Technologies Groundbreaking Innovations in Flow Chemistry
NOVOPYXIS
1DropDiagnostics

DRUG DISCOVERY AND DEVELOPMENT (PROTEIN CRYSTAL)

Lilly
MERCK Be well
iXpressGenes
THE MICHAEL J FOX FOUNDATION FOR PARKINSON'S RESEARCH

Physical Sciences

INDUSTRIAL MATERIALS / CONSUMER PRODUCTS

nemak
COBRA PUMA GOLF
Ras Labs We bring motion to life
Milliken
P&G

Technology Development

ADDITIVE MANUFACTURING

MADE IN SPACE

VIRTUAL REALITY

oculus

MICROGRAVITY ENABLED NOVEL MATERIALS

FOMS
Astrileux
A2M ADVANCED MATERIALS, INC.

Remote Sensing / Aerospace Technology

EARTH OBSERVATION

VISIDYNE
Vision Engineering Solutions
BUSINESSINTEGRA TOGETHER IT IS DONE
Honeywell
JAMSS AMERICA INC. JAI

ENABLING TECHNOLOGY

NANORACKS
Space Tango
ASTRIUM AN EADS COMPANY
MAINSPACE MACHINES
NovaWurks

Other Government Agencies

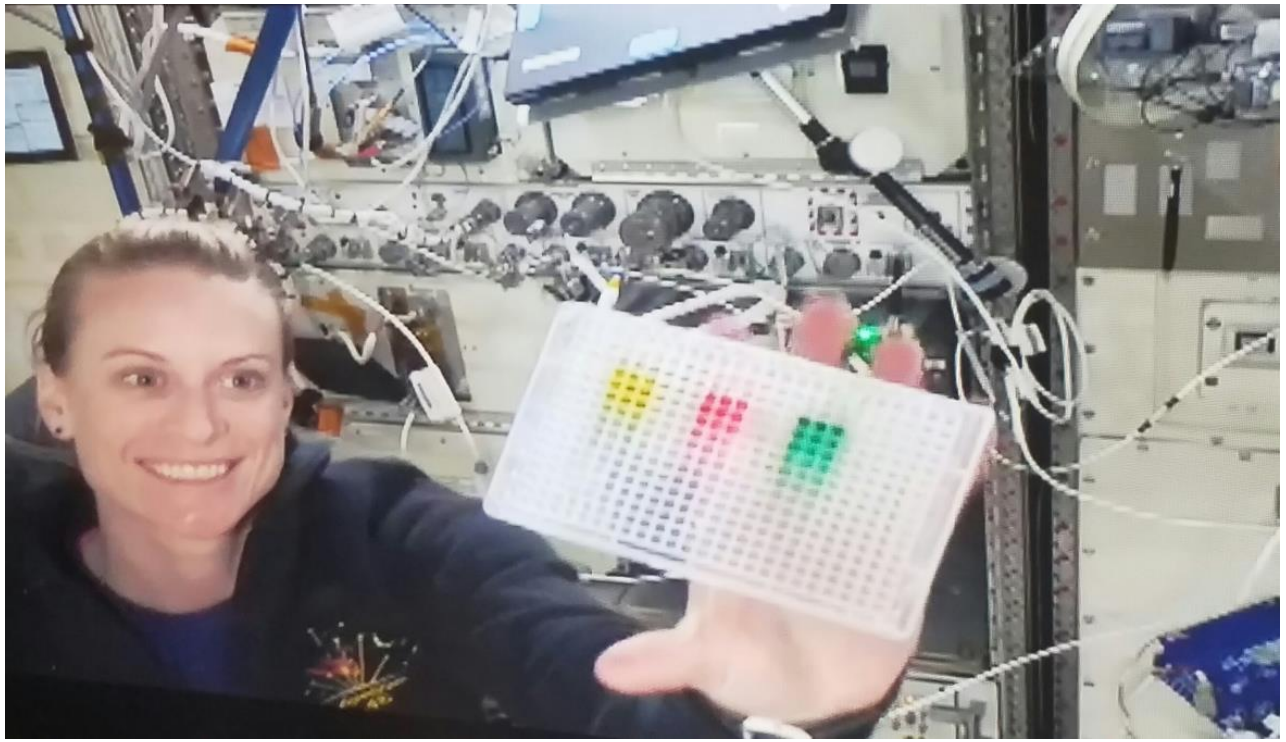
NIH National Institutes of Health

- NIH National Institute on Aging
- NIH National Institute of Arthritis and Musculoskeletal and Skin Diseases
- NIH National Institute of Biomedical Imaging and Bioengineering
- NIH National Center for Advancing Translational Sciences

DEPARTMENT OF DEFENSE UNITED STATES OF AMERICA
DEPARTMENT OF ENERGY UNITED STATES OF AMERICA
NSF
DARPA

RECENTLY COMPLETED INVESTIGATIONS

- ***Fluorescent Polarization in Microgravity*** validated a commercial Plate Reader instrument for support of life and physical science research on orbit.
- Siobhan Malany, Micro-gRx and Sanford Burnham Medical Research Institute, Orlando, FL,
- Payload Developer: NanoRacks, LLC



Images courtesy of NASA.

RECENTLY COMPLETED INVESTIGATIONS

- ***Microchannel Diffusion*** utilized the microgravity environment onboard the ISS to gain a better understanding of fluid flow through very small channels—an area of study called nanofluidics. Results from this project will aid in the development of a type of personalized medicine—a drug delivery implant that can be remotely controlled to deliver a specific dosage.
- PI: Alessandro Grattoni, Houston Methodist Research Institute, Houston, TX,
- Payload Developer: BioServe Space Technologies Inc.

Images courtesy of NASA.

RECENTLY COMPLETED INVESTIGATIONS

- ***Assessment of myostatin inhibition to prevent skeletal muscle atrophy and weakness in mice exposed to long-duration spaceflight (Rodent Research-3-Eli Lilly)*** tested the efficacy of a new therapeutic drug, an anti-myostatin antibody, in preventing muscle wasting in rodent models on the ISS. This new drug has been shown to prevent muscle wasting in mice on Earth, but this is the first time it is being tested in rodents in space to prevent muscle atrophy caused by microgravity. Because microgravity induces rapid muscle loss, the ISS provides a unique environment for accelerated testing of drugs aimed at treating patients on Earth who suffer from muscle atrophy disease and weakness from disuse.
- PI: Rosamund Smith, Eli Lilly and Company, Indianapolis, IN,
- Payload Developer: BioServe Space Technologies Inc.

Images courtesy of NASA.

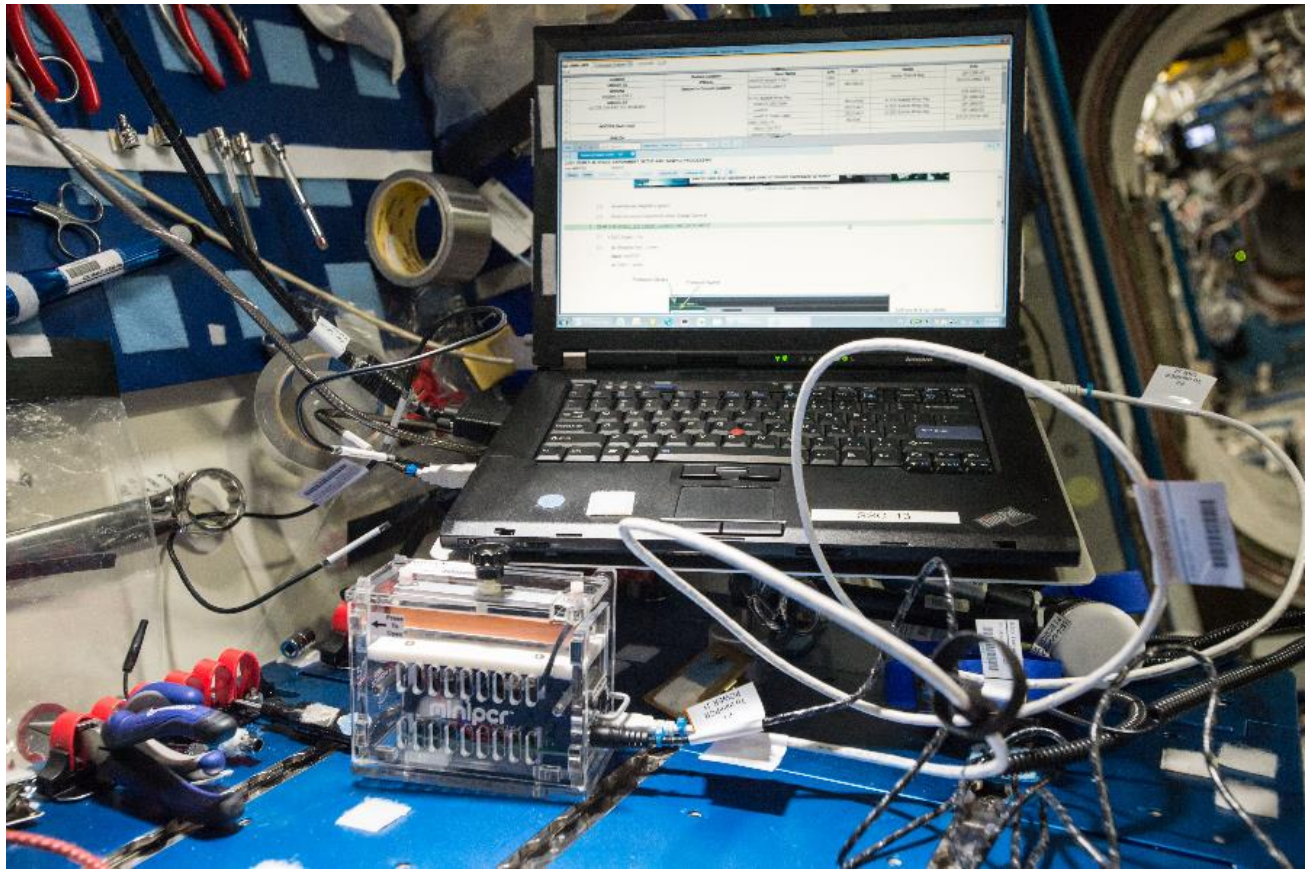
RECENTLY COMPLETED INVESTIGATIONS

- ***Biological Research in Canisters-Natural Product*** (BRIC-NPµG) studied bioactive molecules produced in microgravity by microorganisms originating from the Chernobyl nuclear accident to discover their potential for production of secondary metabolites valuable to medicine and agriculture.
- PI: Kasthuri Venkateswaran, California Institute of Technology, Pasadena, CA
- Payload Developer: Vencore, Inc.

Images courtesy of NASA.

RECENTLY COMPLETED INVESTIGATIONS

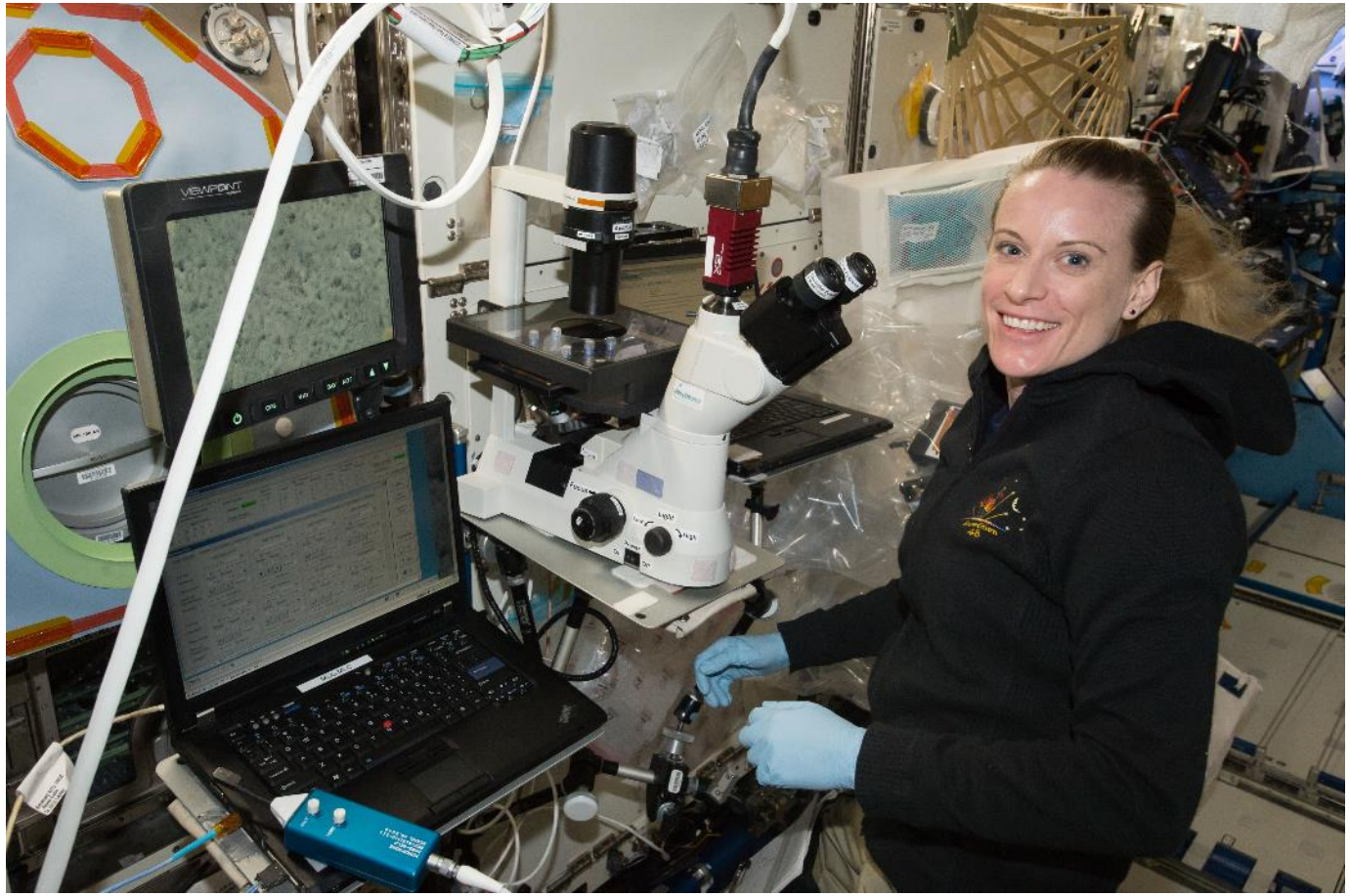
- ***Genes in Space-1*** was the inaugural project of a Boeing-CASIS partnership to select a student (grades 7-12) experiment involving DNA amplification using a miniPCR device. This first experiment sought to determine if changes in the methylation pattern of DNA can be detected using the miniPCR in microgravity, toward exploring a potential link between changes to DNA induced by spaceflight and the immune suppression of astronauts on long-duration missions.
- Student Investigator: Anna- Sophia Boguraev,
- Payload Developer: The Boeing Company, miniPCR, and Math for America



Images courtesy of NASA.

RECENTLY COMPLETED INVESTIGATIONS

- ***Effects of Microgravity on Stem Cell-Derived Cardiomyocytes (Heart Cells)*** Cardiomyocytes derived from hiPSCs were used to study the human heart, specifically how heart muscle tissue, contracts, grows and changes (gene expression) in microgravity.
- PI: Joseph C. Wu, Stanford University School of Medicine, Stanford, CA
- Payload Developer: BioServe Space Technologies Inc.



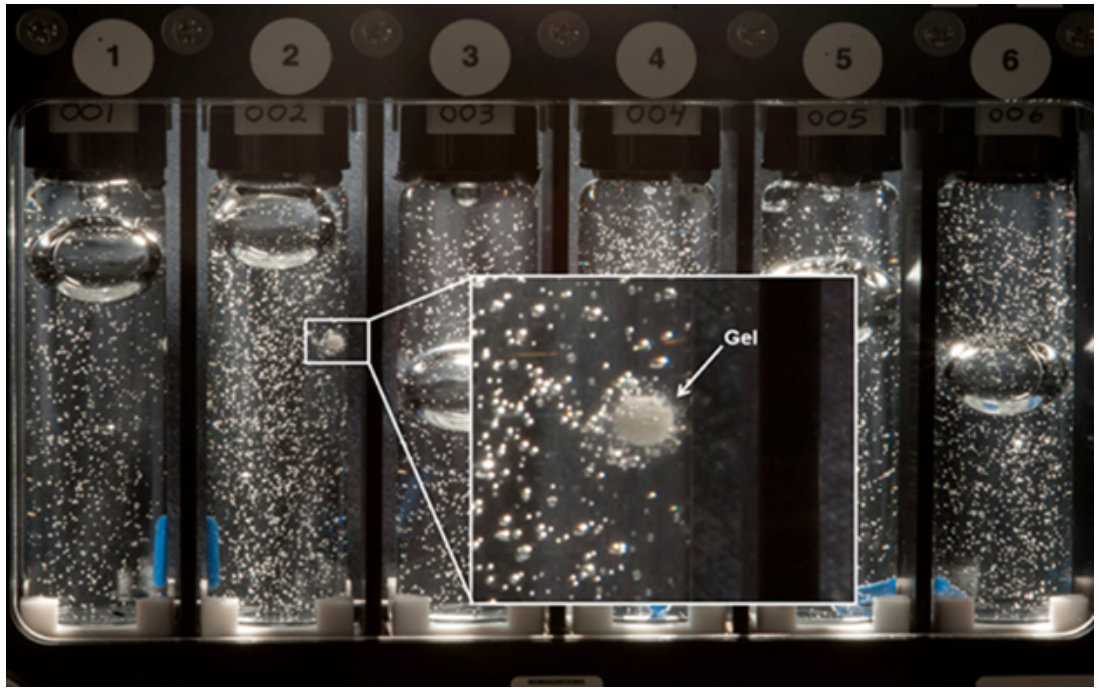
Images courtesy of NASA.

NASA astronaut Kate Rubins observes beating heart cells aboard the International Space Station.

Images courtesy of NASA.

CURRENT INVESTIGATIONS

- ***Hard to Wet Surfaces*** is evaluating wettability and ultimate dissolution rates in microgravity to gain a better understanding of fundamental processes. Results from this investigation may help improve the formulation of drugs to improve drug delivery and improve drug shelf life for drugs used in space and on Earth.
- PI: Richard Cope, Eli Lilly and Company, Indianapolis, IN
- Payload Developer: Zin Technologies Inc.



Images courtesy of NASA.

CURRENT INVESTIGATIONS

- ***WetLab-2*** is a new suite of scientific instruments for molecular analysis of DNA and RNA from biological samples. The system enables in-orbit processing of tissue samples and extraction of high-quality DNA and RNA for gene expression. Samples can either be returned to Earth for analysis or directly analyzed in-orbit using RT-qPCR.
- PI: Julie Schonfeld, Payload Developer: NASA Ames Research Center

Images courtesy of NASA.

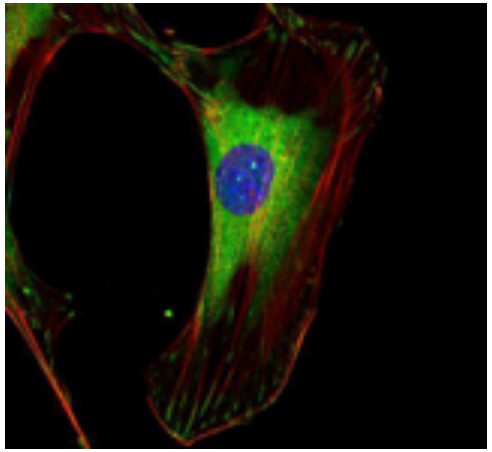
UPCOMING NIH RESEARCH ON ISS NATIONAL LAB

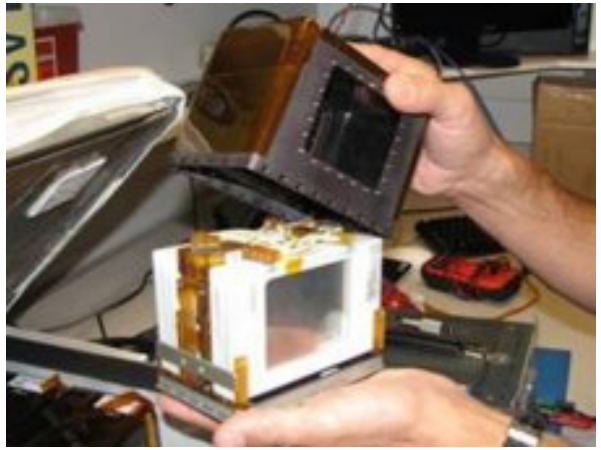
National Institute of Biomedical Imaging and Bioengineering

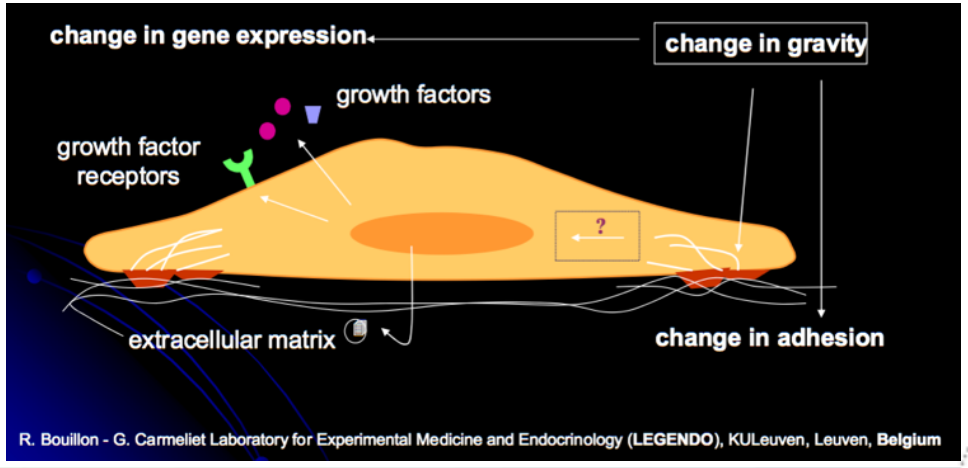
ISS U.S. NATIONAL LABORATORY

Gravitational Regulation of Osteoblast Genomics and Metabolism (OsteoOmics)

- PI: Bruce Hammer, U of Minnesota, CMRR
- Millions of Americans experience bone loss, which results from disease or the reduced effects of gravity that can occur in bed-ridden patients
- New ground-based studies are using magnetic levitation equipment to simulate gravity effects
- Compare genetic expression in osteoclast and osteoblast cells to determine the molecular changes that take place in magnetic levitation and real microgravity







Images courtesy of Dr. Bruce Hammer and NASA.

UPCOMING DoD RESEARCH ON ISS NATIONAL LAB

ISS U.S. NATIONAL LABORATORY

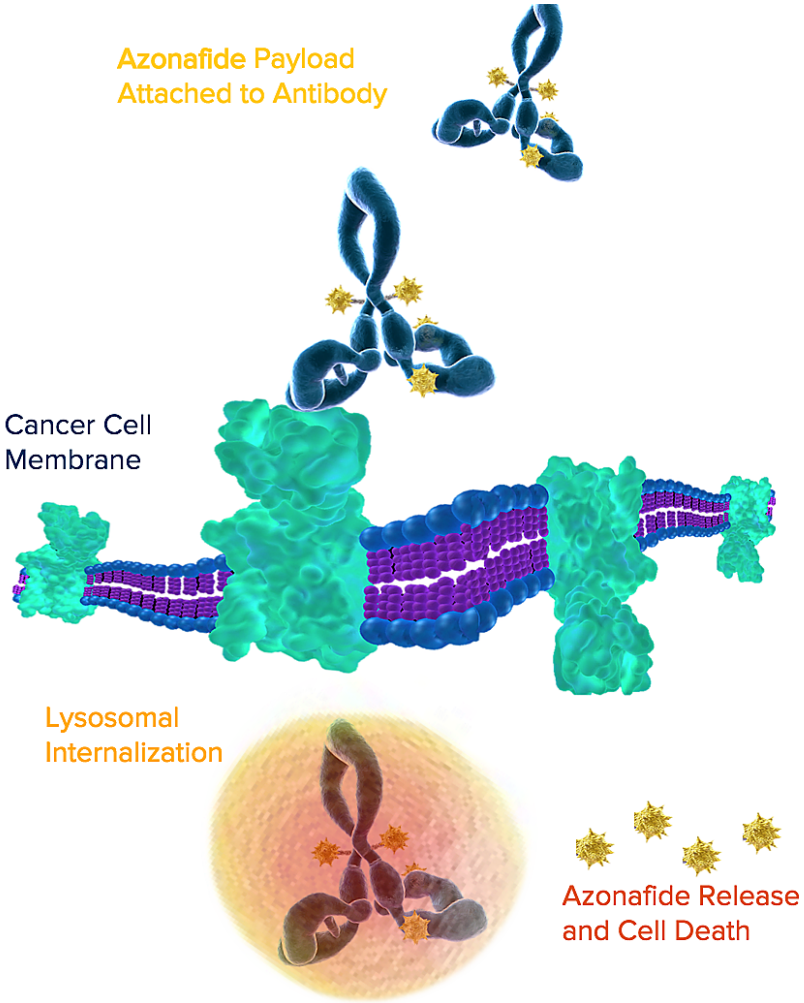
Tissue Regeneration-Bone Defect (Rodent Research-4 CASIS)

- PI: Rasha Hammamieh, US Army
- Lower gravity provides some beneficial effects on the tissue regeneration process. It is therefore warranted to understand the biological interpretation of the healing/ tissue regeneration process in spaceflight. In addition, the therapeutic success of certain agents capable of inducting healing/tissue regeneration is gauged in the spaceflight.
- Transcriptomics, genomics, proteomics, metabolomics and microbiomics aspects of the selected biomaterials critical for healing/ tissue regeneration are evaluated. The pan-omics results are sorted and integrated; enriched circuits and ontologies are mined by a set of heuristic algorithms.
- The results may help to explain the overall impact of microgravity on healing/ tissue regeneration. The potential effects of microgravity on the inductive agents of wound healing are determined.

UPCOMING COMMERCIAL RESEARCH ON ISS NATIONAL LAB

Efficacy and Metabolism of Azonafide Antibody-Drug Conjugates in Microgravity (ADCs)

- PI: Sourav Sinha, Oncolinx Pharmaceuticals, LLC
- Test the efficacy and drug metabolism of Azonafide ADCs in microgravity 3D cell cultures.
- Cultures in microgravity should serve as better in vivo models of tumors than terrestrial cultures and, as such, accelerate the timeline to translational applications of the research. ADCs are toxic therapeutics that target tumors through receptors on the surface of cancer cells, thereby reducing toxicity and increasing effectiveness of the therapy.



Images courtesy of Oncolinx.

UPCOMING NON-PROFIT INSTITUTION RESEARCH ON ISS NATIONAL LAB

Application of Microgravity Expanded Stem Cells in Regenerative Medicine (CASIS Stem Cell Mayo)

- PI: Abba Zubair, Mayo Clinic
- Currently, there is no effective method to expand human stem cells on Earth. This investigation will utilize the microgravity environment for cultivation of clinical grade stem cells for therapeutic applications in humans. Results of this investigation will support clinical trials to evaluate the safety and efficacy of microgravity expanded stem cells and will support subsequent studies for large scale expansion of clinical grade stem cells for the treatment of patients with stroke.

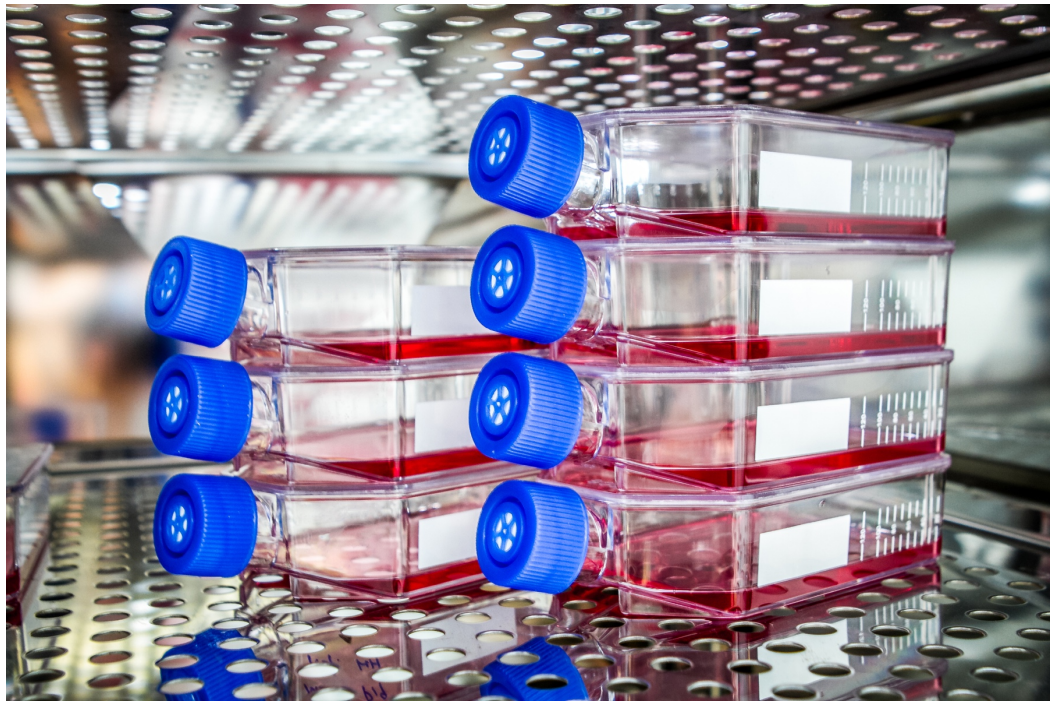


Image courtesy of NASA.

SPONSORED PROGRAM FOCUS AREAS IN STEM CELLS and TISSUE ENGINEERING

Biomedical Research on the International Space Station (BioMed-ISS)

NIH National Institute of Arthritis and Musculoskeletal and Skin Diseases

NIH National Institute on Aging

NIH National Institute of Biomedical Imaging and Bioengineering

I Stem Cell Biology

Flight Projects

Wu (Stanford U) *Heart Cells*	SpX-9
Zubair (Mayo Clinic)	SpX-10
Kearns-Jonker (Loma Linda U)	SpX-11

Ground Projects

Gregory (TAMU)	Bone tumor cells
Hare (U Miami)	Cardiac stem cells
Schwartz (U Houston)	Cardiac progenitor cells
Xu (Emory U)	Cardiomyocytes hiPSC

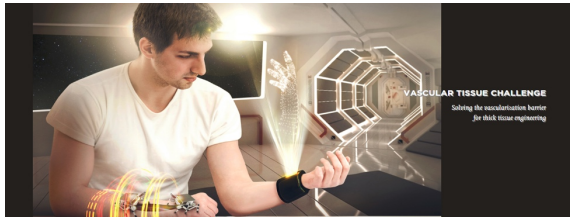
II Microphysiological Systems

Flight Projects

Malany (micro-gRx)	muscle model
Tuan (U of Pittsburgh)	bone model

http://casistissuechip.blogspot.com/

III Tissues to Organs

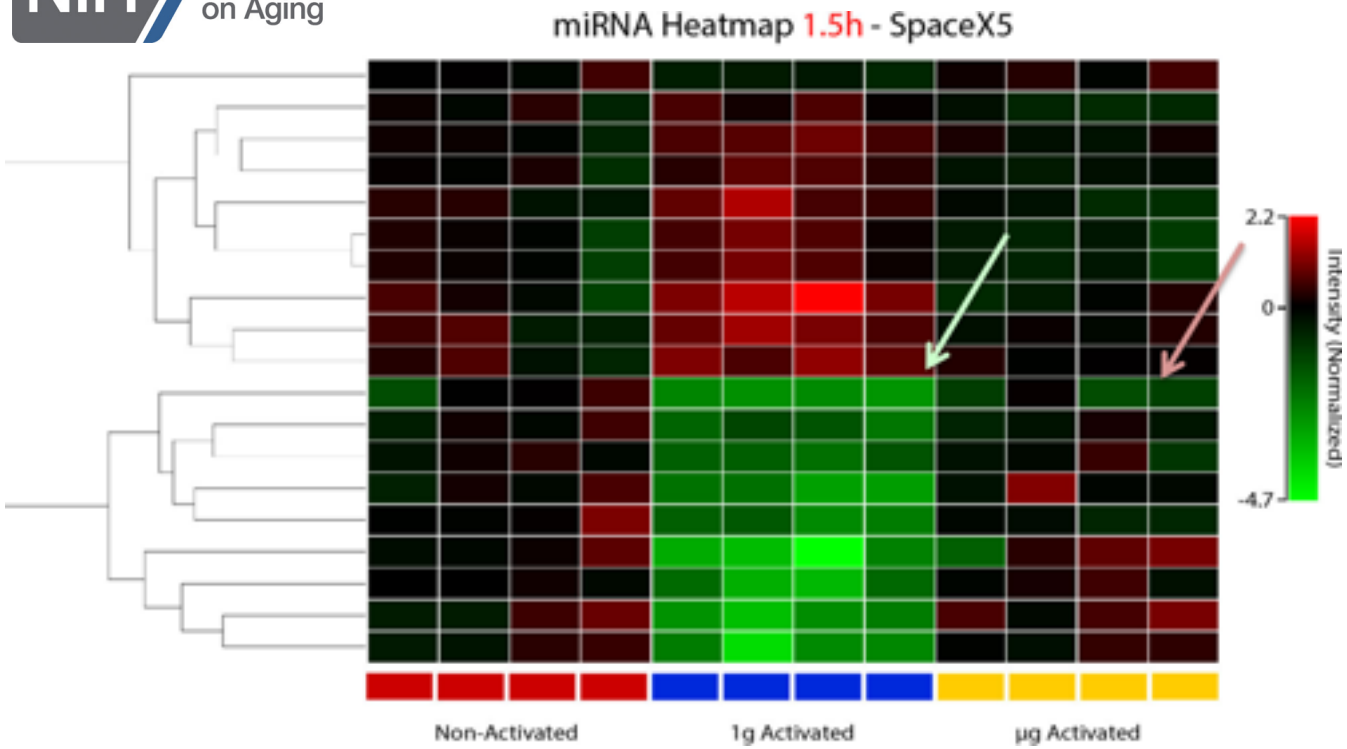


Informational webinar conducted September 8, 2016
https://www.neworgan.org/vtc-prize.php
https://www.neworgan.org/CASIS-prize.php

Vascular Tissue Challenge Roadmapping Workshop conducted November 9-10, 2016 at the NASA-Ames Research Center
https://neworgan.org/vtc-workshop.php

NIH RESEARCH ON ISS NATIONAL LAB

National Institute on Aging



Discovery of miRNAs downregulated in 1-g immune activation are missing in SpaceX-5 experiment.

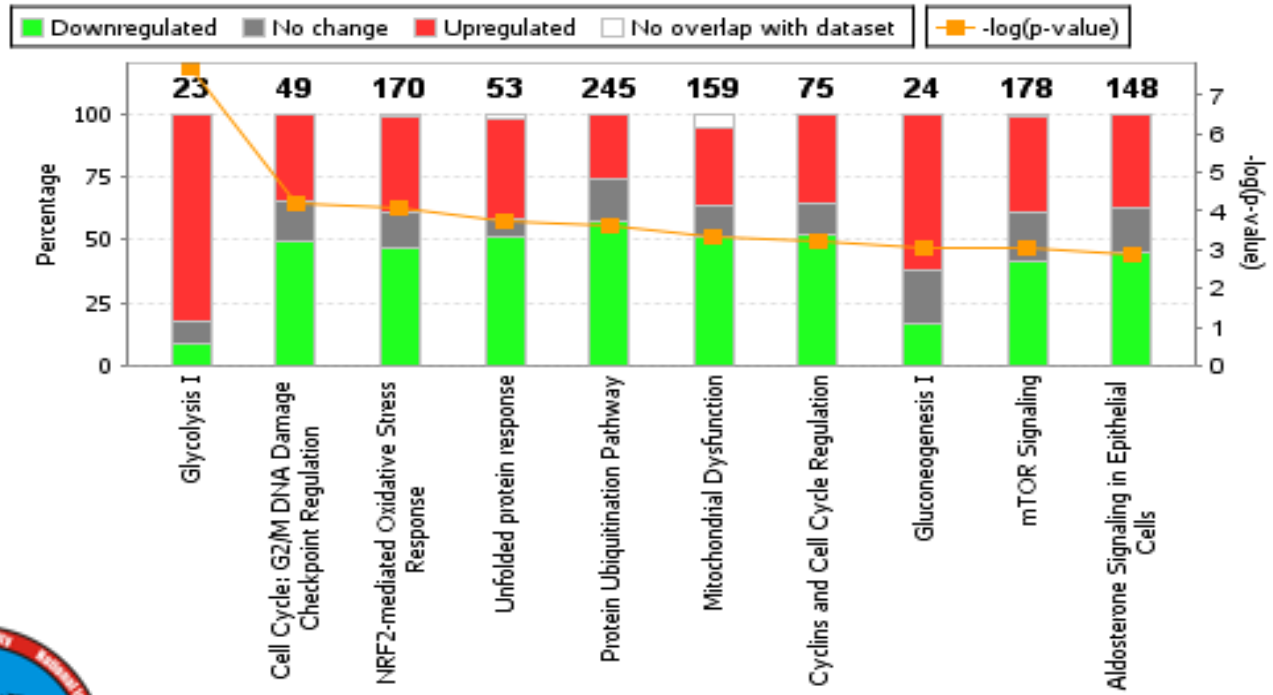
Hughes-Fulford, M., T.T. Chang, E.M. Martinez, and C-F. Li. (2015) Spaceflight alters expression of microRNA during T-cell activation. *FASEB J 29:4893-4900*

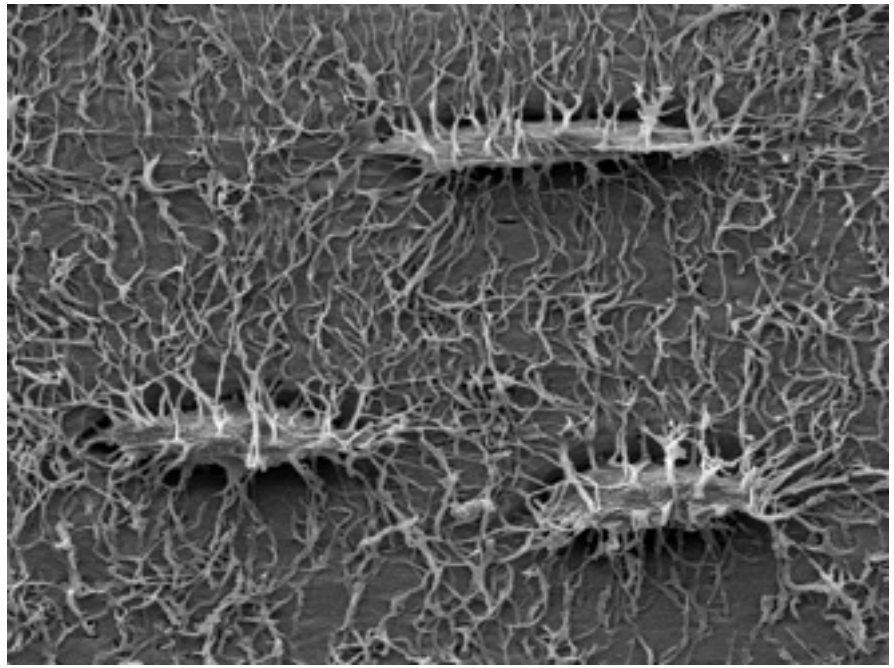
Millie Hughes-Fulford, San Francisco Department of Veterans Affairs Medical Center

Images courtesy of Dr. Millie Hughes-Fulford.

NIH RESEARCH ON ISS NATIONAL LAB

National Institute of Arthritis and Musculoskeletal and Skin Diseases





Paola Divieti Pajevic, Boston University, School of Dental Medicine, Molecular and Cell Biology

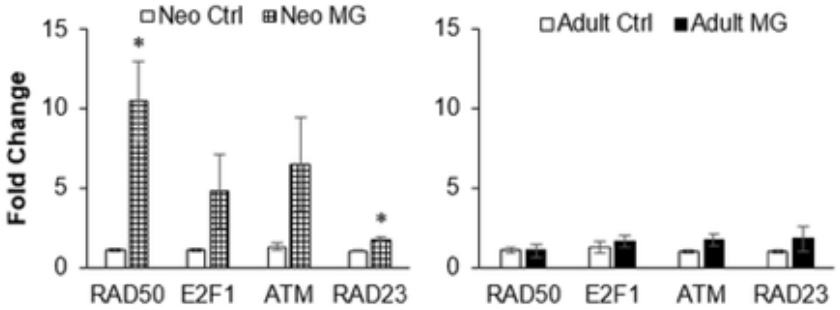
Images courtesy of Dr. Paola Divieti Pajevic.

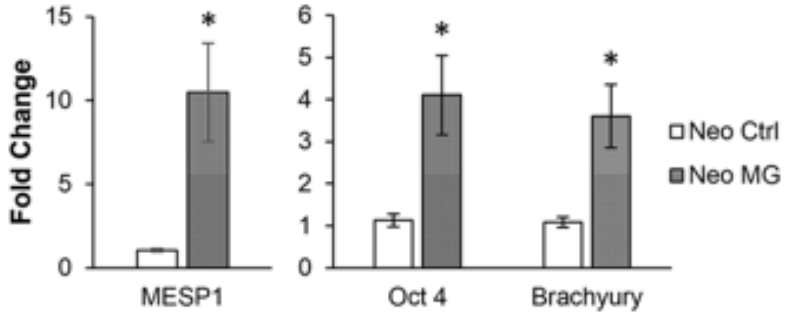
STEM CELL RESEARCH ON ISS NATIONAL LAB

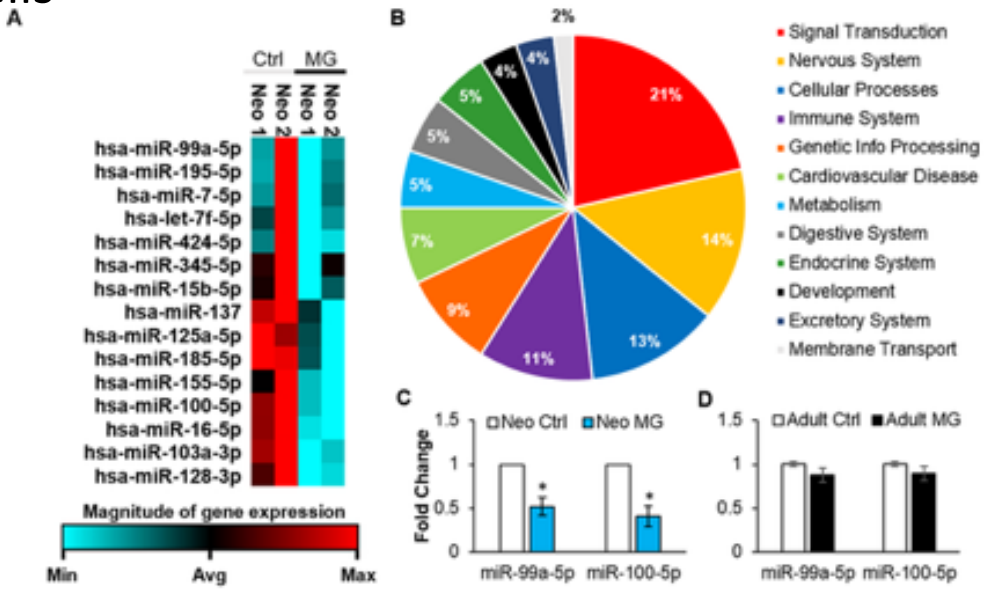
ISS U.S. NATIONAL LABORATORY

Functional Effects of Spaceflight on Cardiovascular Stem Cells

DNA repair transcripts were elevated in neonatal CPCs exposed to simulated microgravity but not in adult CPCs exposed to simulated microgravity.







Different patterns of gene regulation in response to simulated microgravity were observed for neonatal versus adult cells

Fuentes, T.I., et al. (2015) Simulated Microgravity Exerts an Age-Dependent Effect on the Differentiation of Cardiovascular Progenitors Isolated from the Human Heart *PLoS ONE* 10(7): e0132378.

Mary Kearns-Jonker, Loma Linda University

Images courtesy of Dr. Mary Kearns-Jonker.

CASIS

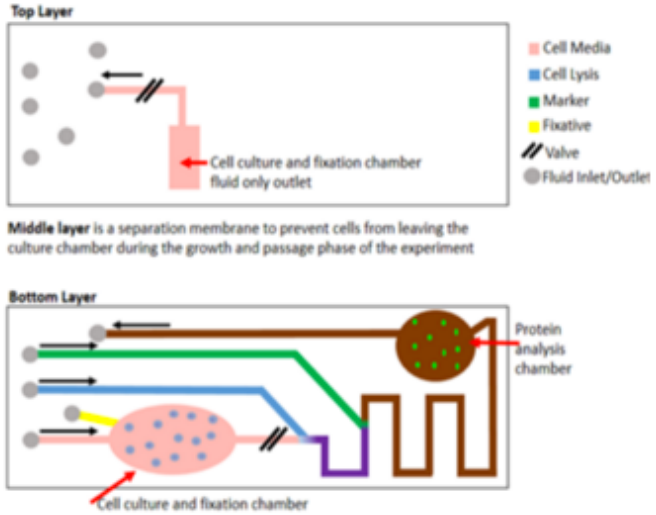
MPS PLATFORM DEVELOPMENT ON ISS NATIONAL LAB

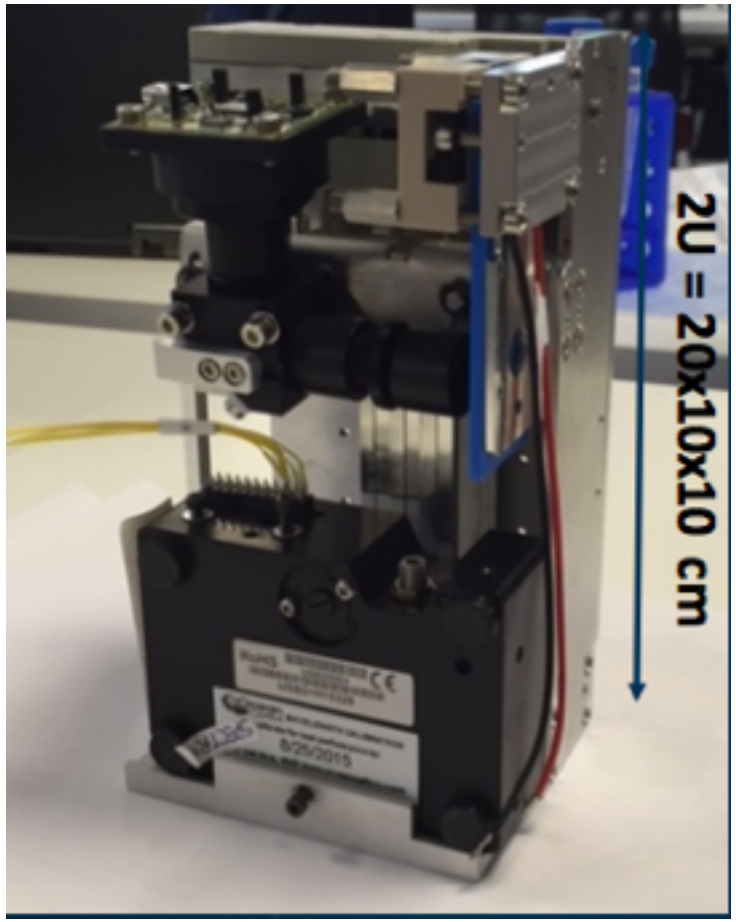
micro-gRx

Siobhan Malany

SpacePharma

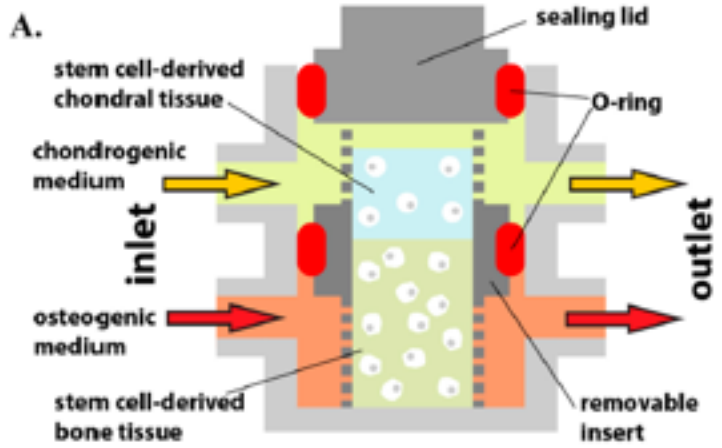
Tissue Chip – OOC
Functional muscle model





Images courtesy of Dr. Siobhan Malany.

MPS PLATFORM DEVELOPMENT ON ISS NATIONAL LAB



Schematic of a bioreactor for in vitro osteochondral engineering.

Title: A Microphysiological 3D Organotypic Culture System for Studying Degradation and Repair of Composite Skeletal Tissues in Microgravity

Principal Investigator: Dr. Rocky Tuan

Affiliation: University of Pittsburgh

Description: A microphysiological system (MPS, a micro-scale system that models the detailed physical structure of human tissue) will be used to evaluate potential therapies for the treatment and prevention of osteoporosis and other musculoskeletal disorders. Unlike animal models of bone loss, which can be confounded by species-specific responses (i.e., bone pathways in mice differ from humans) and require significant resource input even for limited sample sizes, MPS models can use human bone cells in high throughput microfluidic platforms. This project will validate an MPS platform for bone in microgravity to confirm the protective role of bisphosphonates (a class of drugs currently used to treat osteoporosis) for protection during long-term microgravity exposure.

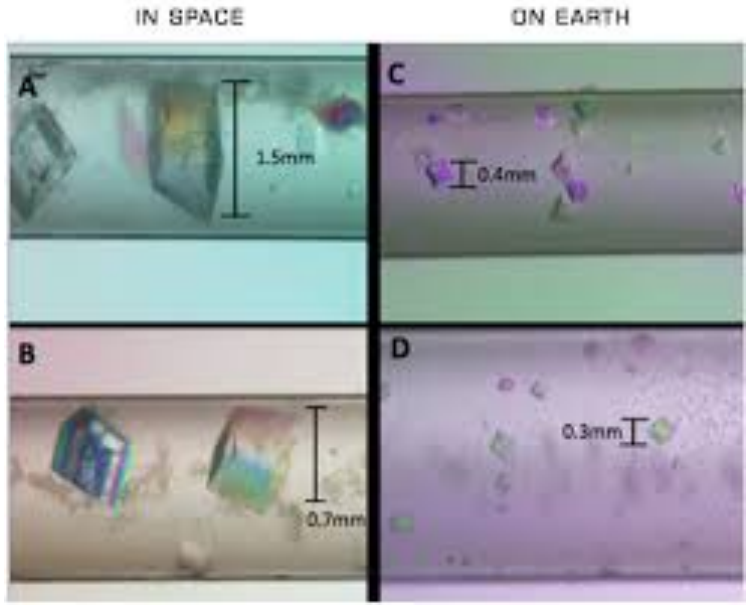
Source: Stem Cell-Based Microphysiological Osteochondral System to Model Tissue Response to Interleukin-1β Hang Lin, Thomas P. Lozito, Peter G. Alexander, Riccardo Gottardi, and Rocky S. Tuan
Molecular Pharmaceutics **2014** *11* (7), 2203-2212 DOI: 10.1021/mp500136b

Images courtesy of Dr. Rocky Tuan.

STUDIES IN MICROBIOLOGY AND PROTEIN CRYSTALLIZATION

Activation of the AES-1 (Antibiotic Effectiveness in Space) experiment in orbit by Astronaut Michael Hopkins.

PI: David Klaus and Luis Zea, University of Colorado, Boulder



IPPase Protein Crystal Growth in microgravity (panel A) and on Earth in 1g (panel B). (Credit, Joseph D. Ng, iXpressGenes Inc. and University of Alabama, Huntsville)

Images courtesy of NASA and Dr. Joseph Ng.

CASIS and Boeing "Technology in Space" Prize: MassChallenge Boston Accelerator

Pioneering a vascular route to cancer therapy

- Endothelial Cells in Microgravity for Evaluation of Cancer Therapy
- Dr. Shou-Ching Jaminet
- Angiex will evaluate the hypothesis that microgravity cultured endothelial cells represent a valid model system for the effects of vascular-targeted agents on normal blood vessels. If the hypothesis is validated, study results will potentially enable Angiex's drug to be designed for lower toxicity, and will create an important model system for testing of any vascular drug.

Changing drug development: One basepair at a time

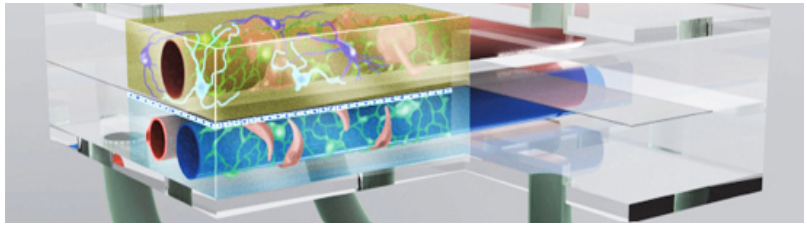
- Microgravity Crystalization of Glycogen Synthase-Glycogenin Protein Complex
- Dr. David S. Chung
- Dover Lifesciences will utilize the International Space Station to perform crystallization experiments with glycogen synthase proteins glycogenin 1 (gyg1) and glycogenin 2 (gyg2) and Additionally each glycogen synthase protein will be co-crystallized in combination with glycogenin, G6P, UDP, and glycogen synthase inhibitor molecules.

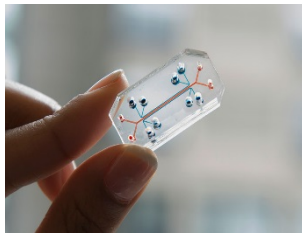
- Enhancement of Performance and Longevity of a Protein-Based Retinal Implant
- Dr. Nicole L. Wagner
- LambdaVision is developing a protein-based retinal prosthetic to restore vision to the millions of people who are blinded by retinal degenerative diseases, including retinitis pigmentosa (RP) and age-related macular degeneration (AM). They hypothesize that multilayer protein/polymer films prepared in microgravity will yield improvements in the homogeneity of the films, the degree of orientation of the protein, and the stability of the resulting multilayer system.

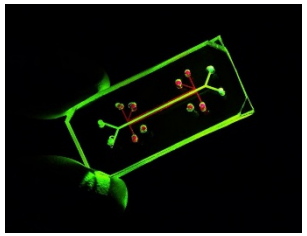
NEW PARTNERSHIPS FOR NOVEL INQUIRY

ISS U.S. NATIONAL LABORATORY

NIH National Center for Advancing Translational Sciences





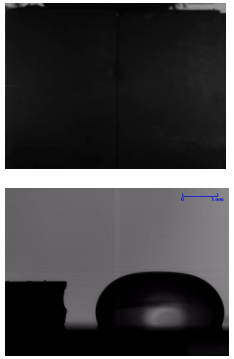


- $12M in total funding from NIH for 3-4 teams
- Anticipated award announcement in July 2017 with 2 ISS National Lab flight opportunities for each team beginning in 2018

http://casistissuechip.blogspot.com/

NSF

- The first NSF/CASIS collaboration resulted in five ISS National Lab flight projects in fluid dynamics awarded by NSF and announced in September 2016
- A second NSF/CASIS collaboration was announced in November 2016 on combustion and thermal transport processes with NSF funding $1.8M for up to 6 flight projects to the ISS National Lab



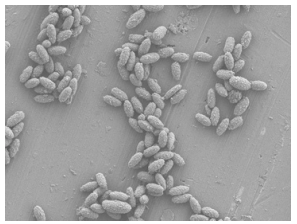
https://www.nsf.gov/news/news_summ.jsp?cntn_id=189921&org=NSF&from=news
https://www.nsf.gov/pubs/2017/nsf17517/nsf17517.htm

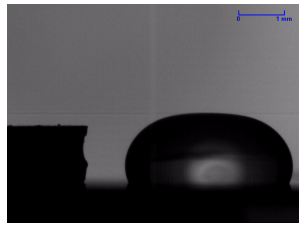
Images courtesy of NASA, NIH and NSF.

National Science Foundation Sponsored Programs - I

5 awardees from the NSF-CASIS fluid dynamics solicitation announced September 2016;
Mission Integration and Operations planning for the National Lab started Q1 2017

- Largest Sponsored Program for CASIS to date and the first partnership with a non-NASA government agency
- NSF is committing approximately $1.5 million in grant funding toward five ISS National Lab flight projects
- Projects will take advantage of the long-duration microgravity environment for the study of fluid dynamics.





ISS: Constrained Vapor Bubbles of Ideal Mixtures
Investigator: Joel Plawsky, Rensselaer Polytech Institute (Troy, NY)

ISS: Inertial Spreading and Imbibition of a Liquid Drop Through a Porous Surface
Investigator: Michael Louge, Cornell University (Ithaca, NY)

ISS: Kinetics of Nanoparticle Self-Assembly in Directing Fields
Investigator: Eric Furst, University of Delaware

ISS: Quantifying Cohesive Sediment Dynamics for Advanced Environmental Modeling
Investigator: Paolo Luzzatto-Fegiz, University of California-Santa Barbara (Santa Barbara, CA)

ISS: Unmasking contact-line mobility for Inertial Spreading using Drop Vibration and Coalescence
Investigator: Paul Steen, Cornell University (Ithaca, NY)

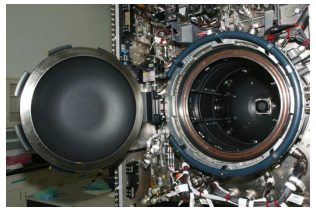
https://www.nsf.gov/news/news_summ.jsp?cntn_id=189921&org=NSF&from=news

Images courtesy of the NSF.

National Science Foundation Sponsored Programs - II

NSF-CASIS Collaboration on Combustion and Thermal Processes Research

- NSF has committed $1.8 M in grant funding for up to 6 ISS National Lab flight projects
- Projects will take advantage of the long-duration microgravity environment for the study of combustion



CIR Combustion Chamber

BASS Hardware Unit

SUBSA Furnace

NSF/CASIS Collaboration on Combustion and Thermal Transport Processes Research on the International Space Station to Benefit Life on Earth

PROGRAM SOLICITATION
NSF 17-517

National Science Foundation

Directorate for Engineering
Division of Chemical, Bioengineering, Environmental and Transport Systems

Center for the Advancement of Science in Space

Submission Window Date(s) (due by 5 p.m. submitter's local time):

February 20, 2017 - March 10, 2017

https://www.nsf.gov/pubs/2017/nsf17517/nsf17517.htm

Images courtesy of NASA.

New Sponsored Program Targets

- Follow-on to NIH NCATS-CASIS Space Tissue Chips Collaboration
  - Discussions with the National Institute of Biomedical Imaging and Bioengineering (NIBIB) at NIH
- Follow-on to NSF Collaborations in Microfluidics and Combustion
  - Discussions with NSF Deputy Division Director of the Chemical, Bioengineering, Environmental, and Transport Systems (ENG/CBET) and the Program Manager of the Biomedical Engineering (BME) program*
- Follow-on to DoD US Army Medical Research and Material Command (USAMRMC) cell and rodent research projects in wound healing
  - Discussions with Wendy Dean, Medical Officer, Tissue Injury and Regenerative Medicine Project Management Office (TIRM PMO)*
- New initiatives with the Defense Advanced Research Projects Agency – Biological Technologies Office (DARPA – BTO)
  - Discussions with Program Manager of the DARPA Living Foundries program**

NIH National Center for Advancing Translational Sciences

NSF **Chemical, Bioengineering, Environmental, and Transport Systems Division (CBET)**

PROTECT PROJECT SUSTAIN

U.S. Army Medical Research and Materiel Command

DARPA

** Resulting from Tissue Bioengineering workshop held at World Stem Cell Summit 2016*

***Resulting from Microbiome Workshop held at ASGSR 2016*

Microbiome/Immunome Workshop

October 25, 2016

Exploring the Microbiome/ Immunome and Disease on the International Space Station

IMPROVING HUMAN HEALTH ON EARTH

CASIS

Workshop Goals

- Define current challenges in R&D to assess the interaction of microbiota, immune function, ecosystem health, and human disease
- Define focus areas for research in microgravity to address current challenges in microbiome/immunome research
- Define research topics for inter-government agency collaboration and public-private industry partnerships on the ISS National Lab

Final Recommendations - Microbiome projects that require microgravity

- Relevant disease models
- Accelerated antibiotic resistance
- Protein structure
- The built environment(e.g., closed systems like the ISS)
- Using microbes for cleaning (e.g. reclamation, filtration and CO2 mitigation)
- Stability of microbiomes in space
- Food production systems (e.g., plants) and cryptic pathways for bacterial production of products (e.g., secondary metabolites)

http://www.iss-casis.org/Workshops/Microbiome.aspx

ISSNL PORTFOLIO MANAGEMENT

An Introduction to Value Impact Assessment

ISS NATIONAL LAB IS ENABLING SCIENCE & LEO COMMERCIALIZATION BY BUILDING CUSTOMER DEMAND, ENABLING SUPPLY FOR SPACE BASED R&D, & FACILITATING INVESTMENT

SUPPLY

COMMERCIAL FACILITIES

Alpha Space Test & Research Alliance
BioServe Space Technologies
HNU Photonics
Made In Space
NanoRacks
Space Tango
STARS
techshot
Teledyne Brown Engineering, Inc. — A Teledyne Technologies Company

ISS National Lab

DEMAND

SPONSORED PROGRAMS

NIH National Institutes of Health
NIH National Center for Advancing Translational Sciences
National Science Foundation — WHERE DISCOVERIES BEGIN
Massachusetts Life Sciences Center
Genes in Space
Boeing
mass CHALLENGE

CUSTOMERS*

nemak
P&G
Houston Methodist — Leading Medicine
Novartis
Honeywell
Merck
Schafer
The Michael J. Fox Foundation for Parkinson's Research
BusinessIntegra
Airbus
Lilly
JAMSS America (JAI)
Milliken

INVESTOR NETWORK

Bessemer Venture Partners
Sherpa Capital
canaan
Binary Capital
LUX
IQT — In-Q-Tel
Starburst Accelerator
Arsenal
venrock
DFJ
Space Angels Network
NG | VP
Bee Partners
Lemnos Labs
Breakout Labs
Santé Ventures

*Not inclusive; these examples represent only a small subset of commercial users

CASIS

IS THERE THE OPPORTUNITY FOR VALUE IN LEO?

The questions we've asked and started to answer…

- **CREATING A SUSTAINABLE MARKET IN LOW EARTH ORBIT (LEO):**
  - How do we translate the unique scientific opportunities in LEO into projects that fulfill the mandate provided in the Congressional legislation that created CASIS?
  - Are we helping to establish a new economy in LEO that benefits the American public and sectors of the U.S. economy?
- **CREATING VALUE:**
  - Is our program actually creating value for our project sponsors / customers and the public at large?
  - What does the future look like?

IS THE ISS NATIONAL LAB CREATING VALUE FOR THE NATION

Value Impact process

- Ensuring credibility, transparency, and independence
  - Utilized consulting expertise
  - Evaluated more than 200 best practice examples from leading organizations
  - Convened independent subject-matter-expert panel

- Value Impact methodology
  - Created an assessment framework with metrics based on best practices
  - 60 ISS National Lab/CASIS projects were evaluated as part of a baseline retrospective analysis
  - Projects were scored and placed on an impact/feasibility matrix
  - Value statements were generated
  - Details on methodology: www.ar2016.iss-casis.org/#section4

CREATING VALUE: A BALANCED SCORECARD FRAMEWORK

ISS U.S. NATIONAL LABORATORY

IMPACT AND FEASIBILITY FACTORS:

Three Impact Benefit Categories Measured Against Feasibility and Risk

IMPACT FACTORS

Economic
- Application Leverage
- Market Innovation
- New Revenue Potential

Innovation
- Discovery Science
- Research Leadership
- Unique Niche

Humankind /Social
- Enduring Capability
- Catalytic
- Quality of Life

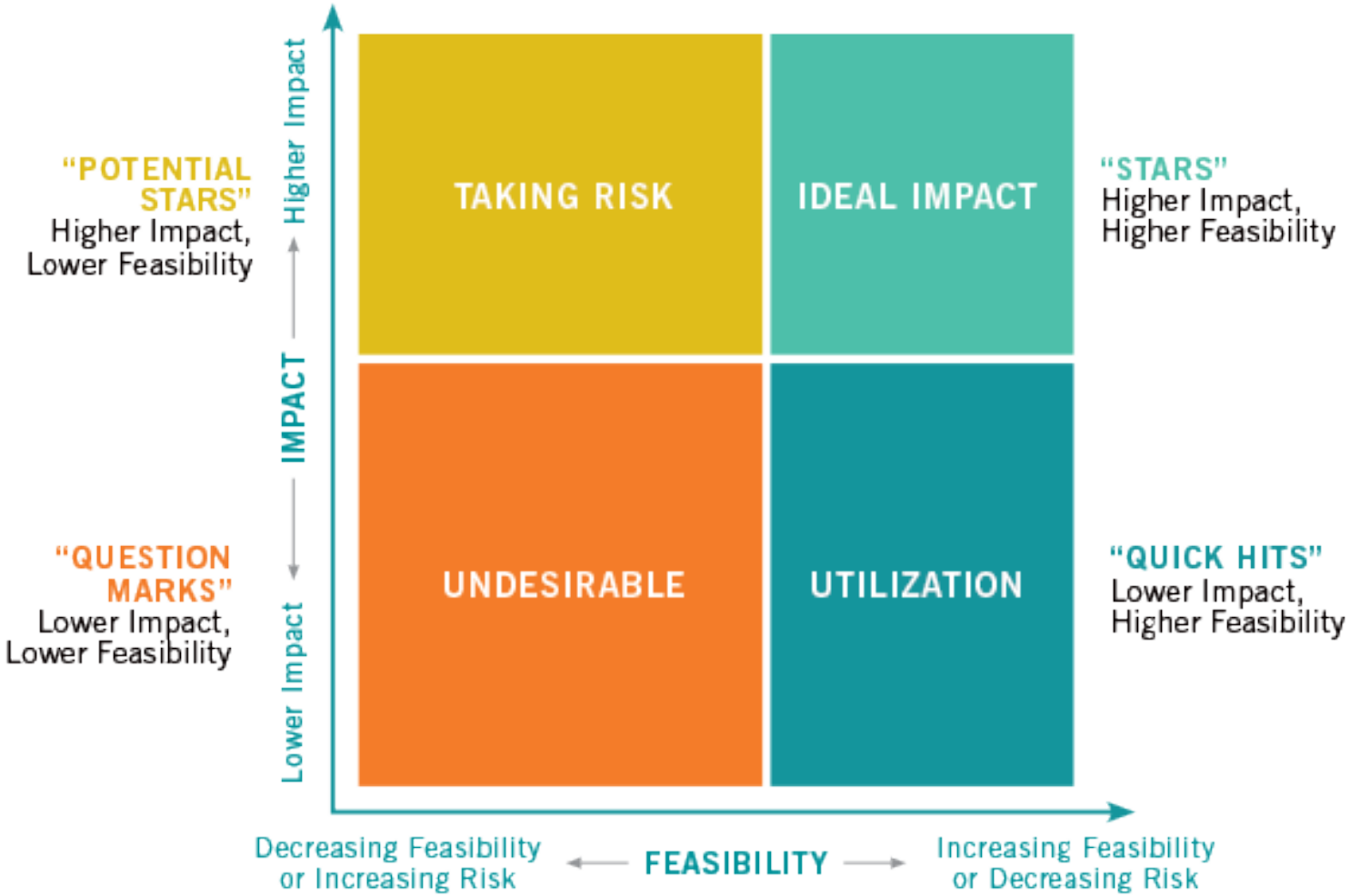
FEASIBILITY FACTORS

Feasibility
- Project Clarity
- Resource Commitment
- Technical Approach
- Commercialization

MEASURING IMPACT FROM THE ISS NATIONAL LAB PORTFOLIO TO CREATE NEW R&D OPPORTUNITIES

ISS U.S. NATIONAL LABORATORY

We can now better assess the composition of our portfolio and apply this framework to our decisions going forward.

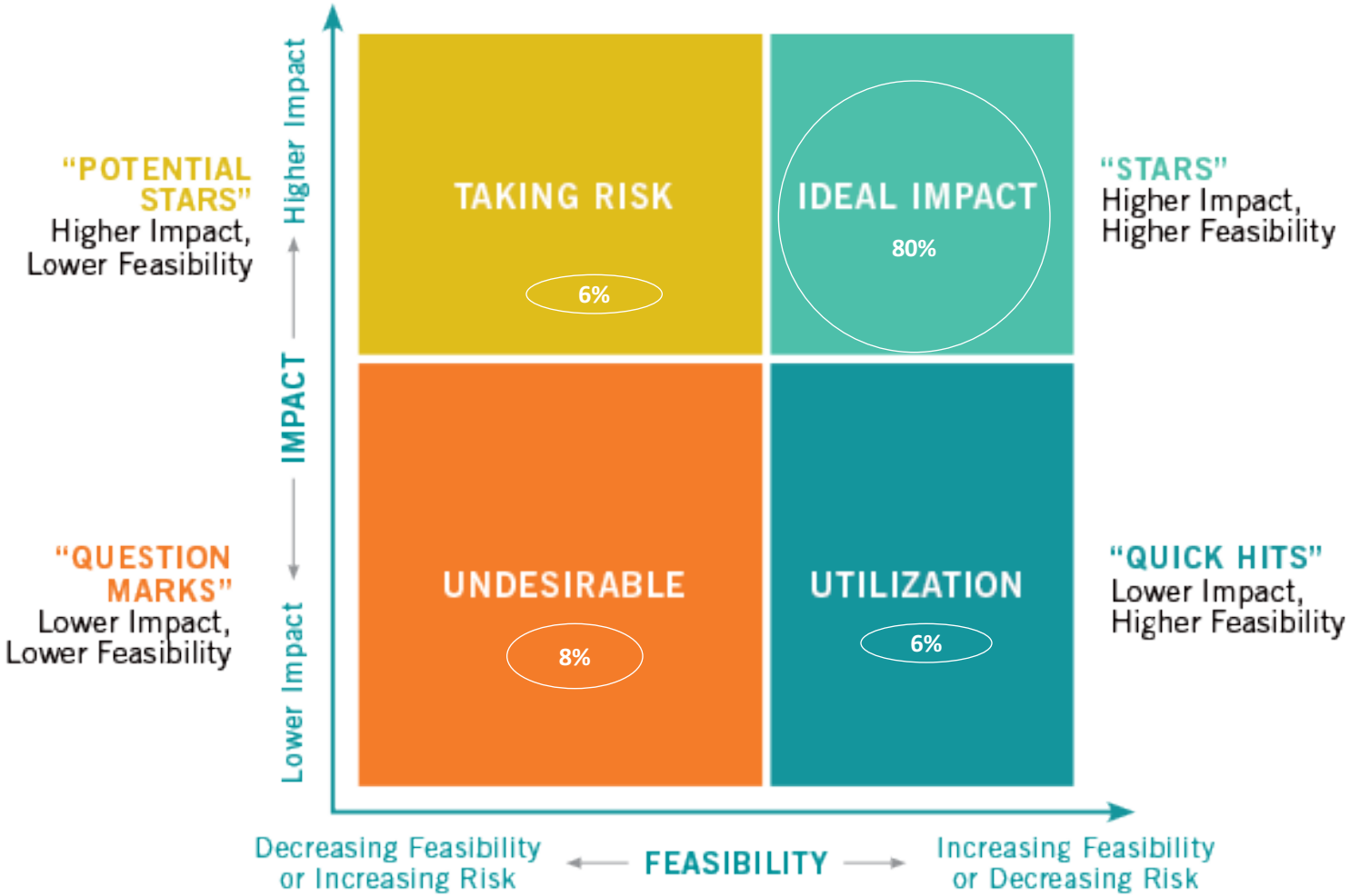


CASIS

MEASURING IMPACT FROM THE ISS NATIONAL LAB PORTFOLIO TO CREATE NEW R&D OPPORTUNITIES

ISS U.S. NATIONAL LABORATORY

Our first baseline results: Total investment % in each quadrant



CASIS

Upward

- The ISS National Lab is making progress toward creating a sustainable LEO marketplace which advances the US microgravity science enterprise.
    - The ISS National Lab cultivates demand and supply (e.g., commercial on-orbit R&D facilities) and facilitates investment to enable economic development of LEO.
    - The creation of a vibrant and sustainable market in LEO supports the use of the ISS through 2024 and future microgravity platforms beyond.
- The ISS National Lab is creating scientific opportunity and value – using the value impact tool, we are able to articulate that the ISS National Lab is a platform for value creation for the American public and the U.S. economy, and as a pathfinder for future LEO platforms…whatever they may be.
- We are seeing a shift in subsidized funding models as more organizations are taking on the costs traditionally born by NASA, such as research and development. It is conceivable that in the next few years, we should see a significant increase in organizations wiling to pay to use a microgravity platform in space. The business model is still evolving and CASIS continues to be forward leaning and responsive to US needs.

ISS NATIONAL LAB: ***WWW.SPACESTATIONRESEARCH.COM***
SPACE STATION EXPLORERS: ***SPACESTATIONEXPLORERS.ORG***
CASIS: ***WWW.ISS-CASIS.ORG***