ISS Utilization and Benefits to Humanity

International Microgravity Strategic Planning Group and
ISPS-7 & ELGRA-25
2 October 2017

Kirt A. Costello, Ph.D., Deputy Chief Scientist, International Space Station
Kirt.Costello-1@nasa.gov

Charts Courtesy Julie. A Robinson, Ph. D. ISS Chief scientist

Overview

- Organizations that Sponsor Research
- Utilization Statistics
- Capabilities for Research
- Benefits from ISS

Organizations that Sponsor Research on ISS

*Allocations of flight resources: upmass, downmass, crewtime, as specified in intergovernmental agreements and U.S. Legislation

ISS

U.S. NATIONAL LABORATORY

CASIS™

POWERED THROUGH PARTNERSHIP

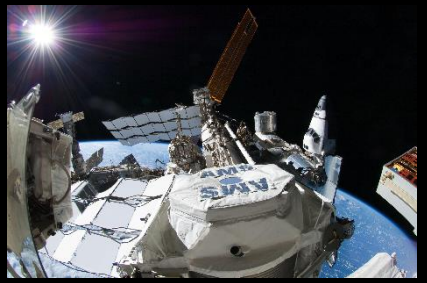
Government-Wide Utilization

U.S. DEPARTMENT OF ENERGY

NIH NSF DEPARTMENT OF COMMERCE UNITED STATES OF AMERICA FEDERAL AVIATION ADMINISTRATION USDA

Department of Energy

- The Alpha Magnetic Spectrometer-02 (AMS-02) is an ISS instrument that collects and analyzes cosmic rays as part of a comprehensive search for dark energy and antimatter. The AMS-02 is operated by an international team composed of 56 institutes from 16 countries and organized under DOE sponsorship *(Flown 2011-Present)*



AMS-02 installed on ISS

Image: NASA

Department of Defense

- DoD SPHERES-RINGS and SPHERES-CSAC satellites test flight formation and atomic clock properties in microgravity *(Flown 2017 and 2011-12)*
- Ten separate MISSE experiments, sponsored by the DoD, test the effects of radiation, atomic oxygen, and extreme temperatures on materials affixed to the outside of the ISS *(Flown 2001-Present)*

SPHERES-RINGS onboard ISS

Image: NASA

National Institutes of Health

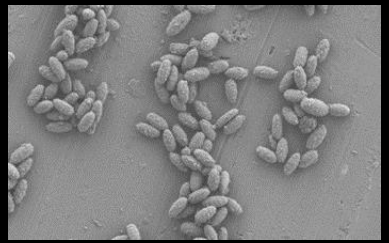
- NIH research onboard the ISS spans over a decade and currently includes an investigation by former space shuttle crew member Millie Hughes-Fullord of the role of T-cells in aging and immune function *(Flown 2010)*
- National Center for Advancing Translational Services (part of NIH) will provide up to $12M to five projects from 2017-2021 to study tissue chip technology onboard the ISS for the benefit of human health on Earth

Former astronaut Michael Hopkins presents research at the NIH campus

Image: NIH

National Science Foundation

- NSF-ISS program continues to award shares of $1.5M to over 300 separate fluid dynamics research proposals that can utilize the ISS to benefit life on Earth
  - These experiments cannot be conducted on Earth, where gravity overpowers the fundamental properties of fluids



External magnetic fields reveal the magnetic properties of clusters of particles

Image: Eric Furst, University of Delaware

Department of Commerce

- Office of Space Commerce fosters economic growth and technological advancement in the commercial space industry, particularly as it pertains to the U.S. Government

Department of Transportation/FAA

- Office of Commercial Space Transportation encourages and facilitates commercial space launches by the private sector, including upcoming private transportation of NASA crewmembers to the ISS

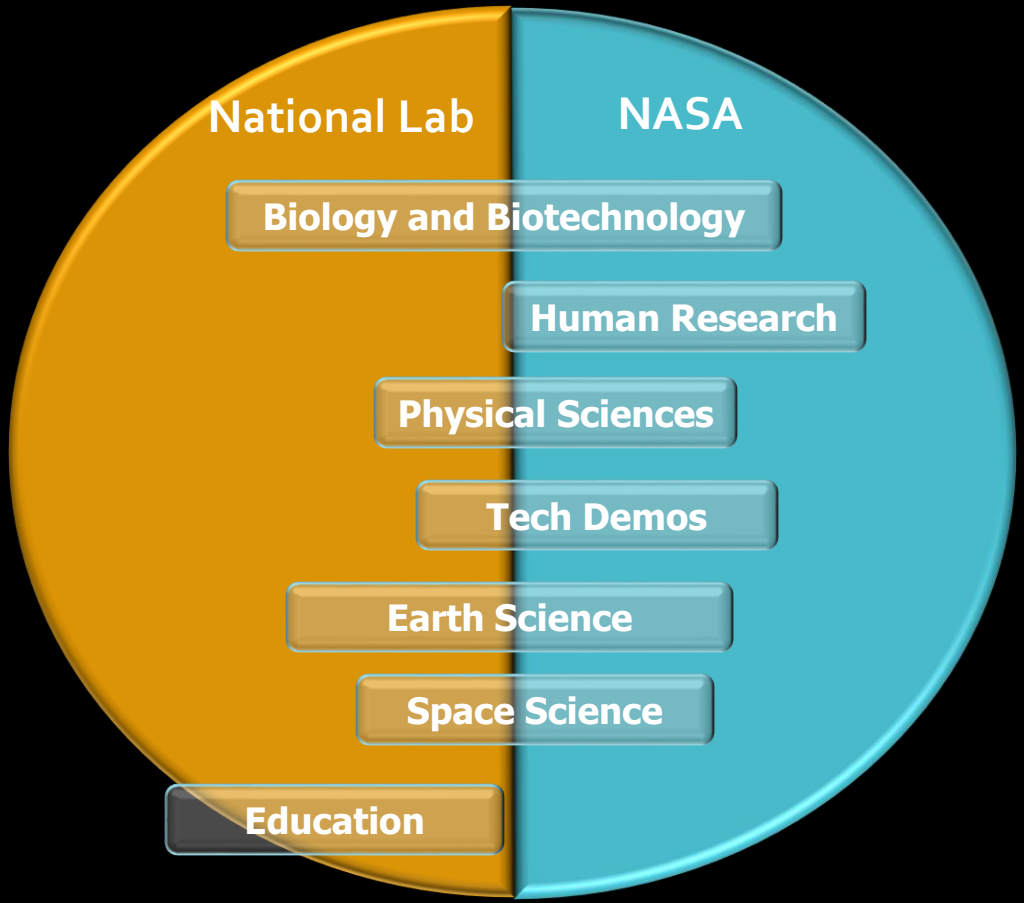
Department of Agriculture

- ISS Agricultural Camera photographed the Great Plains to assist farmers in making agricultural management plans like pesticide application, irrigation, and grazing *(Flown 2009-10)*
- Veggie is an expandable plant growth system featured by USDA and developed by NASA to expand in-orbit food production capabilities *(Flown 2014-Present)*

Crewmembers prepare to taste red lettuce grown on the ISS as part of the Veggie program

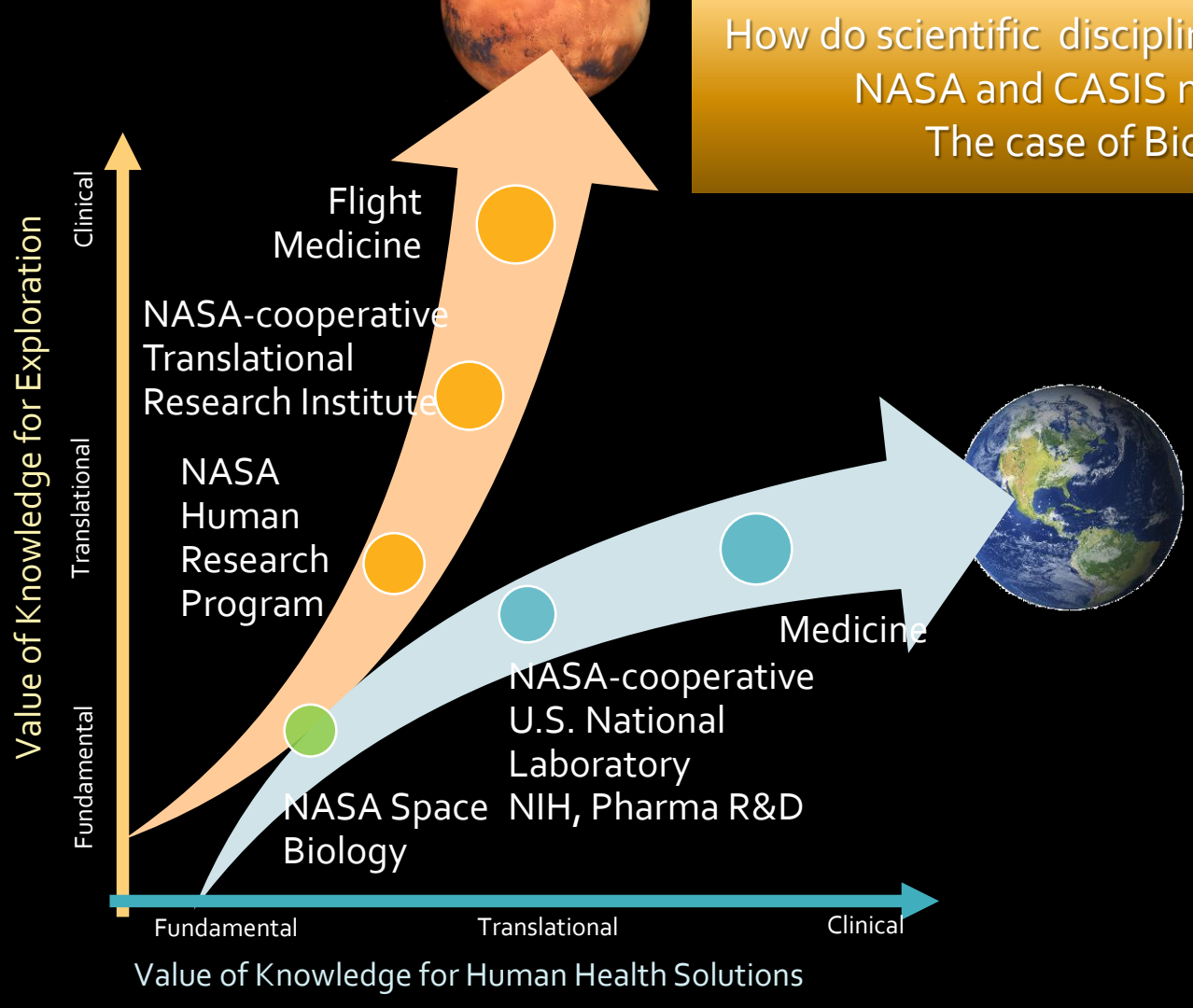
Example R&D Users of the ISS National Laboratory

Scientific Disciplines using ISS Today



Data from Expeditions 51/52, April-Sept 2017

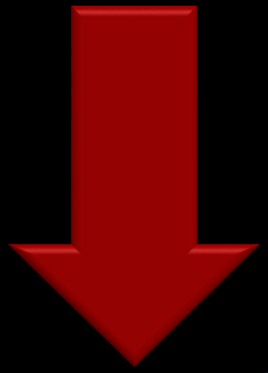
How do scientific disciplines relate to the NASA and CASIS missions? The case of Biology



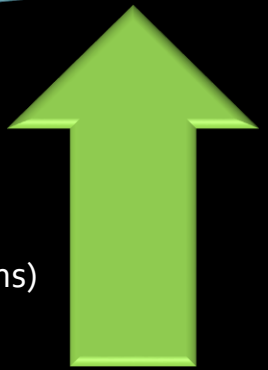
Major factors influencing research use of ISS

Resource limitations (e.g., upmass, downmass, crewtime)
- Flight delays to resupply and return plan
- Operations scenarios that reduce crew time for research

Cost to use the platform
- Transportation costs, cost of schedule delays
- Costs and complexity of payload or facility development
- Costs of implementation



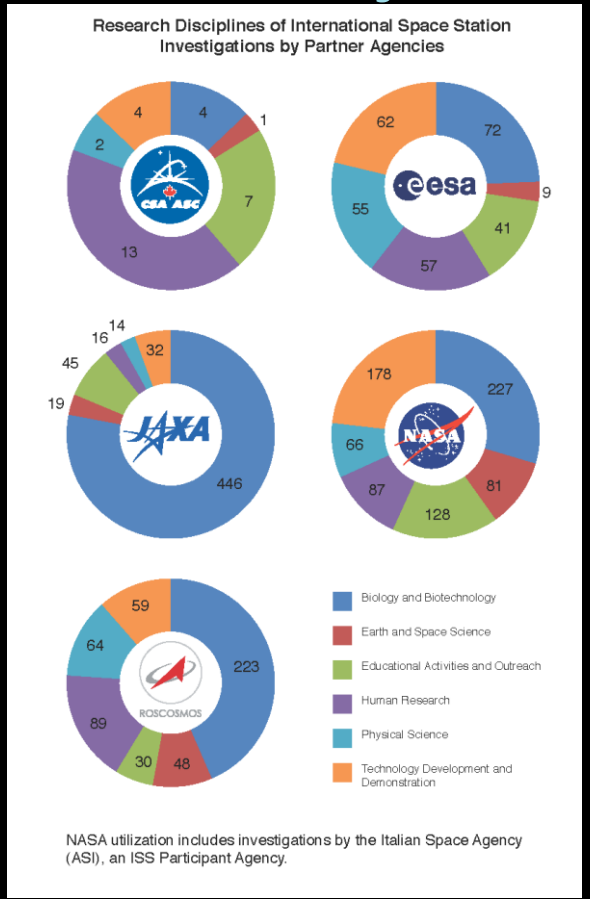
Strategies to tip the balance:
diverse transportation providers, simplify integration, implementation
partner competition, communicate successes



Research Demand
- NASA Funding
- Non-NASA funding
- Research breakthroughs drive funding (Earth applications)

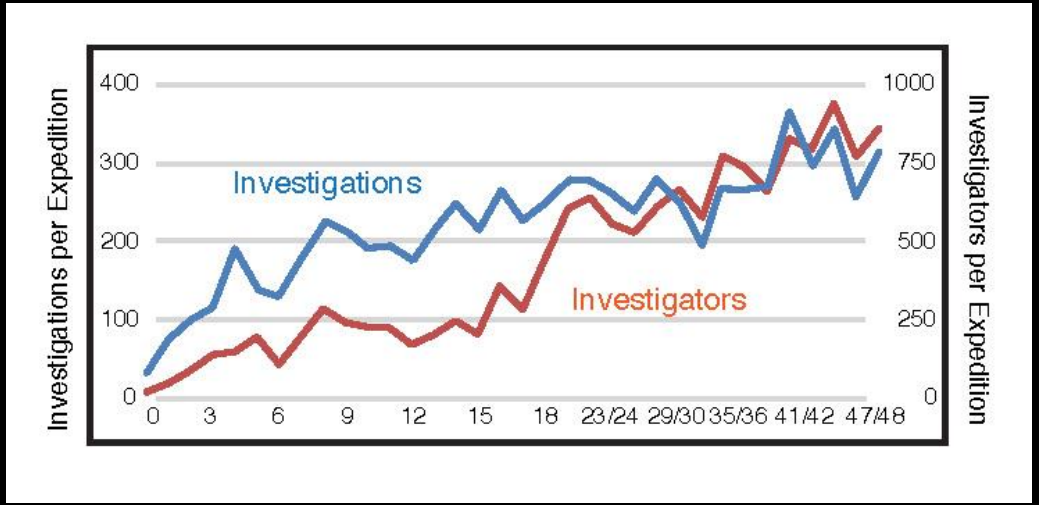
Investigations & Investigators as of September 2016

Number of Investigations



Expeditions 0-48
December 1998 – September 2016

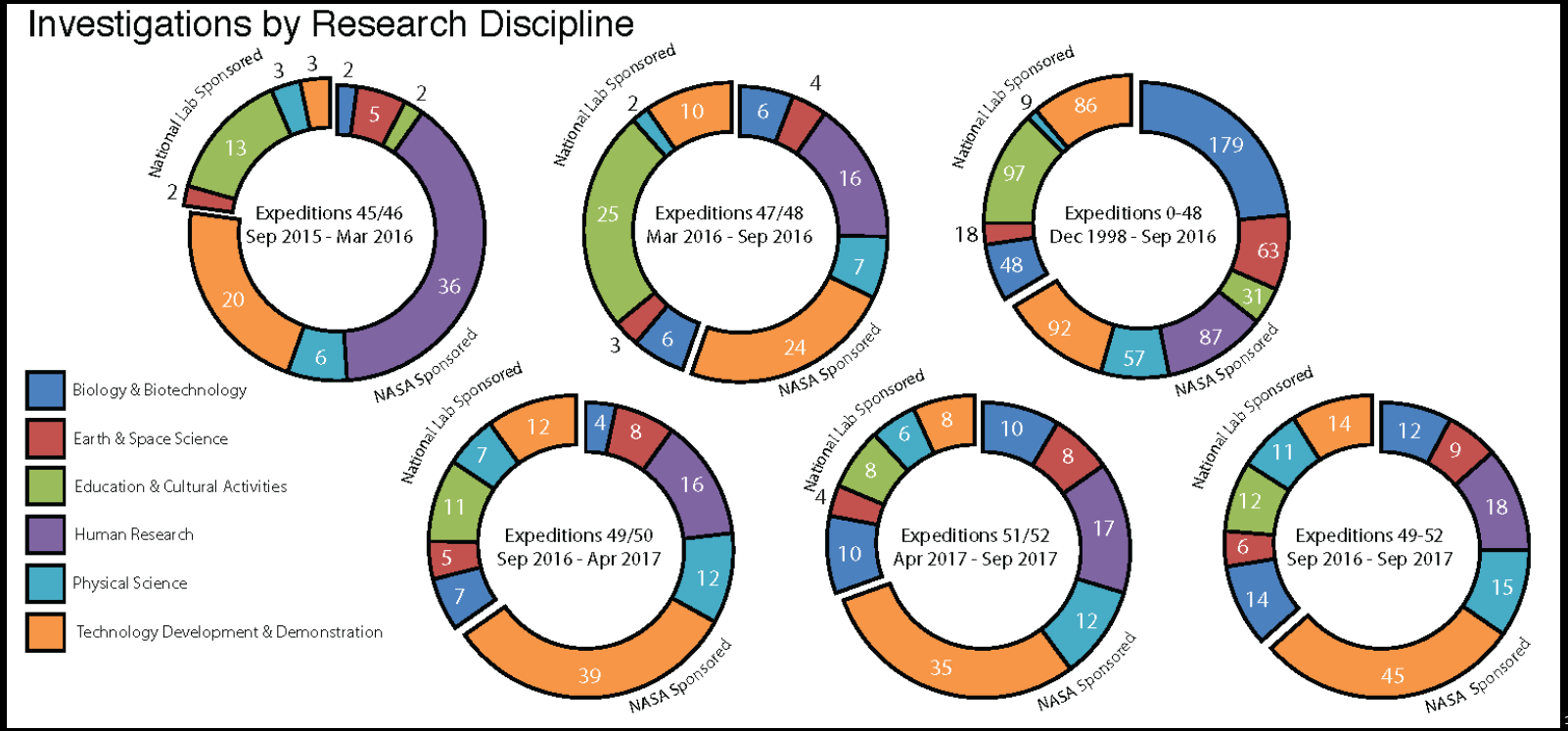
Investigations & Senior Investigators



NASA-National Lab Breakdown in numbers of Investigations, as of September 2016

Number of Investigations

Expeditions 0-48
December 1998 – September 2016



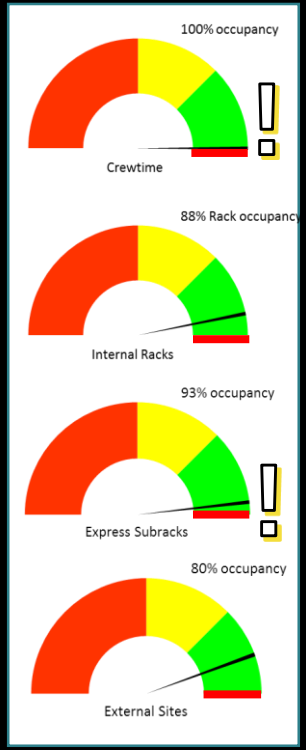
ISS Occupancy as of July 2017

One of the ways that Congress and OMB measure our effectiveness as a research platform

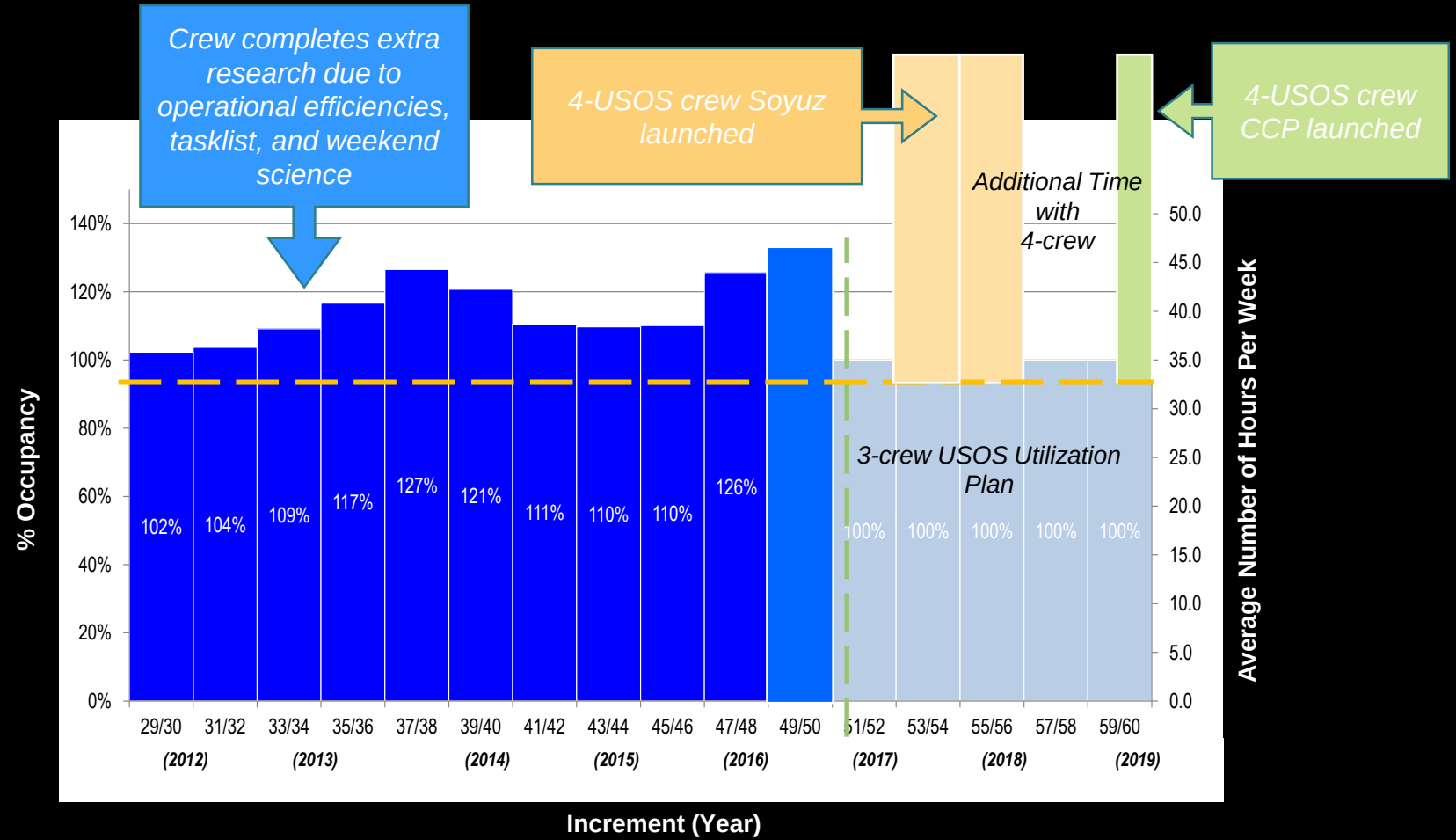
- Crew time heavily oversubscribed (limiting resource for many types of research)
  - Human research and rodent research demand is high, and is crewtime intensive
  - National Laboratory/CASIS demand has grown to fully use the 50% allocation granted in the NASA Authorization of 2010 for crewtime beginning in late 2015, requiring a replanning of NASA-funded research
  - USOS 4-crew will alleviate this problem, at least temporarily

- Internal Occupancy 88%
  - Express racks: will launch additional Express in 2018 to support small payloads
  - Microgravity Sciences Glovebox: oversubscribed, will launch a 2nd Life Sciences Glovebox to deconflict life and physical sciences
  - Expected Occupancy at the end of the year is 95%
  - Express racks expected to be full by mid-2018

- External Occupancy (rotates between 80-95%)
  - End of 2017: only 1 site available (launch of TSIS, SDS, RRM-3, MISSE-FF)
  - 2019: 2-3 sites available



3 → 4 USOS Crew on ISS Doubles Research Throughput



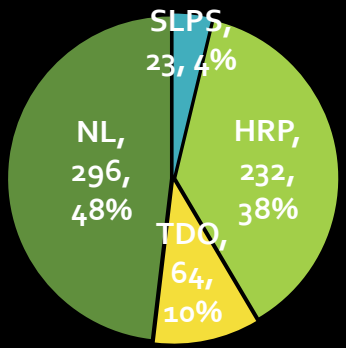
Snapshot: Crewtime Distribution Among U.S. Users

Increment 49/50 (Sept 2016-April 2017)

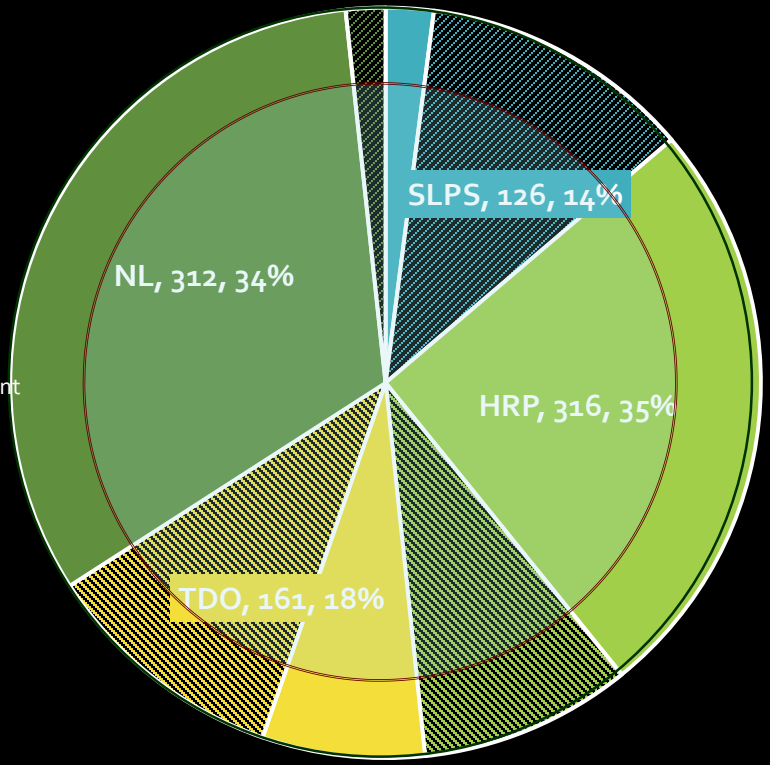
- Enablers
  - Operationally-ready reserve complement
  - Russian Crew time for MARES (HRP), SPHERES ZR (NL), EarthKAM (NL), RR-4 (SLPS), FLEX (SLPS)
  - Launch of reserve life sciences at risk
  - Increase of 69 total crew days
- Challenges
  - Loss of research requirements enabled by Sx11 and OA7 from Increment Pair
  - Utilization hardware anomalies
- Delta Explanations
  - Crew significantly exceeded performance expectations
  - Implemented the majority of the available science, including Reserve science, for all sponsors as permitted by constraints, including facility through-put
  - NL Reserve on orbit was insufficient to make up for the delay of OA7 and Sx11 flight to the next increment

Sept '16 – April '17	Planned	Actual
Research Hours	615	916
Total Crew Days (USOS)	317	386
Cargo Flights	OA-5 HTV6 SpX-10 OA-7 SpX-11	OA-5 HTV6 SpX-10
# EVAs	5	5
Russian Crew hours	169	183

Planned Hours



Actual Hours

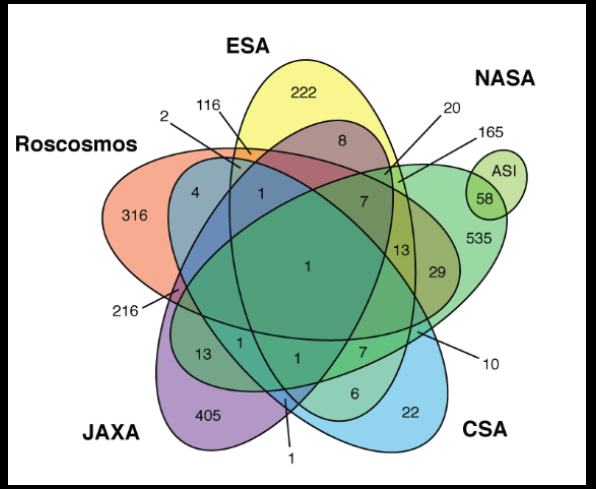


*Hatched wedges indicate increase from plan

Crew Time Strategies:
Collaboration for Efficiency in Facilities and Time

ISS Access Increased Through International Collaboration
Expeditions 0-48, December 1998 – September 2016

	Agency Only	Collaboration (Hosting)	Investigations Implemented	Collaboration (Participating)	Total Agency Impact
CSA	22	9	31	25	56
ESA	222	74	296	273	569
JAXA	405	167	572	102	674
NASA*	593	174	767	93	860
Roscosmos	316	197	513	192	705
			2179		

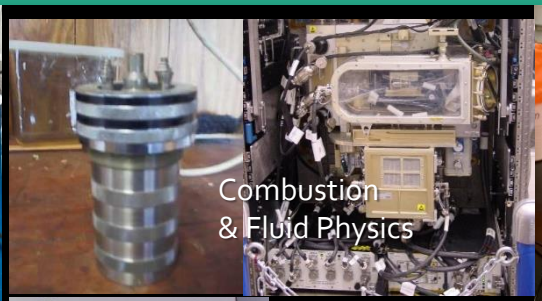


International collaboration investigations are sponsored by one of the ISS Partners and include scientists from other countries.

Ellipses show the intersection of Partner collaborations and counts show the increased number of investigations through international collaboration from the point of view of each Partner.

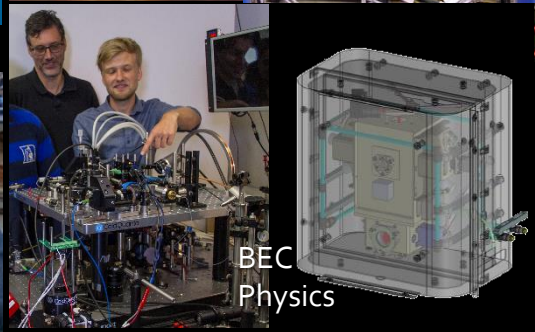
Current and Future Capabilities


Freezers

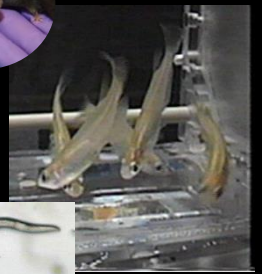

Combustion
& Fluid Physics


Genetic Analysis


Microscopes


BEC
Physics

Model Organisms




Incubators


Human Research

Major Internal Research Facilities ("Racks")

Current US ISS Racks on ISS

EXPRESS (x8)

MELFI (x3)

Human Research Facility (x2)

Combustion Integrated Rack

Microgravity Science Glovebox

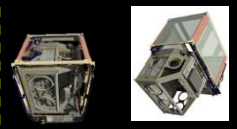
Material Science Research Rack

Window Observation Rack Facility

Muscle Atrophy Research & Exercise System

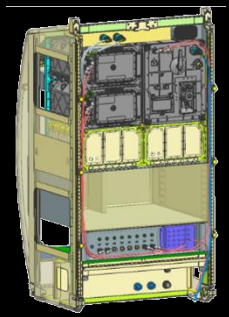
Fluids Integrated Rack

2018



Life Sciences Glovebox

2018



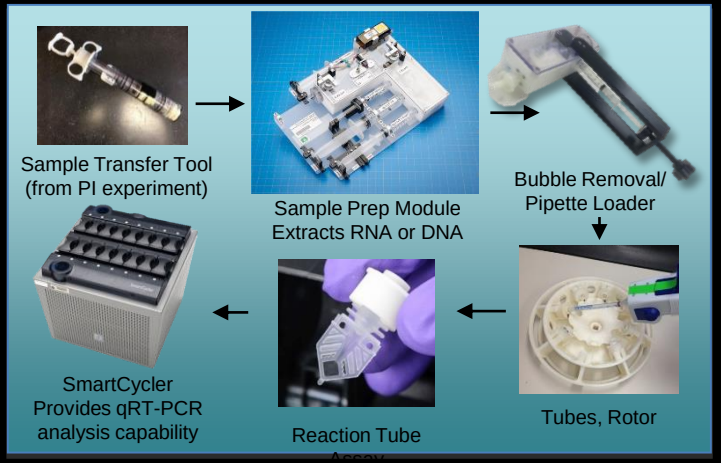
Basic EPRESS Rack (x2-3)

Life Sciences Glovebox (LSG)

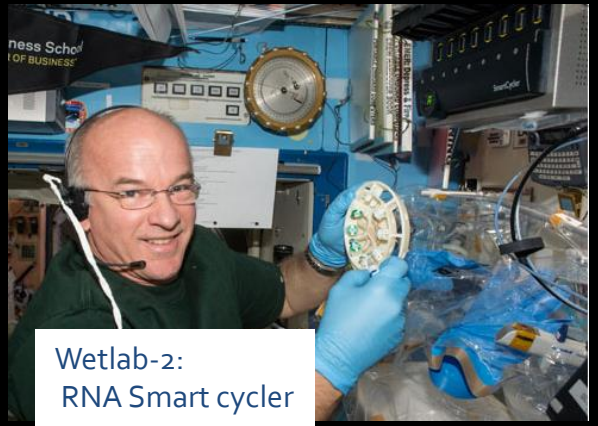
The Life Science Glovebox. Image courtesy of Bradford Engineering.

- Microgravity Science Glovebox (MSG) throughput has become a limiting factor because uses for life science compete with long dwell-time physical science investigations
- LSG goes up on HTV7, early 2018
- Primary workplace for rodent research missions/operations and other biological experiments, such as Cell Science and other cell growth experiments.

Life Sciences Sample Analysis Capabilities

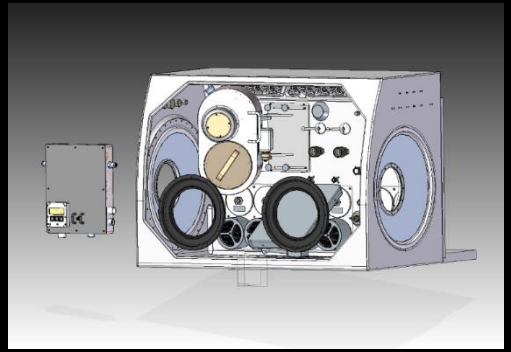


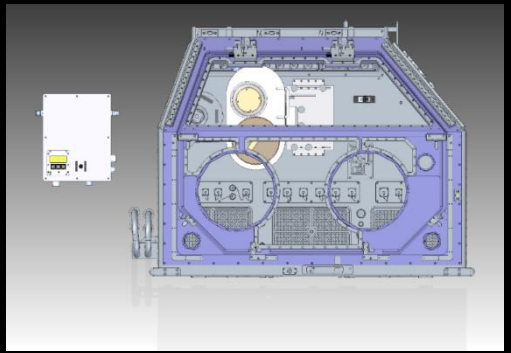
Sample Preparation System: extracts RNA or DNA and prepares samples to be analyzed



Flash Freeze

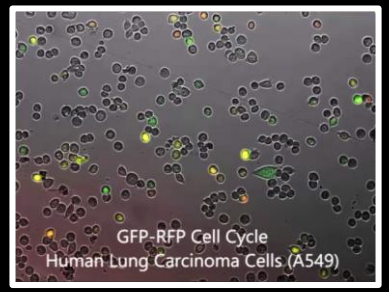
- Single Mobile Rapid Freeze (SMRF) for gloveboxes (MSG and LSG)
- Transportable Express Rapid Freeze (TERF) for transport
- Awarded to UAB, recently passed preliminary design review
- Capability to rapidly freeze biological samples on the ISS
  - Provide freeze rates approaching LN2
  - Freeze multiple samples over short period of time
  - Freeze many samples during a crew workday
  - Maintain consistent freeze rate from sample to sample
  - Enable transfer of frozen samples to ISS storage freezer

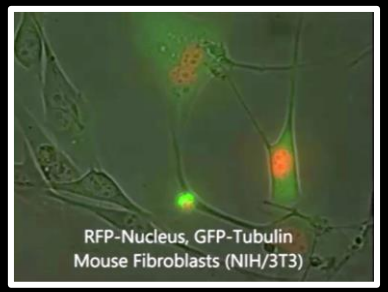


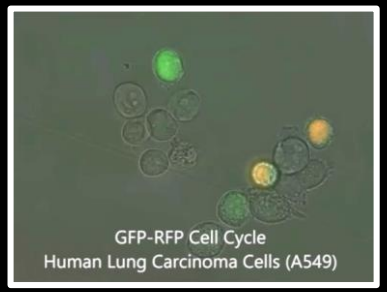


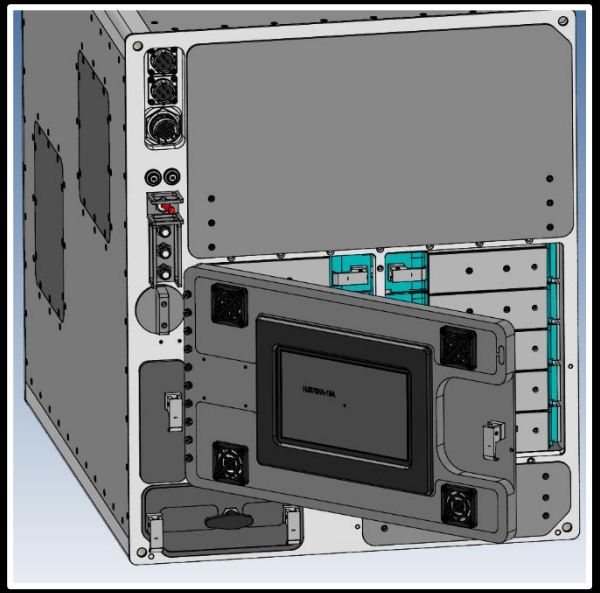
BioChip SpaceLab: An Automated Cell Biology Platform in Space

The BioChip SpaceLab (BCSL) is an automated cell biology platform that enables short and long-term experiments to run on-board the International Space Station National Lab (ISS-NL), incorporating microfluidic delivery of multiple reagents, 1g controls, and high resolution time-course fluorescence imaging.





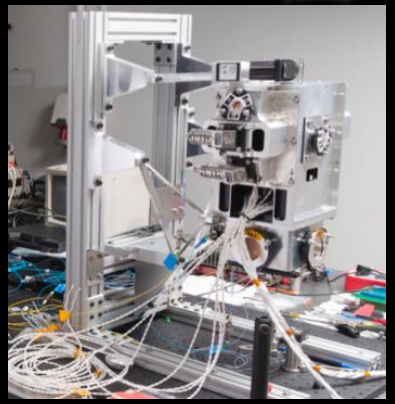


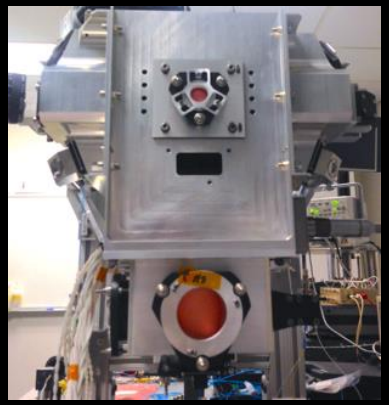


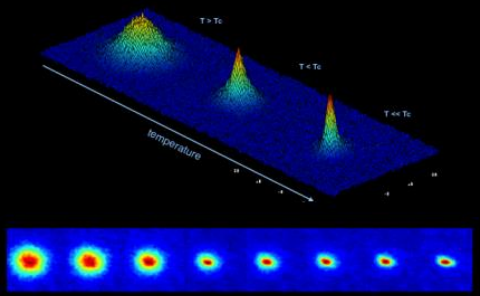
Cold Atom Laboratory (Bose Einstein Condensates)

Cold Atom Lab (CAL)

The coldest spot in the known universe…





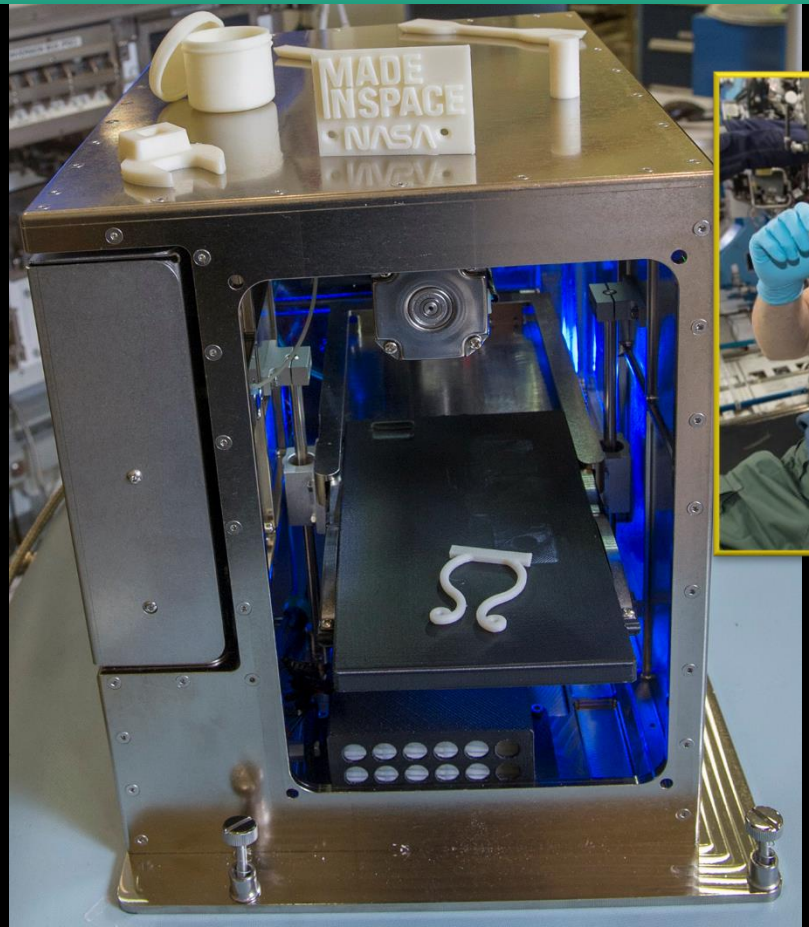


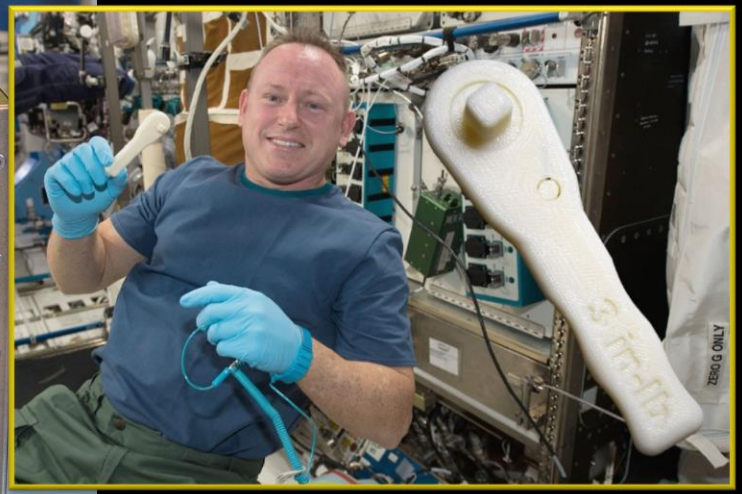
Microgravity enables laser cooling technology to reach temperatures colder than ever achieved on earth and to therefore analyze atom wave functions never observed.

Exploring this realm will help scientists to answer some of the most fundamental questions in science:

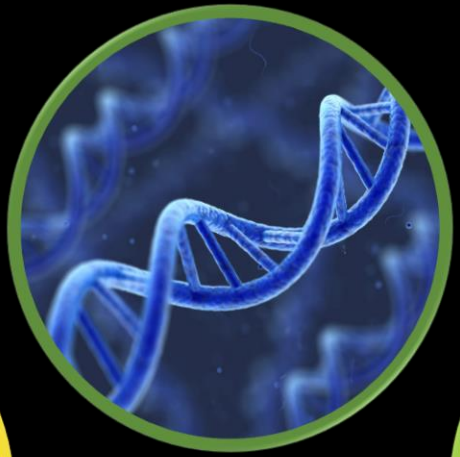
-How does complexity arise in the universe?
-What is the nature of dark energy?
-Did Einstein have the last word on gravity?
-How did the universe begin?
-How do high temperature superconductors work?
-Facilitate development of future ultra-cold atom-based quantum sensors for gravitational and magnetic fields, rotations, and tests of the equivalence principle.

Additive Manufacturing Technology Demonstrations





What kind of benefits come from research in space?



Scientific Discovery

Benefits for Humanity

Enabling Future Exploration

Five major Earth benefits themes

Human Health

Earth Observation and Disaster Response

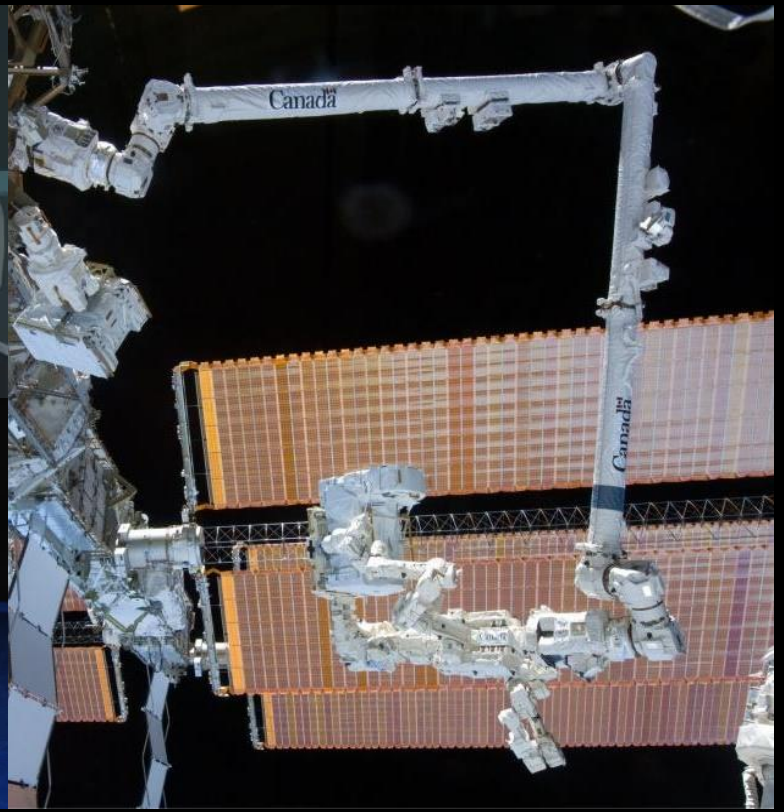
Innovative Technology

Global Education

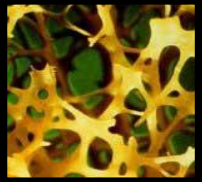
Economic Development of Space

Robotic Surgery Applications

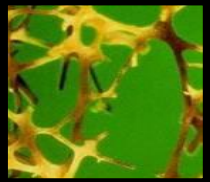
Left image credits: CSii and MDA



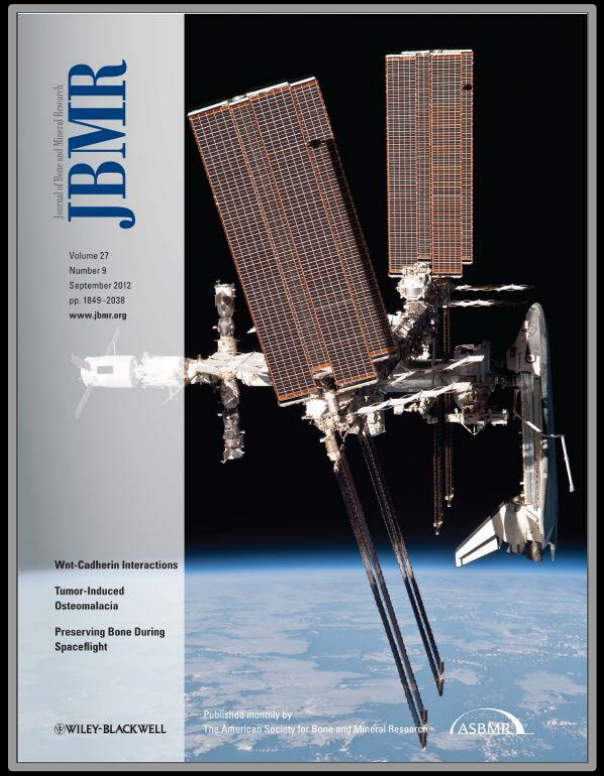
Alternatives to Pharmaceuticals for Preventing Bone Loss



Normal Bone



Osteoporotic Bone



Wound treatment with cold plasmas


Image credit: Roscosmos

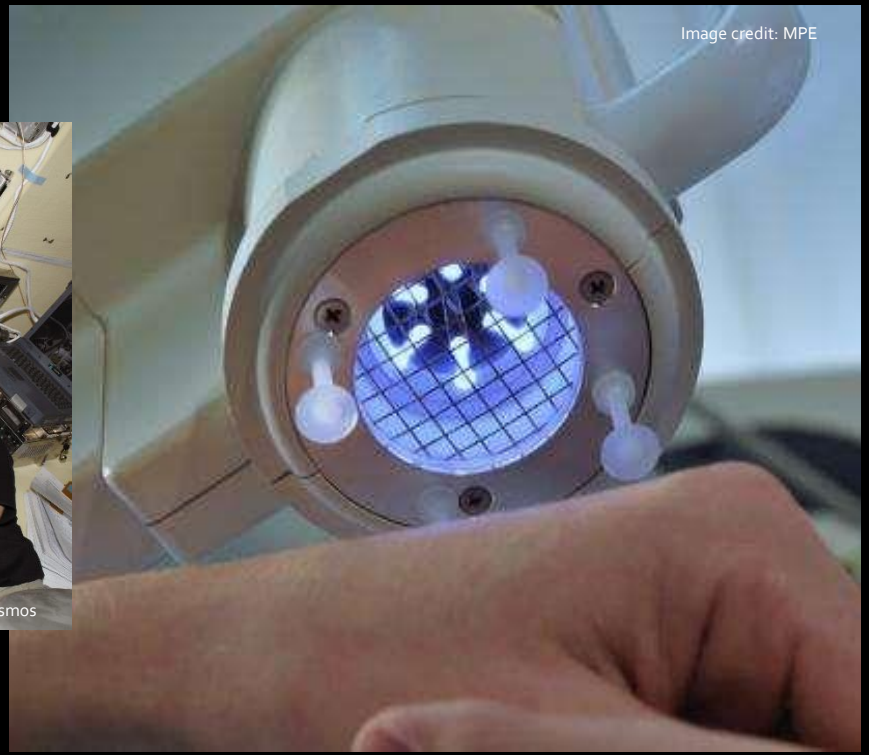
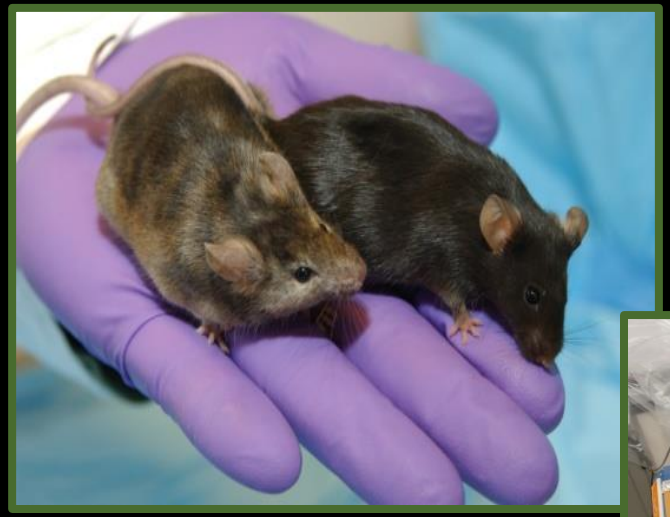
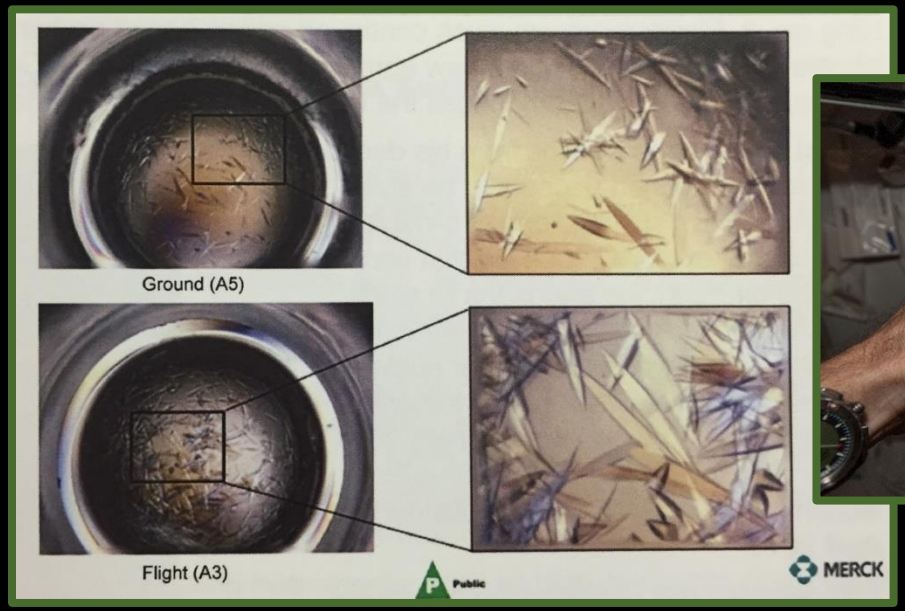


Image credit: MPE

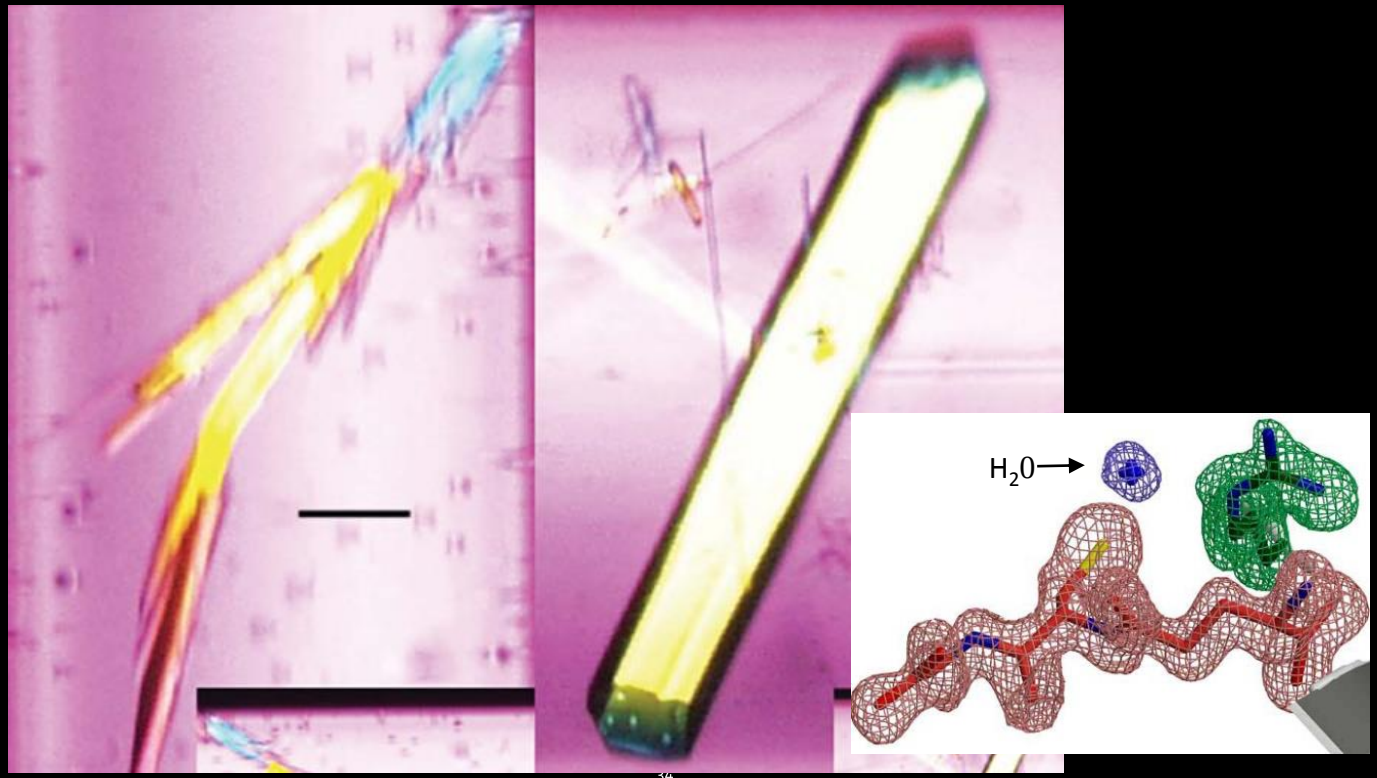
Pharmaceutical tests of drugs in development



Purification of Monoclonal Antibodies on ISS (Merck)

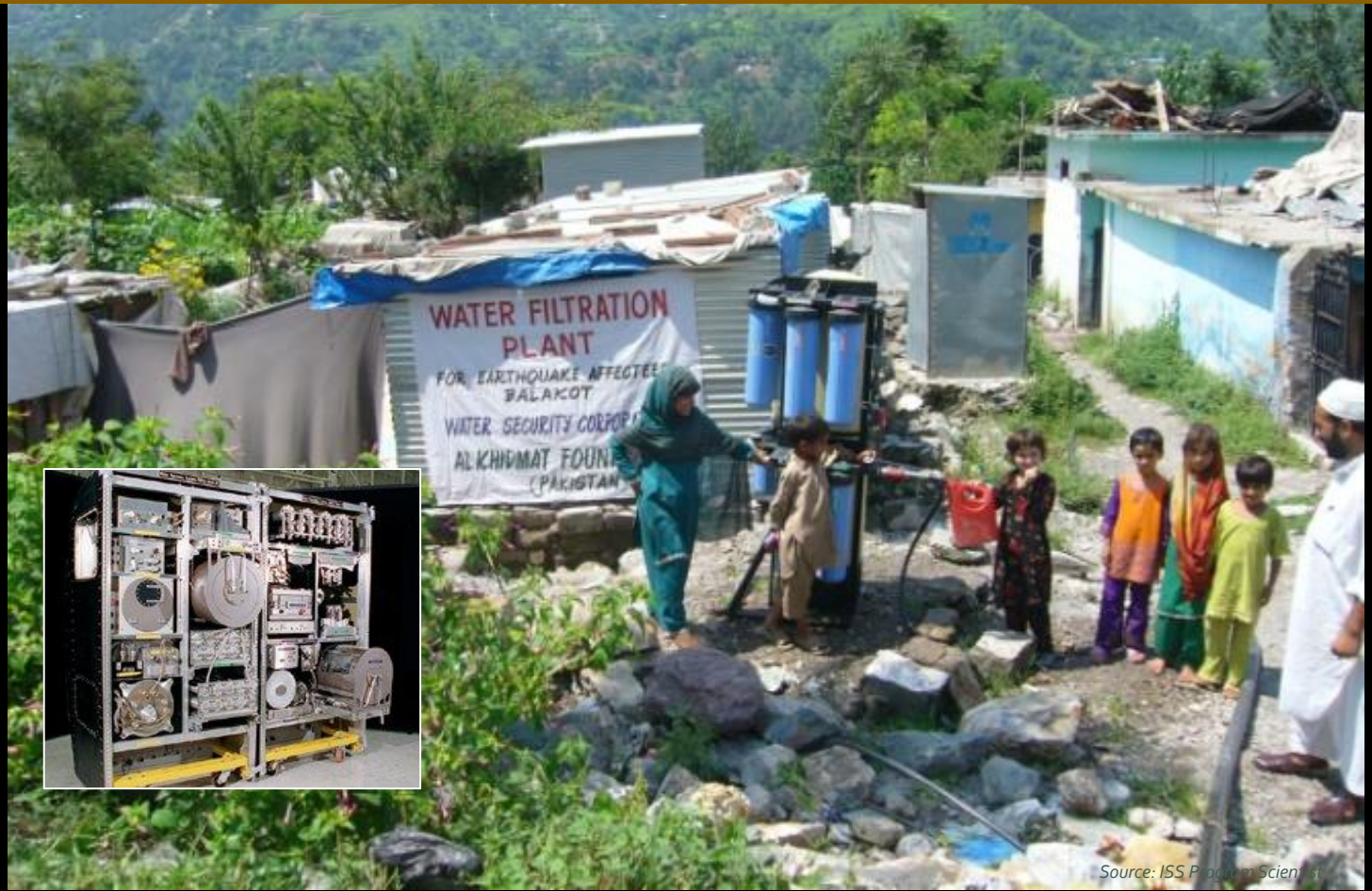


New drug for Duchenne's Muscular Dystrophy in clinical trials



Acta Cryst. (2010). F66, 846–850

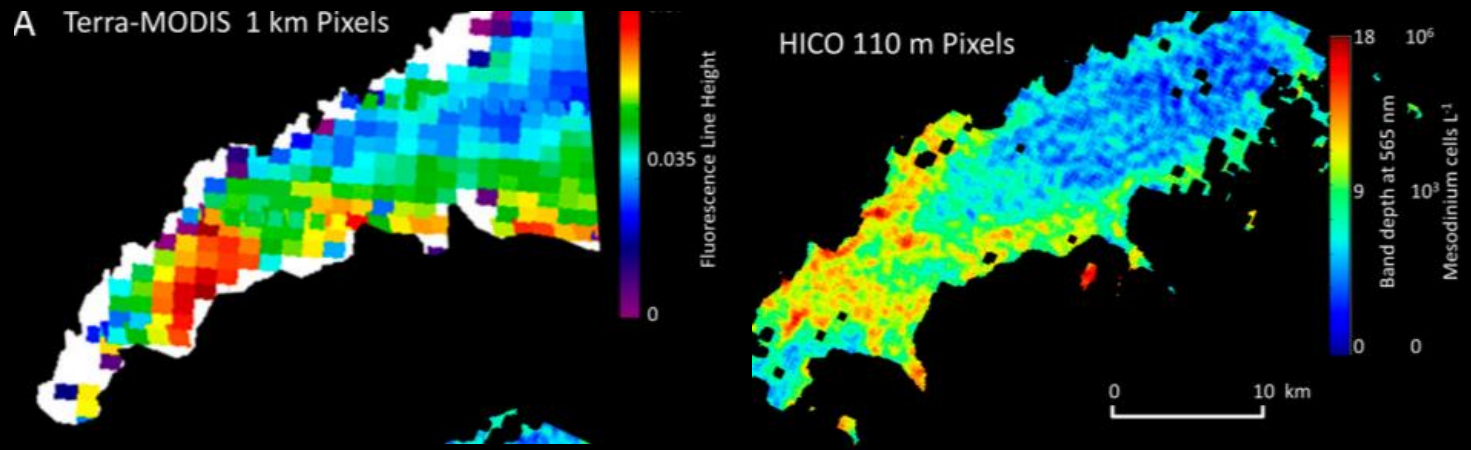
Technology Applications for Clean Water



Source: ISS Program Scientist

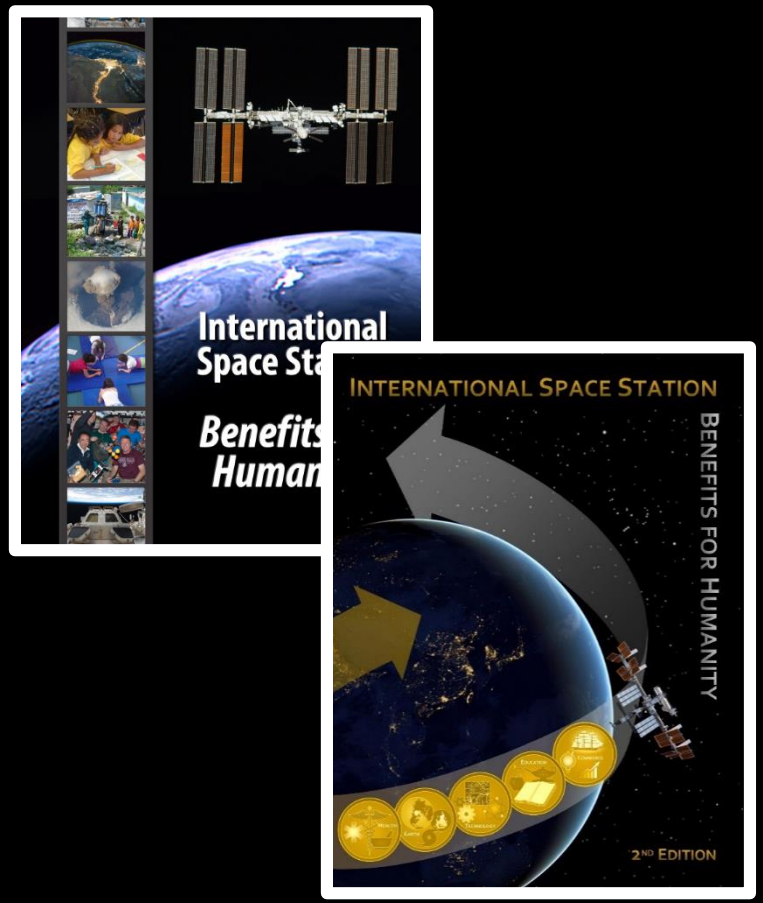
Improving Semiconductors with Nanofibers

Identification of Harmful Algal Blooms



Proceedings of the National Academy of Sciences of the United States of America. 2015; 112(48):14783-14787

Tracking ISS Benefits



ISS Benefits for Humanity Document

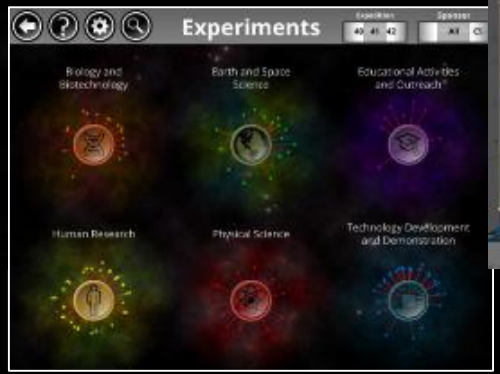
http://www.nasa.gov/mission_pages/station/research/benefits/index.html

Space Station Research Explorer

- iPad
- Android

Apple

Google Play



For More Information

ISS Research & Technology
http://www.nasa.gov/iss-science

CASIS ISS National Laboratory
http://iss-casis.org

@ISS_Research