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
• Organizations that Sponsor Research
• Utilization Statistics
• Capabilities for Research
• Benefits from ISS
Organizations that Sponsor Research on ISS

- Commercial Sector
- Non-profit organizations
- U.S. Government Agencies
- International Partner Research

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

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)
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-Fulford 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

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

Former astronaut Michael Hopkins presents research at the NIH campus

Image: NIH

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)
Example R&D Users of the ISS National Laboratory
Scientific Disciplines using ISS Today

National Lab
- Biology and Biotechnology
- Human Research
- Physical Sciences
- Tech Demos
- Earth Science
- Space Science
- Education

NASA

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

Research Disciplines of International Space Station Investigations by Partner Agencies

Expeditions 0-48

Investigations & Senior Investigators

Investigations per Expedition

Investigators per Expedition

NASA utilization includes investigations by the Italian Space Agency (ASI), an ISS Participant Agency.
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

Crew completes extra research due to operational efficiencies, tasklist, and weekend science.

4-USOS crew Soyuz launched

Additional Time with 4-crew

3-crew USOS Utilization Plan

4-USOS crew CCP launched

Average Number of Hours Per Week

% Occupancy

Increment (Year)

(2012) 29/30 31/32 33/34 35/36 37/38 39/40 41/42 43/44 45/46 47/48 49/50
(2013) 102% 104% 109% 117% 127% 121% 111% 110% 110% 126%
(2014) 100% 100% 100% 100% 100% 100% 100% 100% 100% 100%
(2015) 100% 100% 100% 100% 100% 100% 100% 100% 100% 100%
(2016) 100% 100% 100% 100% 100% 100% 100% 100% 100% 100%
(2017) 100% 100% 100% 100% 100% 100% 100% 100% 100% 100%
(2018) 100% 100% 100% 100% 100% 100% 100% 100% 100% 100%
(2019) 100% 100% 100% 100% 100% 100% 100% 100% 100% 100%
**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 throughput
- NL Reserve on orbit was insufficient to make up for the delay of OA7 and Sx11 flight to the next increment

### Planned Hours

<table>
<thead>
<tr>
<th></th>
<th>Planned</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Hours</td>
<td>615</td>
<td>916</td>
</tr>
<tr>
<td>Total Crew Days (USOS)</td>
<td>317</td>
<td>386</td>
</tr>
<tr>
<td>Cargo Flights</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OA-5 HTV6 SpX-10 OA-7 SpX-11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OA-5 HTV6 SpX-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td># EVAs</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Russian Crew hours</td>
<td>169</td>
<td>183</td>
</tr>
</tbody>
</table>

*Hatched wedges indicate increase from plan*
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
- Model Organisms
Major Internal Research Facilities ("Racks")

- 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

Current US ISS Racks on ISS

2018

Fluids Integrated Rack

2018

Life Sciences Glovebox

Basic EPRESS Rack (x2-3)
Life Sciences Glovebox (LSG)

• 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 Transfer Tool (from PI experiment)

Sample Prep Module
Extracts RNA or DNA

Bubble Removal/
Pipette Loader

Reaction Tube

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

SmartCycler Provides qRT-PCR analysis capability

Wetlab-2: RNA Smart cycler

MinIon

Mini-PCR

Razor PCR
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.
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?

- Benefits for Humanity
- Scientific Discovery
- 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
Alternatives to Pharmaceuticals for Preventing Bone Loss
Wound treatment with cold plasmas
Pharmaceutical tests of drugs in development
Purification of Monoclonal Antibodies on ISS (Merck)
New drug for Duchenne’s Muscular Dystrophy in clinical trials

Technology Applications for Clean Water

Source: ISS Program Scientist
Improving Semiconductors with Nanofibers
Identification of Harmful Algal Blooms
Tracking ISS Benefits

ISS Benefits for Humanity Document

Space Station Research Explorer

- iPad
- Android

Benefits:
- Human Health
- Earth Benefits
- Global Education

Destiny

Experiments:
- Biology and Biotechnology
- Earth and Space Science
- Educational Activities and Outreach

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