

# International Space Station Research Accomplishments Overview



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Outreach Seminar on the ISS  
United Nations  
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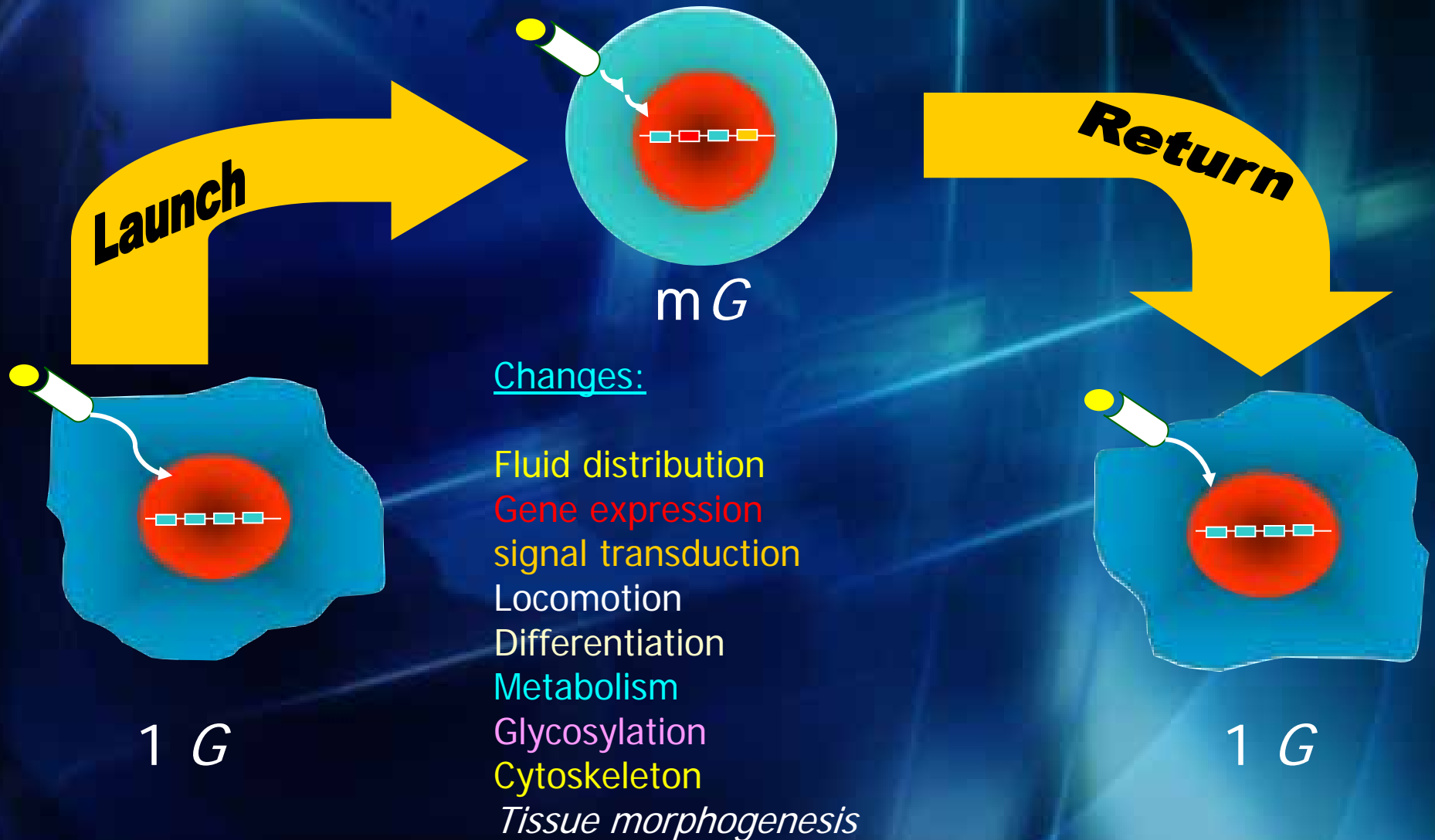
# Outline

- Why space research?  
And why on the International Space Station?
- What has been done?
- What are the most important results?
- How have non-partners participated?

# Disciplines that use the Laboratory

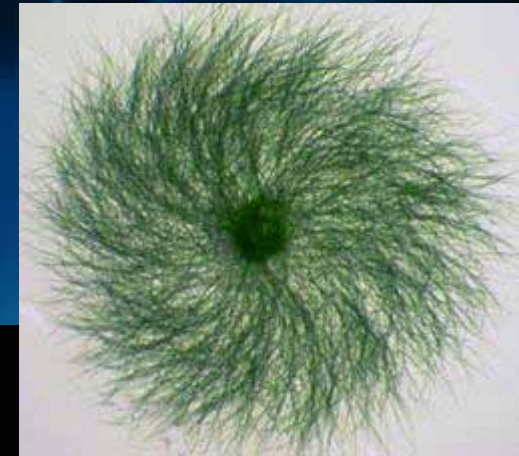
- Biology & Biotechnology
- Human Physiology & Performance
- Physical Sciences
- Technology Development & Demonstration
- Earth and Space Science
- Education

# Biology: Animal Cells in Space



# Biology: Plant Research in Space

- Discovery potential for plant biology
  - Growth and development
  - Gravitropism, Circumnutation
  - Plant responses to the environment: light, temp, gases, soil
  - Stress responses
  - Stem cells/pluripotency
- Plants as a food source
- Plants for life support



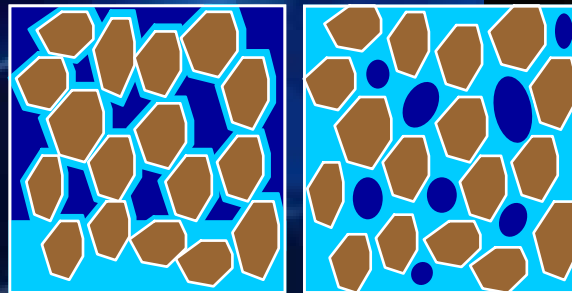
Moss grown in the dark  
On the Space Shuttle



Peas grown on ISS



5:40:06 02

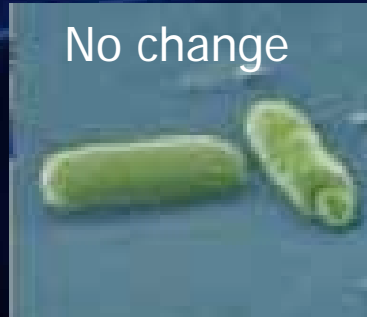


Earth

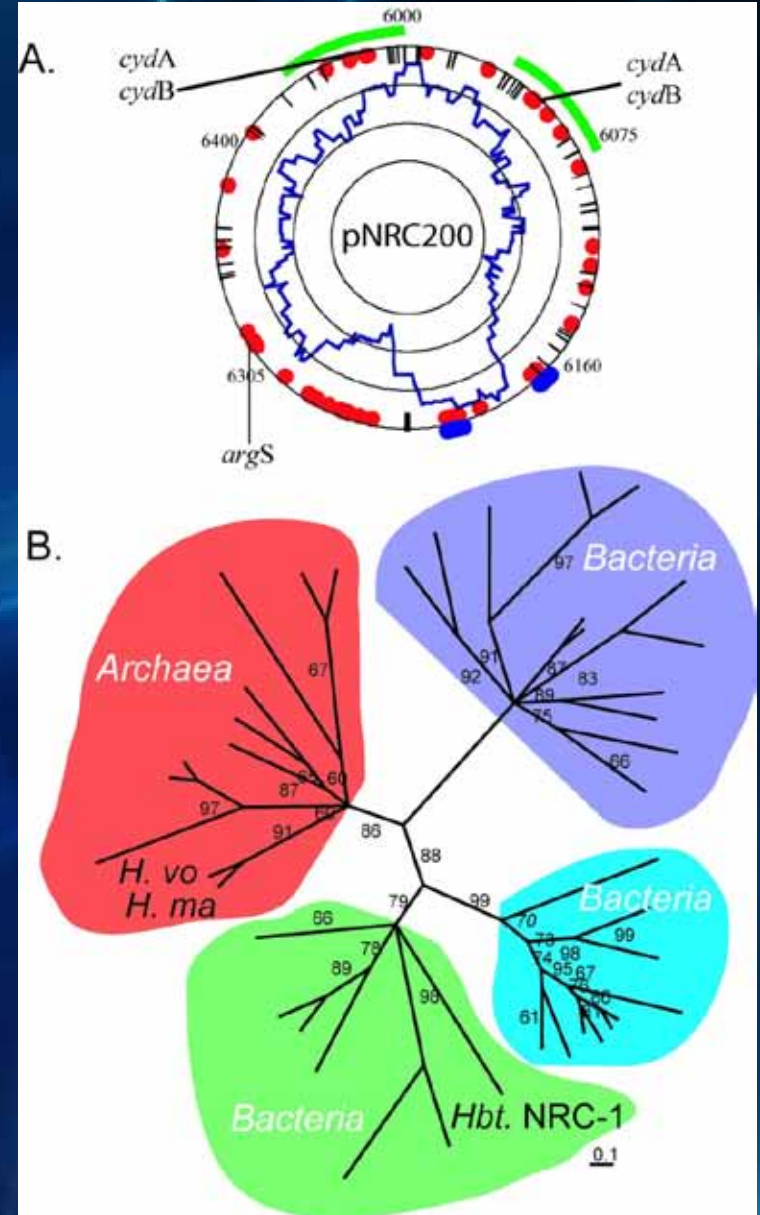
Microgravity

Soil structure

# Biology: Microbes in Space



3 modes of response



# Human Physiology: Response to Spaceflight

Astronauts experience a spectrum of adaptations in flight and postflight



Balance disorders  
Cardiovascular deconditioning  
Decreased immune function  
Muscle atrophy  
Bone loss



- Neurovestibular
- Cardiovascular
- Bone
- Muscle
- Immunology
- Nutrition
- Behavior
- Radiation

ISS includes international research  
on medical risks to astronauts



So that humans can  
explore outside Earth  
orbit



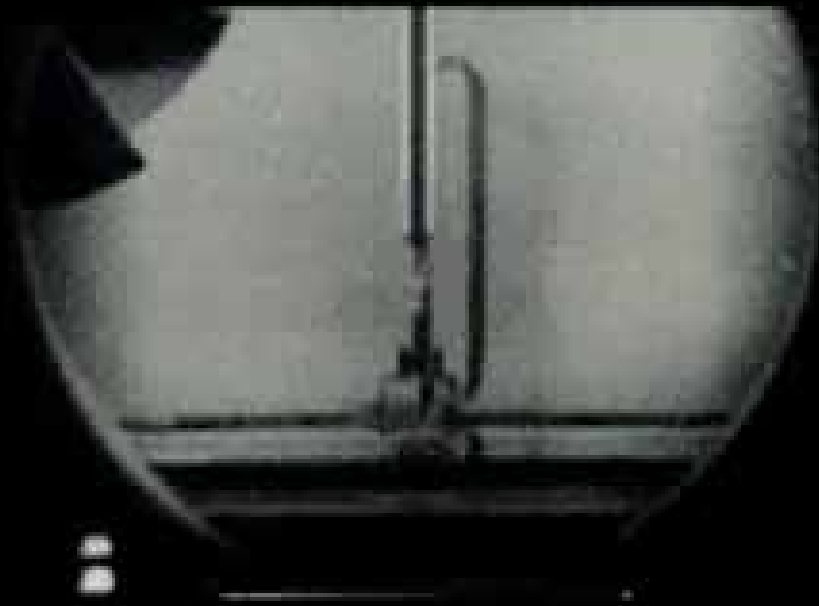


Physiology and Medical Technology research in space can also benefit health on Earth

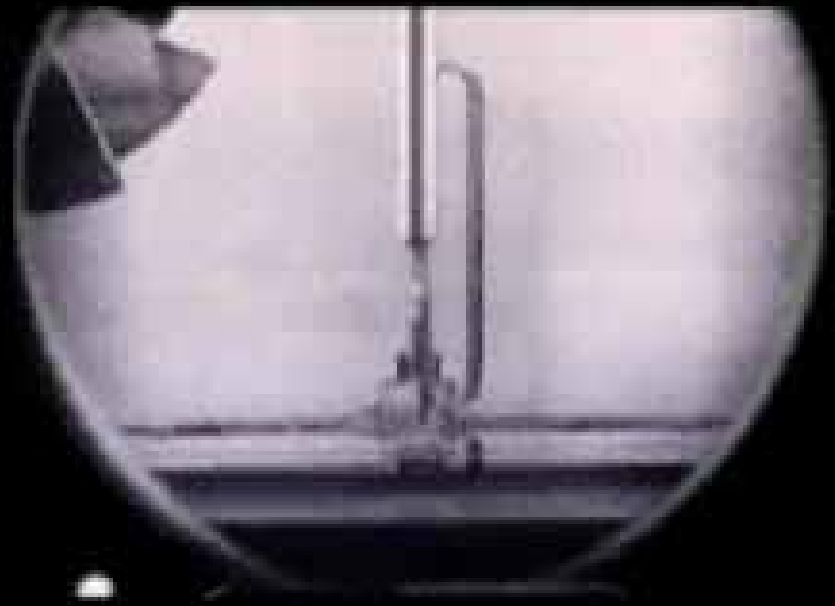




# Boiling on Earth and in Microgravity



**1g (Earth)**



**Micro-g (space)**

# Earth Science



- Platform with full services (power, data, thermal) in low earth orbit (~400 km)
  - All geographic locations between 51.6 North and South latitude
  - 85% of the Earth's surface
  - 95% of the world's populated landmass every 1-3 days
  - External sites for nadir, zenith, ram and wake
  - Variable (and precessing) lighting (changes with subsequent passes)
  - Well-suited for test bed concepts with hardware change out and upgrades

# Astrophysics/Fundamental Physics, Heliophysics, X-ray Astronomy

- Platform with full services (power, data, thermal)
  - Positioned above atmospheric interference
  - External sites for zenith, ram and wake
  - Stability, contamination, and vibration can be managed for many users
  - Well-suited for test bed concepts

# Technology Development and Demonstration

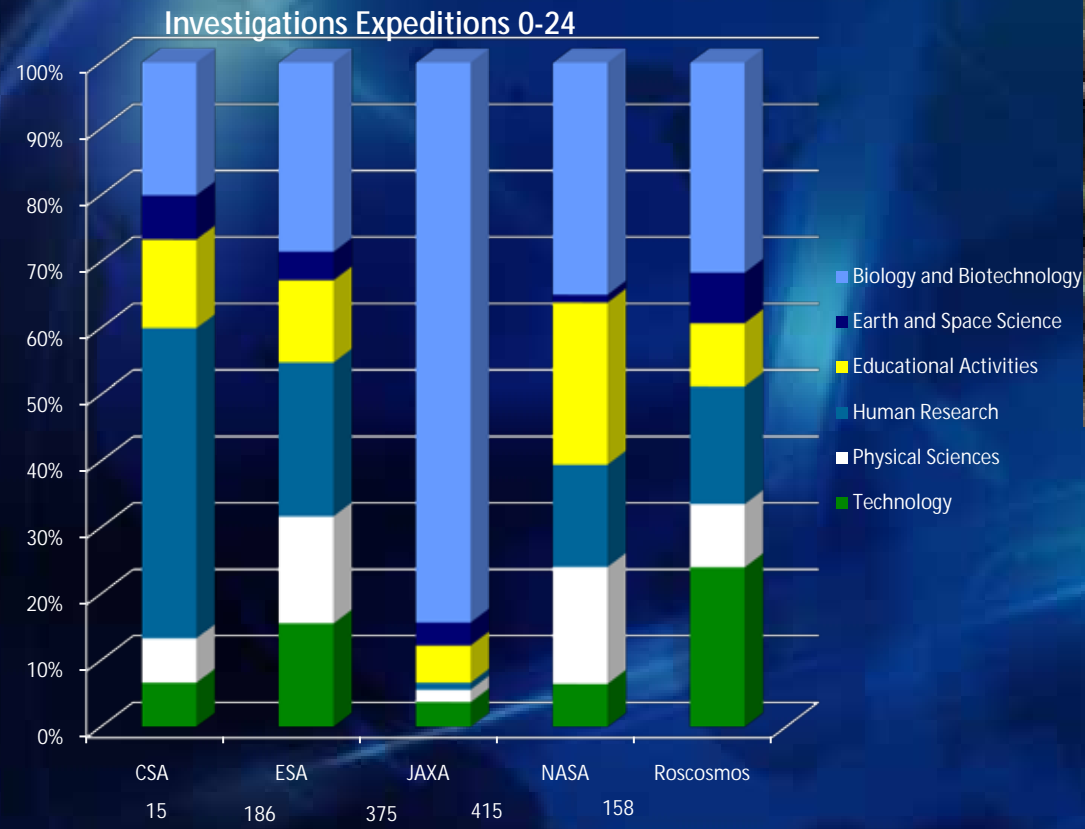


- Long term space environment (microgravity, radiation, etc.)
- Prove reliability in relevant environment (advance TRL-technology readiness level)
- Prove logistics, maintenance, consumables, and operations models (advance IRL-integration readiness level, SRL-systems readiness level)
- Reduce risk to performance when system is implemented elsewhere

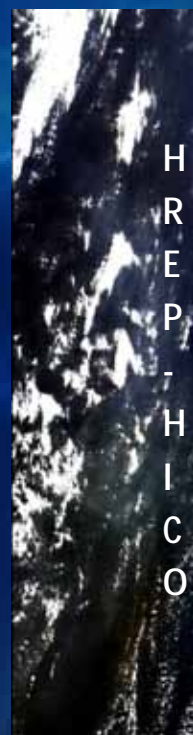
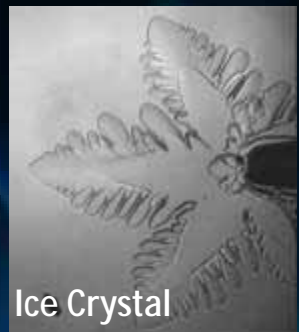
# Our Accomplishments

# ISS Research Accomplishments

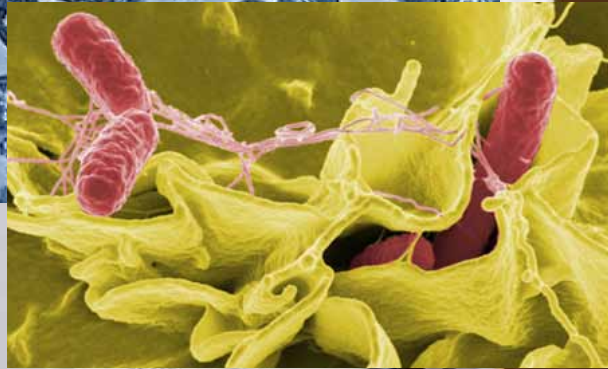
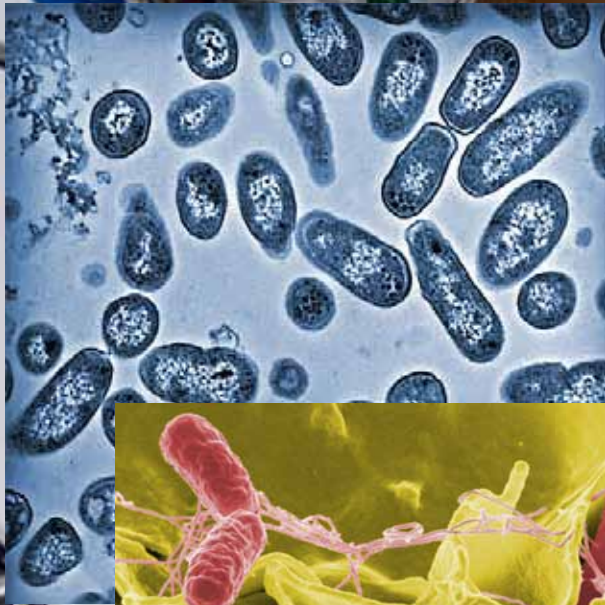
(Expeditions 0 – 24, September 2000 – October 2010, data as of January 20, 2011)




- Expeditions 0 – 24
  - 1149 Investigations
    - 454 completed investigations
    - 734 International Partner investigations
    - 25 National Lab investigations
  - > 1600 scientists
  - 310+ scientific publications (international count ongoing)





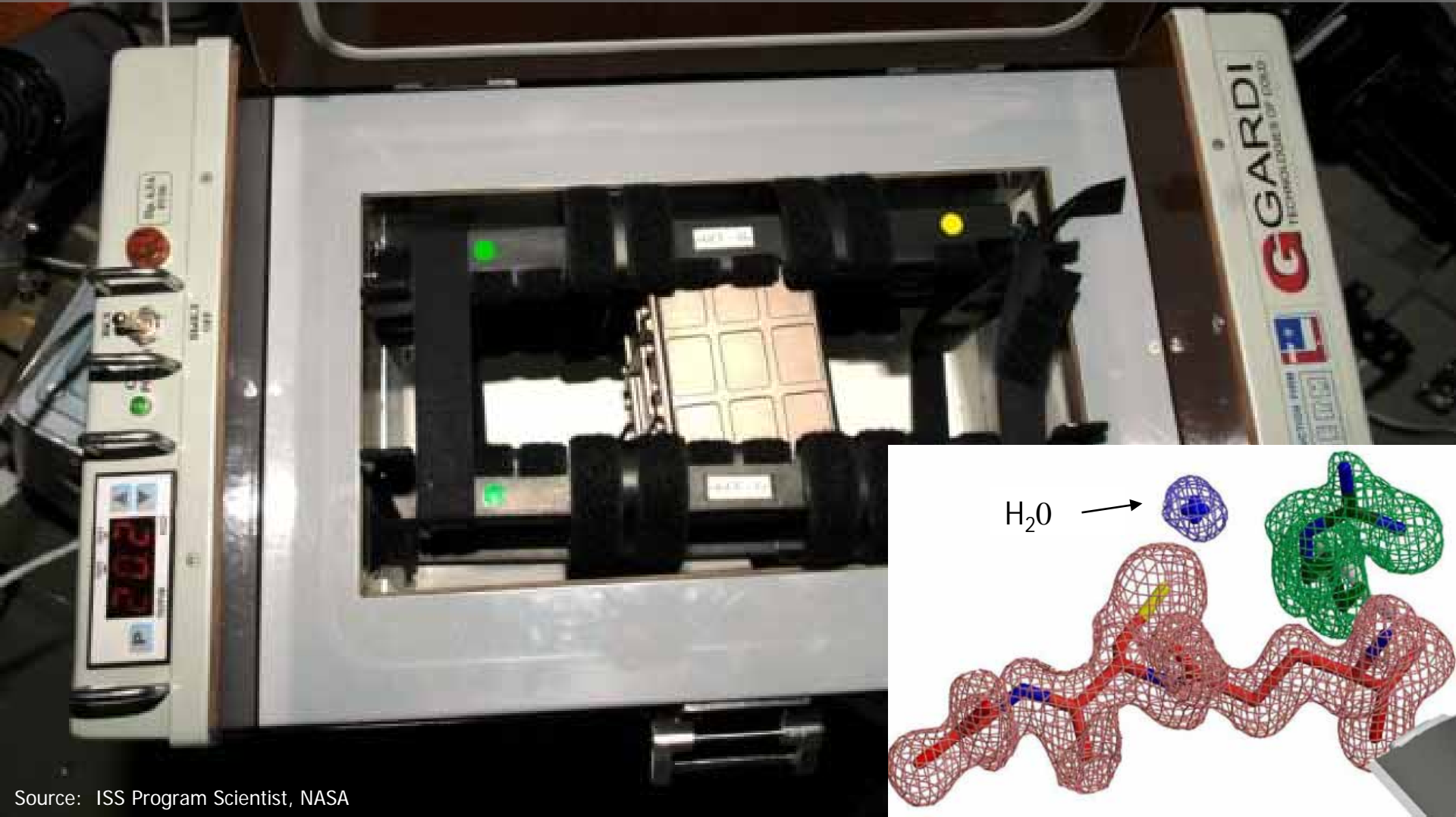


**Microbial Vaccine Development** – Scientific findings from *International Space Station* research have shown increased virulence in *Salmonella* bacteria flown in space, and identified the controlling gene responsible. AstroGenetix, Inc. has funded their own follow-on studies on ISS and are now pursuing approval of a vaccine as an Investigational New Drug (IND) with the FDA. They are now applying a similar development approach to methicillin-resistant *Staph aureus* (MRSA).

A microscopic image showing several cells and microcapsules. The cells are spherical with a distinct nucleus and cytoplasm. The microcapsules are smaller, spherical structures with a thin outer layer and a darker inner core. The background is a light, textured surface.

**Cancer Treatment Delivery**– Microcapsules (micro-balloons) for drug with desirable properties developed on the *International Space Station* were reproduced on Earth and were successful in targeting delivery of anti-cancer drugs to successfully shrink tumors in ground tests. A device to produce similar capsules on Earth has now been patented, and clinical trials of the drug delivery method are beginning.

**Macromolecular Crystallization**— A Japanese scientist crystallized HQL-79 (human prostaglandin D2 synthase inhibitor protein) on the *International Space Station*, identifying an improved structure and an associated water molecule that was not previously known. This protein is part of a candidate treatment for inhibiting the effects of Duchenne's muscular dystrophy. Continuing work is looking at other proteins and viruses.



**Plant Growth** – Numerous plant growth experiments have investigated both the effects of microgravity, as well as the capability for growing regenerable food supplies for crew. In addition, technology developed for the ADVASCÔ greenhouse flown on the *International Space Station* led to a new technology that is widely used on Earth, killing 98% of airborne pathogens (including Anthrax) for food preservation, doctors' offices, homes and offices.





**Insight into Immune Function**— Human T-Lymphocyte s cultures flown to the *International Space Station* have shown altered genetic expression of Interleukin-2 and/or its receptor, and, combined with ground studies , suggests a role in the suppressed immunity seen in astronauts. These space flight results aid clinical researchers in identifying the cellular and genetic mechanisms involved in immuno-suppression as they search for potential treatments.



## Mitigating Bone Loss

### Phase 1 studies (~ 11 major publications)

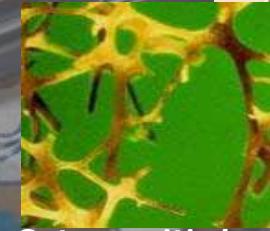
- Astronauts lost an average of 1.5% bone/month (similar to loss in post-menopausal women per year)
- Took 3 years to get back to pre-flight bone density
- Crew loaded to less than 60% with harnesses
- Many crew Vitamin D deficient

### Phase 2 studies

- More effective exercise hardware (COLBERT, ARED, harnesses)
- New studies of countermeasures: Bisphosphonates (pharmaceutical), Pro K (nutritional)



Normal bone



Osteoporitic bone

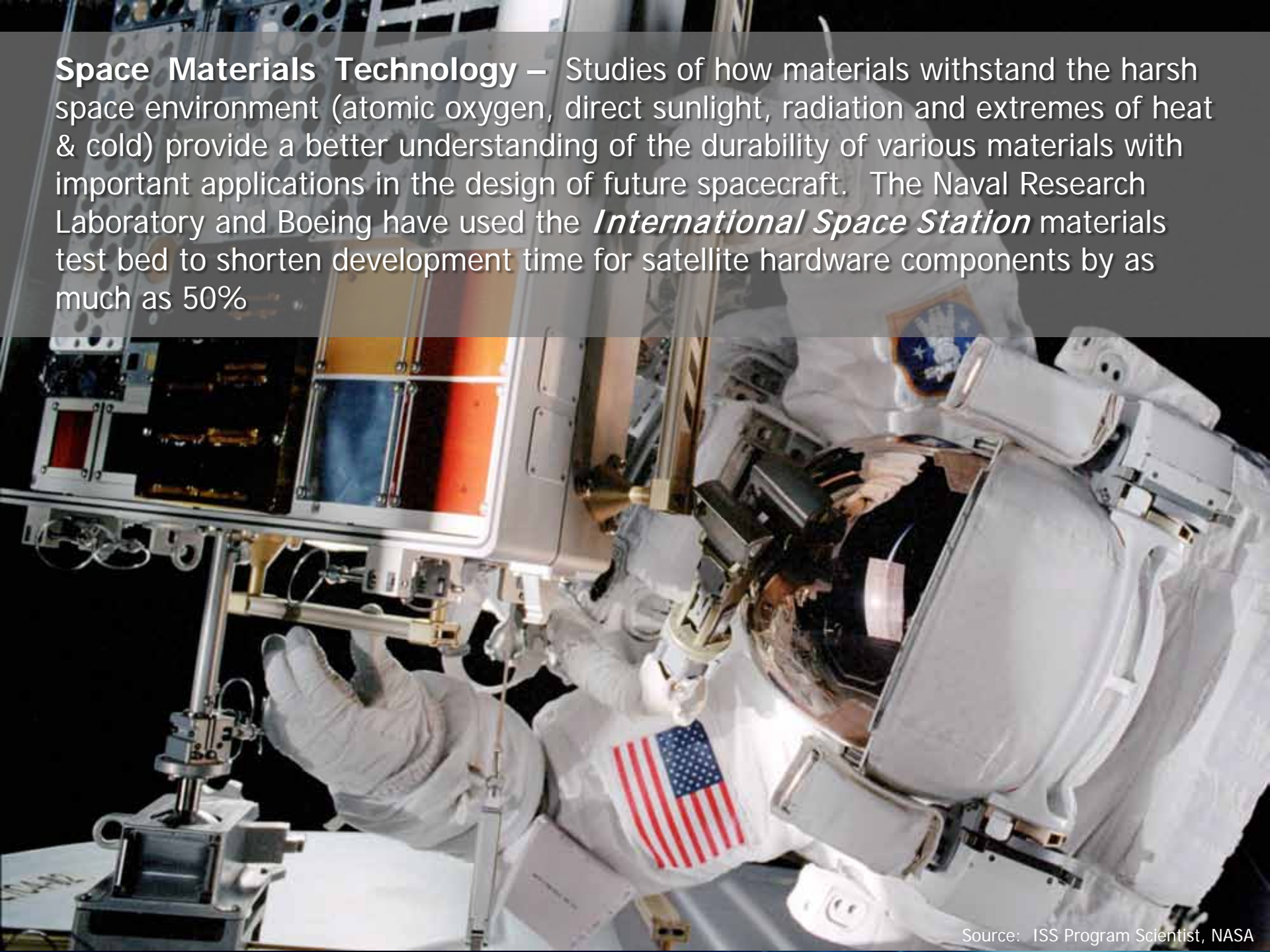




**Maintaining Bone Health through Nutrition** – Results from the Nutritional Study on the *International Space Station*, bed rest analogs, and laboratory cellular experiments have shown that Omega-3 fatty acids counteracted bone loss, indicating that diet changes to include more fish may protect bone loss both in space and on Earth.

Source: ISS Program Scientist, NASA

**Space Materials Technology** – Studies of how materials withstand the harsh space environment (atomic oxygen, direct sunlight, radiation and extremes of heat & cold) provide a better understanding of the durability of various materials with important applications in the design of future spacecraft. The Naval Research Laboratory and Boeing have used the *International Space Station* materials test bed to shorten development time for satellite hardware components by as much as 50%





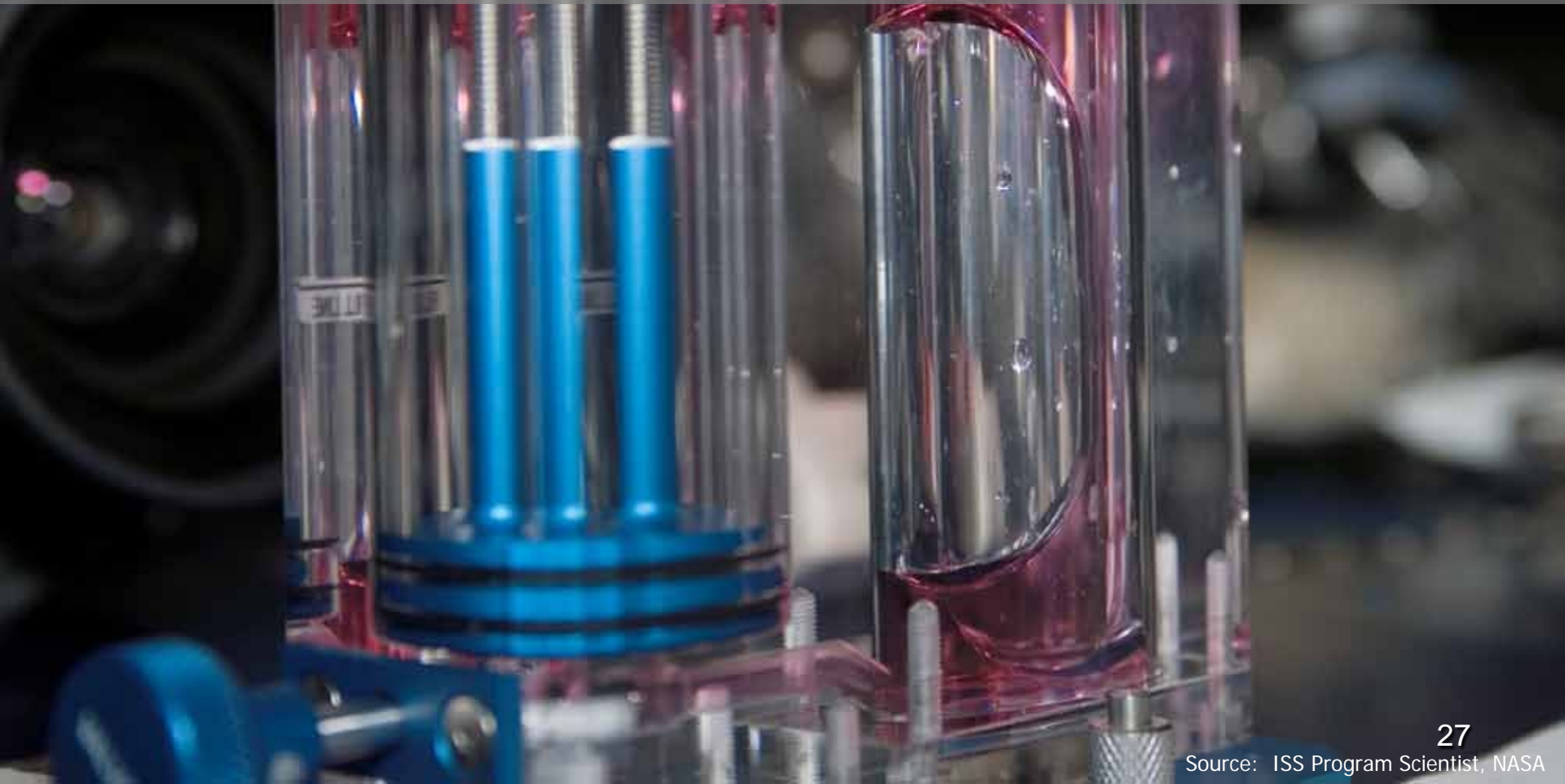
**Regen ECLSS** – Water recycling, oxygen generation, and carbon dioxide removal are critical technologies for reducing the logistics re-supply requirements for human spaceflight. The *International Space Station* demonstration project is applying lessons learned from operational experiences to next generation technologies. The resin used in the ISS water processor assembly have been developed as a commercial water filtration solution for use in disaster and humanitarian relief zones.





**Spinal Cord Changes**— Studies on the *International Space Station* have shown that spinal cord reflexes and nerve cell activity diminished by about 35% in space, implicating the role nervous system has in maintaining muscle health in space. These implications are critical to understanding the effects of long-duration spaceflight on muscle and bone systems.

**Fluid Flow** – Controlling the flow of fluids in the absence of gravity is a challenge for designing spacecraft liquid propellant, water and recycling systems. In space, liquids can climb container walls, making it hard to empty containers, measure the contents of storage vessels, and obtain consistent performance in devices where liquids and vapor mix. Capillary flow experiments on the *International Space Station* produced the first space-validated models describing fluid behavior in space. Three patents have been filed.





Source: ISS Program Scientist, NASA

**Smart Materials** – Studies on the *International Space Station* have investigated the internal structure of fluids that change properties in response to magnetic fields, without additional gravitational effects. Resulting technology has promise to improve the design of structures, such as buildings and bridges, to better withstand earthquakes.

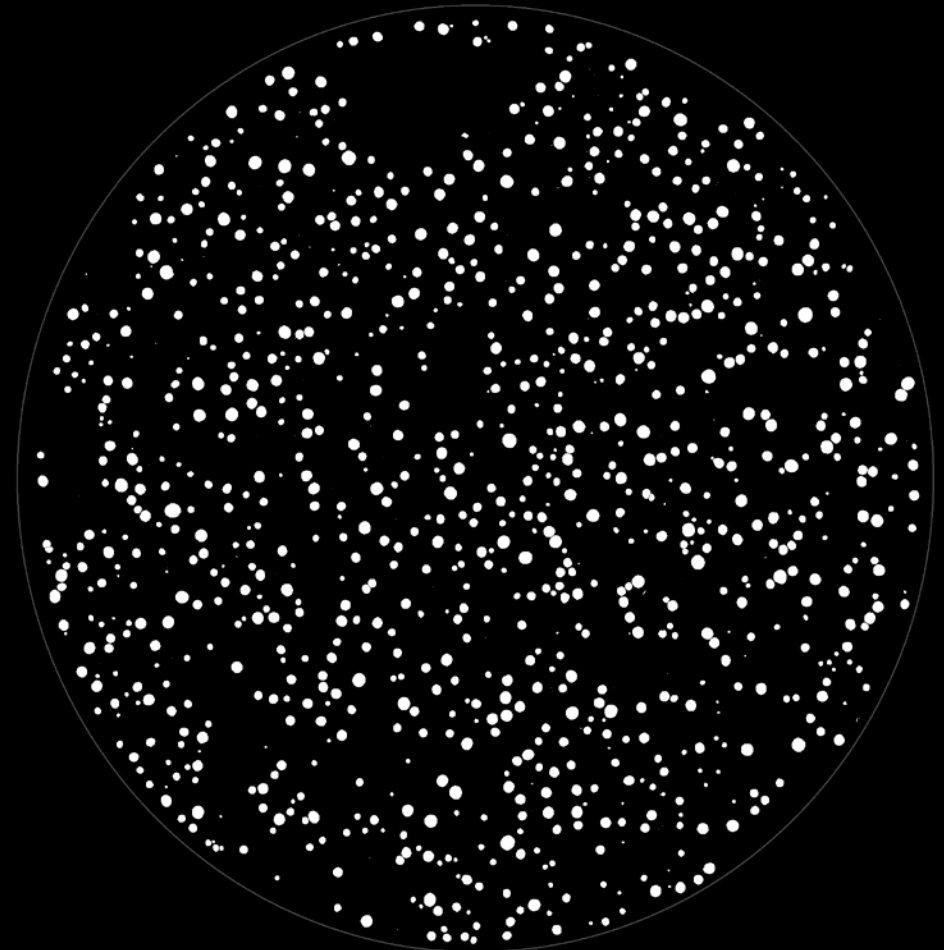
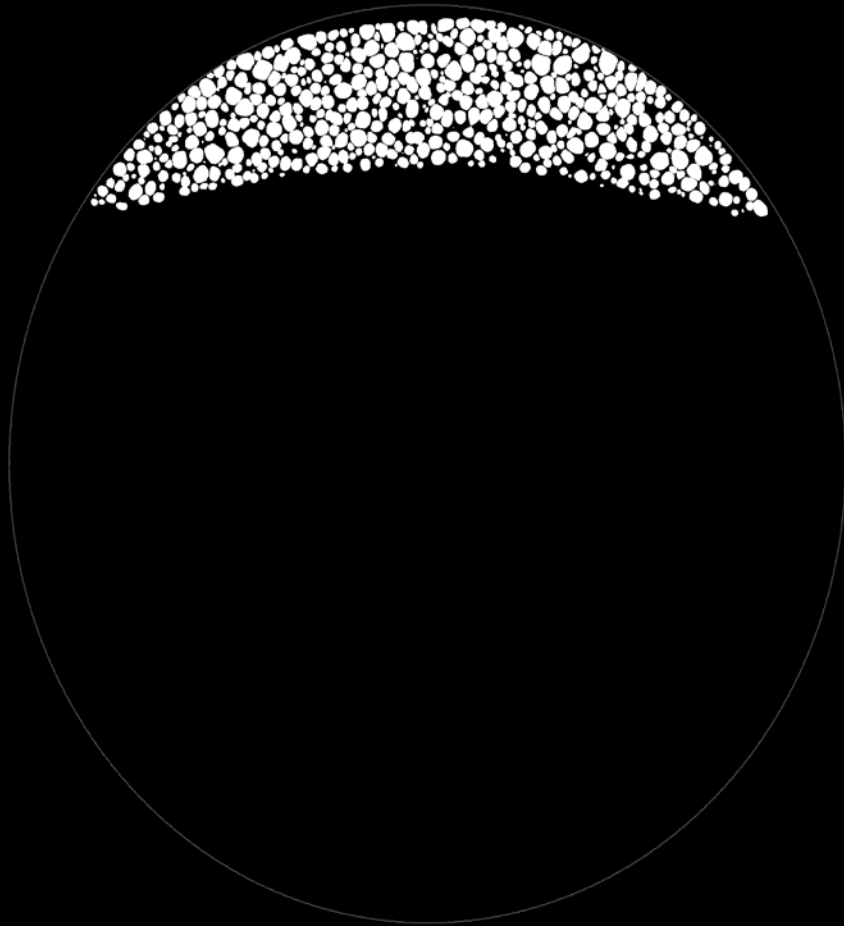
25 mm

b

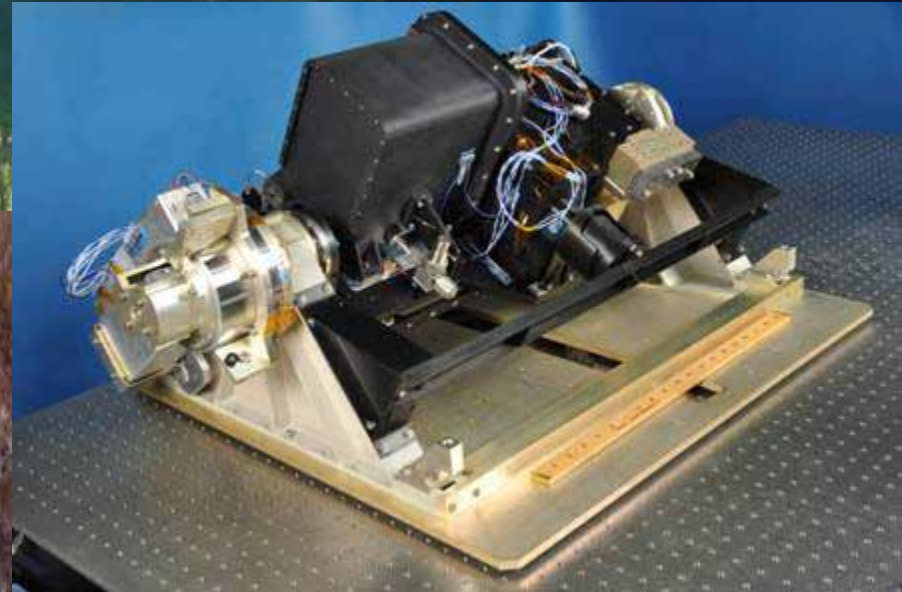
c

d

**Metal Alloy processing** – The reduced gravity on the *International Space Station* allows even distribution of particles in solid-liquid mixtures, thus providing a platform to understand the coarsening process in the development of metal alloys. The results of the CSLM-2 experiment will provide data that will guide the design of new alloys on Earth at reduced development costs and improved materials properties.



**Earth Imaging** – HREP-HICO operates a visible and near-infrared Maritime Hyperspectral Imaging system, to detect, identify and quantify coastal geophysical features from the *International Space Station*.

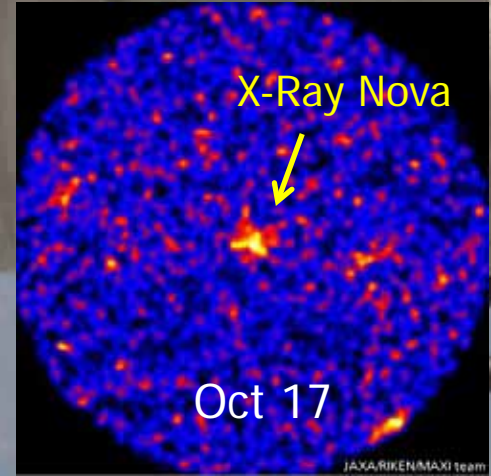
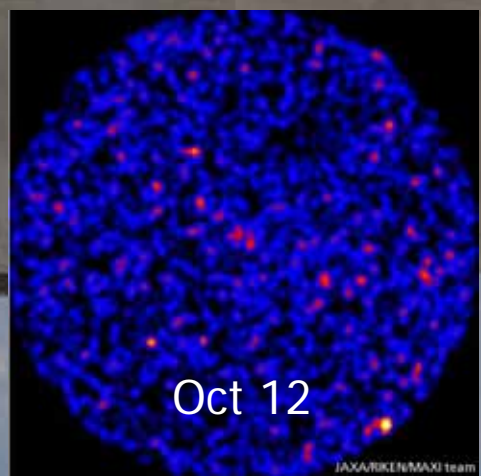
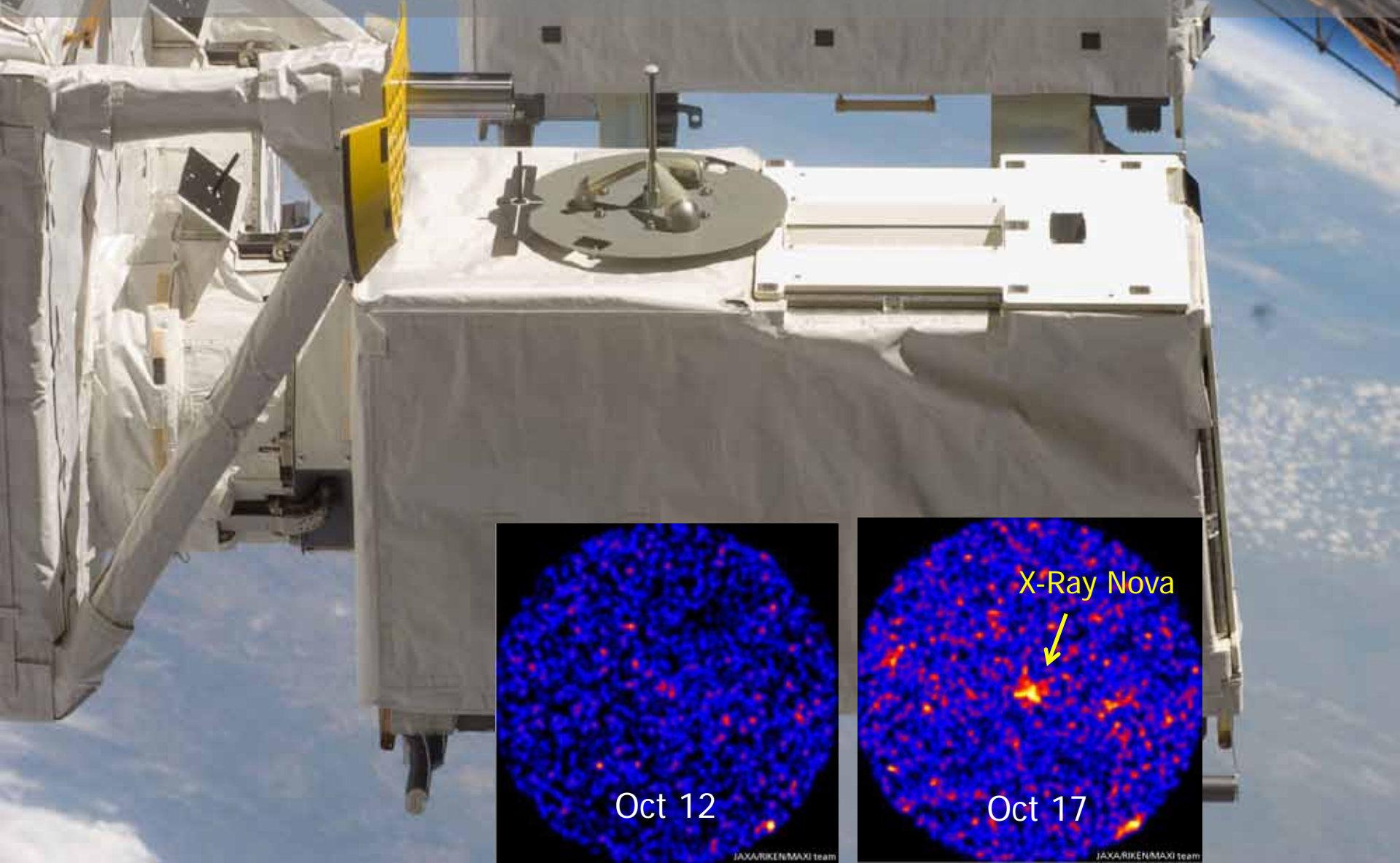


**OIL**

**Earth Observations** – Photographs taken from the *International Space Station* document global change, weather and geological events and urban growth. Researchers with the National Snow and Ice Data Center monitor the breakup of large icebergs as they drift into the South Atlantic Ocean.



**X-ray Monitoring** – MAXI is a highly sensitive X-ray slit camera externally-mounted to the *International Space Station* for monitoring more than 1,000 X-ray sources in space, including black holes and neutron stars. In 2010, MAXI found two new X-ray sources from its sky scans.







**New Smoke Detector Concepts**– Research on the *International Space Station* has shown that soot particle sizes can differ substantially in microgravity, and that other forms of smoke show increases in particulate size by as much as a factor of 10 in space. These results have led to the development of new smoke detector technologies that are currently being tested on the space station that offer improvements in the discrimination between smoke particulate from fire and other airborne particulates (dust, vapors, etc) currently on the commercial market.

**Multi-body Maneuvering in Space** – The Massachusetts Institute of Technology (MIT) is using color coded bowling-ball sized spherical satellites to demonstrate space-based autonomous rendezvous and docking on the *International Space Station*. The results have applications for satellite servicing, space-based vehicle assembly and formation flying spacecraft configurations.



**Portable Test System** - Handheld devices enable crew on the *International Space Station* to rapidly detect a variety of biological and chemical substances of concern to crew safety. This type of environmental testing technology has Earth-based, as well as future exploration missions and planetary protection applications.



**Global Maritime Traffic Tracking** – The first space-based method of tracking global maritime traffic from space is mounted outside the Columbus Laboratory on the *International Space Station*. It can track ships' speed, position, course, cargo, and voyage information to and from other vessels and shore. This autonomous system can monitor traffic in open waters, whereas Earth-based systems can only monitor maritime vessels in coastal waters.

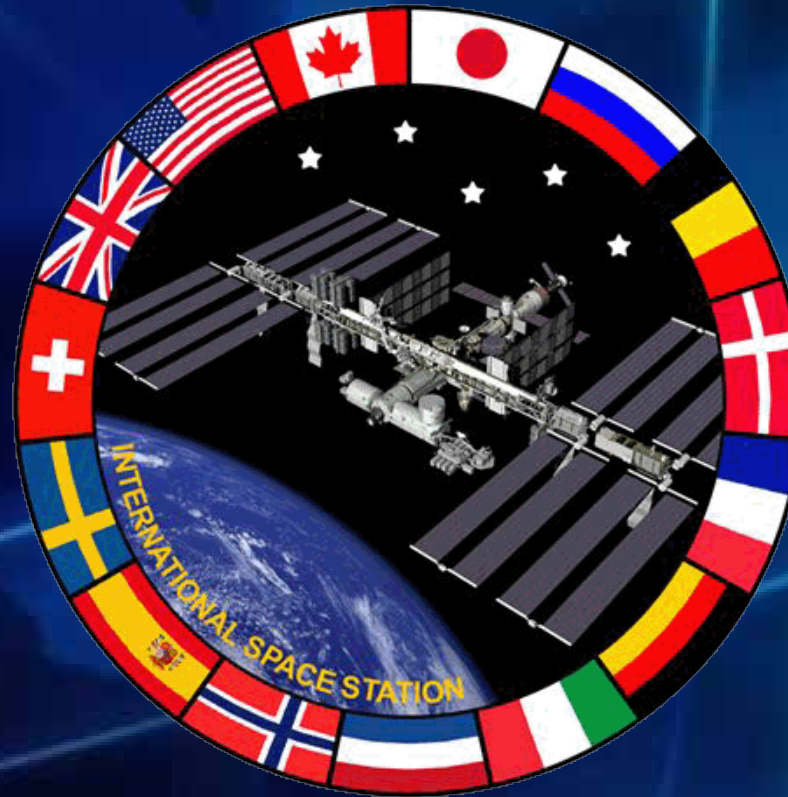


Source: ISS Program Scientist, NASA

First Summary Plot of Data from NORAIS Receiver (after first hours) (Image: FFI)

# 58 Countries Have Participated in ISS Utilization through 2010

Argentina  
Australia  
Austria  
Brazil  
Bulgaria  
Belarus  
Chile  
China  
Columbia  
Croatia  
Czech Republic  
Dominican Republic  
Ecuador  
Egypt  
Fiji  
Finland  
Greece  
Guatemala  
Hungary  
India  
Ireland



Flags= ISS Partners  
Names=ISS Non-partner Countries

Israel  
Kazakhstan  
Kenya  
Kuwait  
Lebanon  
Malaysia  
Mali  
Mexico  
New Zealand  
Peru  
Poland  
Portugal  
Puerto Rico  
Republic of Korea  
Romania  
Senegal  
Slovenia  
South Africa  
Taiwan  
Thailand  
Turkey  
Ukraine

# Highlights/examples of Non-Partner ISS Research

- Brazil (implemented through Roscosmos)
  - Effects of Micro-g on Fermentative Kinetics (MEK): kinetic rates of enzymatic reaction with lipase and invertase
- India (implemented through JAXA)
  - JAXA – ISRO Cooperation agreement to develop Japan-India Microorganism Cultivation Unit for cultivation of cyanobacteria, launch expected in 2011
- Kazakhstan (implemented through Roscosmos)
  - Investigation of a Closed Ecological System (Biosfera): investigation of a closed ecological system under space conditions.
- Malaysia (implemented through NASA and JAXA)
  - Commercial Generic Bioprocessing Apparatus Science Insert - 01 (CSI-01): Malaysian seeds (orchids, Malaysian red sandalwood and rosewood) exposure to the space environment.
  - JAXA and Malaysian Government have an agreement on cooperation for high quality protein crystal growth with a total of 6 investigations planned from 2009-2012
- Republic of South Africa (Implemented through Roscosmos)
  - Soluble Protein Crystallization: Obtaining Crystals of Soluble Proteins FcgIII and FcgeII (SPC)
- South Korea (Implemented through Roscosmos with NASA cooperation and through JAXA)
  - Korean Astronaut Program-13 Measuring of Small Mass in Microgravity (KAP-13): testing of small mass measurement system in microgravity
  - JAXA and KARI have a protocol for feasibility studies for Kibo utilization and will select investigations jointly
  - NASA-Korean collaboration in physical sciences is under development

# International Working groups for coordination of ISS utilization



- ISS User Operations Panel (UOP)—coordination of strategic planning and program research objectives
- ISS Program Science Forum (PSF)—coordination of research issues, research communication, and results tracking

# International Working groups for coordination of ISS Utilization

- Discipline Working Groups
  - International Space Life Sciences Working Group (ISLSWG)
  - International Microgravity Science Planning Group (IMSPG)
  - ISS Technology and Operations Working Group (ISS utilization link to International Space Exploration Coordinating Group, ISECG)
  - International Space Educators Board



# ISS for Humanitarian Missions

**Yellow Shading Denotes Potential Virtual Secretariat Responsibility  
NASA to Provide Integration for Overall Visibility**

## *Earth-Focused Mission*

## *Health-Focused Mission*

## *Education-Focused Mission*

	<b>Geospatial Monitoring Network</b>	<b>Biomedical &amp; Telemedicine Technology Transfer Node</b>	<b>Global Educational Gateway to Space</b>
<b>Canada (CSA)</b>	- TBD	- Bioanalysis, Biodiagnostics and Telemedicine - Potential Leadership/Partnership in Node	- Regional Education Projects
<b>Europe (ESA)</b>	- Climate Change and Earth Observation	- <b>Worldwide Web Portal</b> - VECMAP Feasibility Study - Human Explorations Countermeasures with Additional Benefits to Health on Earth -WHO Strategic Alliance	- Regional Education Projects - Expanding to International Collaboration
<b>Japan (JAXA)</b>	- <b>Worldwide Web Portal</b> --Earth Viewing with External HD Cameras and Super sensitive HD Camera - Geosphere monitoring from ISS (contribution to Disaster charter)	- TBD	- Regional Education Projects
<b>Roscosmos</b>	- Wide Collaboration with Earth Observation Instruments, Current and Future - URAGAN-FSS System - CEO Weblink	- TBD	- Regional Education Projects - Expanding to International Collaboration
<b>United States (NASA)</b>	-EarthKAM Weblink - CEO Weblink -WORF Timesharing - I/SERV & SAGE-III -USAID Strategic Alliance of Agency Interest(TBD)	-Bio/Telemedical Systems Dbase - Center for Human Health and Performance	- <b>Worldwide Web Portal</b> - Regional Education Projects - Expanding to International Collaboration

Green denotes potential future projects that do not exist today, but could be achieved at small marginal cost.

# For More Information

ISS Reference Guide

Cumulative Results Reports:

NASA/TP-2009-213146-REVISION A

Education on ISS 2000-2006:

NASA/TP-2006-213721

World Wide Web

<http://www.nasa.gov/iss-science/>

Facilities Catalog

click on "Facilities" at web link above

ISS Research Blog "A Lab Aloft"

<http://go.usa.gov/atl>

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