International Space Station and the Science of Microgravity

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Outline

- What is the International Space Station (ISS)
- The Value of the ISS
- How and Why We do Science on ISS
- “So what?”—what we have learned so far
- What are the most important benefits to humankind?
- How have non-partners participated?

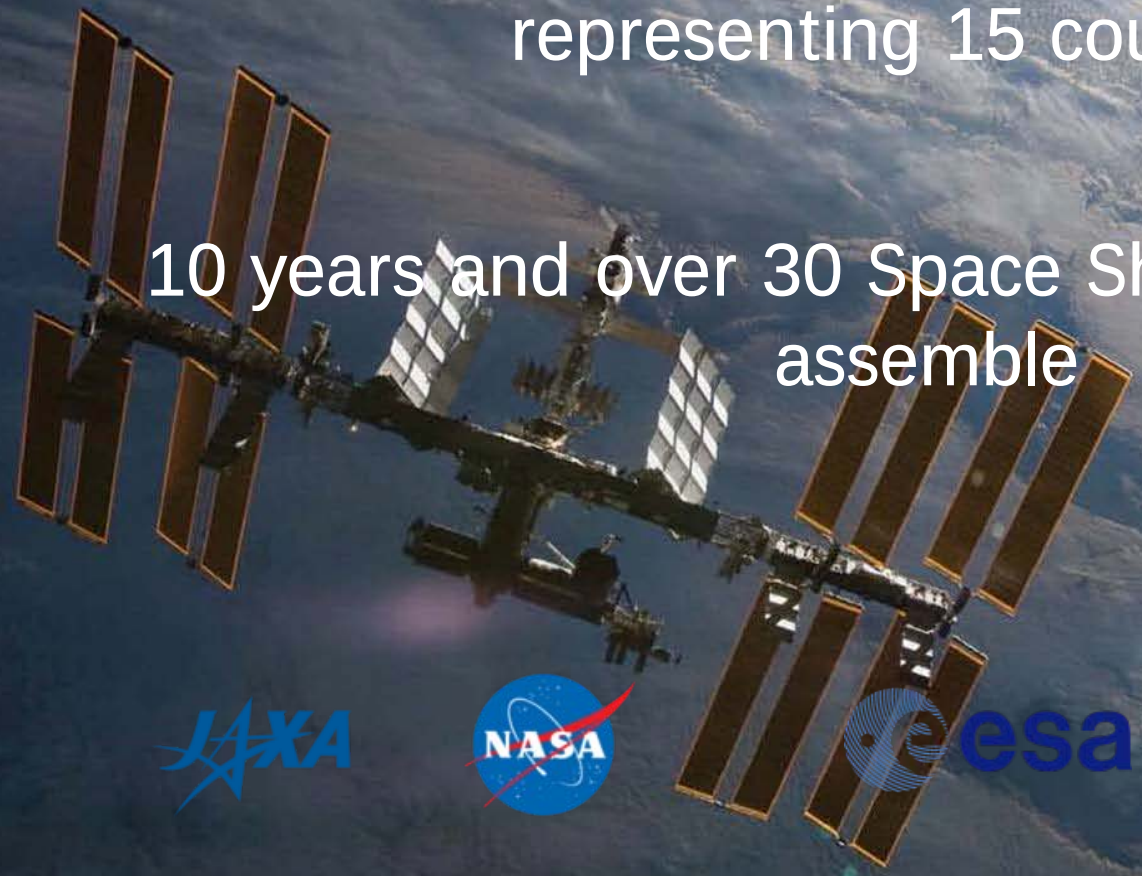
The International Space Station

Background

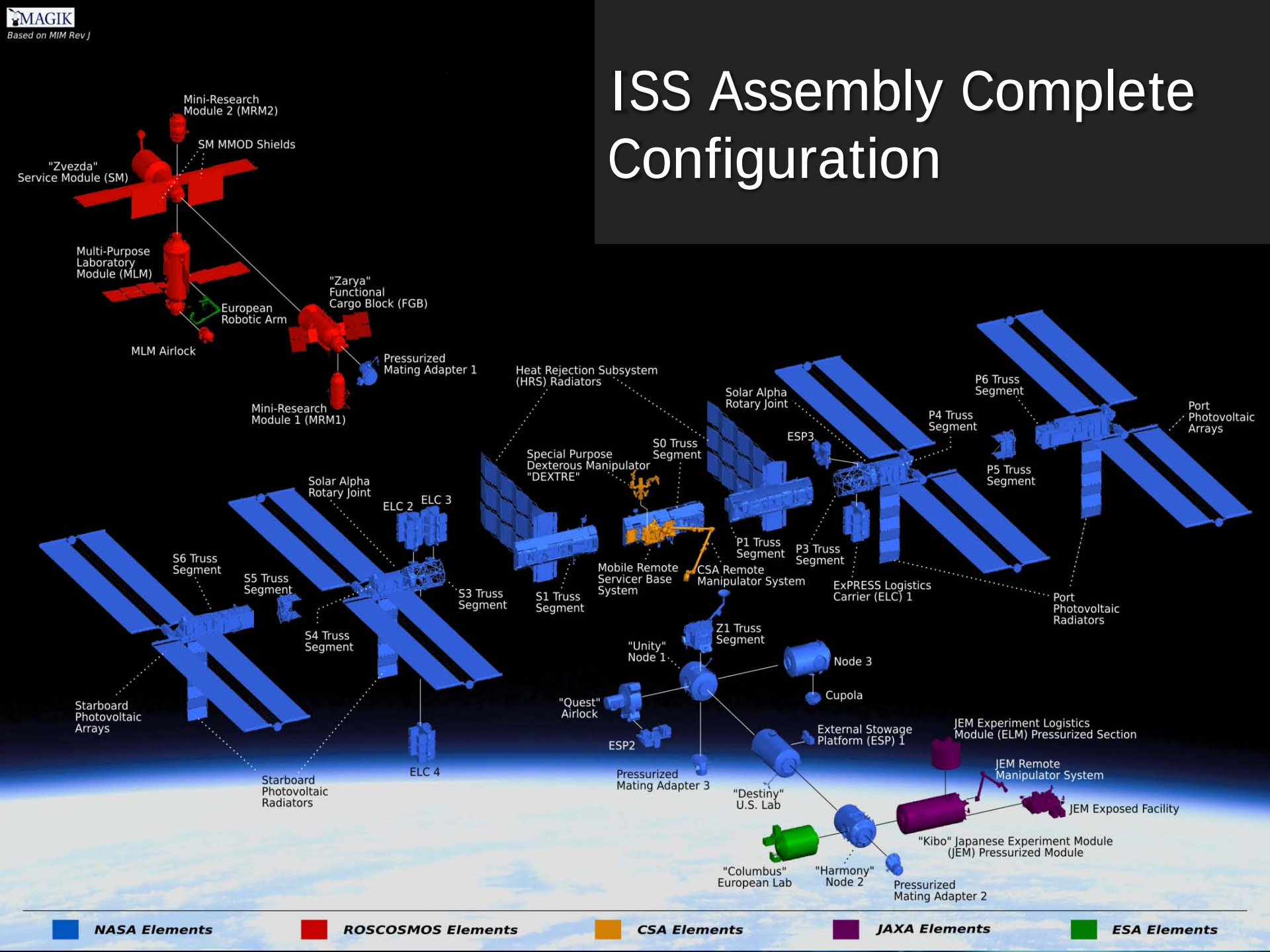
International Space Station as a Laboratory

Created by a partnership of 5 space agencies representing 15 countries

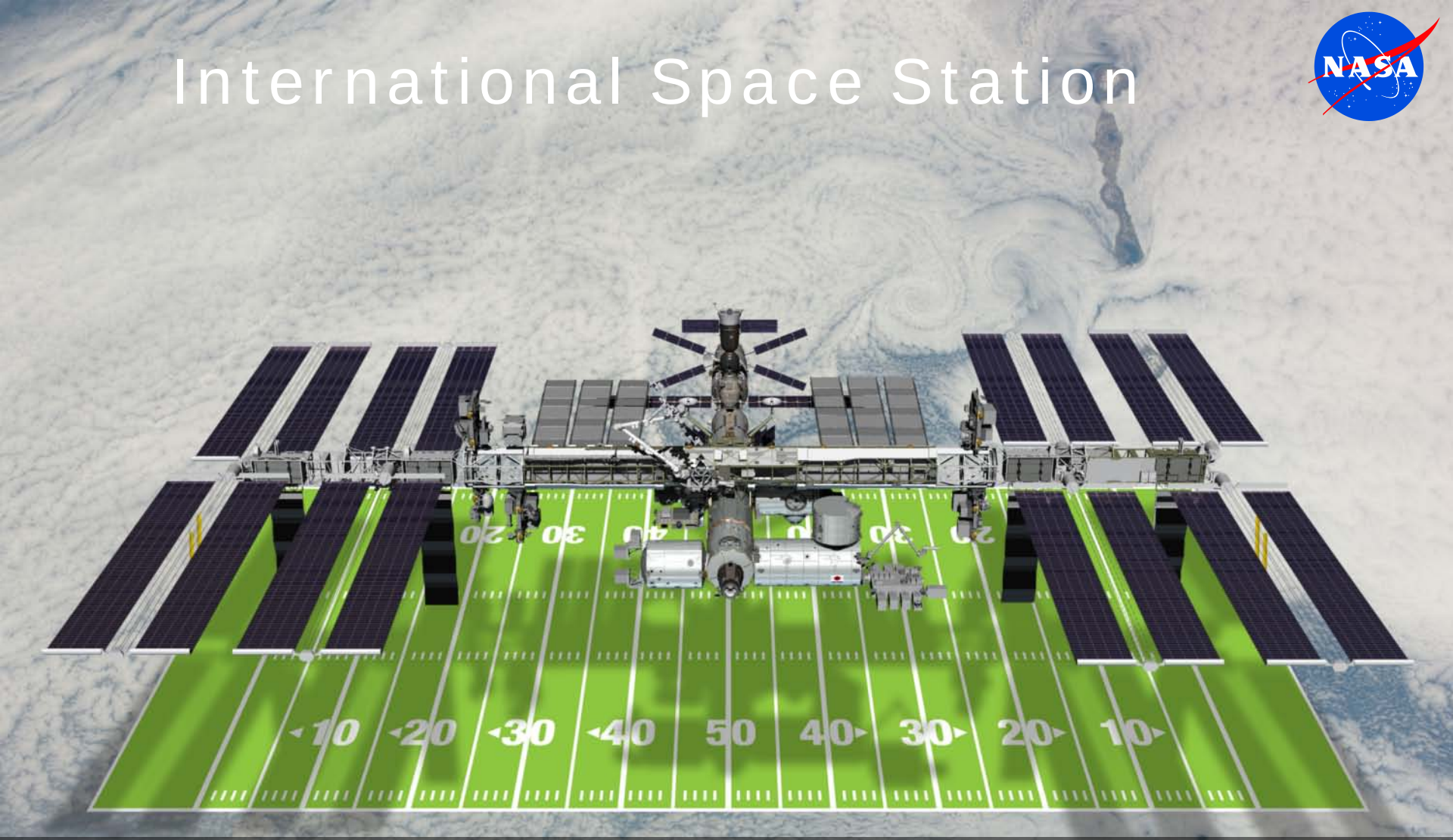
10 years and over 30 Space Shuttle missions to assemble



ISS Assembly Complete Configuration



International Space Station



Spacecraft Mass: 799,046 lb (362,441 kg)
Spacecraft Pressurized Volume: 29,771 ft^3 (29,771 m^3)
Velocity: 17,500 mph (28,200 kph)
Science Capability: Laboratories from four international space agencies – US, Europe, Japan, and Russia.

ISS Launch and Logistics

Space Shuttle

An International fleet of space vehicles:

- Rotates crews
- Delivers propellant & supplies
- Replenishes science experiments

ROSCOSMOS

Progress

Soyuz

esa

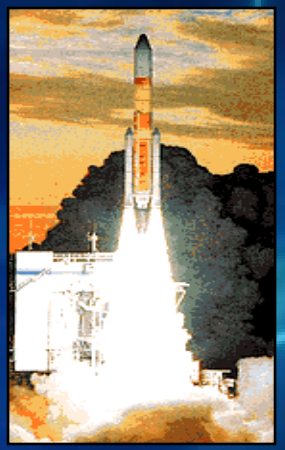
European Space Agency

Ariane 5 / ATV

Future Launch Capabilities

JAXA

H II / HTV



2009

U.S. Commercial

Falcon 9 / Dragon (SpaceX)

Taurus II / Cygnus (Orbital)

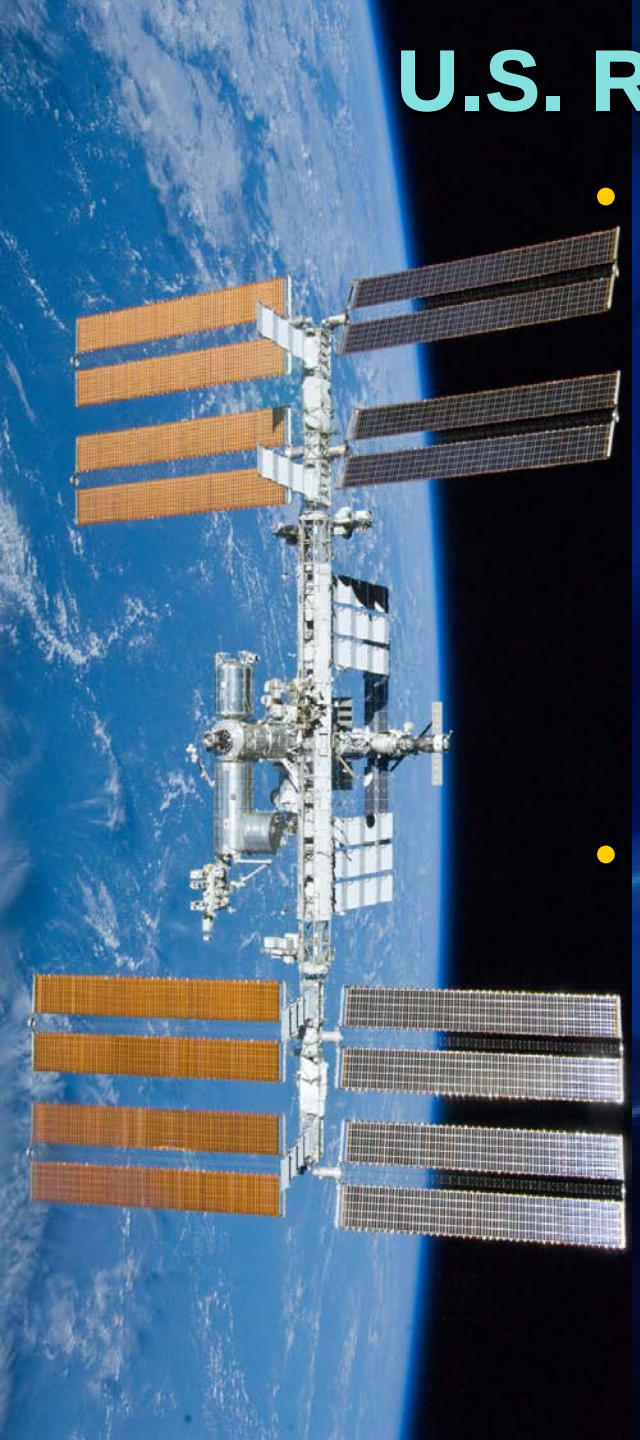
2010-2011

NASA

MPCV / SLS

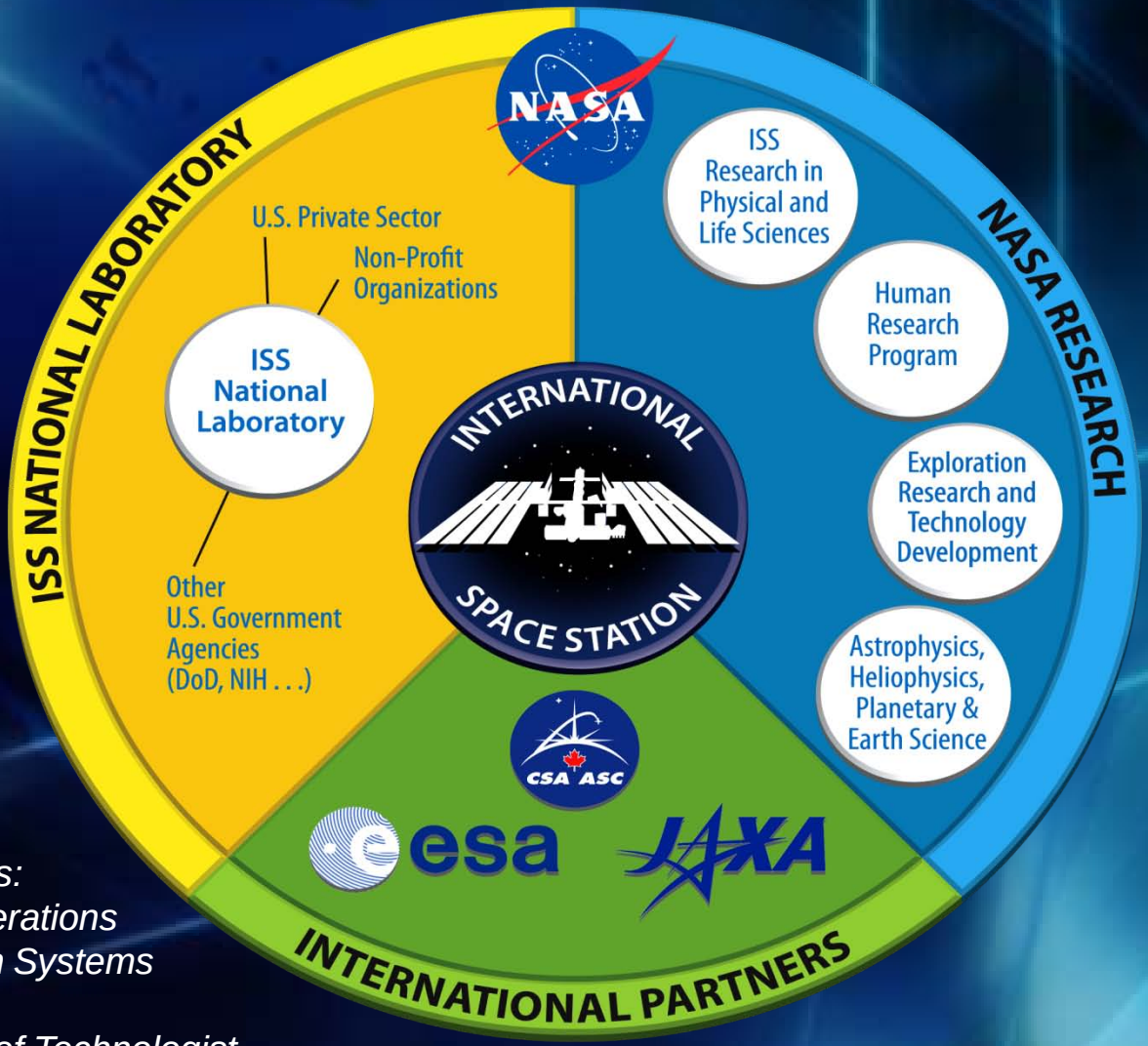
201X?

U.S. Research on ISS - Objectives



- NASA Utilization of the ISS (Vision for Space Exploration, January 14, 2004, and NASA Authorization act of 2005)
  - Astronaut health and countermeasure development for space exploration
  - Testing research and technology developments for future space exploration
  - Developing and validating operational procedures for long-duration space missions
  - Microgravity physical and life sciences program to maintain U.S. capability in these areas
- ISS National Laboratory beginning in 2010 (NASA Authorization Acts of 2005 and 2008)
  - Other U.S. government agencies use ISS to meet their agency objectives
  - Commercial and non-profit organizations use ISS in the interests of economic development in space
  - Pathfinders starting in 2008

Objectives for Research on ISS



NASA Mission Directorates Manage Agreements:
SOMD – Space Operations
ESMD – Exploration Systems
SMD – Science
OCT – Office of Chief Technologist

ISS Program Office Plans, Integrates and Operates

How and Why We Do Science

NASA Research Infrastructure

2 Human Research Facility Racks

6 ExPRESS Racks

Materials Science Research Rack

Window Observational Research Facility

Muscle Atrophy Research Exercise System (MARES)

Fluids Integrated Rack (FIR)

MELFI-3

Microgravity Science Glovebox (MSG)

2 Minus Eighty-Degree Laboratory Freezers for ISS (MELFI)

Combustion Integrated Rack (CIR)

ExPRESS-7 and 8

Added for ISS National Lab

2001-2010

Source: ISS Program Scientist

ESA and JAXA Research Infrastructure

ESA

Biolab

European Drawer Rack (EDR)

European Physiology Module (EPM)

European Transport Carrier (ETC)

Fluid Science Lab (FSL)

Solar

JAXA

Ryutai (Fluids)

Saibo (Cell Biology)

Monitor All-sky X-ray Image **(MAXI)**

Space Environment Data Acquisition **(SEDA)**

Superconducting Sub millimeter-wave Limb-Emission Sounder **(SMILES)**

2008-2009

Kobairo (Gradient Heating Furnace)

Multi-Purpose Small PayloadRack

2011

Multi-purpose Racks

Gloveboxes

Incubators, Culture Systems & Centrifuges

Freezers & Refrigerators

Why Microgravity Research?

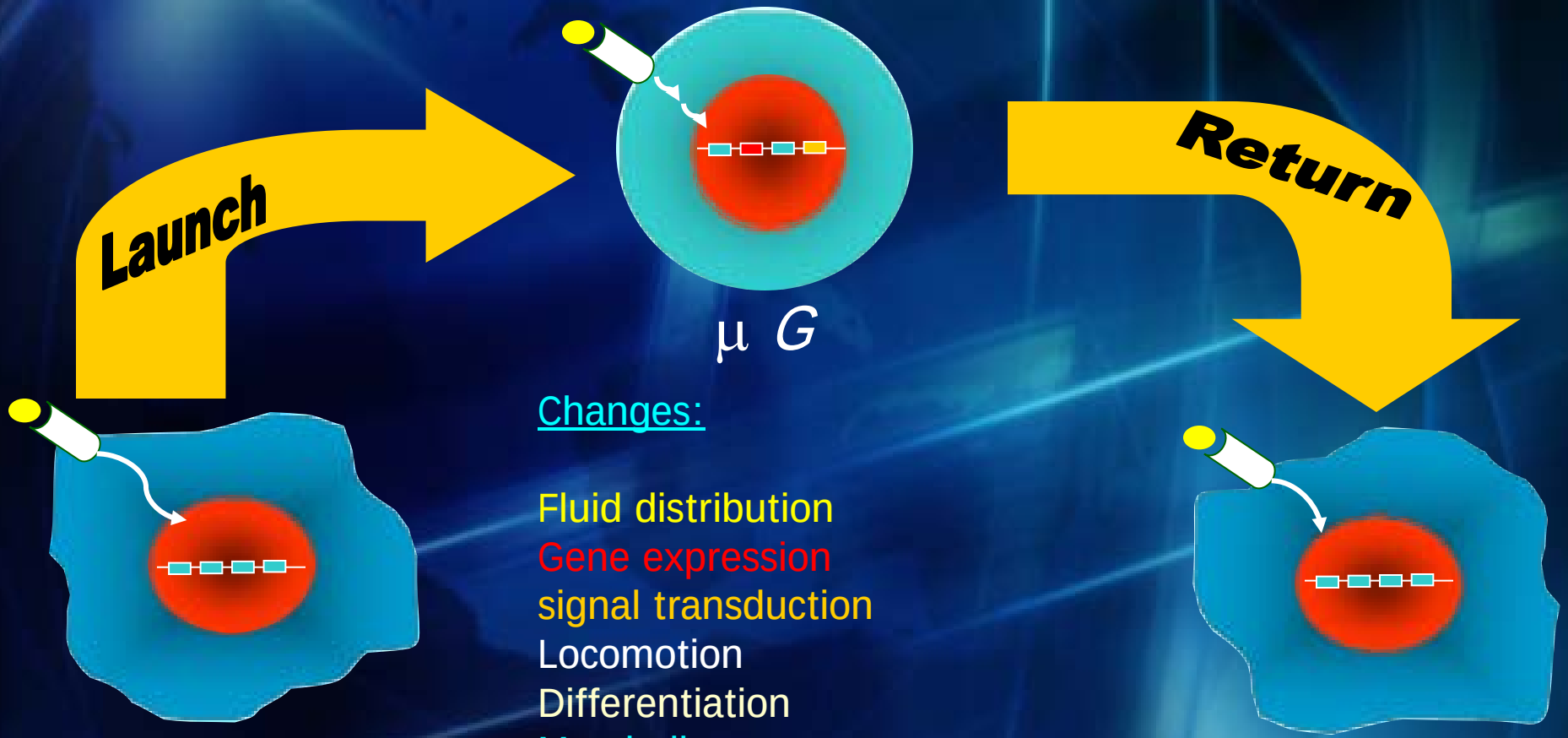
- Scientific Discovery
  - Gravity is a constant force on Earth
  - It cannot be completely controlled or removed in experiments
  - It dominates and masks other forces in processes
  - The ISS provides a laboratory environment to control this force

Disciplines that use the Laboratory

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

What have we learned so far?

Biology: Animal Cells in Space



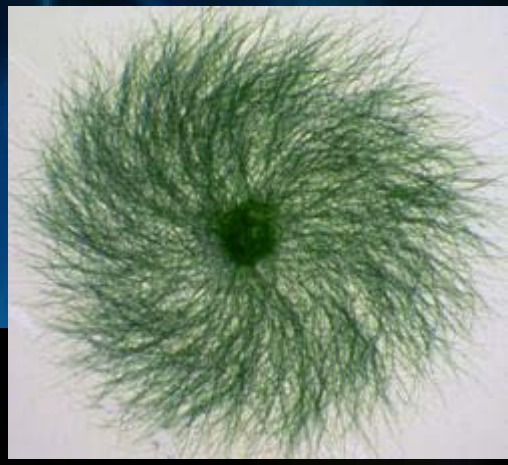
Changes:

Fluid distribution
Gene expression
signal transduction
Locomotion
Differentiation
Metabolism
Glycosylation
Cytoskeleton
Tissue morphogenesis

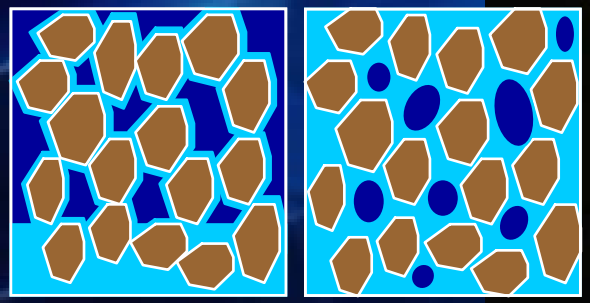
Courtesy of Neal Pellis

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



Soil structure

Peas grown on ISS

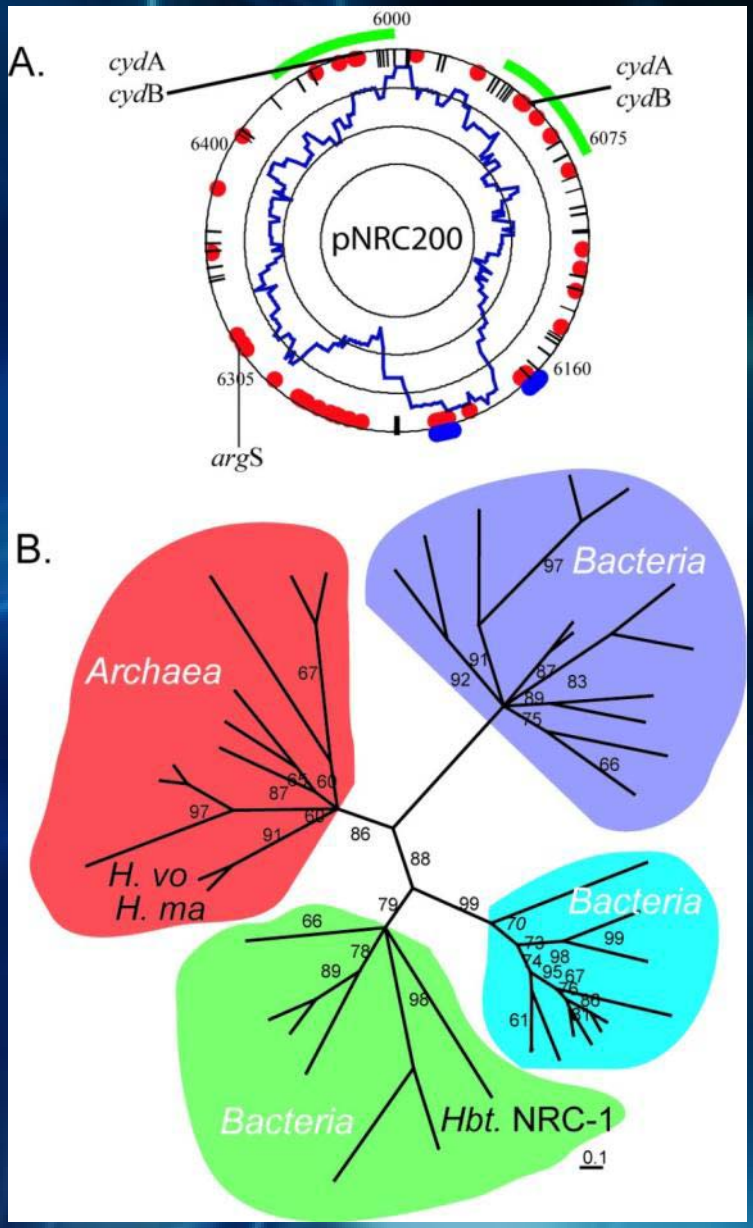
Biology: Microbes in Space

3 modes of response

More virulent

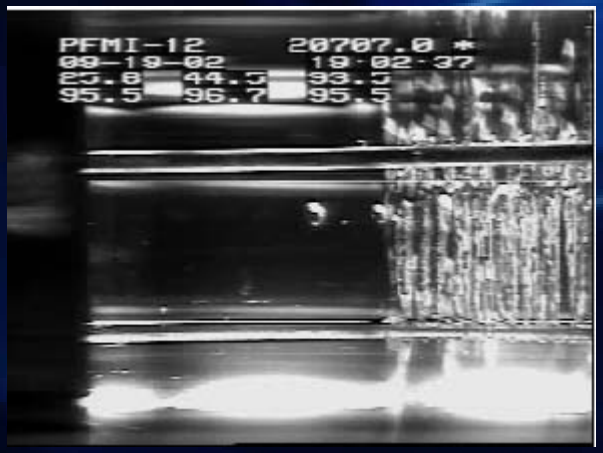
Multiply more rapidly

No change

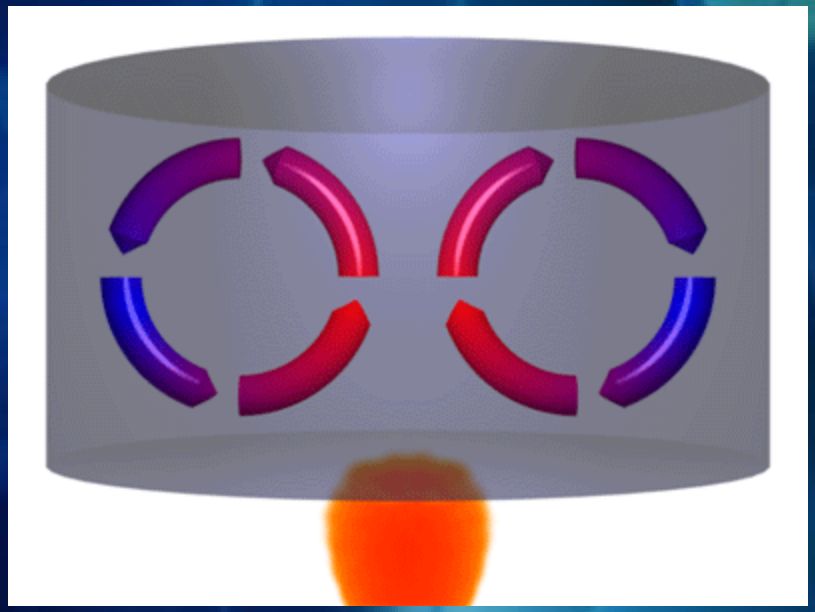


Physical Sciences: Convection

Combustion

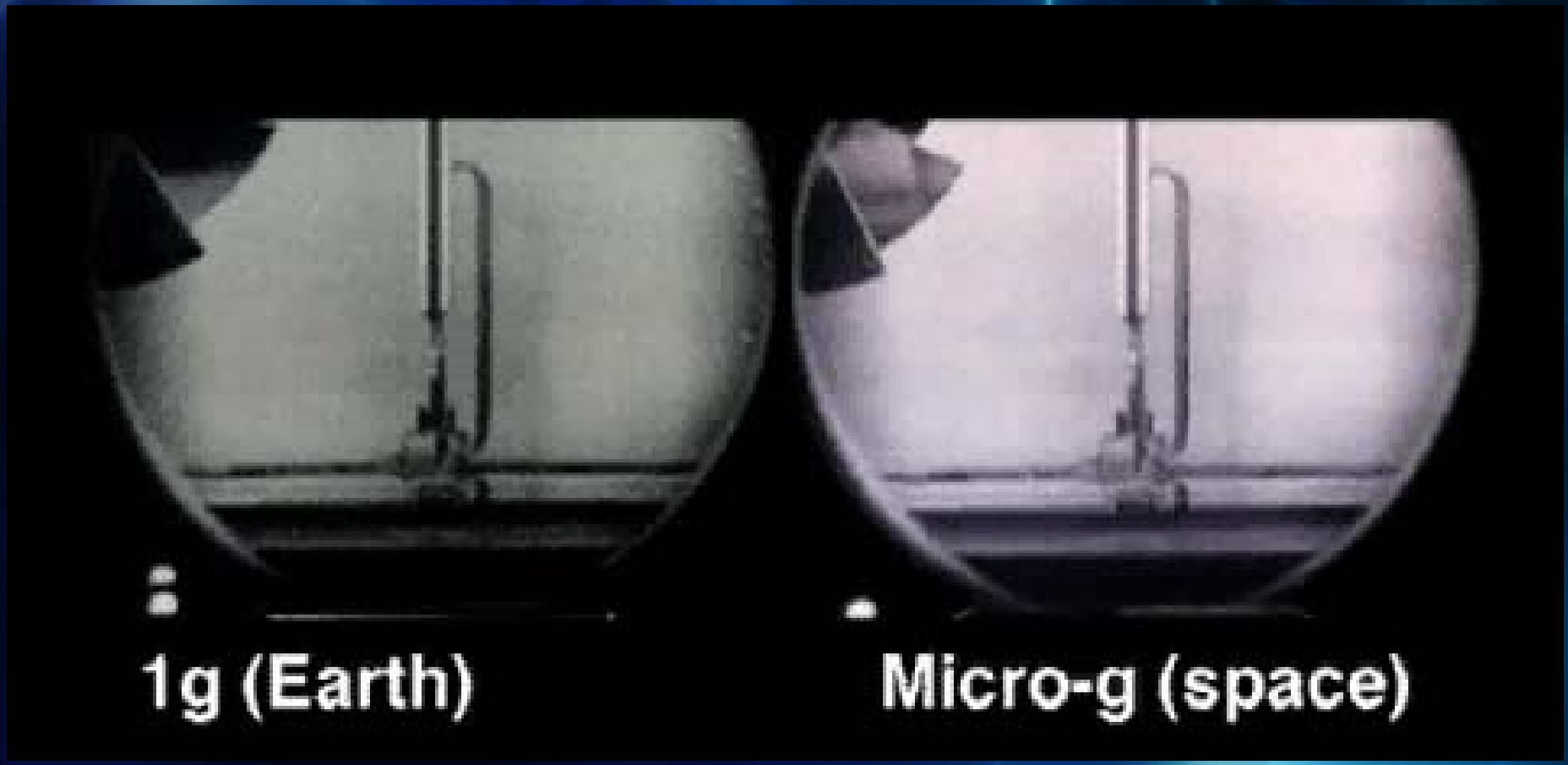


Pore formation and Coarsening



Fluids: No density or buoyancy driven Convection!

Boiling on Earth and in Microgravity



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

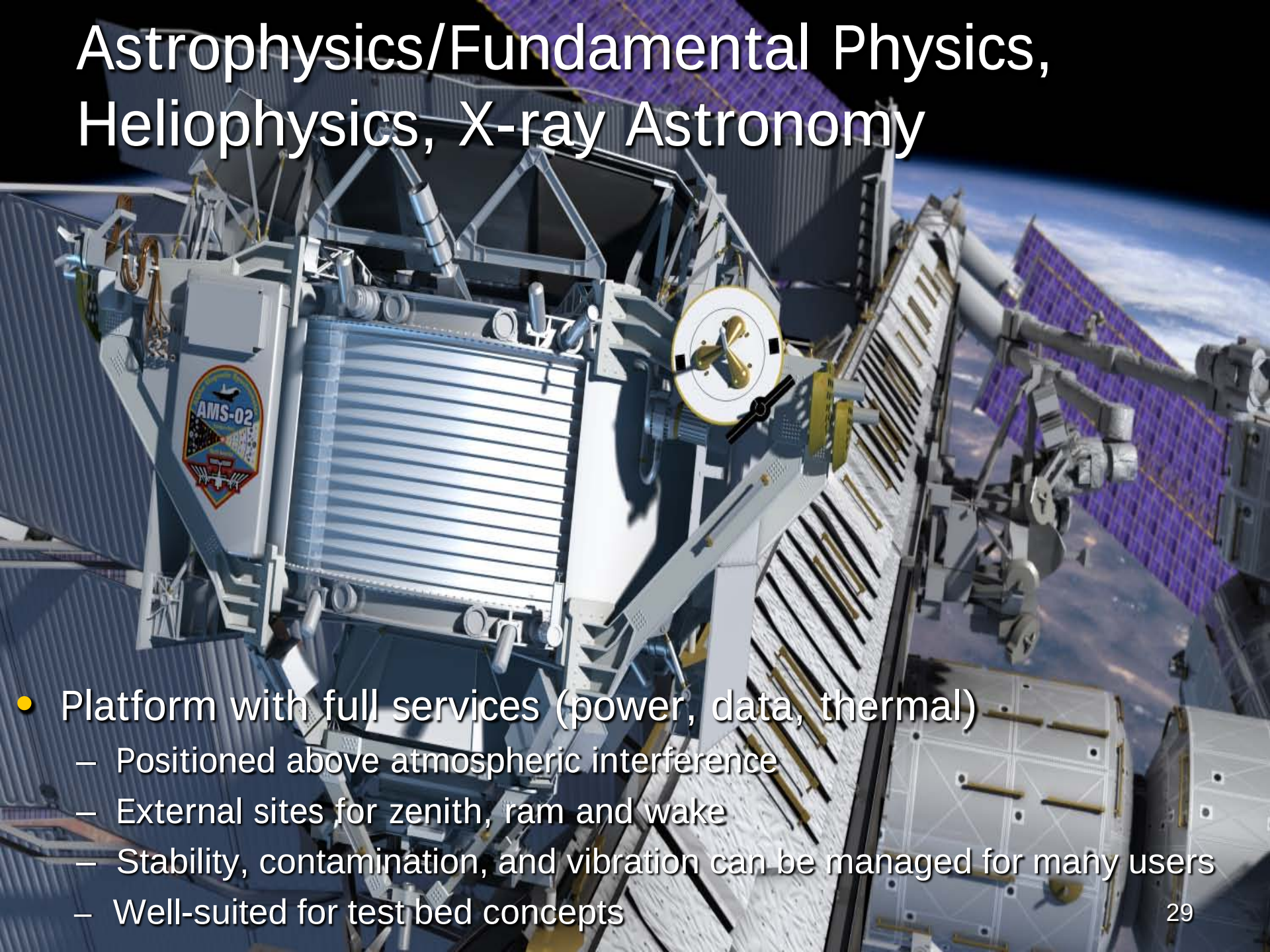
Technology Development and Demonstration

- 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

Earth Science

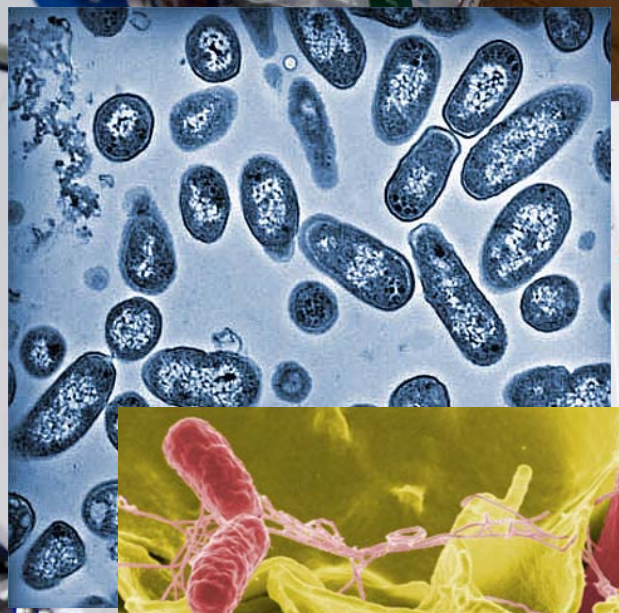
- Platform with full services (power, data, thermal) in low earth orbit (~400 km)
  - All geographic locations between 51.6 North and South latitude
  - 85% of the Earth's surface
  - 95% of the world's populated landmass every 1-3 days
  - External sites for nadir, zenith, ram and wake
  - Variable (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

Benefits to Humankind



Microbial Vaccine Development – Scientific findings from ***International Space Station*** research have shown increased virulence in ***Salmonella*** bacteria flown in space, and identified the mechanisms 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 the methycillin-resistant *Staph aureus* (MRSA).

Top image credit: Pacific Northwest National Laboratory

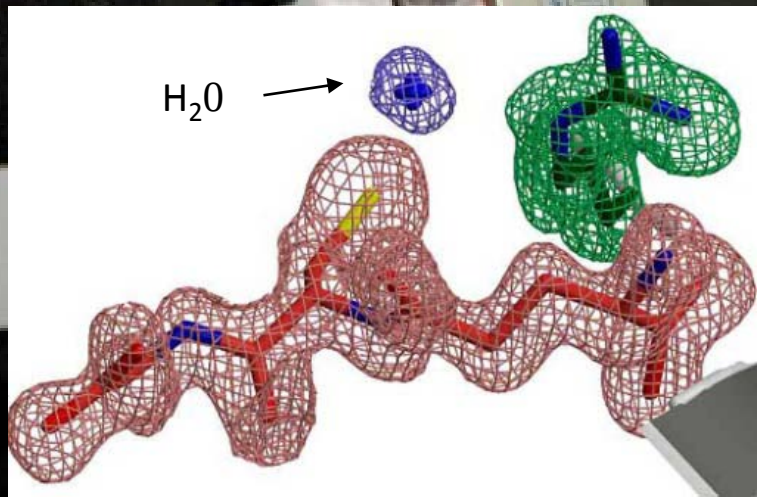
Bottom image credit: Rocky Mountain Laboratories

Source: ISS Program Scientist, NASA

Cancer Treatment Delivery– Microcapsules (micro-balloons) 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 will begin soon at MD Anderson Cancer Center in Houston and the Mayo Cancer Center in Scottsdale, AZ.

Source: ISS Program Scientist, NASA

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 investigating other proteins and viruses.



Source: ISS Program Scientist, NASA

Telemedicine Advancements - Ultrasound training methods developed for evaluating medical issues on the *International Space* Station have been used by the American College of Surgeons to teach ultrasound techniques to surgeons. Additional applications could include diagnosis of injuries and illnesses in remote locations on Earth, including rural areas, disaster areas and the battlefield.

Images on right provided courtesy of Scott A. Dulchavsky, M.D., Ph.D., Henry Ford Health System, Detroit, MI.

Source: ISS Program Scientist, NASA

Medical Technology - The development and use of the robotics arm for space missions on the Space Shuttle and the ***International Space Station*** has led to the world's first MRI (Magnetic Resonance Imaging) compatible image-guided, computer-assisted device specifically designed for neurosurgery. The device now being used to augment surgeons' skills to perform neurosurgeries that are traditionally considered difficult or impossible, thus leading to better patient outcomes.

Source: ISS Program Scientist, NASA

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 form 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.

Source: ISS Program Scientist, NASA

Understanding Bone Loss- Studies done on the ***International Space Station*** have found that astronauts lost an average of 1.5% bone/month (similar to loss in post-menopausal women per year), and took as much as 3 years to rebound to pre-flight bone density. Comparison of bone mineral density in the hip and spine between astronauts and healthy normal subjects will help to improve understanding of the prevalence of osteoporosis between different race and gender sub-groups on Earth as well as in space.

Source: ISS Program Scientist, NASA

Bone Loss Countermeasure supports drug development – In an investigation performed on the *International Space Station* by BioServe Space Technologies and Amgen Inc., found the use of the protein Osteoprotegerin (OPG) as a bone loss treatment nearly reversed bone resorption and declinations in bone strength. Results of this study also yielded fundamental insight into mechanisms of OPG function. An OPG pharmaceutical has since been released for use in bone loss in cancer patients.

Source: ISS Program Scientist, NASA

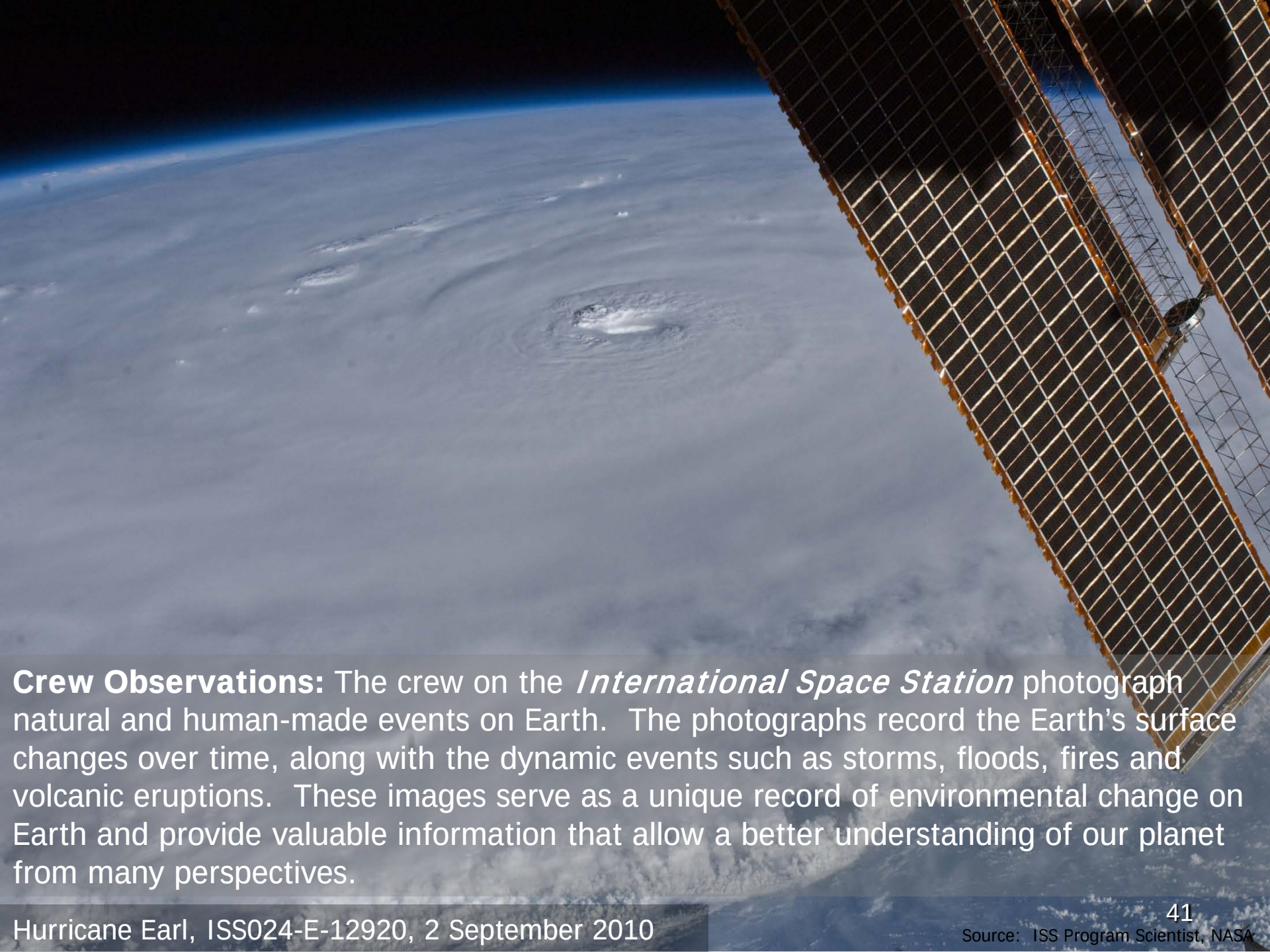
Maintaining Bone Health through Nutrition – Results from the Nutritional Study on the ***International Space Station***, bed rest analogs, and laboratory cellular experiments have shown that Omega-3 fatty acids counteracted bone loss, indicating that diet changes to include more fish may protect bone loss both in space and on Earth. Studies have also identified a loss of Vitamin D as a concern for spaceflight, leading to recommendations for increased intake in astronauts. This recommendation was considered in the latest USRDA recommendation to increase Vitamin D intake for all Americans.

Source: ISS Program Scientist, NASA

ISS014E13728

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***. Extensive experience with airborne hyperspectral image data has demonstrated its utility for land use and land cover, vegetation type, vegetation stress and health, and crop yield.

Source: ISS Program Scientist, NASA



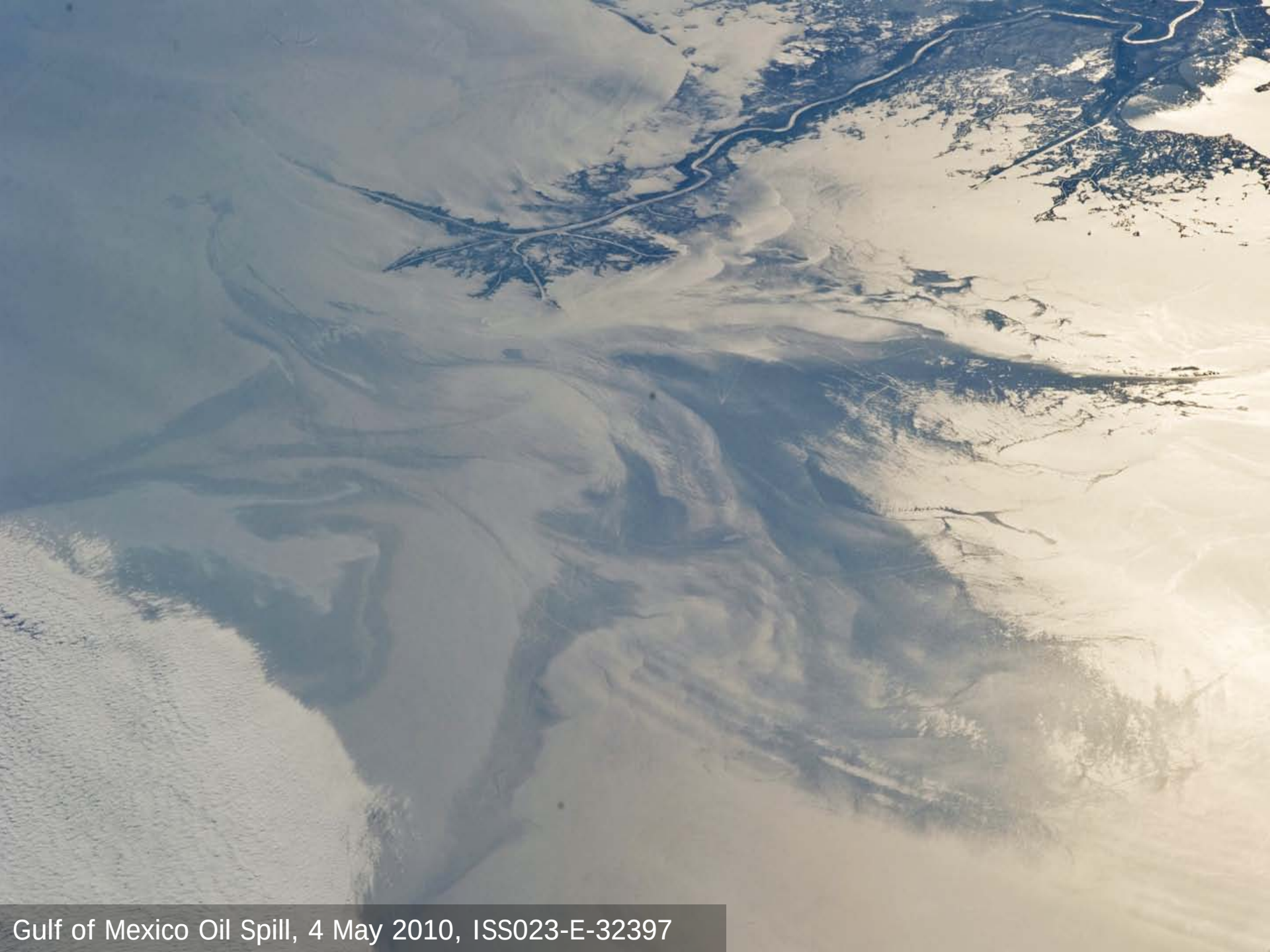
Crew Observations: The crew on the *International Space Station* photograph natural and human-made events on Earth. The photographs record the Earth's surface changes over time, along with the dynamic events such as storms, floods, fires and volcanic eruptions. These images serve as a unique record of environmental change on Earth and provide valuable information that allow a better understanding of our planet from many perspectives.

Hurricane Earl, ISS024-E-12920, 2 September 2010

Source: ISS Program Scientist, NASA

Ash and Steam Plume, Soufriere Hills Volcano, Montserrat ISS021-E-5555, 18 October 2009

Sarychev Peak, Kuril Islands, ISS020-E-9048, 12 June 2009



Gulf of Mexico Oil Spill, 4 May 2010, ISS023-E-32397

Tsunami in Japan, 13 March 2011, ISS026-E-33647

Education

Education - *International Space Station* research has involved over 900,000 students in the U.S. and over 31 million worldwide have participated in educational demonstrations performed by crewmembers onboard ISS.

Importance of ISS as an Education Platform

- Students are excited about space!
- Motivate in math, science, engineering, and technology
- Long duration laboratory = many students reached

Educational Activities on ISS

- Student-developed experiments, including contests
- Students perform classroom versions of ISS experiments
- Students participate in actual experiments
- Students participate in engineering, hardware development, and operations activities
- Educational demonstrations by astronaut/cosmonauts

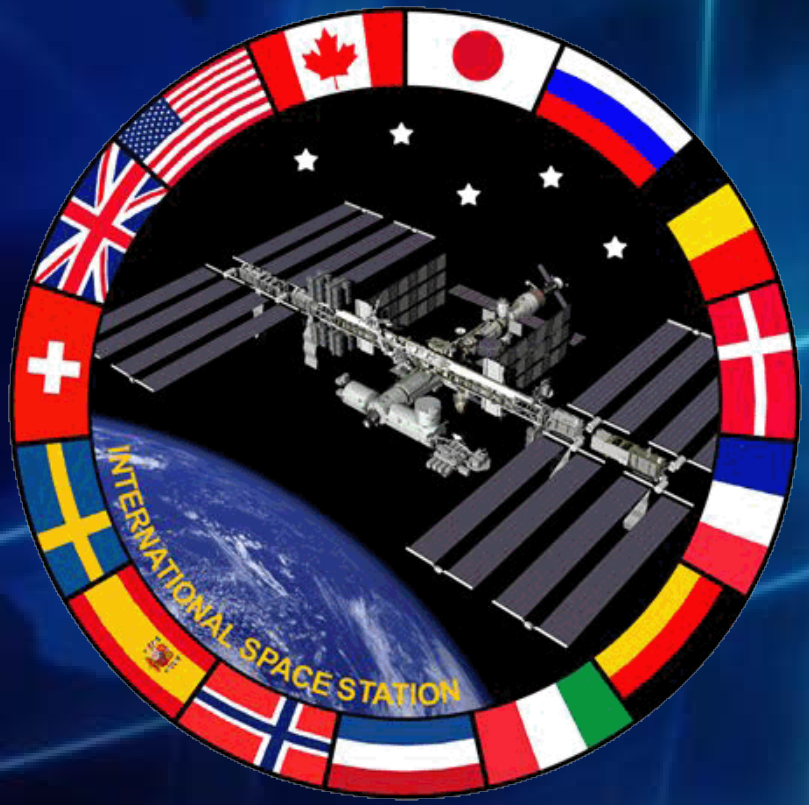
NASA-led International Opportunities

- Over 31 million students around the world
- Amateur Radio on ISS (ARISS)
  - 39 countries
  - Over 550 sessions with the ISS crew
- Earth Knowledge Acquired by Middle School Students (EarthKAM)
  - Students from 16 countries
  - Control Earth observations cameras onboard ISS

How Have Non-Partners Participated

59 Countries Have Participated in ISS Utilization through 2010

Argentina
Australia
Austria
Brazil
Bulgaria
Byelorussia
Chile
China
Columbia
Croatia
Czech Republic
Dominican Republic
Ecuador
Egypt
Fiji
Finland
Greece
Guatemala
Hungary
Ile de La Reunion
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 hight quality protein crystal growth with a tital 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, NASA, and 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

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/atI

Twitter @ISS_Research

http://twitter.com/@ISS_Research


NASA/TP–2009–213146–REVISION A

NASA

International Space Station Science Research Accomplishments During the Assembly Years: An Analysis of Results from 2000-2008

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