XXVIII Planetary Congress of the Association of Space Explorers

20-27 September 2015

Status of Research On the ISS

State of the Station

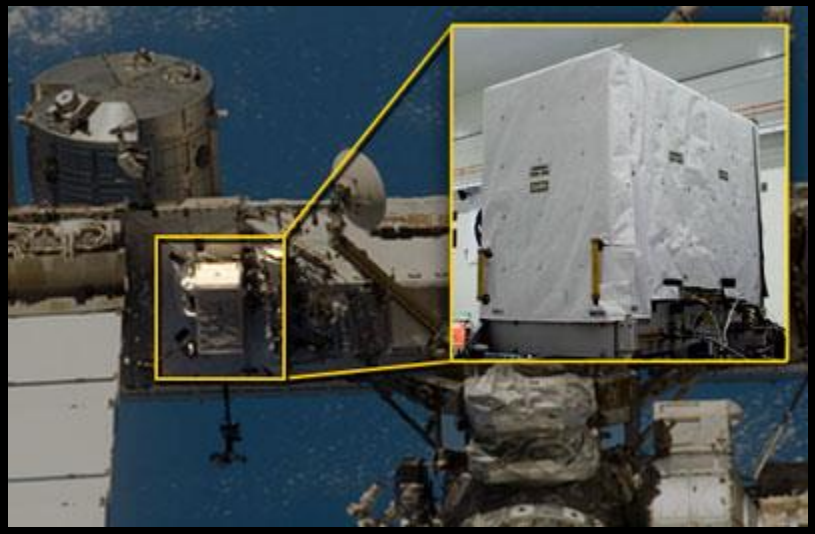
- Struc and Mech
- EPS
- ECLSS
- Robotics
- EVA
- Health and Habitability
- Operations & Research

- Struc and Mech
- MMOD penetration risk
- Operations in depressed state
- SAW mast stability
- UBNT pressue leak detection

State of the Station

- Current Status: agreements to 2024
  - EPS
  - ECLSS : pressure leak detection, NORs
  - Cooling: RTOC and tank filling
  - Robotics: Lube & RMCT
  - EVA
    - EMU – water, servicing, lifetime extensions
    - Plans – RTOC, IDAs, batteries, AMS blanket
  - Health and habitability
    - Galley, projector, CO2, table, lights, exercise, VIIP, windows, social media
  - Ops
    - Comm upgrades
    - Task-listing
    - Tablets
    - Hololens
    - MCC21
- New challenges
  - Loss of supply vehicles
  - Reconfiguring for commercial vehicles
  - More research on the way

Current status: cooling: RTOC P6 2B



Loss of resupply: Date to reserve/zero consumables

- Oxygen with Elektron at 3 crew support and no OGA – September 3 2015/December 17 2015
- Food - December 06 2016/January 17 2016
- Water – February 9 2016/June 1 2016
- LiOH (no CDRA or Vozduch) – 14 days to zero
- Nitrogen, KTO, filter inserts, ACY, EDV and TUBSS, pretreat also considered

Robotics

- LEE lubing successful to preserve latching capability
- LEE latching
  - (for Cygnus, SPDM, and walk-offs)

ECLSS: Water

Currently at a 75% recovery rate for water

- System functional - spares
- Siloxanes – MF bed changeout impact. No crew health issue.
- Urine processing affefcted by Calcium salt precipitation. New pretreat.

ECLSS: CO2

Resources:

- 2 CDRAs - Nominal Ops is 1 CDRA
- Vozdukh - Nominally operating between Modes 1-3 for 3-6 crew
- Amine Swingbed - reserved
- 20 US LiOH Cans – contingency use only. 14 days for 3 crew.

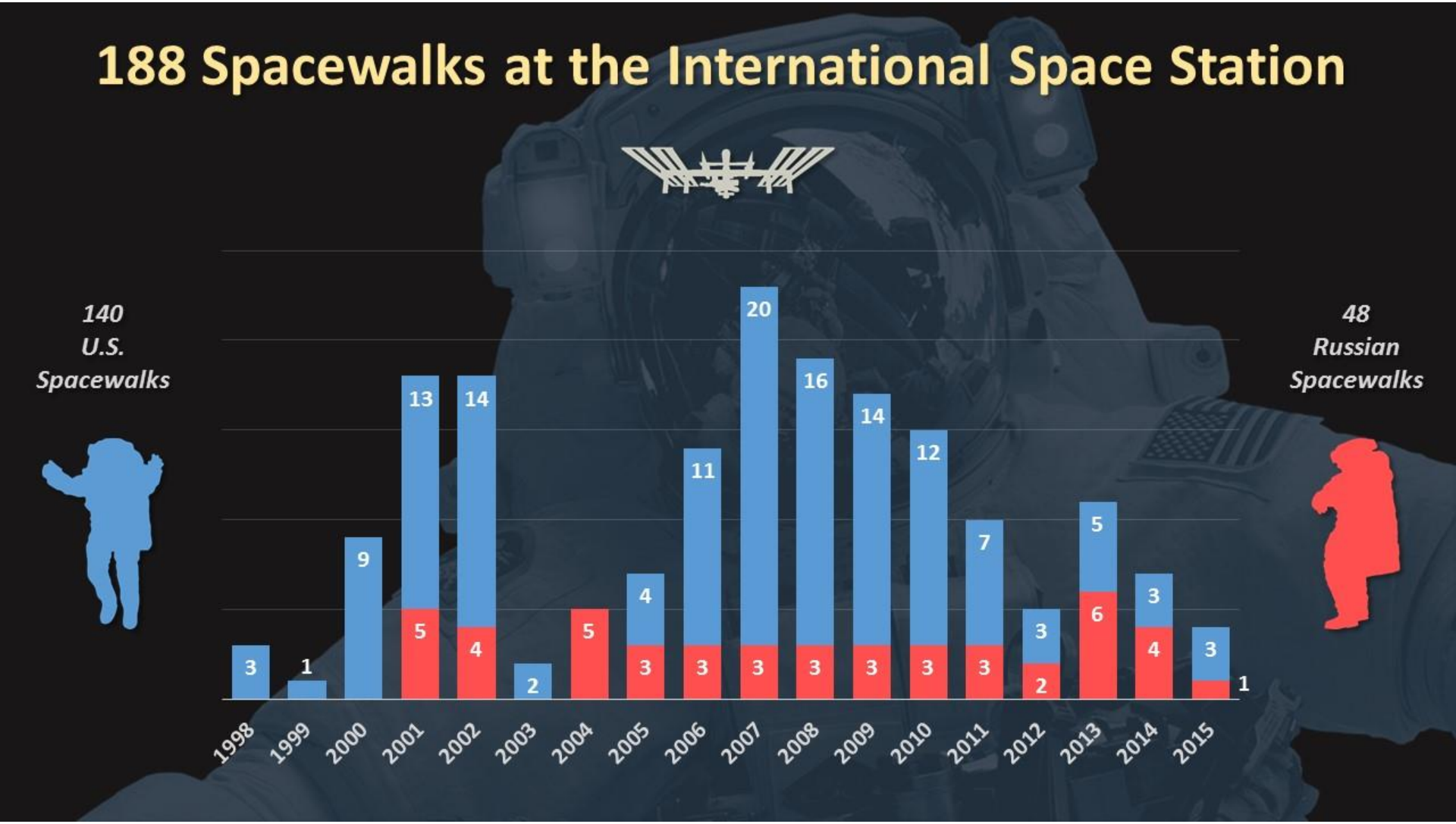
Goal:

- 1 CDRA+ Vozdukh (Mode 1-3) = 3.1 – 3.6 mmHg
- Can get to 2.2 – 2.6 mmHg
  - Higher CDRA fan speeds, higher Vozduckh mode, uAmine Swingbed

Other issues:

- Awaiting NORs tank arrival
- Existing barter with Roskosmos to sustain FGB ends in June 2016.

188 Spacewalks at the International Space Station

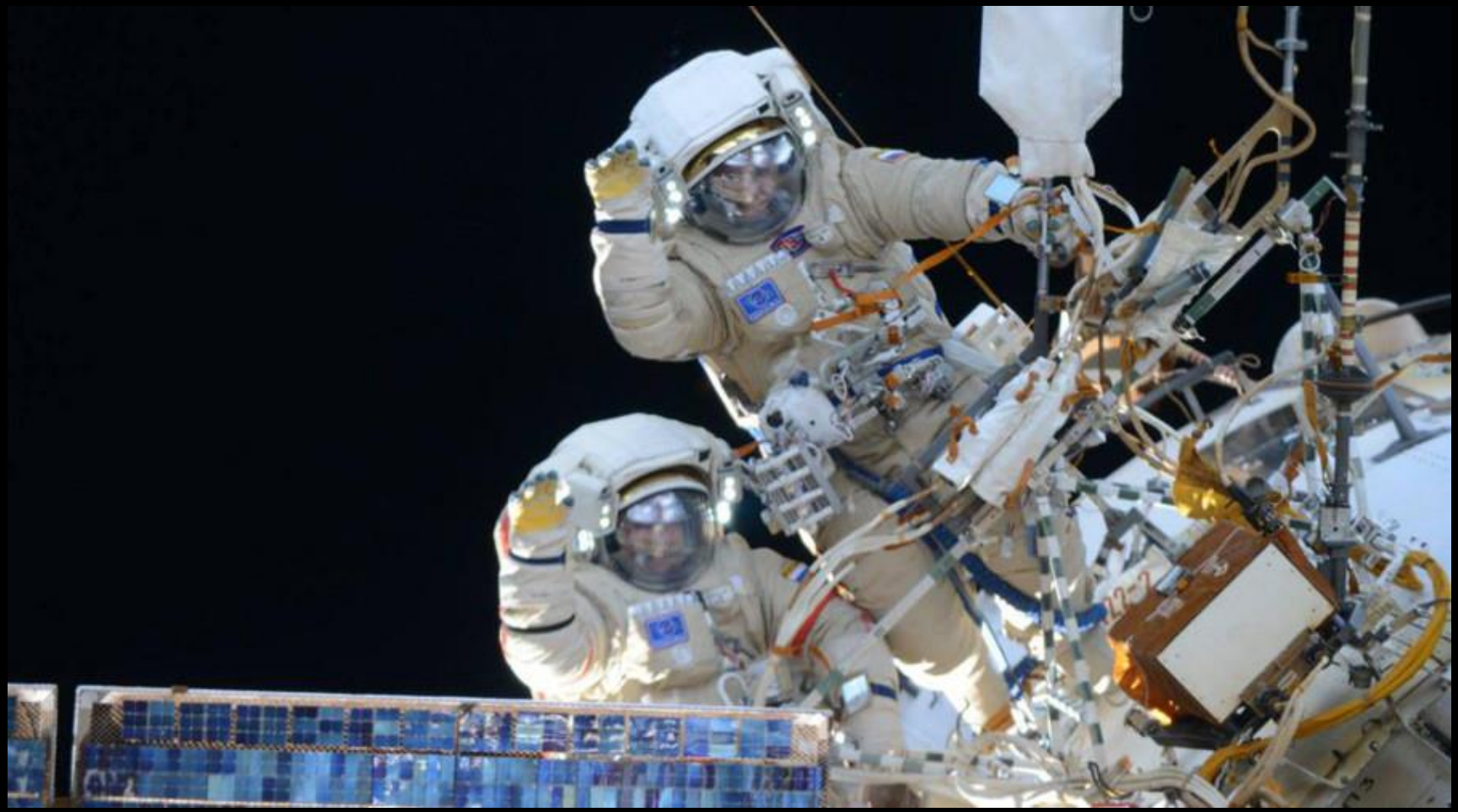


The Past Year

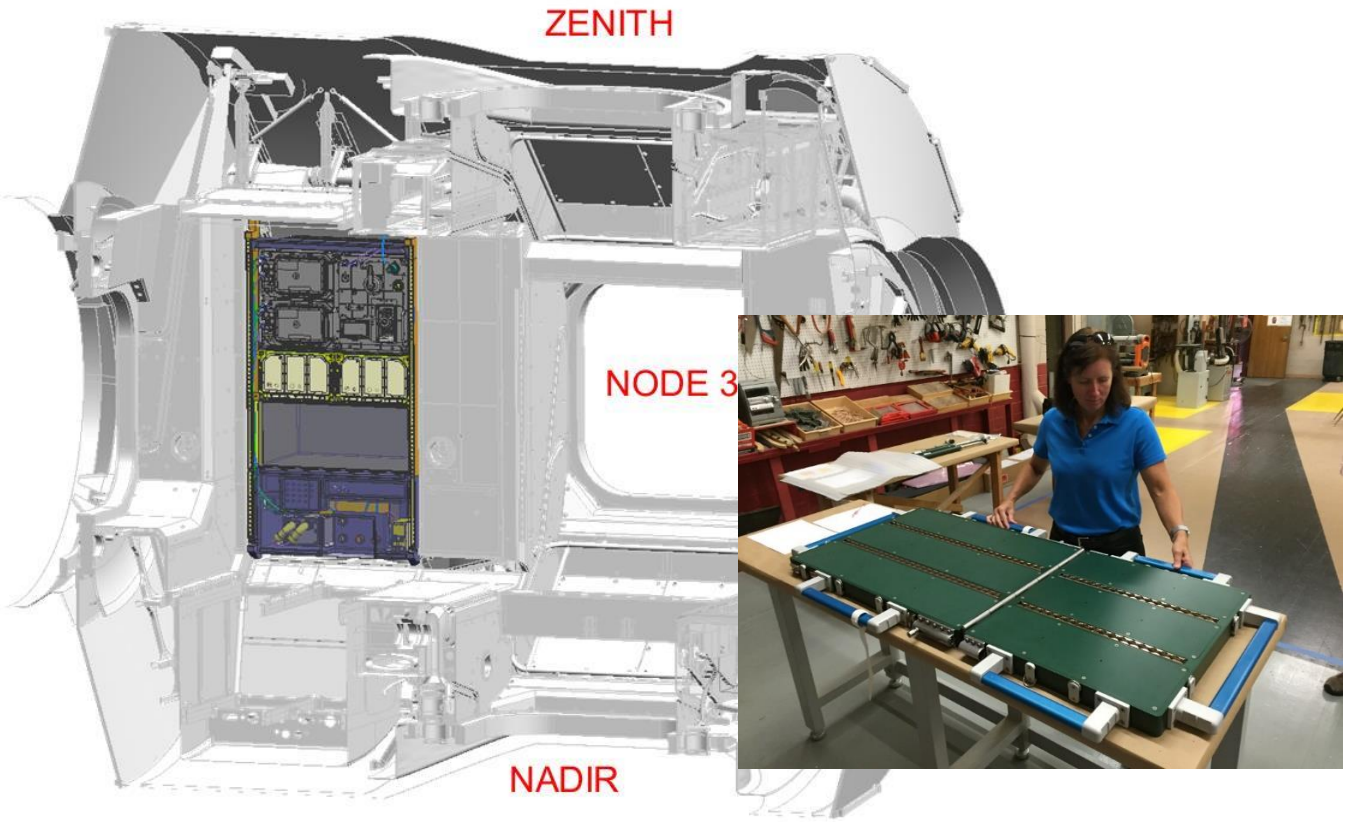
- RS EVA 41 Aug 10 5:31 Padalka Kornienko
- US EVA 31 March 01 5:38 Virts Wilmore
- US EVA 30 February 25 6:43 Wilmore Virts
- US EVA 29 February 21 6:41 Wilmore Virts
- RS EVA 40 October 22 ‘14 3:38 Suraev Samokutayev
- US EVA 28 October 15 ‘14 6:34 Wiseman Wilmore
- US EVA 27 October 07 ‘14 6:13 Wiseman Gerst

EVA

- EMU
  - Life extension
  - Servicing
  - Mishap Investigation Board Results
- US future EVAs
  - RTOC
  - IDA installations
  - S4 1A/3A Battery installations
  - Contingency: Big 13

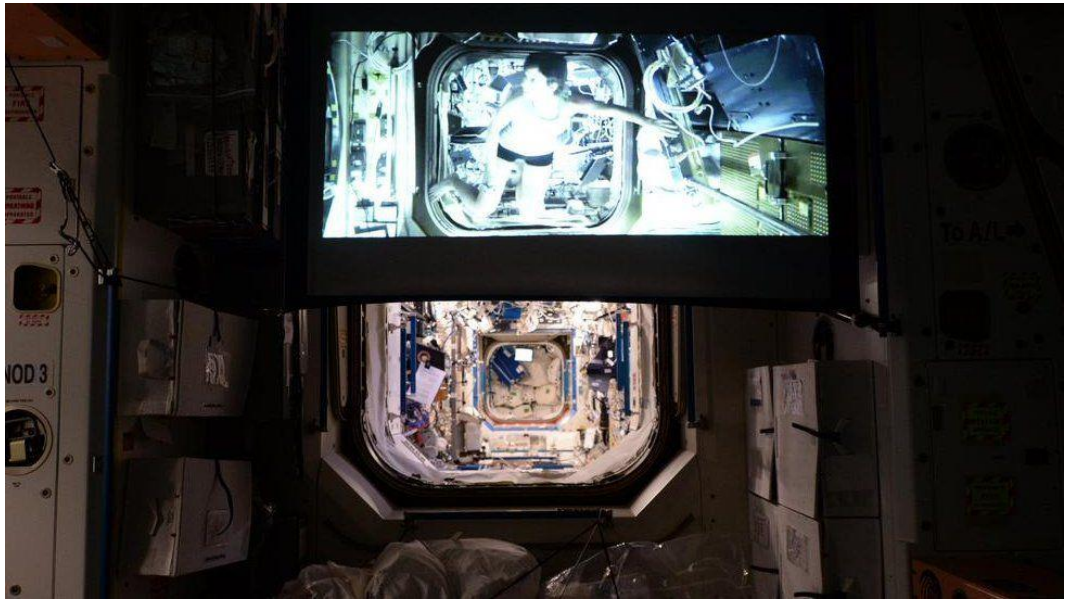


New Galley and table in NOD1P4



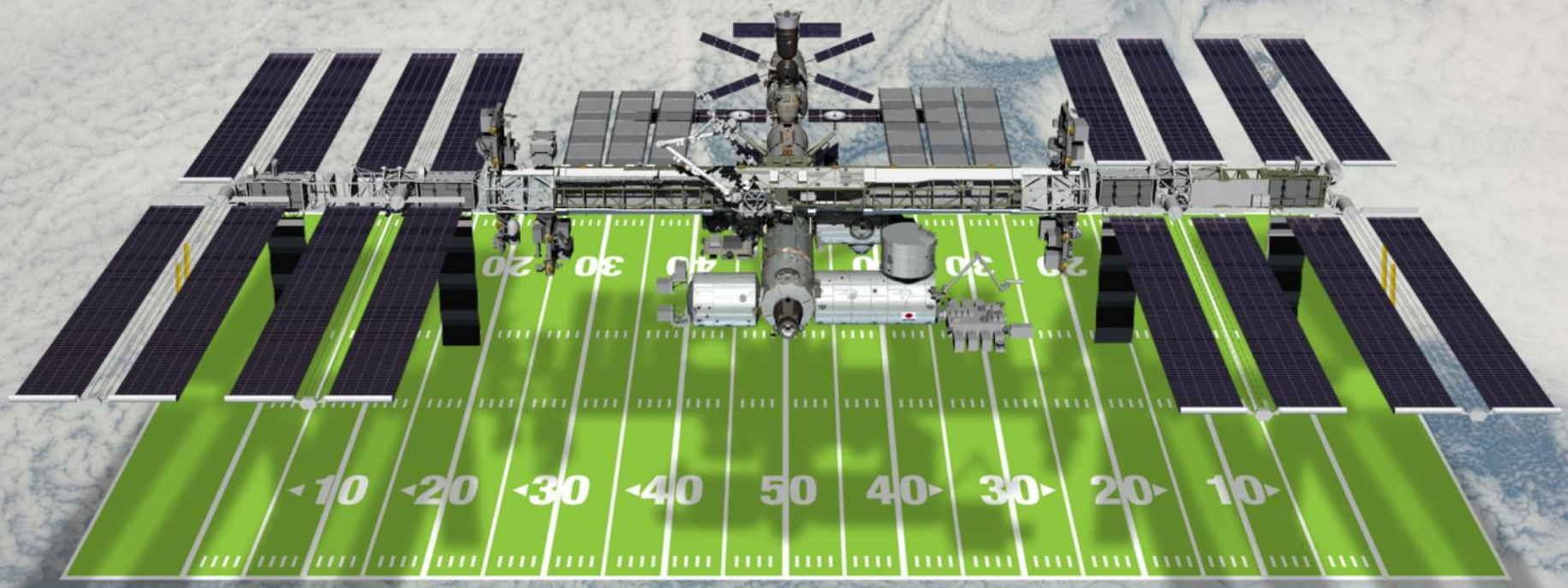
Operations and Habitability improvements

Tablets
IP phone at 6 locations
Hololens
New lights
Projector/screen
Workload: Task listing and reserve science.



International Space Station

By the Numbers

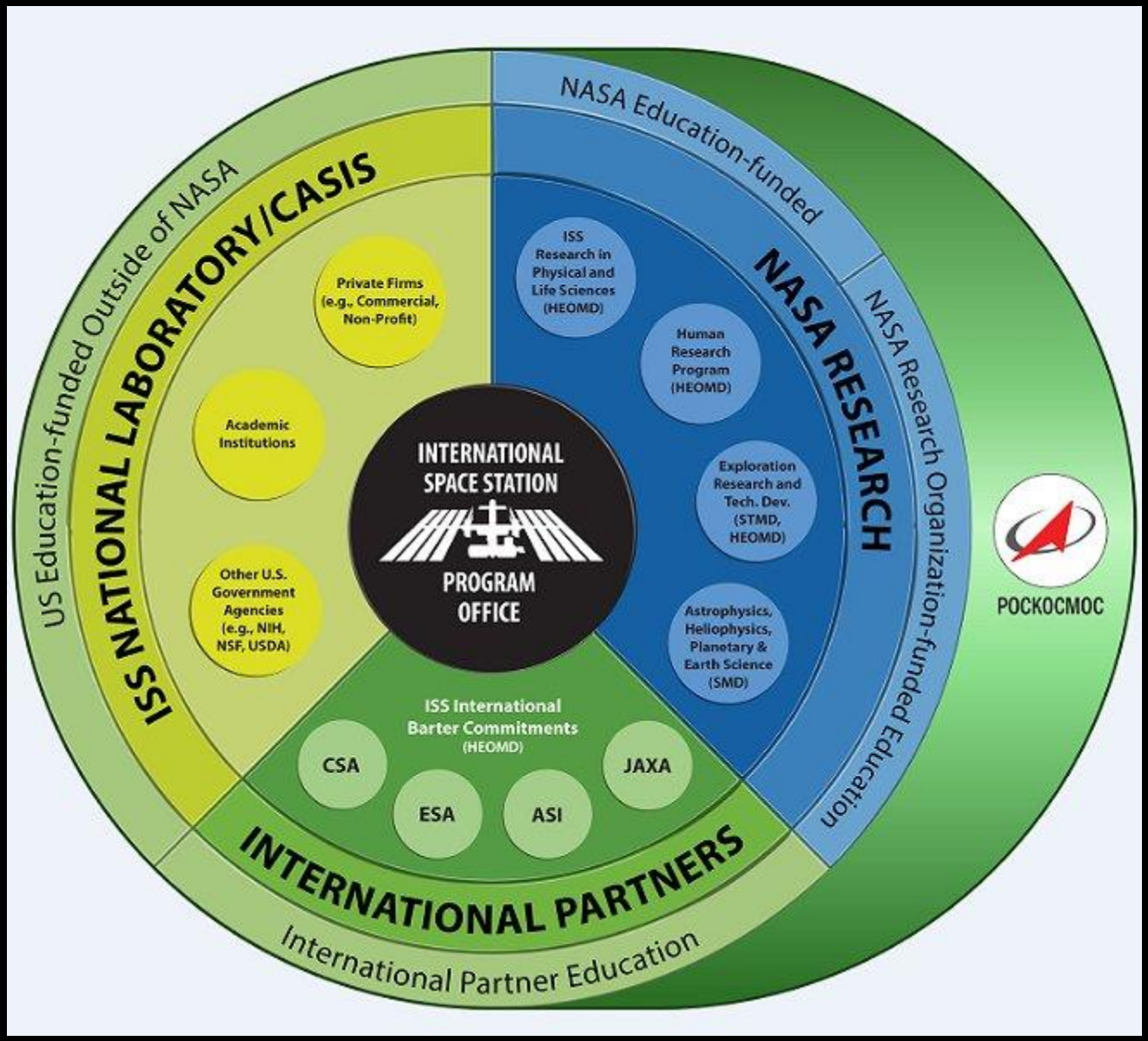


Spacecraft Mass: 924,739 lb

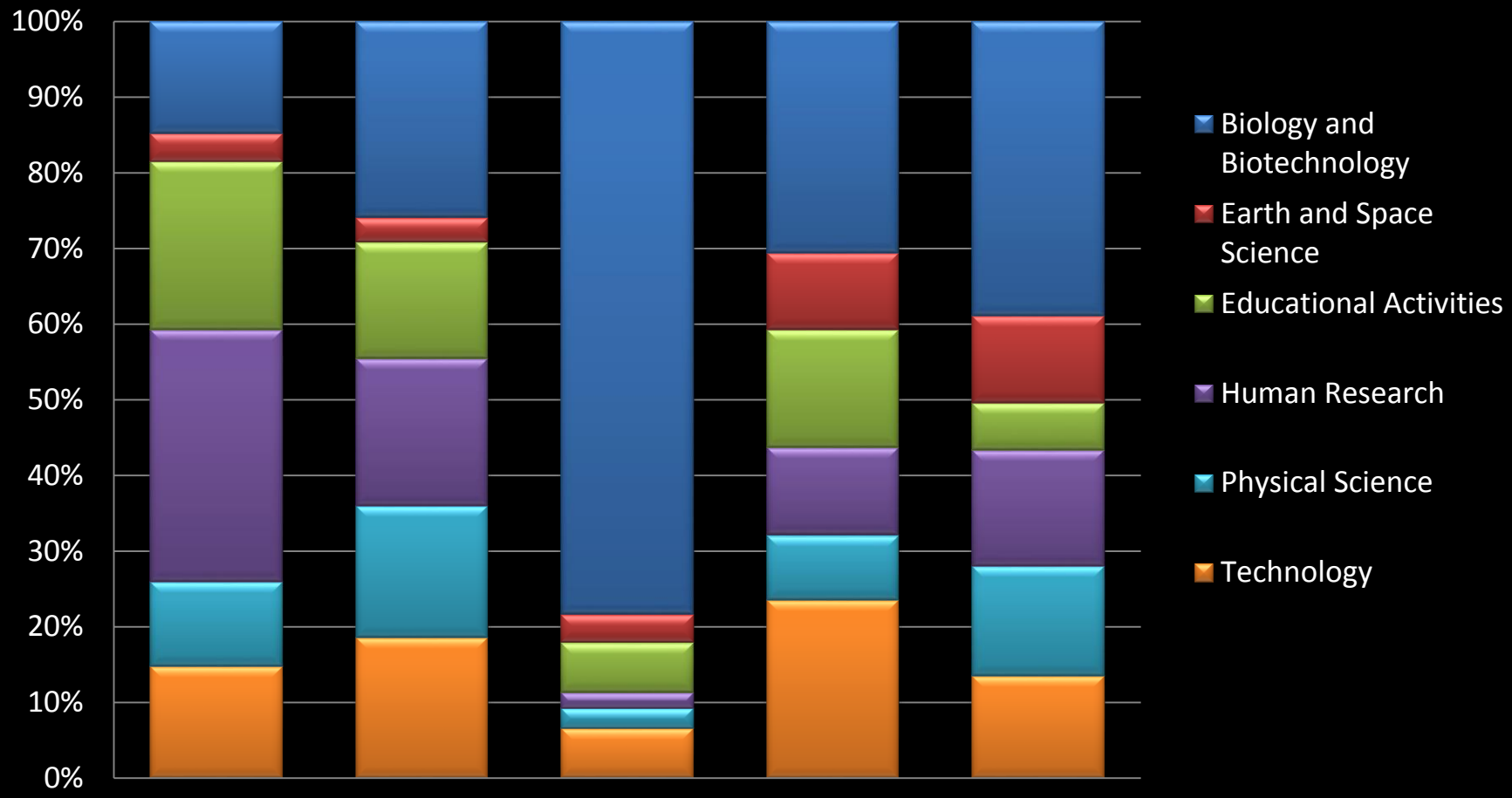
Spacecraft Pressurized Volume: 32,333 ft^3

Velocity: 17,500 mph

Science Capability: Laboratories from four international space agencies conducting research from US, Europe, Japan, Russia and Canada


US Education-funded Outside of NASA
ISS NATIONAL LABORATORY/CASIS
Private Firms (e.g., Commercial, Non-Profit)
Academic Institutions
Other U.S. Government Agencies (e.g., NIH, NSF, USDA)
NASA Education-funded
NASA RESEARCH
ISS Research in Physical and Life Sciences (HEOMD)
Human Research Program (HEOMD)
Exploration Research and Tech. Dev. (STMD, HEOMD)
Astrophysics, Heliophysics, Planetary & Earth Science (SMD)
NASA Research Organization-funded Education
INTERNATIONAL SPACE STATION
PROGRAM OFFICE
ISS International Barter Commitments (HEOMD)
CSA
ESA
ASI
JAXA
INTERNATIONAL PARTNERS
International Partner Education
POCKOCMOC

Research Discipline of ISS Investigations By Partner Agency: Expeditions 0-40 December 1998 - September 2014

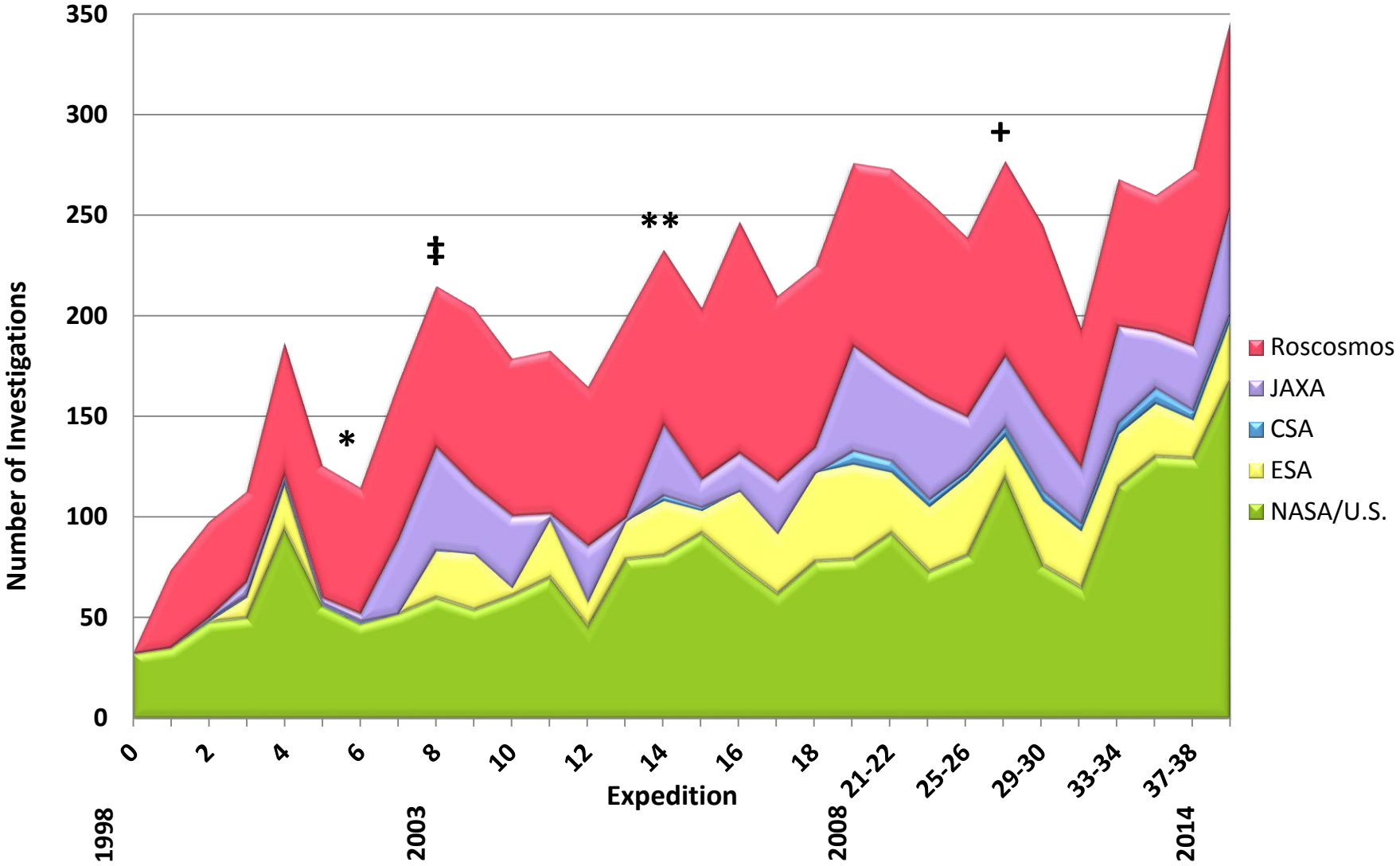


ISS Utilization Statistics: Expeditions 0-40 Dec 1998 – Sept 2014

	ISS Expeditions 37/38	ISS Expeditions 39/40	ISS Expeditions 0-40
Number of Investigations	273	346	1762
New Investigations	50	109	--
Completed/Permanent Investigations	41	85	1233
Number of Investigators with Research on the ISS	649	749	2471
Countries with ISS Investigations/Education Activities	48	38	83

Number of Investigators with Research on the ISS and Countries per Expedition
December 1998 - September 2014

ISS Utilization Statistics
Expeditions 0-40

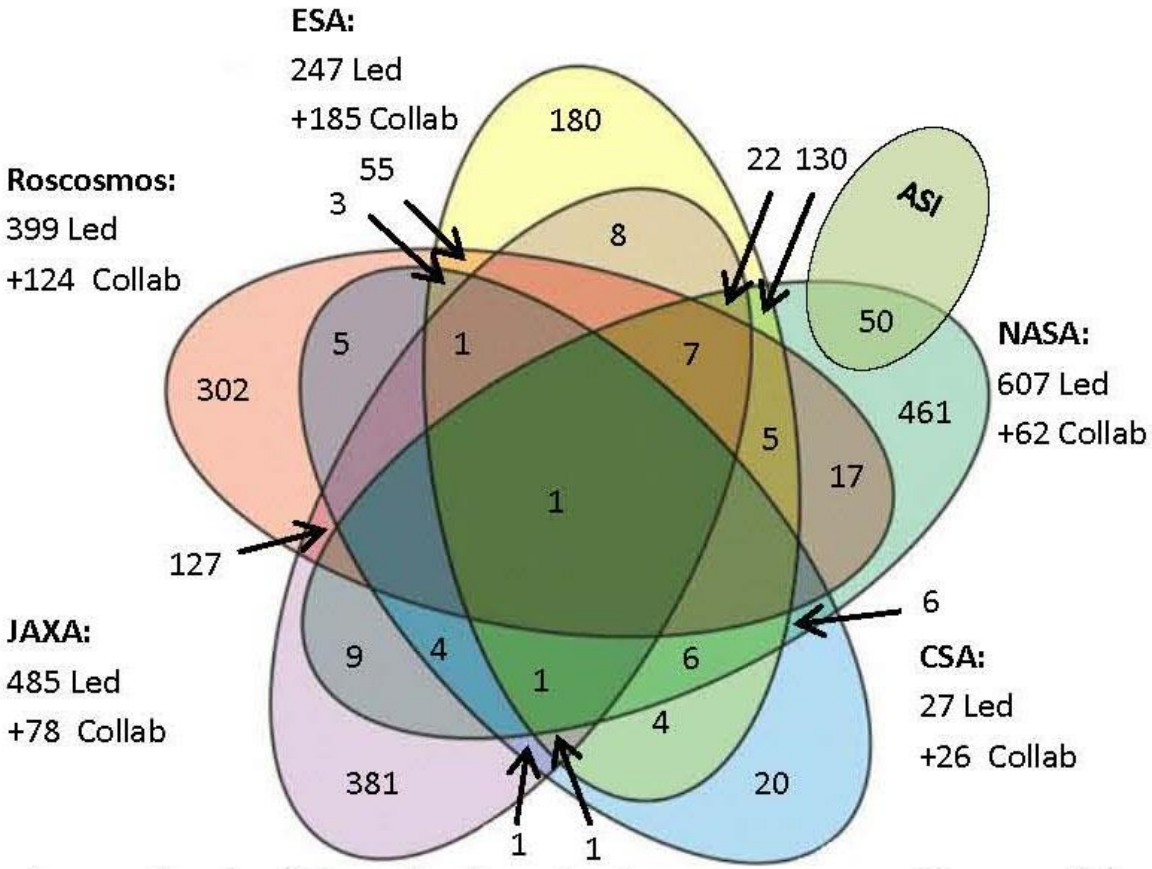


* Post *Columbia* ‡ Japanese investigation surge in protein crystal growth ** Shuttle Return to Flight + Final Shuttle Flight

ISS Benefits Increased Through International Collaboration

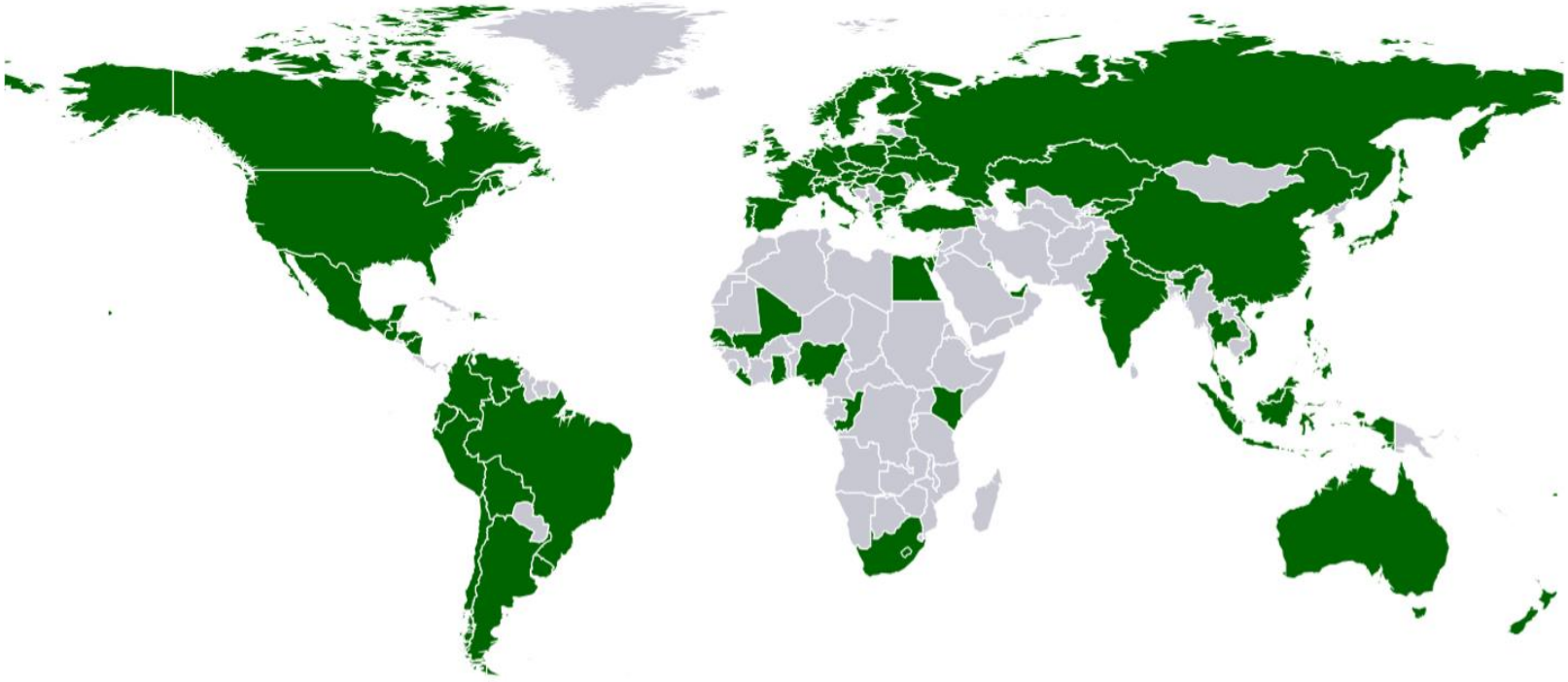
Expeditions 0-40

December 1998 – September 2014



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.

ISS Utilization Statistics
Expeditions 0-40



83 countries and areas

Research Resources

Research Resources	ISS Expeditions 37/38	ISS Expeditions 39/40	ISS Expeditions 0-40
Upmass	739.5 kg	2141.0 kg	52,742.3 kg
Downmass	37.9 kg	762.5 kg	12,743.7 kg
Crew Time	1710.5 hrs	1897.5 hrs	24,764.8 hrs

ISS Utilization Statistics: Future Expeditions

	ISS Expeditions 41/42	ISS Expeditions 43/44*	ISS Expeditions 41-44*
Number of Investigations	364	238	441
New Investigations	107	78	186
Number of Investigators with Research on the ISS	896	789	1052
Countries with ISS Investigations/Education Activities	35	37	37

* Roscosmos data is preliminary

- About 1750 science experiments have been conducted by researchers in 83 countries and areas.
- During the current expedition, about 200 experiments are occurring on-board.
- Categories of space station research include: biology and biotechnology, Earth and space science, human research, physical sciences, education and technology demonstration.

As of August 12, 2015

- From standpoint for formal research, since March 2001 to date, there have been 14 years 5 months continuously crewed research operations.
- 29 research racks onboard; 15 external payloads attached (not counting AMS).
- Number of investigations, Expeditions 1-42: 1922

Trends:

- **More US-Russian collaboration**
  - **SPHERES**
  - **Rodent research**
  - **Fluid Shifts**
- **More commercial vendors**
- **Increased complexity**

Operations:

- **More tablet use**
- **4 channels of communications**
- **“Reserve Science”**
- **Hololens use for remote instruction**


Dad

Biology and Biotechnology

Rodent Research - Studies on model organisms are informing new pharmaceuticals for bone loss and other maladies.

Rodent Research (RR) Background

Successful inaugural mission (RR1) completed last fall on SpX-4:

- 10 National Lab (NL) animals and 10 NASA animals were flown.
- Validation of hardware, dissection procedures, kits, preservation methods, etc.

The RR2 mission was carried out on SpX-6 (Novartis):

- 20 NL-only animals were flown. On-orbit ops now complete!

The RR3 mission will be carried out on SpX-8 (Eli Lilly):

- SpX-8 will carry 20 NL-only animals.

The RR4 mission will be carried out on SpX-10 (Department of Defense):

- SpX-10 will carry 40 NL-only animals.

The RR5 mission is being planned for SpX-12 (University of California, Los Angeles):

- SpX-12 will carry 40 NL-only animals. Currently being defined.

Growing Vegetables - Understanding the effects of gravity on plant life is essential in preparation for future exploration missions. Provide unique insight to how plants can adapt to challenging environments on earth, including lands that are recovering from extreme environmental assault and how other plants, such as crops, may respond to rising levels of CO_2 in the atmosphere

Plant Growth - Technology developed for a space station greenhouse led to a new tool for eliminating airborne pathogens (like Anthrax) on Earth.

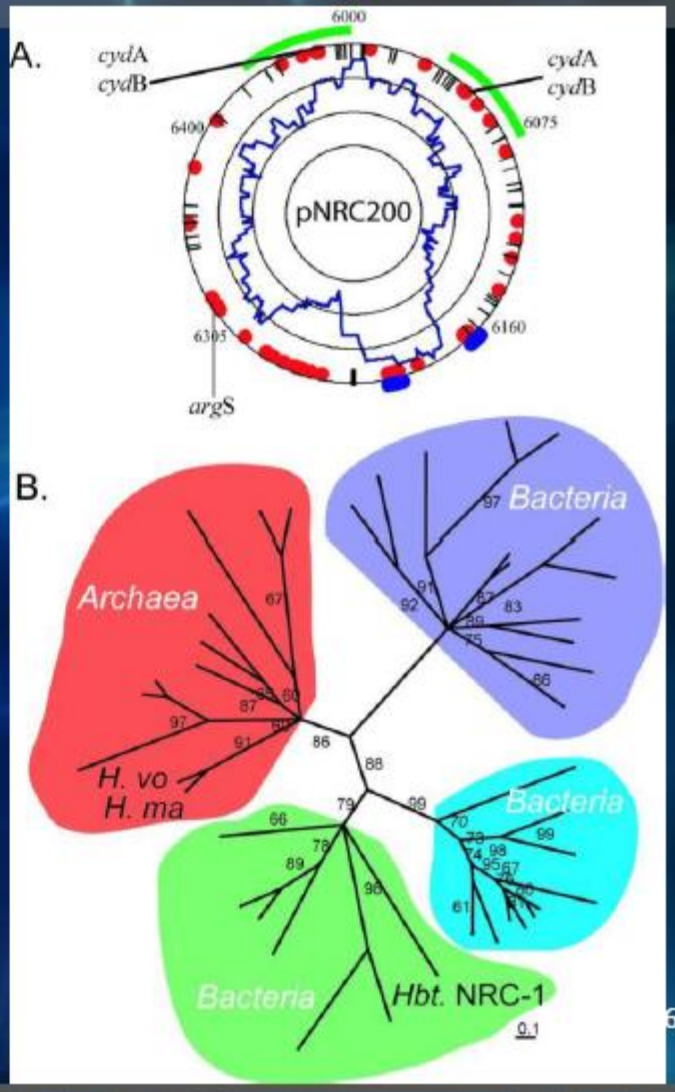
Microbial Virulence – Studies done during assembly of the ***International Space Station*** identified a new pathway that Salmonella bacteria use in becoming more able to cause disease. This information is now being evaluating in other bacteria and leveraged for the development of new vaccines.

3 modes of response

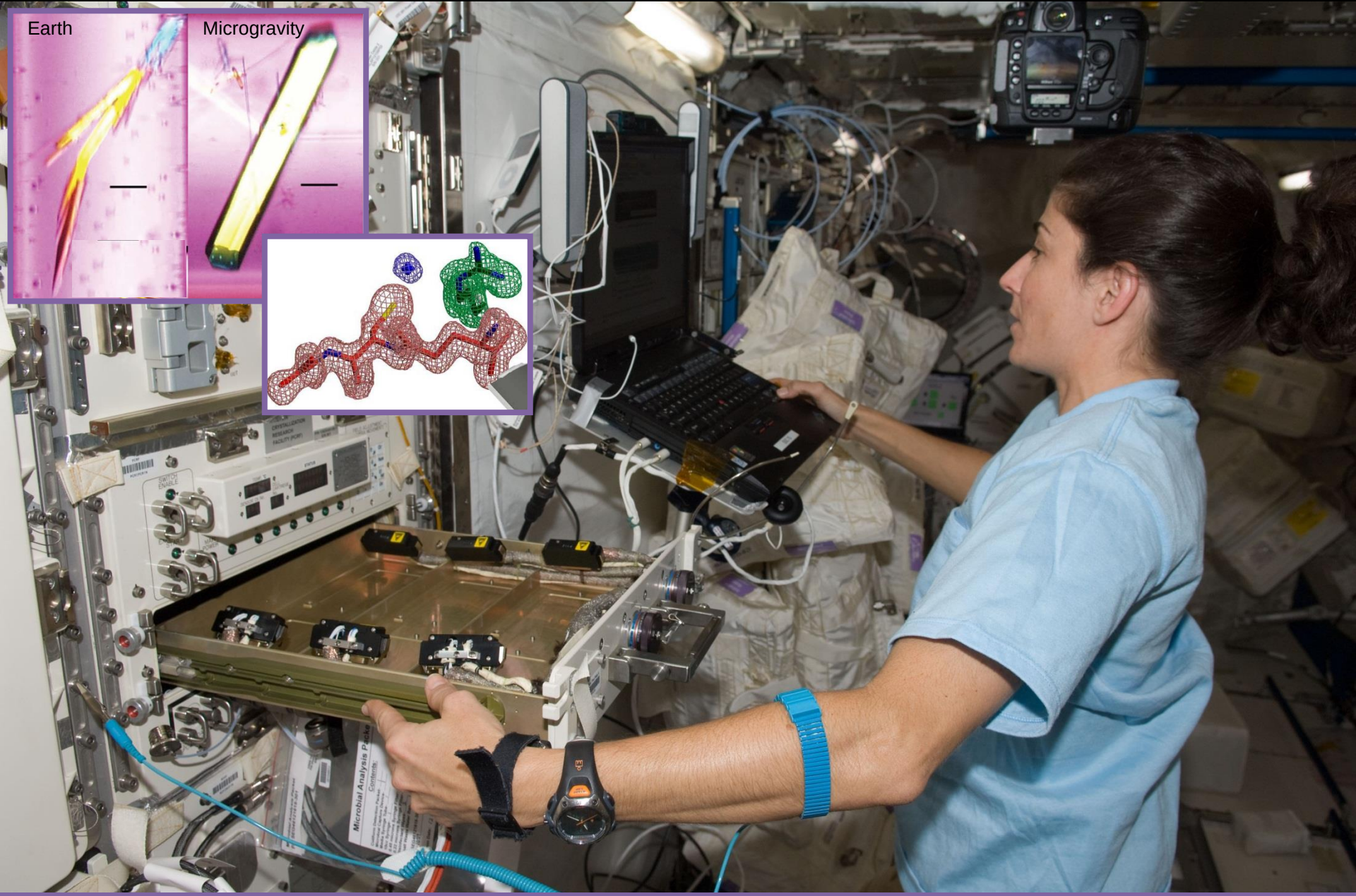
More virulent

Multiply more rapidly

No change

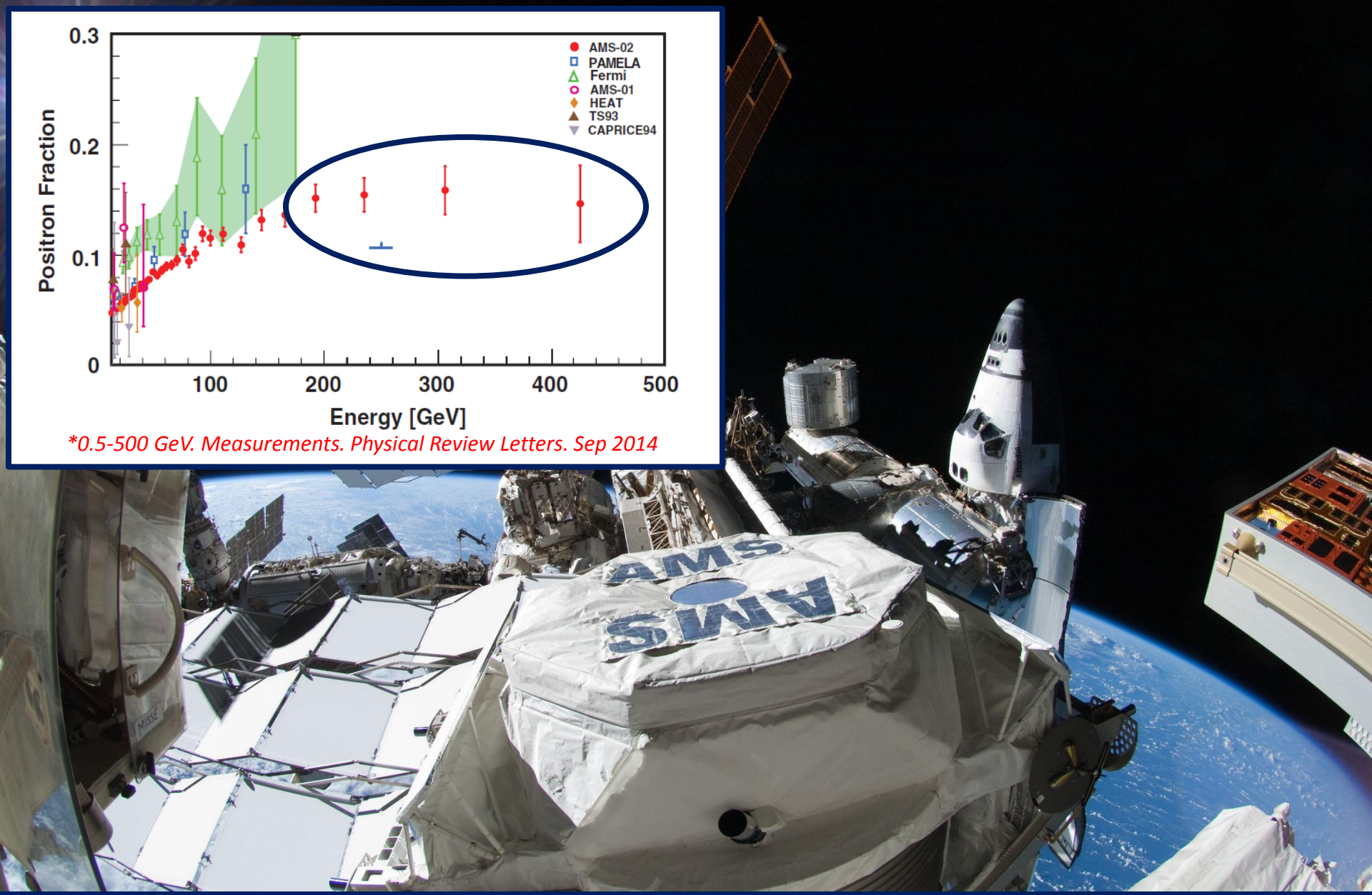


Julie A. Robinson, ISS Program Scientist



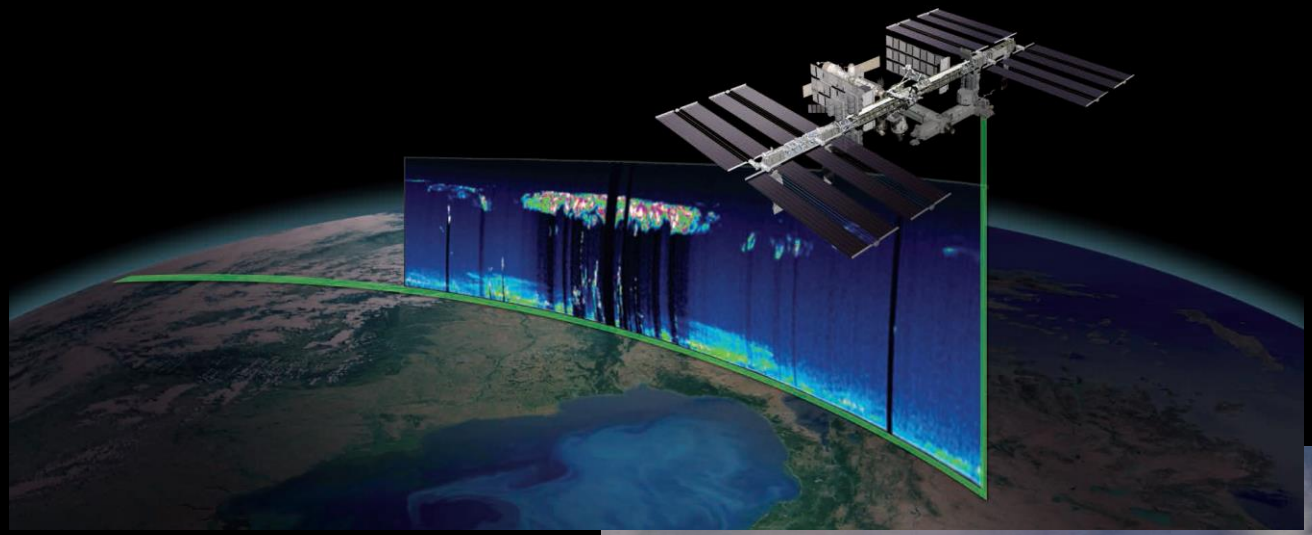
Protein Crystal Growth - Improved structure of biological proteins grown in microgravity can lead to better pharmaceuticals on Earth.

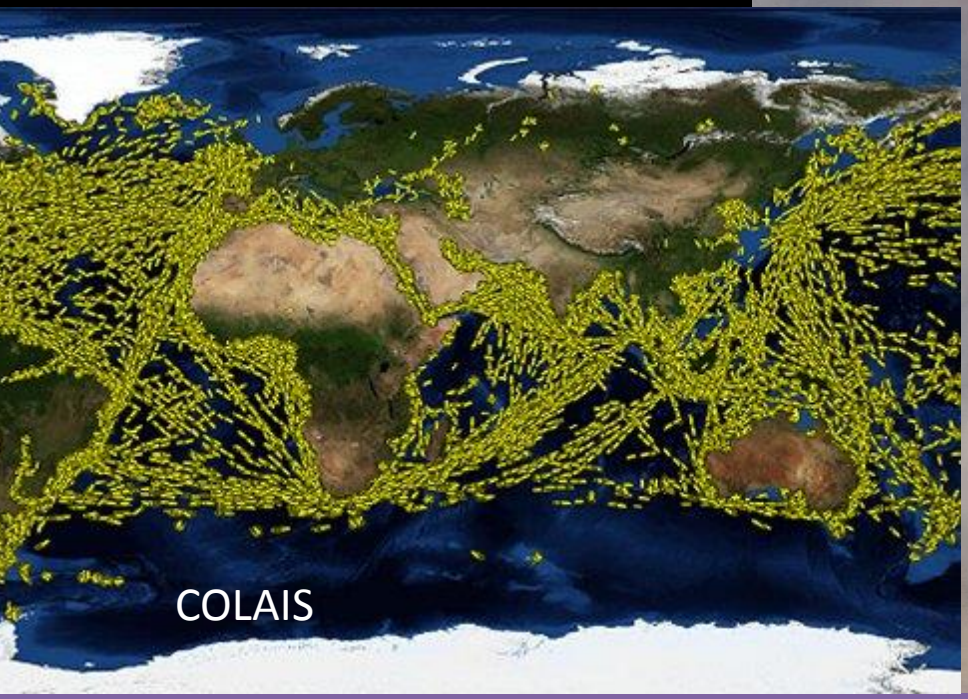
Earth and Space Science



*0.5-500 GeV. Measurements. Physical Review Letters. Sep 2014

Astrophysics – The Alpha Magnetic Spectrometer measures particles in cosmic rays which can help us understand the formation of the Universe.



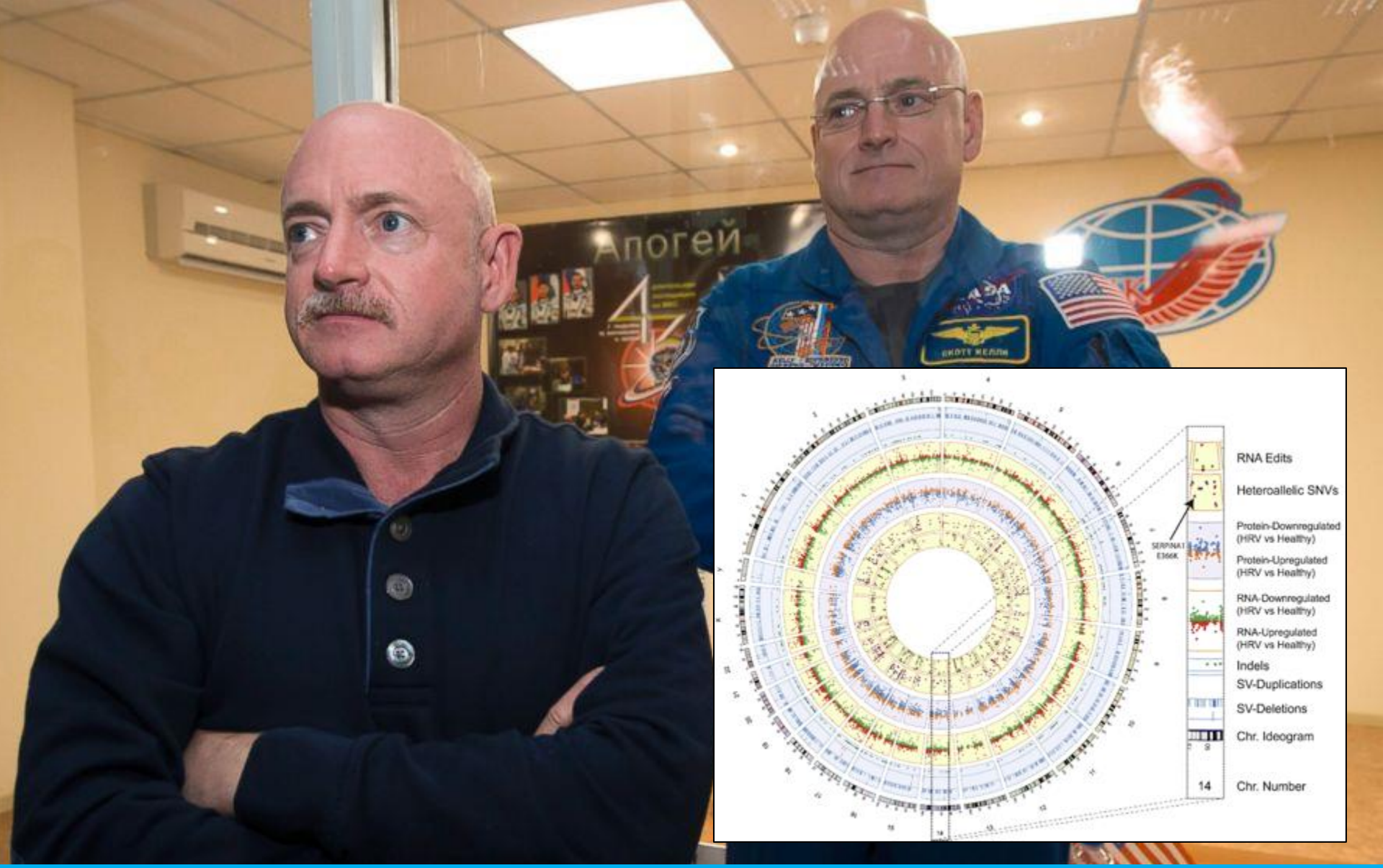


Disaster Response Networks - The space station is a unique vantage point for observing the Earth with both hands-on and automated equipment.

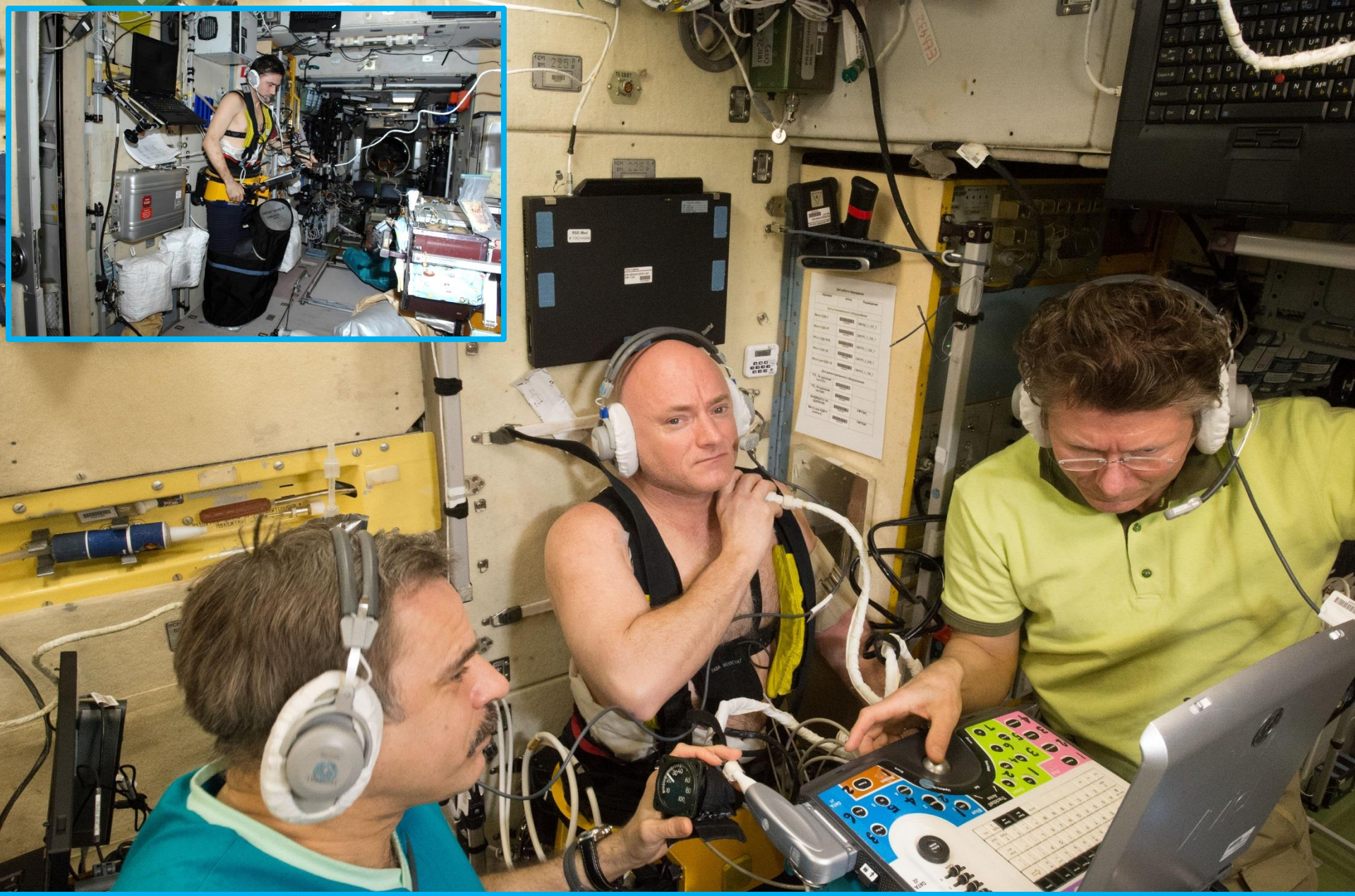

Human Research

KELLY · КОРНИЕНКО
YEAR IN SPACE - ГОД В КОСМОСЕ
ISS 43 • 44 • 45 • 46 МКС

One Year Mission

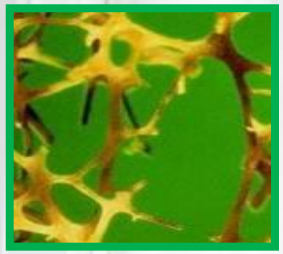


Twin Study – Using integrated human -omic analyses to better understand the biomolecular responses to the physical, physiological, and environmental stressors associated with spaceflight.



Fluid Shifts – To better understand human physiology, and determine role, if any, in Vision Impairment / Intracranial Pressure (VIIP) syndrome.

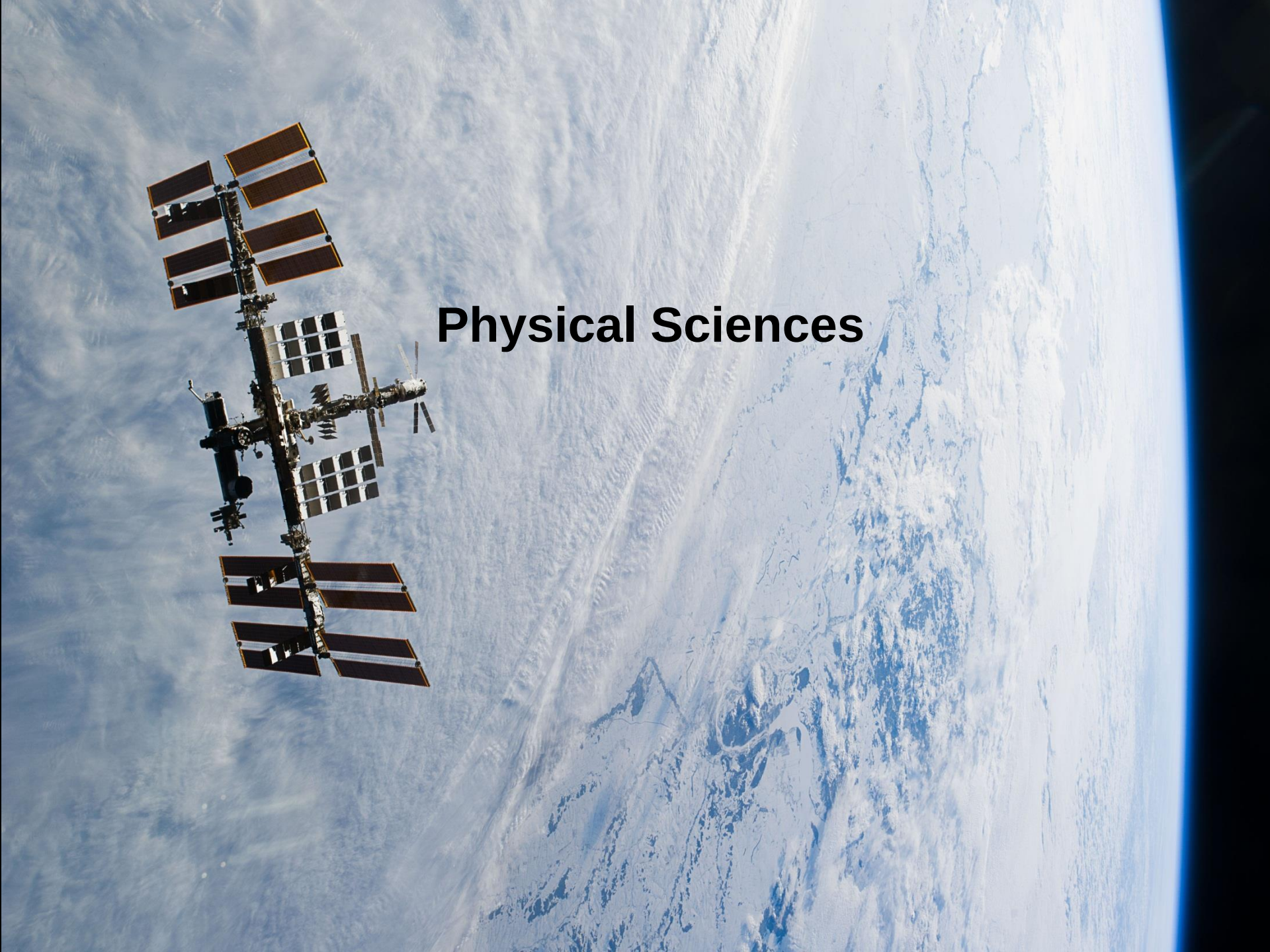
Normal Bone



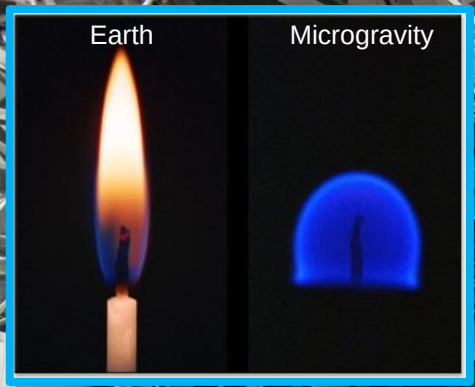
Osteoporotic Bone

Preventing Bone Loss - High intensity resistive exercise, along with adequate calorie intake and Vitamin D has reduced bone loss from up to -2% to -0.5%/mo

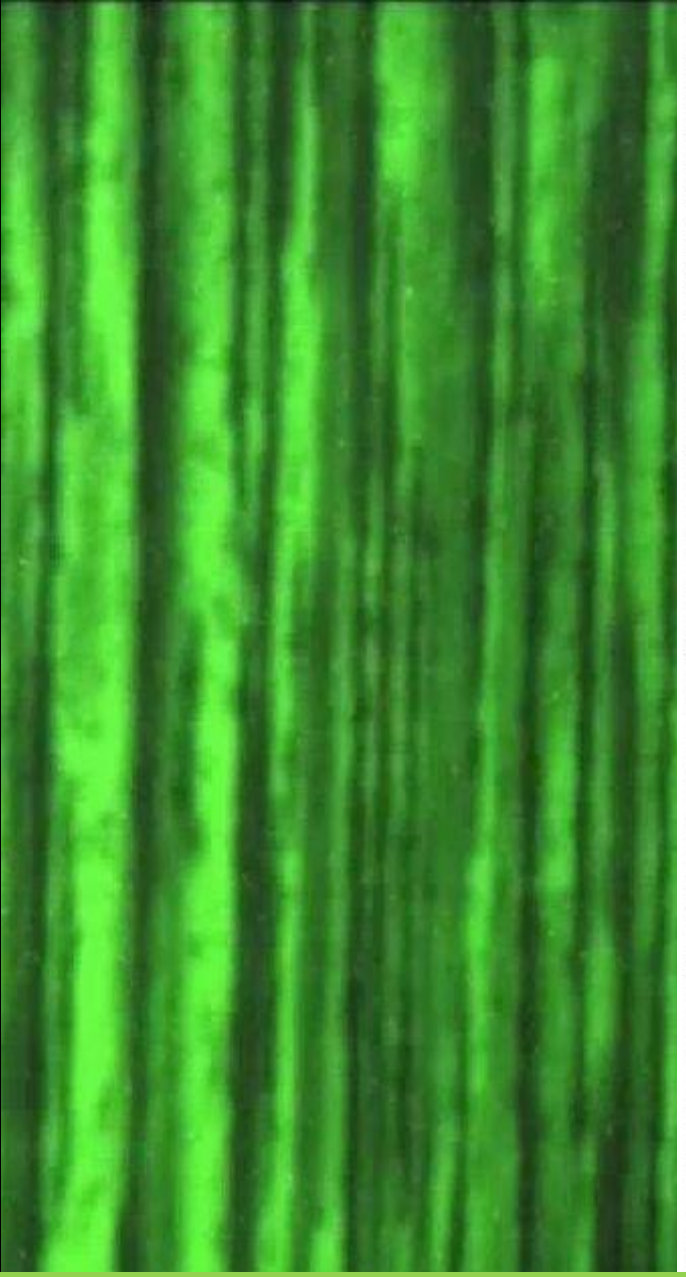
Vision Impairment - Some astronauts' vision deteriorates during spaceflight; this is an active area of research on the space station.

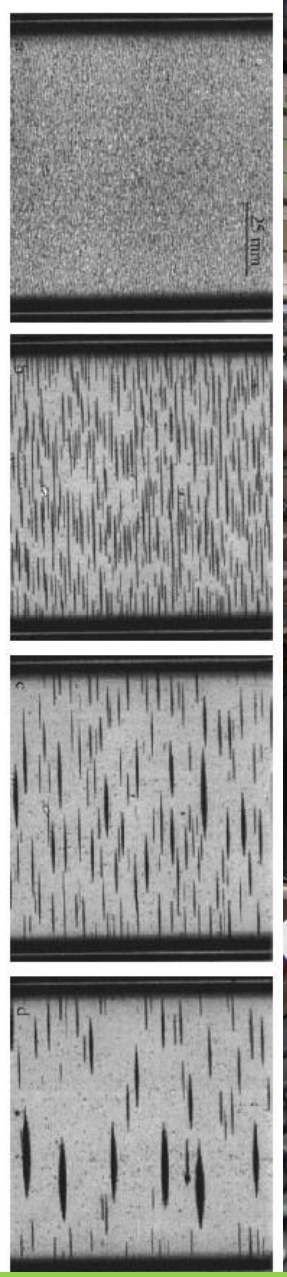

Physical Sciences

Fluid Behavior - Studies on liquid movement and surface tension are informing better spacecraft tanks and portable medical diagnostics on Earth.



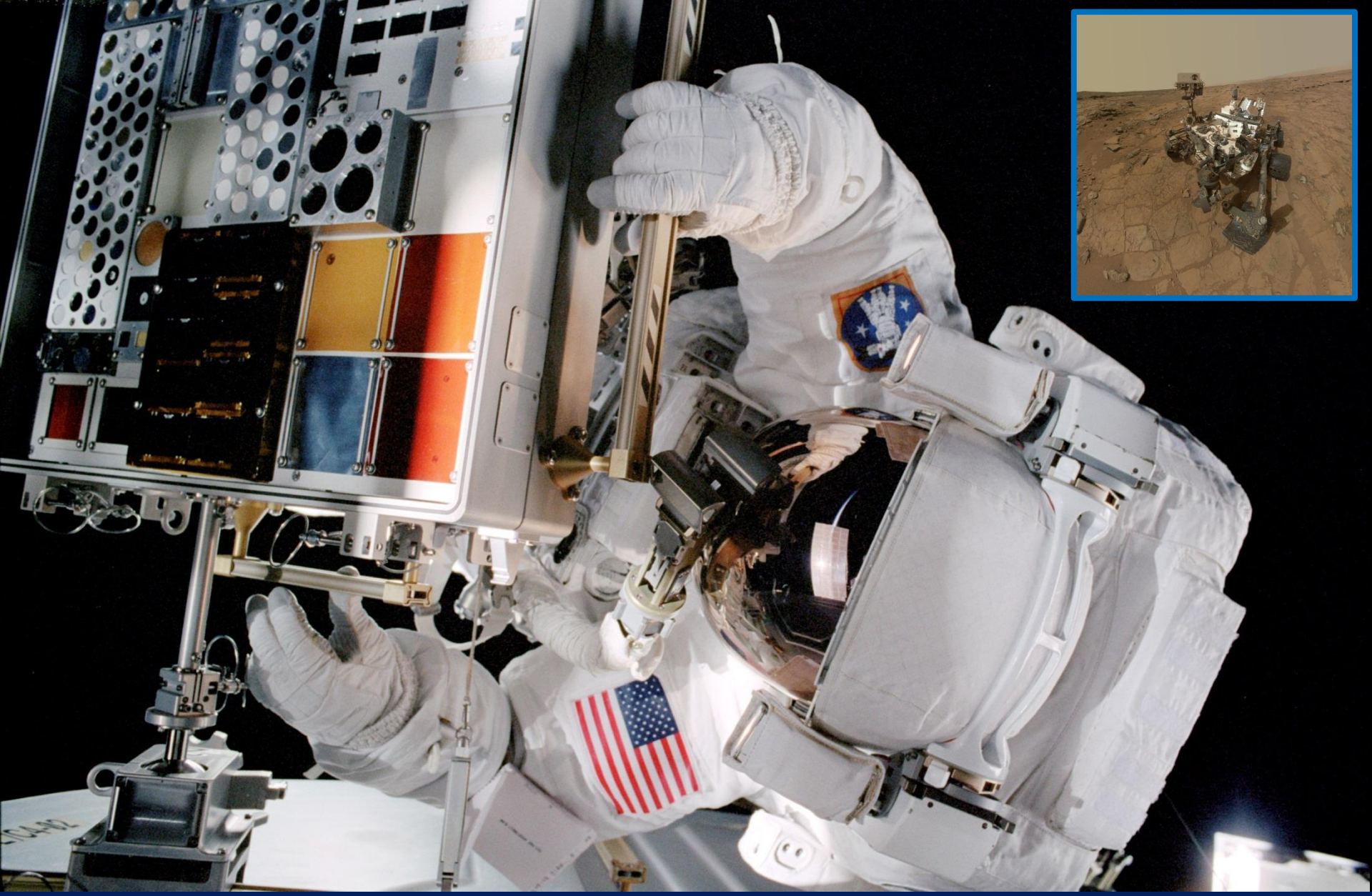
Combustion - Studies on flame behavior and fuel mixtures on the space station may lead to improved fuel efficiency and reduced pollution on Earth.





Nanotechnology - Smart fluids change stiffness in response to magnetic fields and are already used in buildings and bridges in earthquake-prone regions.

Technology



Materials Testing - An electrically conductive coating was validated outside the space station; it now protects Mars Curiosity's power unit from static electricity.

Satellite Control - SPHERES demonstrate algorithms for autonomous formation flying, rendezvous and docking.

Robotic Surgery - The development of robotic arms for space missions has led to computer-assisted devices specifically designed for neurosurgery.

- Beam
- Bios Cell Science
- Cold Atom Lab
- External site demand increased

CubeSat deploys - the International Space Station for a variety of customers.

International Space Station
Research Benefit Examples

- **Discoveries**
  - MAXI imaged a black hole swallowing a star (Nature)
  - Microbial virulence (PNAS)
  - Vision impacts and intracranial pressure (Ophthalmology)
- **Results with Potential Earth Benefits**
  - Candidate vaccines for salmonella and MRSA
  - Candidate treatment for prostate cancer
  - Candidate treatment for Duchenne Muscular Dystrophy

- **Technology Spinoffs**
  - Robotic assist for neurosurgery (J. Neurosurgery)
  - Remote-guided ultrasound for medical care in remote regions
  - Air filtration devices
- **NASA Exploration Mission**
  - Life support equipment reliability and sustaining
  - Bone health (J. Bone and Mineral Research)
  - Models for atomic oxygen erosion in orbit

Benefits for Humanity Videos

- Robotic Surgery
  - https://youtu.be/LIWSyyT3w98
- Protein Crystal Growth
  - https://youtu.be/1jEx4Q_nBW8
- Remote Medicine
  - https://youtu.be/GhHe3oiLCo4
- Clean Drinking Water
  - https://youtu.be/DayWXWbVW4g
- Education
  - https://youtu.be/yzN9jSDKR8c
- Ship Tracking
  - https://youtu.be/TrsKZma-LTk
- Cooperation with EPA
  - https://youtu.be/w6XumQvbKag

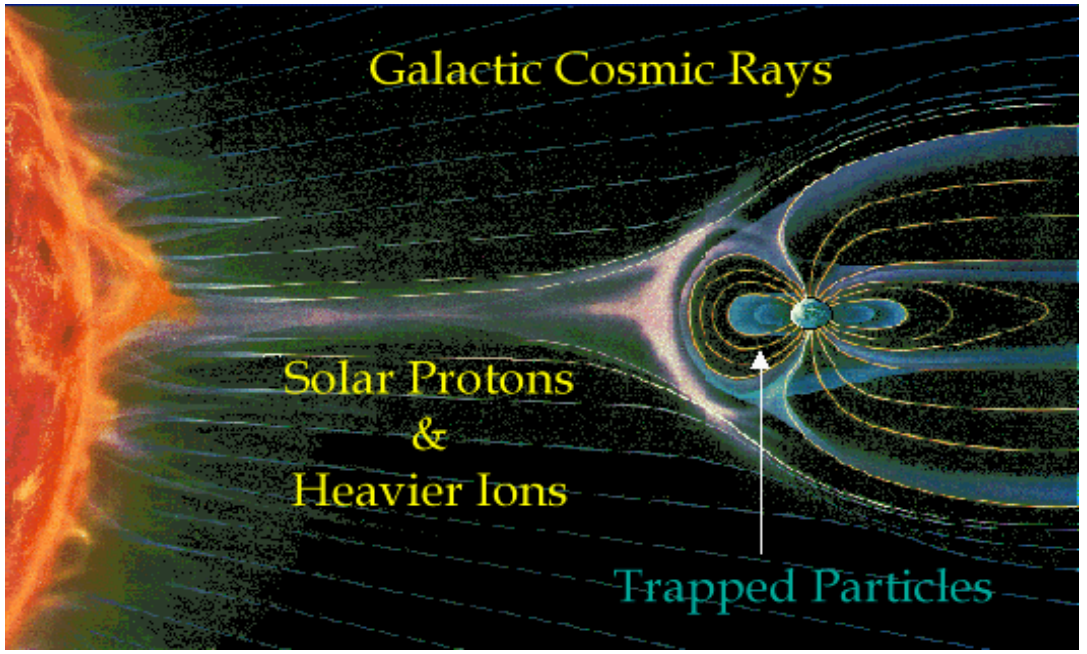

44
КОРНИЕНКО ПАДАЛКА KELLY 油井 КОНОНЕНКО LINDGREN

Pervasive Physical Risks

Ionizing Radiation

Astronauts considered radiation workers

Allowed 10x the annual terrestrial occupational exposure limits (age / gender weighted); 10 rem in 6 mo ISS flight possible



Major risk is associated with excess cancer mortality

Age and gender weighted calculation of career limits based on 3% excess mortality from cancer, other effects

Recent findings suggest premature cataracts associated with spaceflight radiation; CNS effects; cardiovascular tissue degeneration

New Hope for Bone and Muscle

Preliminary data very compelling:

Scott M Smith, et al. Benefits for Bone from Resistance Exercise and Nutrition in Long-Duration Spaceflight: Evidence from Biochemistry and Densitometry†

Journal of Bone and Mineral Research e Pub: Date Final Disposition Set April 23, 2012

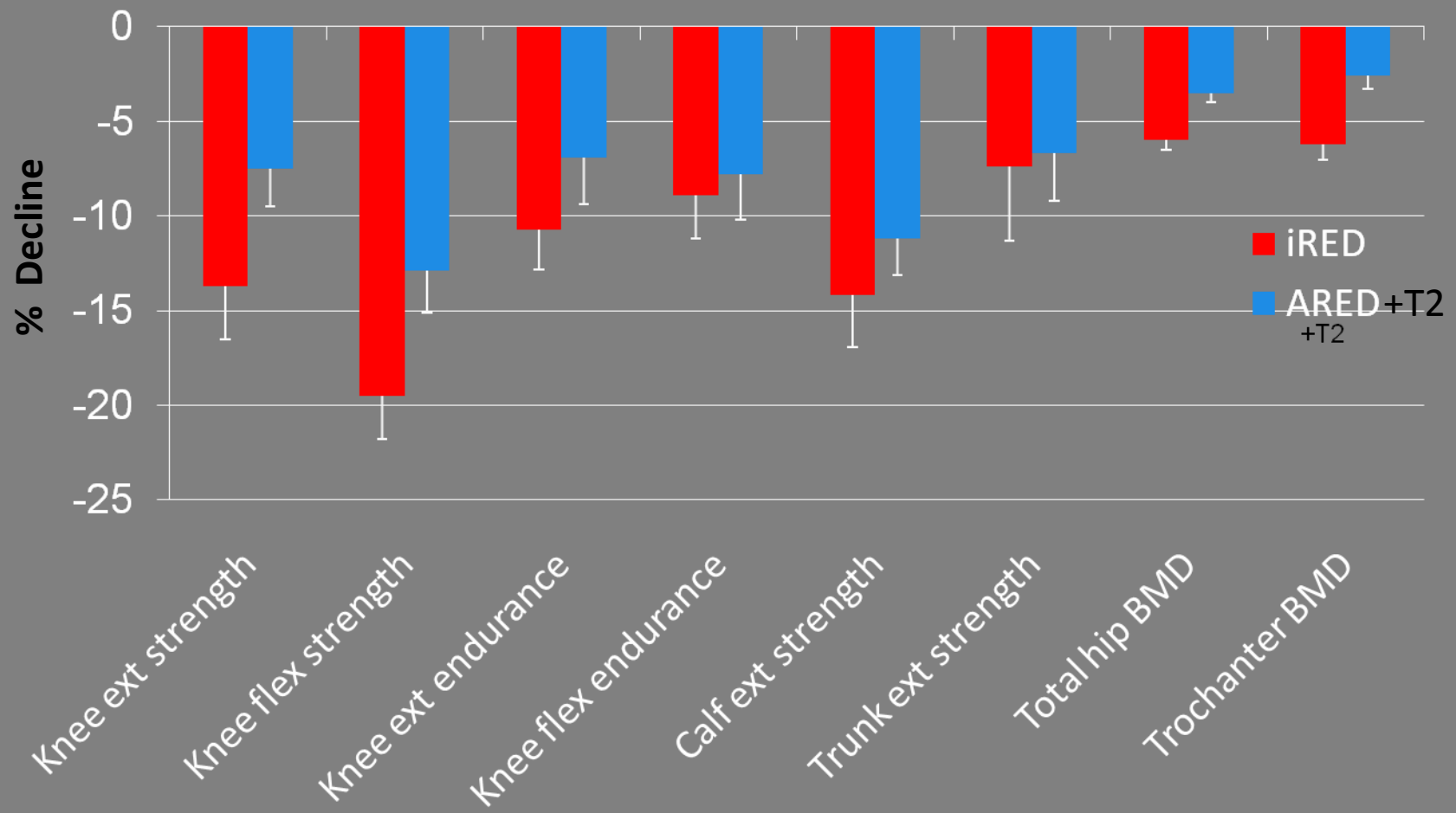
With current nutrition and exercise countermeasures suite on board ISS, especially heavy resistive exercise, for standard 6 month tours, now seeing:

- **Preserved body mass – no change**
- **No change in bone density in pelvis, femoral neck, trochanter,**
- **Increase lean body mass%, decrease body fat%**
- **Bone turnover remains high inflight: increase in inflight markers of bone resorption (N and C Telopeptide, pyridinium crosslinks, deoxypyridinoline, helical peptide)**

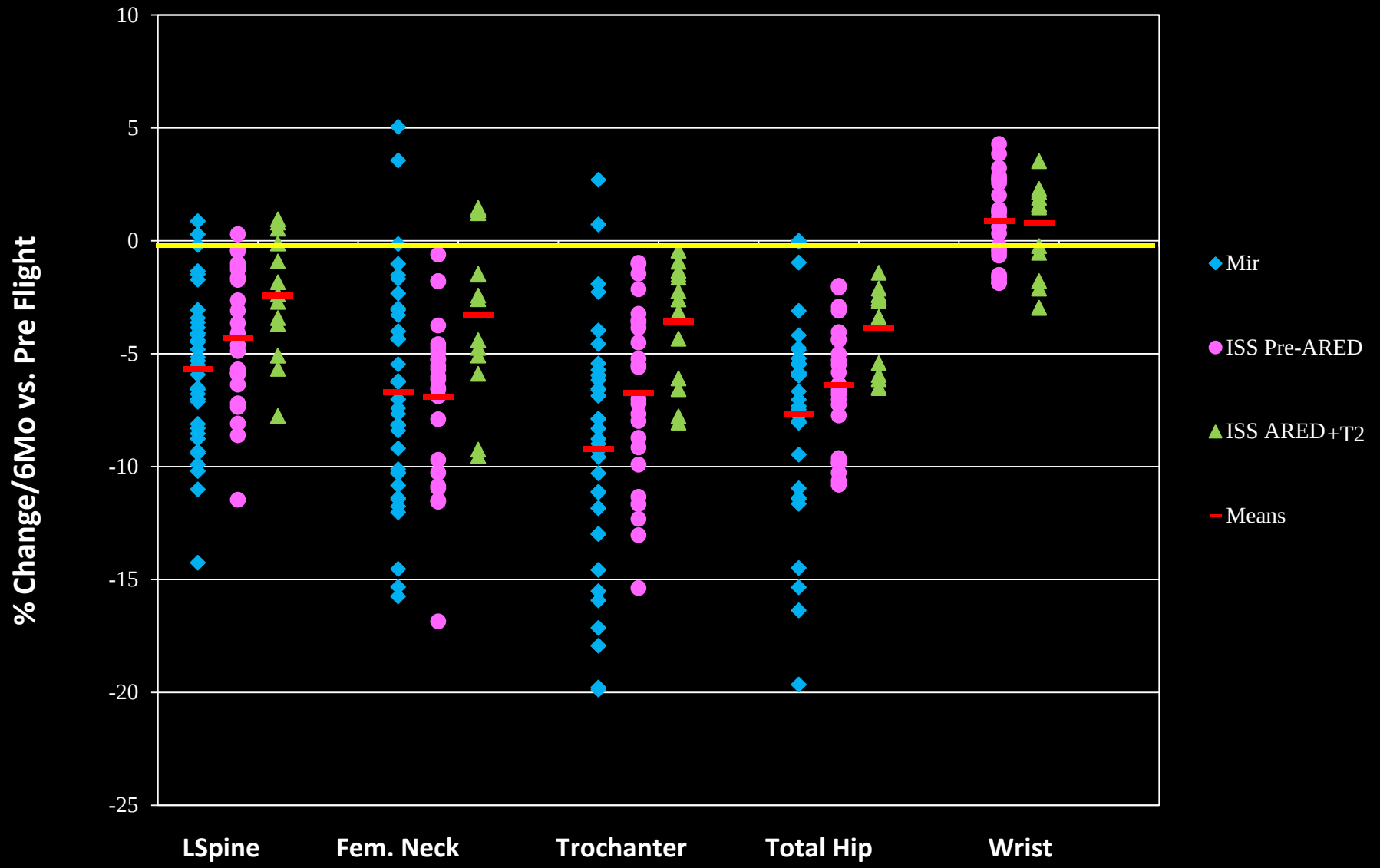
Muscle strength & bone mineral density on ISS

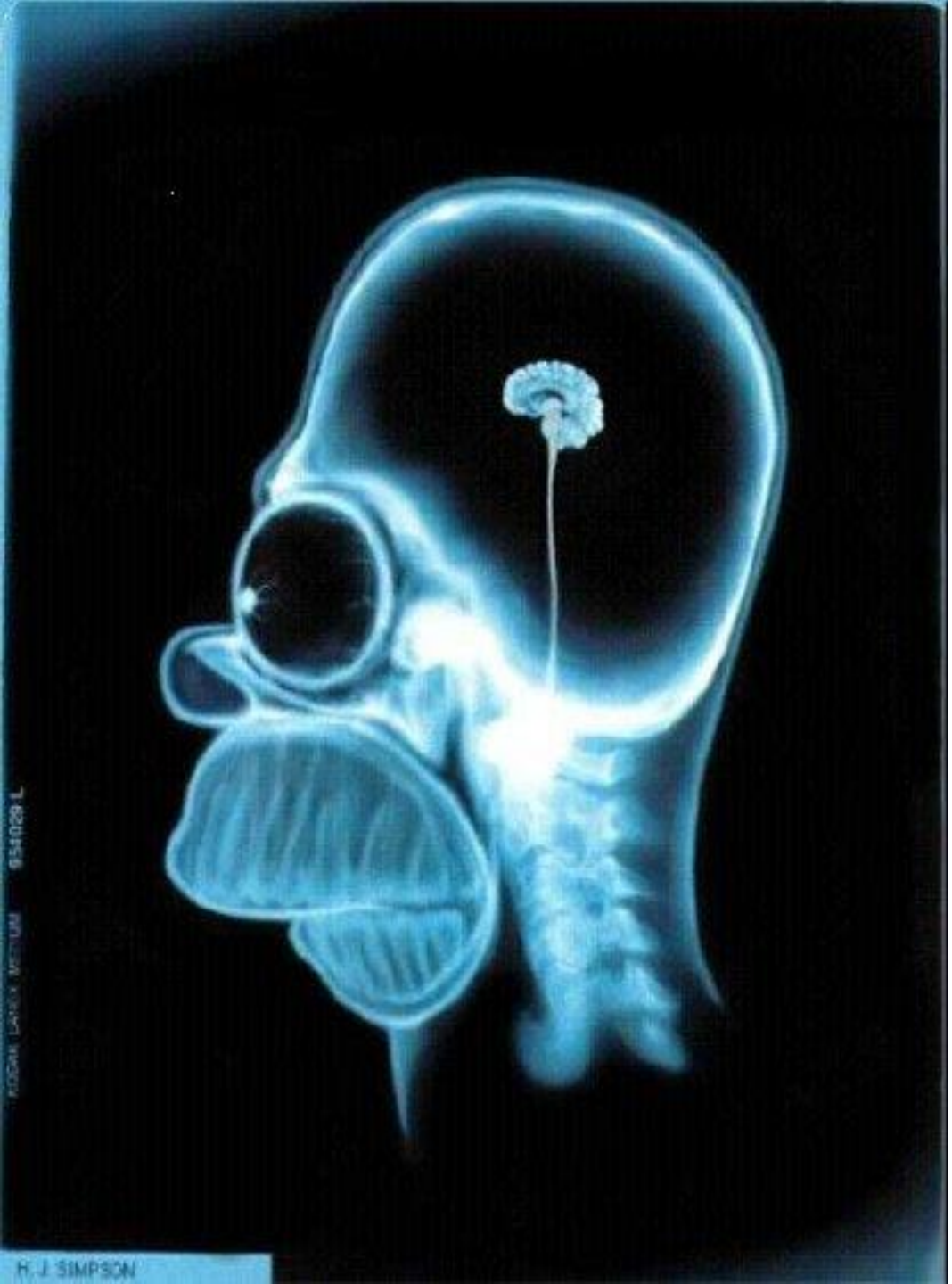
(iRED22; ARED=26)

(BMD iRED=24;ARED=11)



Change in DXA BMD





Vision Changes
Intracranial Pressure

The New Thing

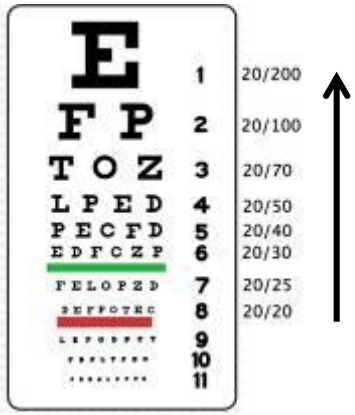
Visual Impairment Intracranial Pressure Project
Syndrome Signs

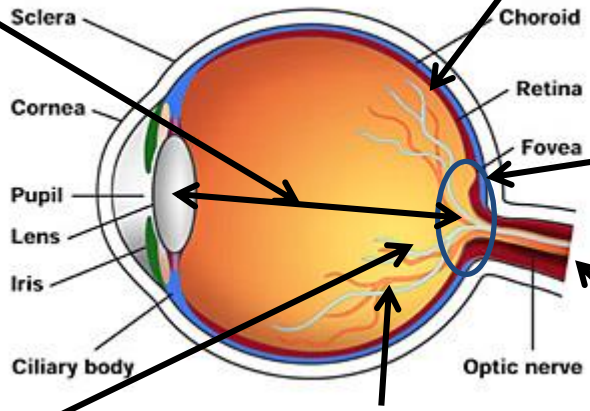
Background:

- 15 known "clinical cases" (of 36 U.S. long duration ISS crew) members
  - Each with different degrees of symptoms
  - Some with elevated measures of Intracranial Pressure (ICP) post flight
  - Incidence numbers vary with criteria and time period

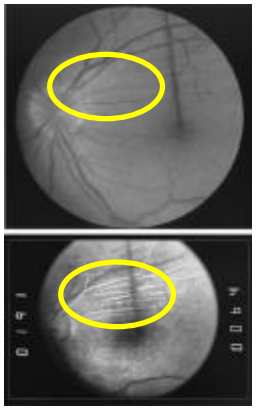
•Hyperopic Shifts

-Up to +1.75 diopters





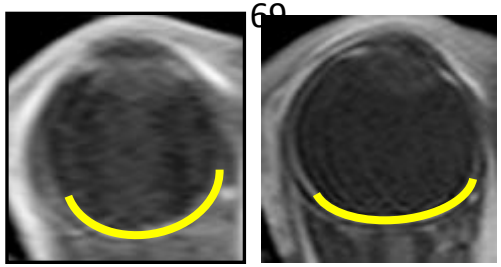
•Choroidal Folds - parallel grooves in the posterior pole



•Optic Disc Edema (swelling)

ICP

•Globe Flattening



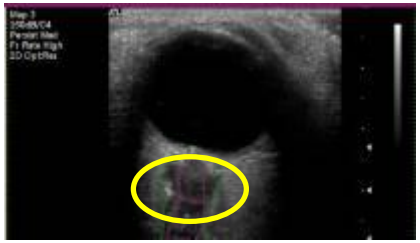
Normal Globe | Flattened Globe

MRI Orbital Image showing globe flattening

•Altered Blood flow

•"cotton wool" spots

•Increased Optic Nerve Sheath Diameter



The Syndrome / Findings

Vision Changes (this is the symptom threshold)

- Decreased near visual acuity - Hyperopic shifts
- Rare visual field obscurity

Eye findings

- Swelling of optic disk (papilledema)
- Choroidal folds (defected in the retinal layers)
- Globe flattening (shape change leads to vision change)
- Retinal lesions (cotton wool spots)

Intracranial pressure increase

- Slightly higher than normal range
- Requires invasive test (spinal tap) to assess
- Have confirmed in 4/10 cases only

The Syndrome / Findings (Cont'd)

Optic Nerve Sheath thickening

May overlap with other more well known effects of flight

- Facial swelling
- Jugular venous distension (JVD)
- Mild headaches / SMS

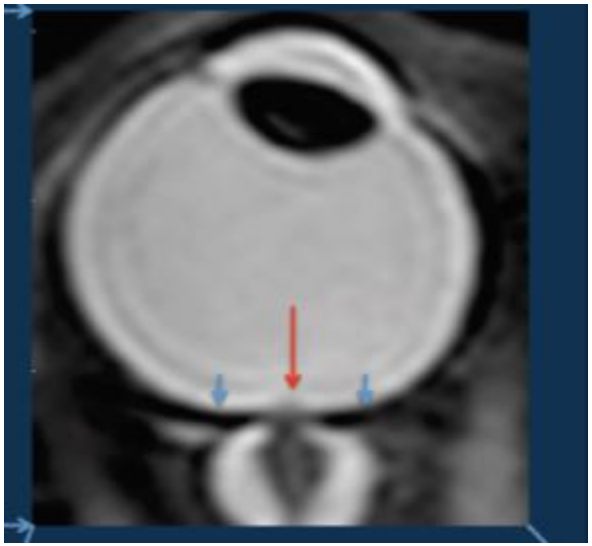
Eye Findings Imagery

Decrease in near visual acuity (hyperopic shift)

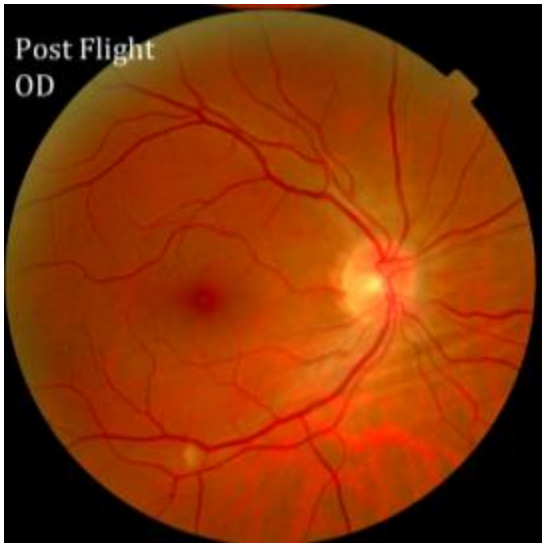
+

Optic Disk Edema (papilledema)

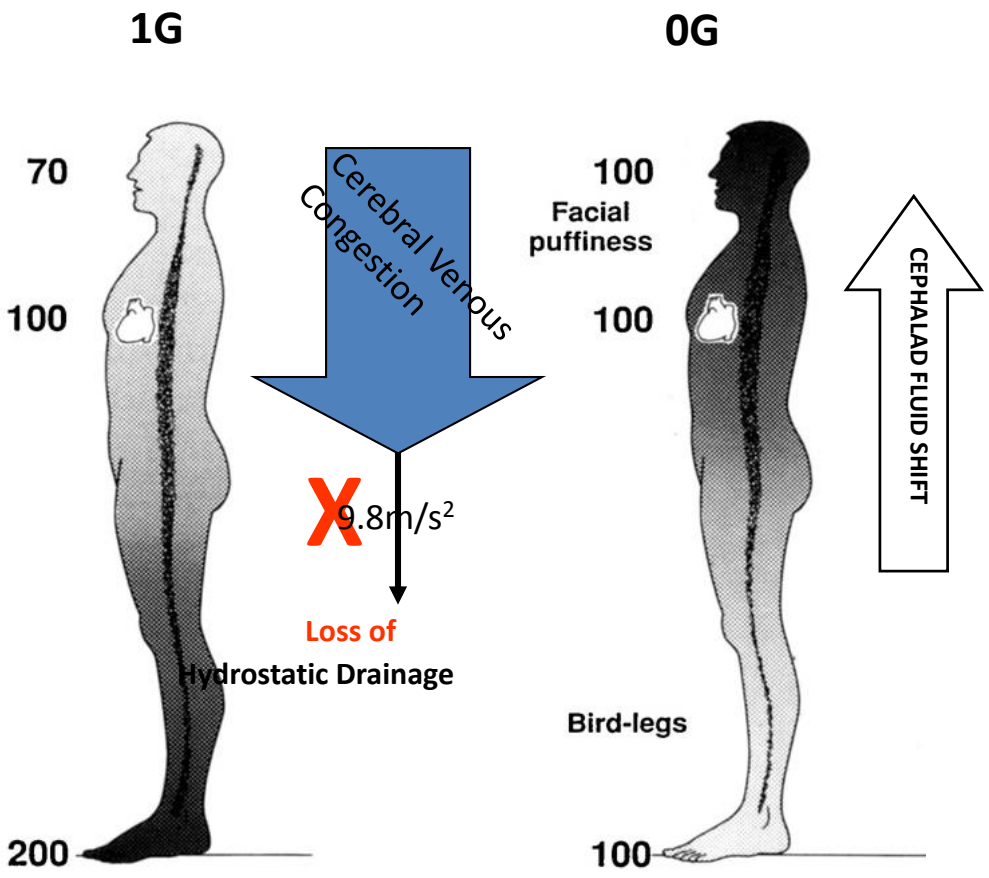
Globe flattening, optic nerve sheath distension

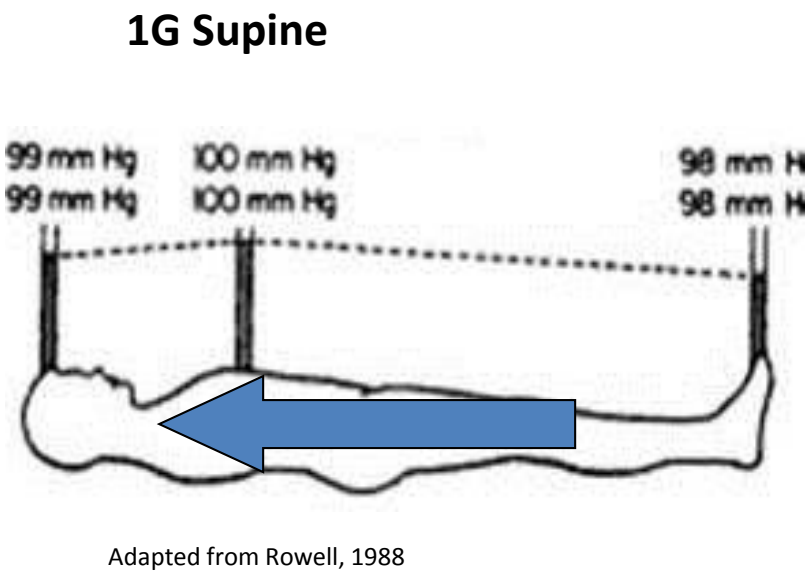


Choroidal folds (retinal surface)



Loss of Hydrostatic Drainage & Cerebral Venous Congestion





Adapted from Rowell, 1988

This is the most likely “engine” of the syndrome; other factors contribute and determine why some affected and others not.

Adapted from Hargens & Richardson, Respiratory Physiology & Neurobiology. 2009
Borrowed from Christian Otto

Fluid Shift

Individual Responses

Hypercarbia

XY

(Gender)

Possible Co-Contributors to Increased ICP

Resistive Exercise

Metabolic,
Genetic,
Anthropometry

Low Venous Compliance
Venous Occlusion

Overall Rubric

Spaceflight Ocular Syndrome (generic term) most likely a manifestation of adaptive changes to weightlessness thus far unrecognized

In survey of 500 flight experiences, even Shuttle crew noted 23% subjective and 11% documented degradation in vision (Mader et al)

Imagery among 27 flyers, both short and long duration, showed at least subtle changes in 26/27, suggesting a progression over time (Kramer et al)

Persistent changes well beyond end of flight suggest neuro-anatomical remodeling

Treatment / Mitigation

Medication: Diamox (acetazolamide) – maybe; used to treat increased ICP in other clinical scenarios, like acute mountain sickness. Can cause harm if intraocular pressure (IOP) low

Prevention: ??? Short of artificial G, cannot prevent without understanding of mechanism; Lower Body Negative Pressure, Thigh Cuffs (Brazlet) being considered; possible metabolic supplements

Mitigation of effects – corrective lenses available on board.

Implications - Immediate

Medical monitoring required to detect, identify cases; means time and machinery

Preflight baselines (acuity, optical coherence tomography [OCT], 3Tesla-MRI, intra-ocular pressure [IOP], fundoscopy, ultrasound)

Inflight (acuity, retinal imagery, IOP, U/S)

Postflight (all of preflight, +/- ICP assessment via spinal tap)

Anticipatory vision correction for missions

Inform stakeholders – crew, SSPO, agency, commercial world, public

Implications – Long Term

Medical monitoring – may have to continue beyond flight career; Long term implications unknown

Investigation – aggressive effort is needed to characterize complete syndrome and determine mechanism

Look for inflight OCT, development of non-invasive intracranial pressure devices, recruitment of Russian crew

Flight Status – The AMB has drafted a recent clinical practice guideline, still refining. Has not thus far affected flight status

With large incidence (say 35 – 45% range), significant impact on ISS staffing, inflight ops and monitoring