KTH ROYAL INSTITUTE
OF TECHNOLOGY

Image credit: NASA

Advances in Human Research for Space Exploration

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Outline

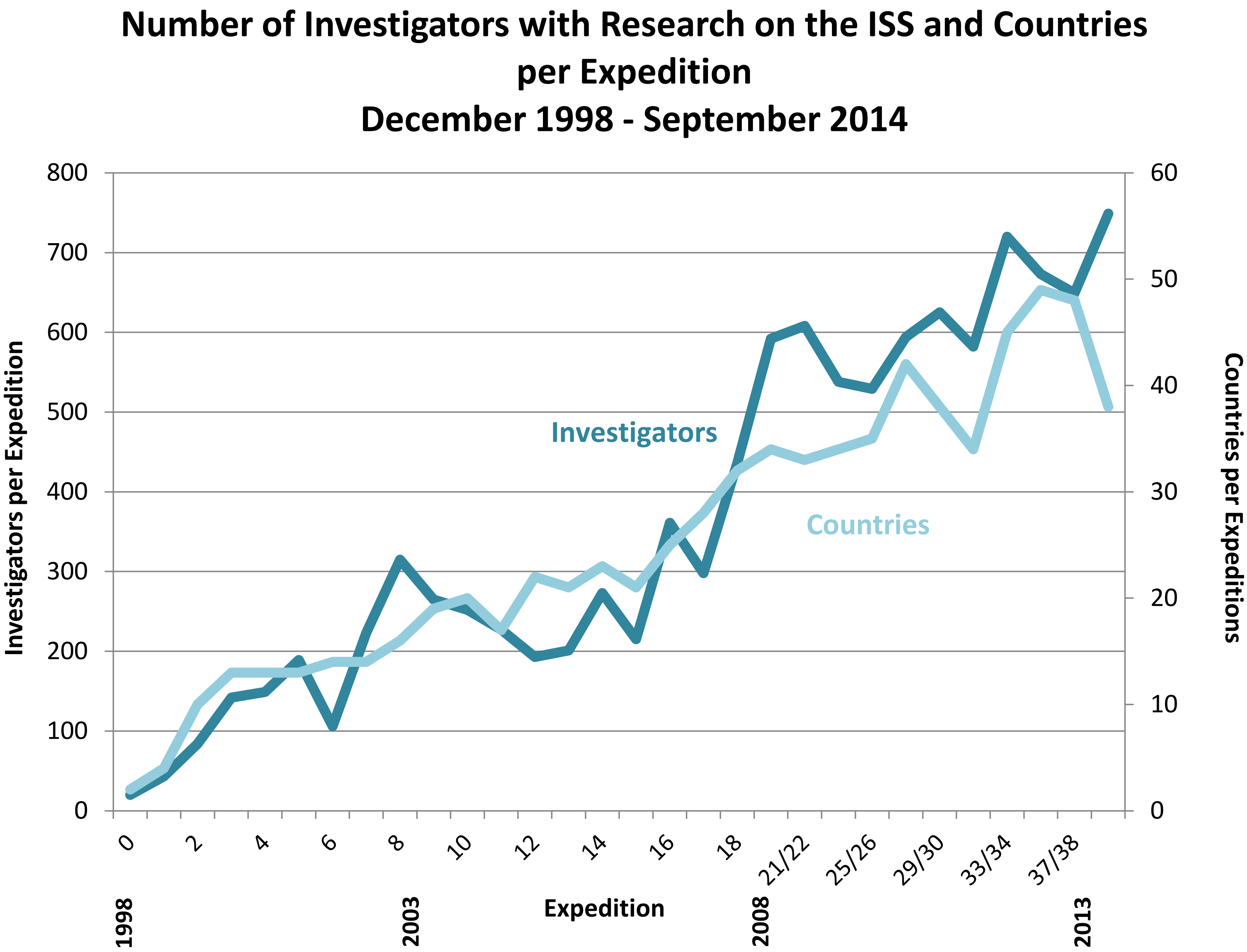
- Research on the International Space Station
- Medical research in Space – some results
- Research Roadmaps

A Laboratory in space

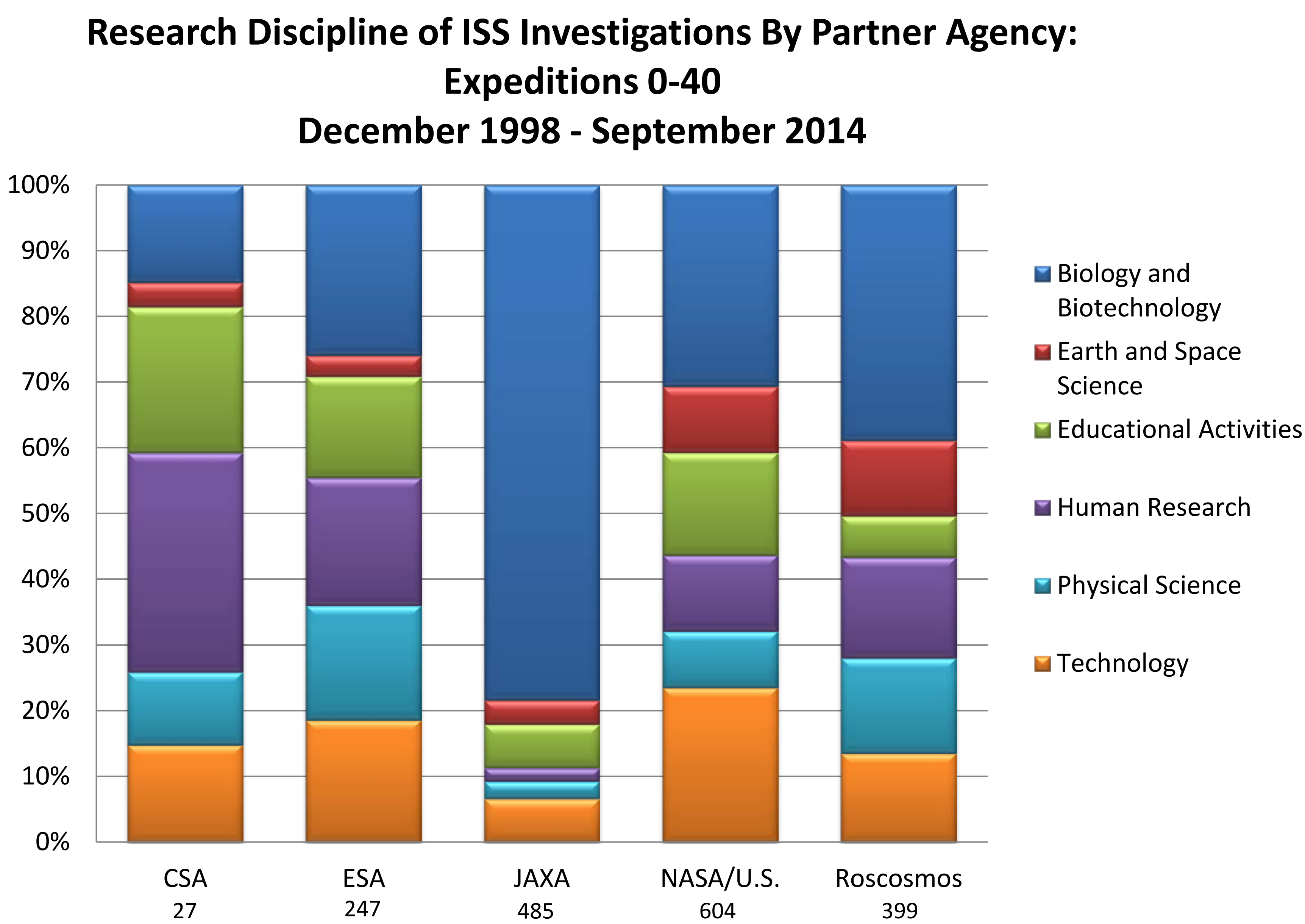
Image credit: NASA

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 and Countries per Expedition
December 1998 - September 2014
Investigators per Expedition
Countries per Expeditions
800
700
600
500
400
300
200
100
0
60
50
40
30
20
10
0
Investigators
Countries
0
2
4
6
8
10
12
14
16
18
21/22
25/26
29/30
33/34
37/38
1998
2003
2008
2013
Expedition

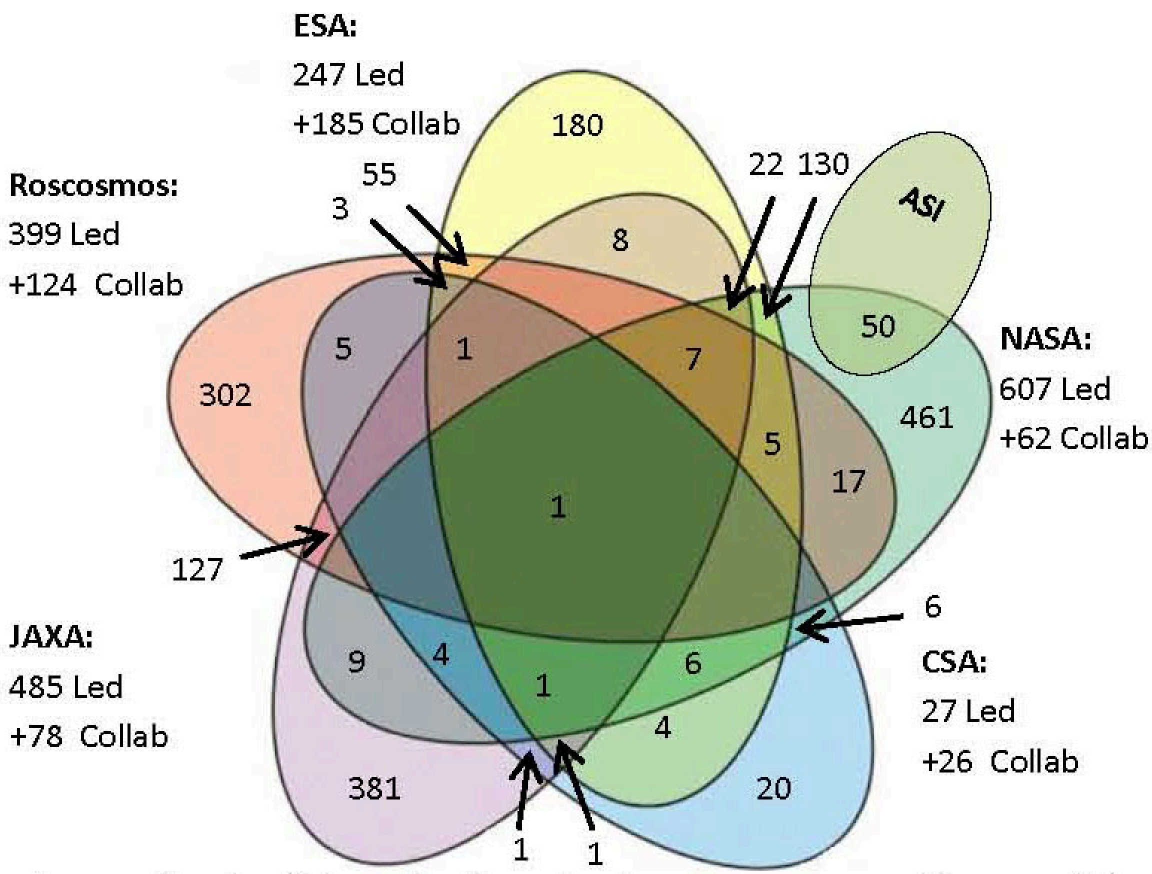


Research Discipline of ISS Investigations By Partner Agency:
Expeditions 0-40
December 1998 - September 2014
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Biology and Biotechnology
Earth and Space Science
Educational Activities
Human Research
Physical Science
Technology
CSA 27
ESA 247
JAXA 485
NASA/U.S. 604
Roscosmos 399

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.

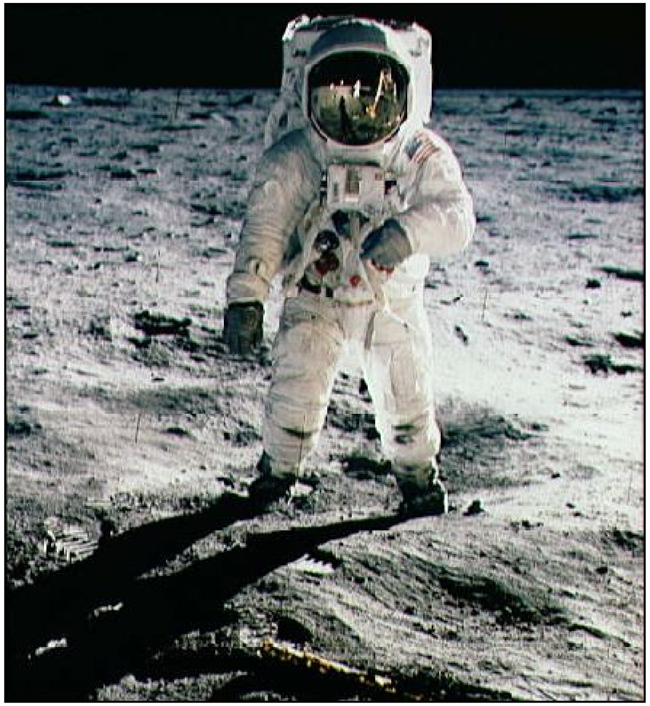
Space Stressors

Space Environment

e.g., Low or No Gravity,
Vacuum, Radiation,
no normal day/night cycle

Mission

e.g., Workload, mission
duration, emergencies,
isolation for many months



Space Habitat

e.g., Noise, confinement,
LSS, limited resources

Social Situation

e.g., small crew, restricted
communication with Earth

Benefits of Medical Research in (and for) Space

- Synergistic R&D:
- Maintenance of Astronaut Health and Performance
- New fundamental medical knowledge

Significant overlap between areas

Neurosensory

Finding
Our balance and the overall control of eye movements are indeed affected by weightlessness. These two systems work closely together under normal gravity conditions but become somewhat dissociated in weightlessness.

Tech Spin-off
the Eye Tracking Device equipment is now being used in a large proportion of corrective laser surgeries throughout the world

PI: A. Clarke, Charité Universitätsmedizin, Berlin, Germany

Former ESA astronaut Thomas Reiter undertakes the Eye Tracking Device experiment on the ISS in 2006.
Image credit: ESA

Tele-diagnostics

Developed for examination of ISS crew…

NASA astronaut Tom Marshburn assists Canadian Space Agency astronaut Chris Hadfield with an Ultrasound 2 scan in the Columbus Module of the International Space Station.
Image credit: NASA

PI: Scott Dulchavsky, M.D., Henry Ford Hospital, Detroit, Michigan

…now over 20,000 physicians and physician extenders trained in 68 countries

World Interactive Network Focused on Critical Ultrasound (WINFOCUS) and Henry Ford Innovation Institute members, Dr. Luca Neri and Alberta Spreafico work with Kathleen Garcia from Wyle Engineering to help train Dr. Chamorro from the rural community of Las Salinas, Nicaragua, using the Advanced Diagnostic Ultrasound in Microgravity and tele-ultrasound applications.
Image credit: WINFOCUS/Missions of Grace

Diagnostic devices

The Swedish company Aerocrine AB, with funding from ESA, developed a lightweight, easy-to-use, accurate device (NIOX MINO) for measuring nitric oxide in exhaled air. The aim was to investigate possible airway inflammation in astronauts

NIOX MINO® is now used by patients at health centers. They can monitor levels of asthma control and the efficiency of medication—leading to more accurate dosing, reduced attacks and improved quality of life.

Former European Space Agency (ESA) astronaut Thomas Reiter undertakes science activities for the Nitric Oxide Analyzer experiment in 2006.
Image credit: ESA

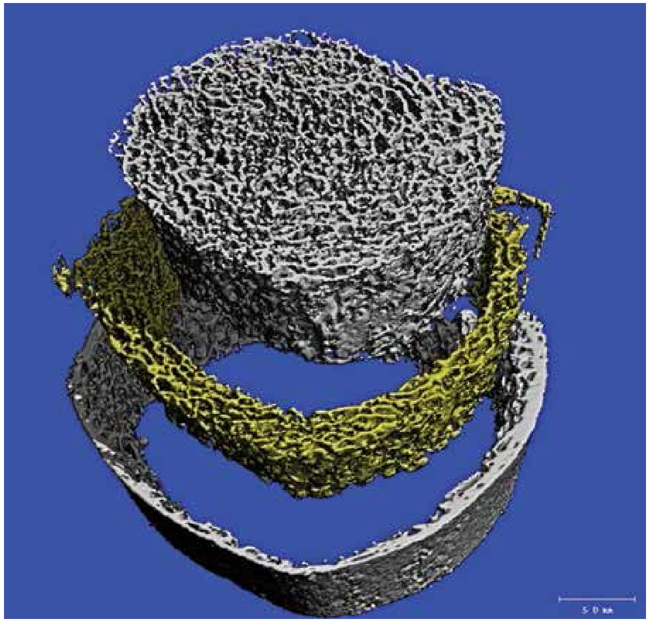
PI's: D. Linnarsson, L. Karlsson, L. Gustafsson

Maintenance of bone

With heavier resistance exercise, together with sufficient calories and Vit D, bone mass can be protected to a large extent..

“After 51 years of human spaceflight, we have made significant progress in protecting bone health through diet and exercise.”

PI’s: Scott Smith and Jean Sibonga, NASA



Xtreme CT distal radius.
Image credit: SCANCO Medical

Maintenance of bone

<u>Salt intake</u>

Sodium is retained (probably in the skin), and affects the acid balance of the body and bone metabolism. So, high salt intake increases acidity in the body, which can accelerate bone loss.

Countermeasure:
Bicarbonate?

European Space Agence (ESA) astronaut André Kuipers (left) and Russian cosmonaut Oleg Kononenko (right) with food items on the International Space Station in December 2011. In the SOdium LOad in microgravity experiment, astronaut subjects undergo two different diet regimes to determine the physiological effects of sodium on the body. Image credit: ESA

PI: Petra Frings-Meuthen, German Aerospace Center (DLR)

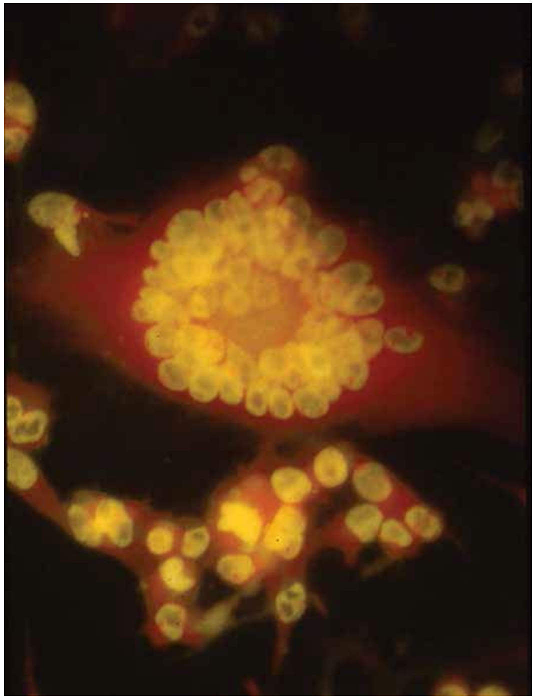
Immunity - viruses

Immunological function is altered/decreased during/after spaceflight.
Dormant viruses, herpes family, reactivates and appear in bodily fluids.

Diagnostics rather cumbersome, new method have been developed (patent pending) for rapid detection of Zoster virus.

Immunological research bring new fundamental knowledge and technology developments useful for patient groups.

PI: Satish K. Mehta, Duane L. Pierson, and C. Mark Ott, NASA



Varicella zoster-infected MeWo cells showing typical herpes virus-induced, multinucleated giant cells. Cultures are stained with acrydine orange to identify RNA (red) in the cytoplasm. Image credit: NASA

Regulation of Temperature

Weightlessness removes passive convection and brings a headward fluid shift -> core body temperature raises faster during physical work -> coupled to fatigue.

New non-invasive core temperature measurement device developed.

Physiological knowledge and the novel sensor technologies both relevant for work in extreme environment *i.e.* firefighters, miners, soldiers etc…

PI: HC Gunga, Charité, Berlin

NASA astronaut Sunita Williams uses the Portable Pulmonary Function System whilst on the CEVIS cycle exercise device during a session of the joint Thermolab/EKE/VO2Max experiments in August 2012. Image credit: NASA

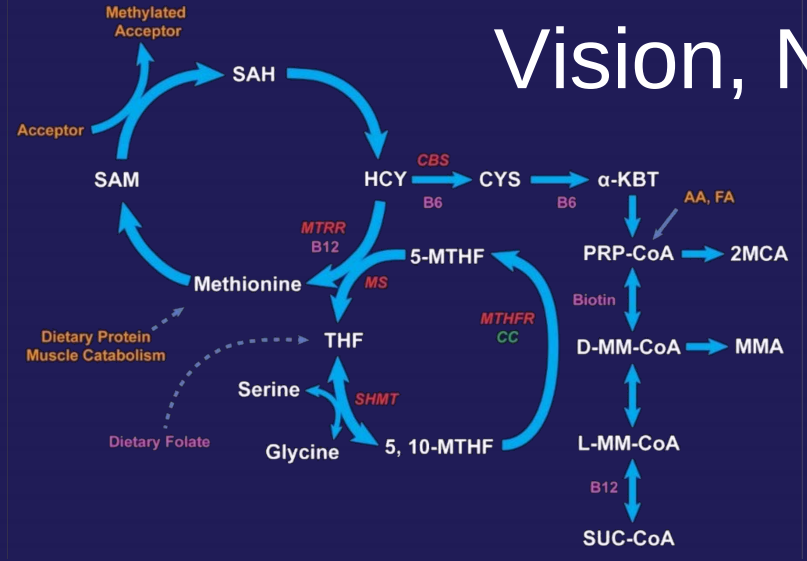
Vision Impairment

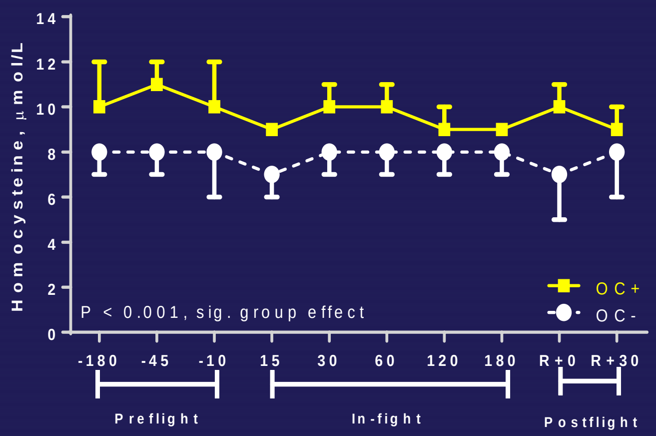
Currently regarded as one of the main medical risks to long-duration spaceflight – various degrees of symptoms seen in a large part of crews on ISS

Optic disc edema, globe flattening, choroidal folds, hyperopic shifts and/or an increased intracranial pressure have been documented in these astronauts

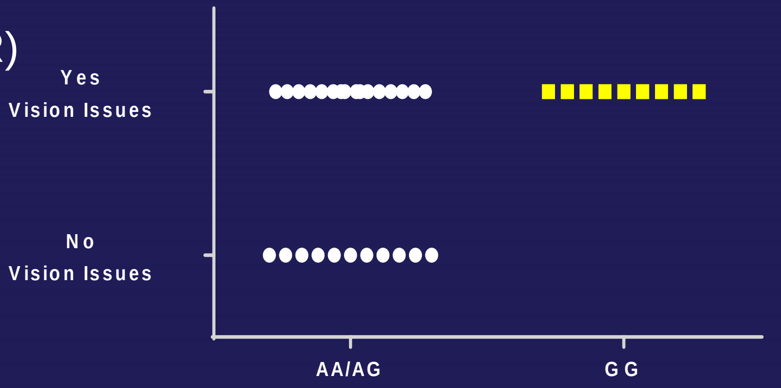
- Elevated CO_2?
- High sodium intake?
- Resistance exercise?
- Genetic polymorphism related to Homocystein/folate/B12 metabolism?

Vision, Nutrition, and Genetics

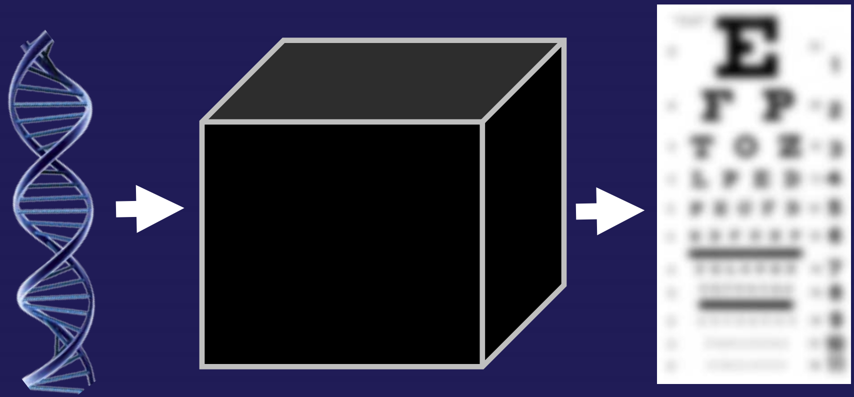




- Nutrition research identified *preflight* biochemical differences in astronauts who had vision issues. (top R)
- Follow on research identified genetic differences in the one carbon metabolism pathway (middle R).
  - All who had one form of the gene (GG) developed vision issues. OR – nobody without vision issues had that form of the gene.



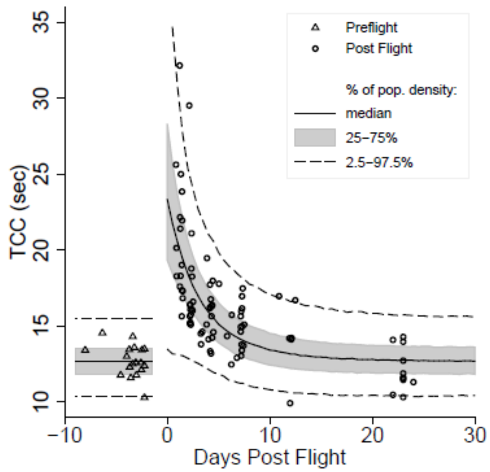
- More work required to clarify the nature of these data, but the data suggest an interaction with genetics may predispose some to vision issues. Mechanism unknown.
- This line of research may ultimately:
  - Inform risks of space flight
  - Inform research/countermeasure options
  - Have broad application in health and medicine

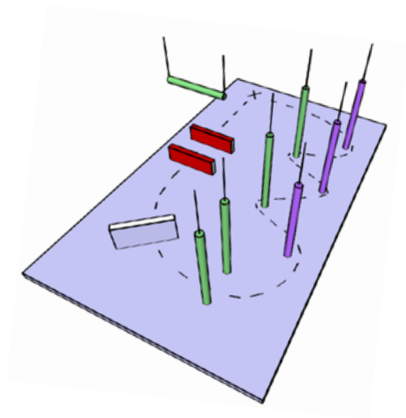


Zwart et al., *J Nutr* 2012, and *FASEB J, in press Jan 2016*

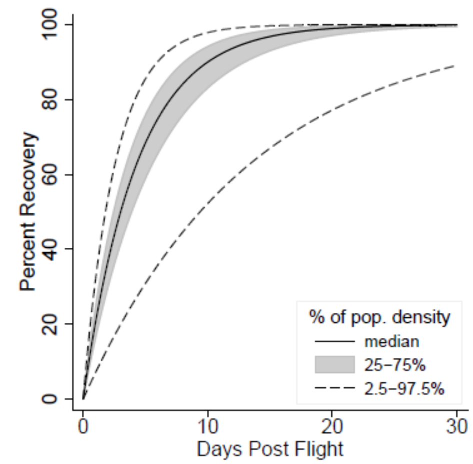
Functional Mobility after Long-Duration Space Flight (ISS)

Time to Complete Course





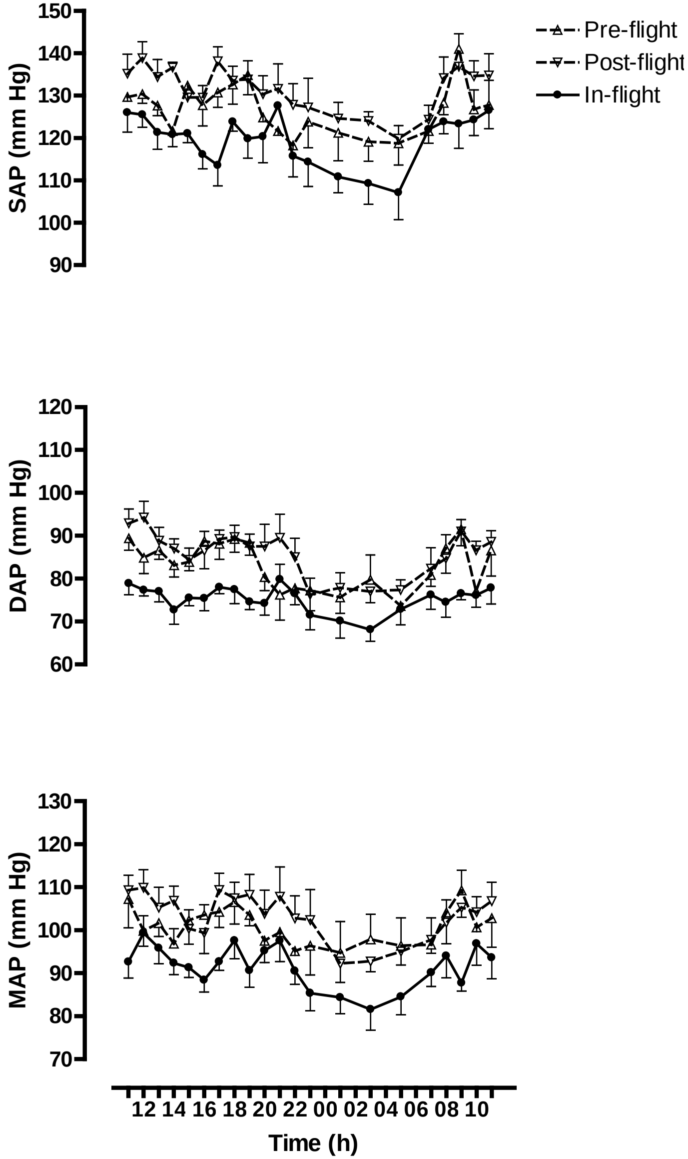
Percent Recovery



- Subjects showed a 48% increase in time to complete the course on R+1
- Recovery of functional mobility to 95% of preflight level took 15 days

Mulavara AP, Feiveson A, Feidler J, Cohen HS, Peters BT, Miller CA, Brady R, Bloomberg JJ. Experimental Brain Research. 202(3): 649-59. 2010.

Blood Pressure
(24-h ambulatory brachial)



- 10 mm Hg decrease
- No change in heart rate
- Nightly dip maintained

PI: P. Norsk, USRA

Roadmaps – Medical Risks Mitigation

NASA Human Research Roadmap – very comprehensive with evidence books, identified risks, knowledge gaps and research tasks

THESEUS – an European Life Science Roadmap for Space Exploration – similar objective but different approach compared to NASAs roadmap. Emphasize integration over several research fields and benefits for earth issues.

US NRC Decadal Survey on Life and Physical Sciences in Space – addresses the needs of exploration missions, but also generic science priorities.

ISECG Global Exploration Roadmap – mention medical risks, but so far on a high level

http://humanresearchroadmap.nasa.gov/explore/
http://www.theseus-eu.org
http://www.nap.edu/catalog.php?record_id=13048
http://www.globalspaceexploration.org

Main Human Health and Performance Risks for Exploration	Not mission limiting GO	Not mission limiting, but increased risk GO	Mission limiting NO GO
	Green	Yellow	Red

Main Human Health and Performance Risks for Exploration	Mission			
	ISS (6 mo)	**Lunar** (6 mo)	**Deep Space** (1 yr)	**Mars** (3 yr)
Musculoskeletal: Long-term health risk of early onset osteoporosis Mission risk of reduced muscle strength and aerobic capacity	Green	Green	Yellow	Red
Sensorimotor: Mission risk of sensory changes/dysfunctions	Green	Yellow	Green	Yellow
Ocular Syndrome: Mission and long-term health risk of microgravity-induced visual impairment and/or elevated intracranial pressure	Yellow	Yellow	Red	Red
Nutrition: Mission risk of behavioral and nutritional health due to inability to provide appropriate quantity, quality and variety of food	Green	Green	Yellow	Red
Autonomous Medical Care: Mission and long-term health risk due to inability to provide adequate medical care throughout the mission (Includes onboard training, diagnosis, treatment, and presence/absence of onboard physician)	Green	Yellow	Red	Red
Behavioral Health and Performance: Mission and long-term behavioral health risk	Green	Yellow	Red	Red
Radiation: Long-term risk of carcinogenesis and degenerative tissue disease due to radiation exposure—Largely addressed with ground-based research	Green	Yellow	Red	Red
Toxicity: Mission risk of exposure to a toxic environment without adequate monitoring, warning systems or understanding of potential toxicity (dust, chemicals, infectious agents)	Yellow	Yellow	Red	Red
Autonomous Emergency Response: Medical risks due to life support system failure and other emergencies (fire, depressurization, toxic atmosphere, etc.), crew rescue scenarios	Yellow	Yellow	Red	Red
Hypogravity: Long-term risk associated with adaptation during intravehicular activity and extravehicular activity on the Moon, asteroids, Mars (vestibular and performance dysfunctions) and postflight rehabilitation	Green	Green	Yellow	Red

Thank you!

http://www.researchgate.net/publication/280026134_International_Space_Station_Benefits_for_Humanity_Second_Edition

Acknowledgement:

Some information provided by the ISS Program Forum and the Human Research Program at NASA (via P. Norsk)

Statistics provided by J. Robinson (ISS Program Scientists)