NASA, Astronaut Occupational Surveillance Program and Lifetime Surveillance of Astronaut Health, LSAH: Astronaut Exposures and Risk in the Terrestrial and Spaceflight Environment

Sean Keprta, MS CIH, Occupational Health Officer, Associate Division Chief, Space Medicine and Clinical Operations, Johnson Space Center, National Aeronautics and Space Administration

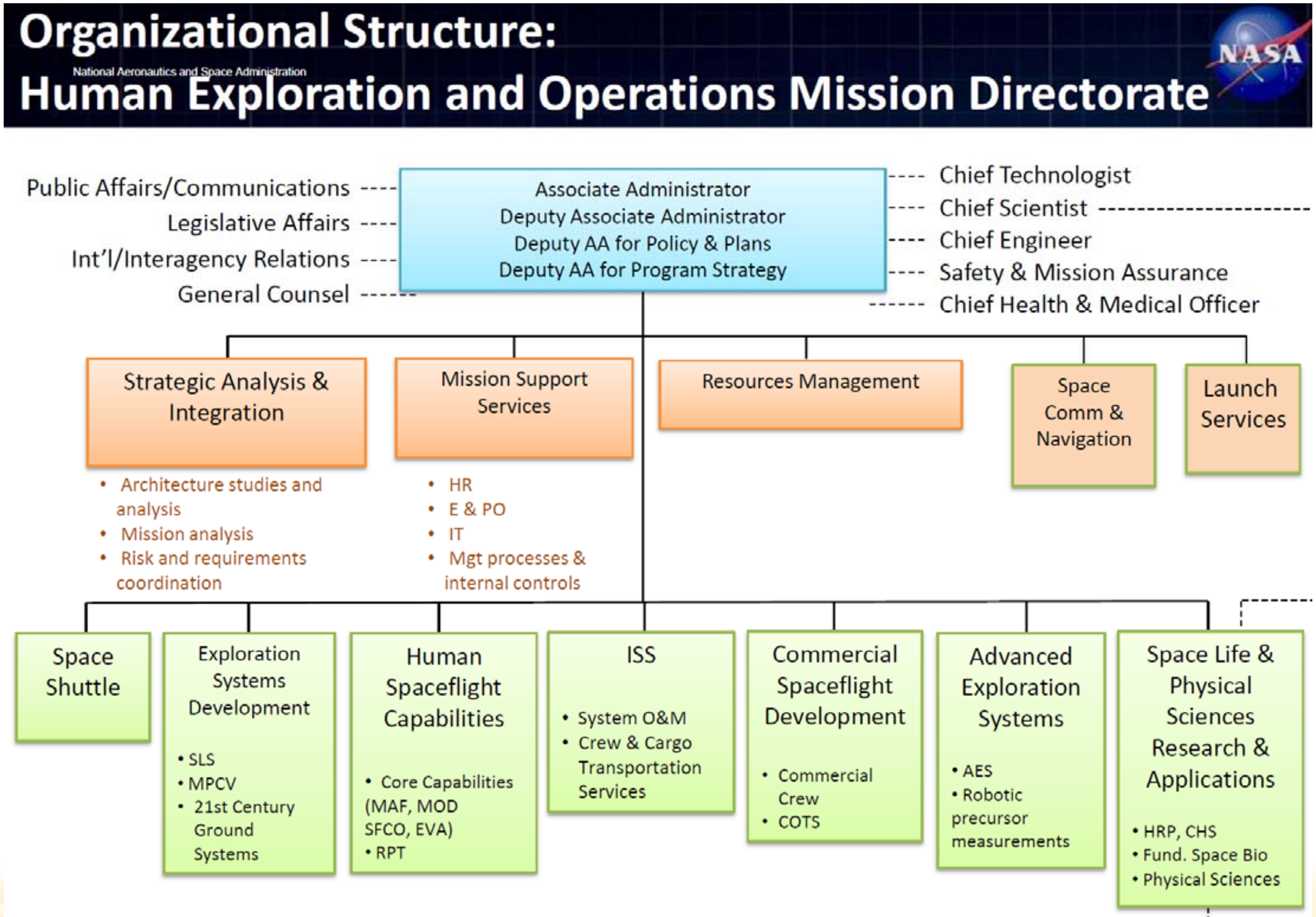
Dr. William Tarver, Mary Van Baalen PhD, Torin McCoy , Johnson Space Center, National Aeronautics and Space Administration

This presentation represents the efforts of a large number of very dedicated Health and Engineering professionals over many years at NASA and the Johnson Space Center.

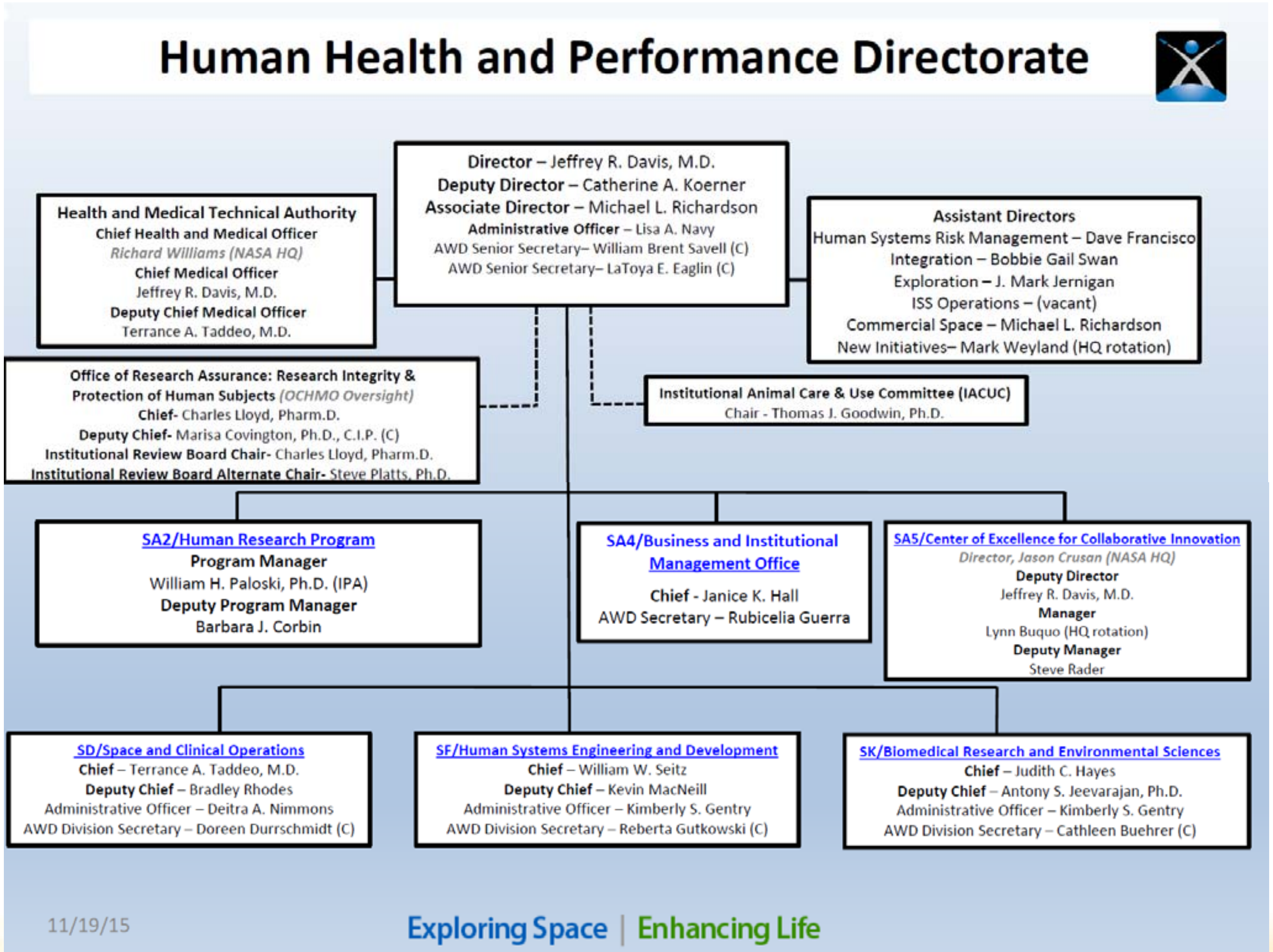
Overview

- **Background Organizations responsible for Astronaut Health,**
  - Human Exploration and Operations Directorate, HEOMD, NASA Johnson Space Center, Human Health and Performance Directorate, HHPD, Human Research Program HRP,
- **NASA Astronaut Corp**
  - Flight Operations Directorate
- **Early Astronaut Medical Care and Surveillance, Longitudinal Surveillance of Astronaut Health LSAH**
  - Early mission and focus
  - Mission Operations Philosophy
  - Shuttle Years and Retirement, time for change….
- **Changes to Lifetime Surveillance of Astronaut Health, LSAH New Focus and Direction**
  - International Space Station ISS era
  - Outside Orgs, ASAP, IOM,
  - Benchmarking DOD, NIOSH
- **Astronaut Occupational Health Program AOHP Occupational Medicine, Risk System/Human System Risk Board**
  - Astronaut Occupational Health Management Group
  - LSAH Advisory Board
  - OHMG
  - Astronaut Corp (Similar Exposure Group)
- **The Workplace Environment**
  - Terrestrial
  - Space

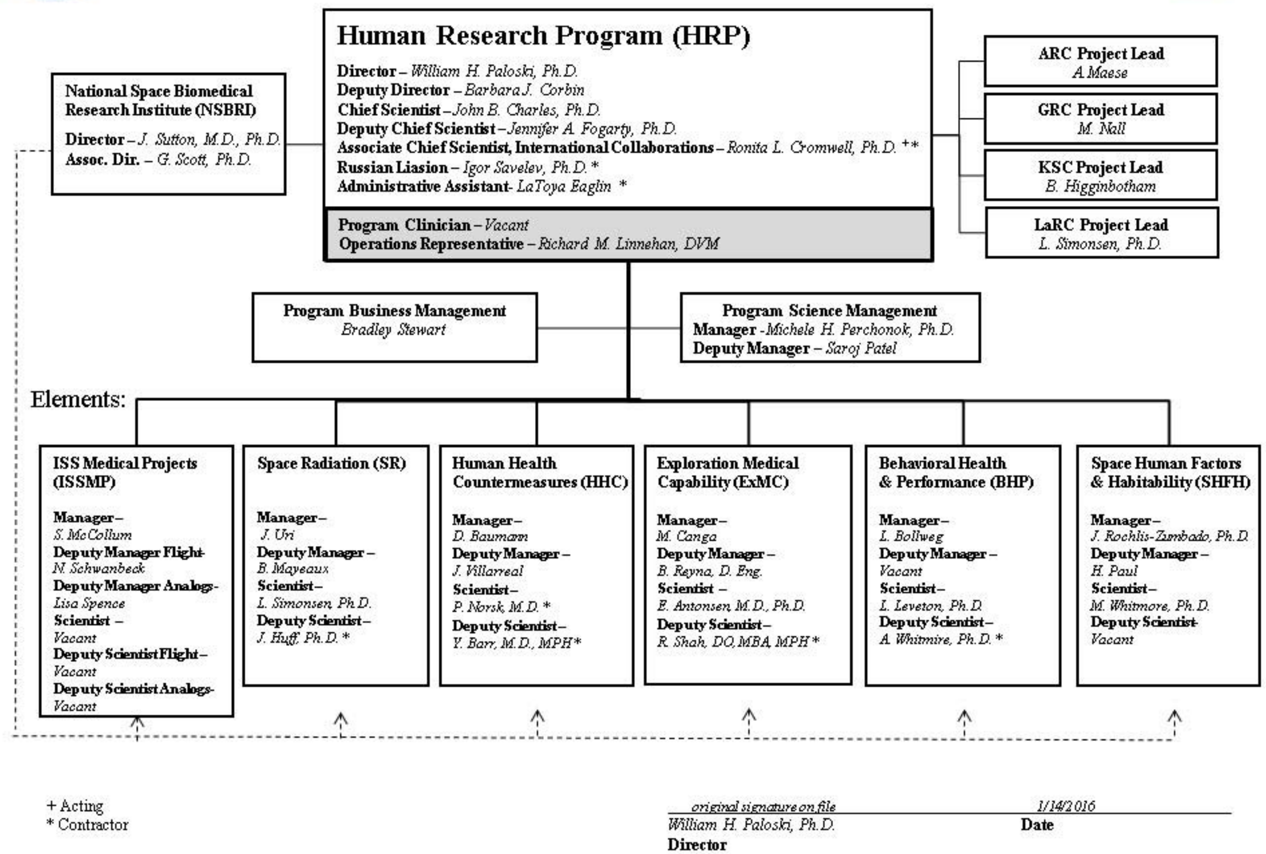
Organizations



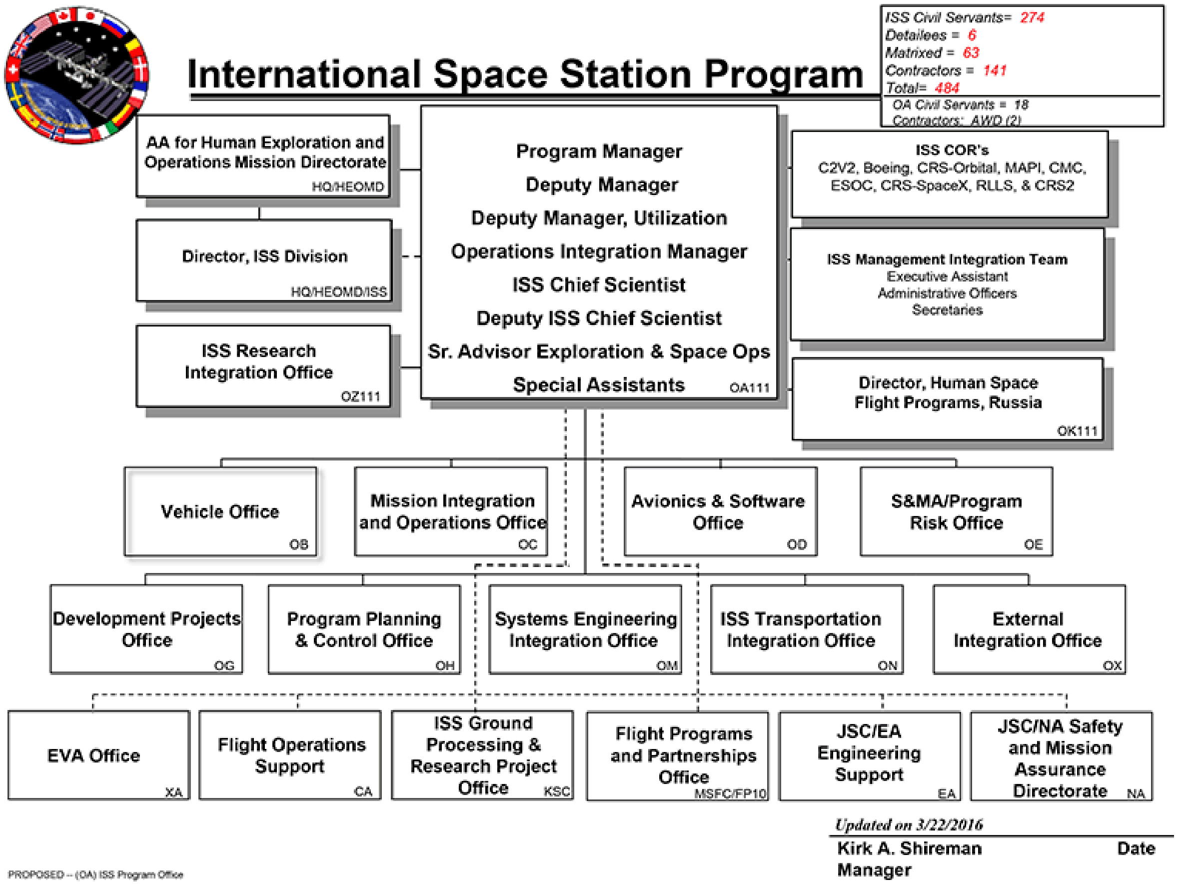
Organizations



Organizations

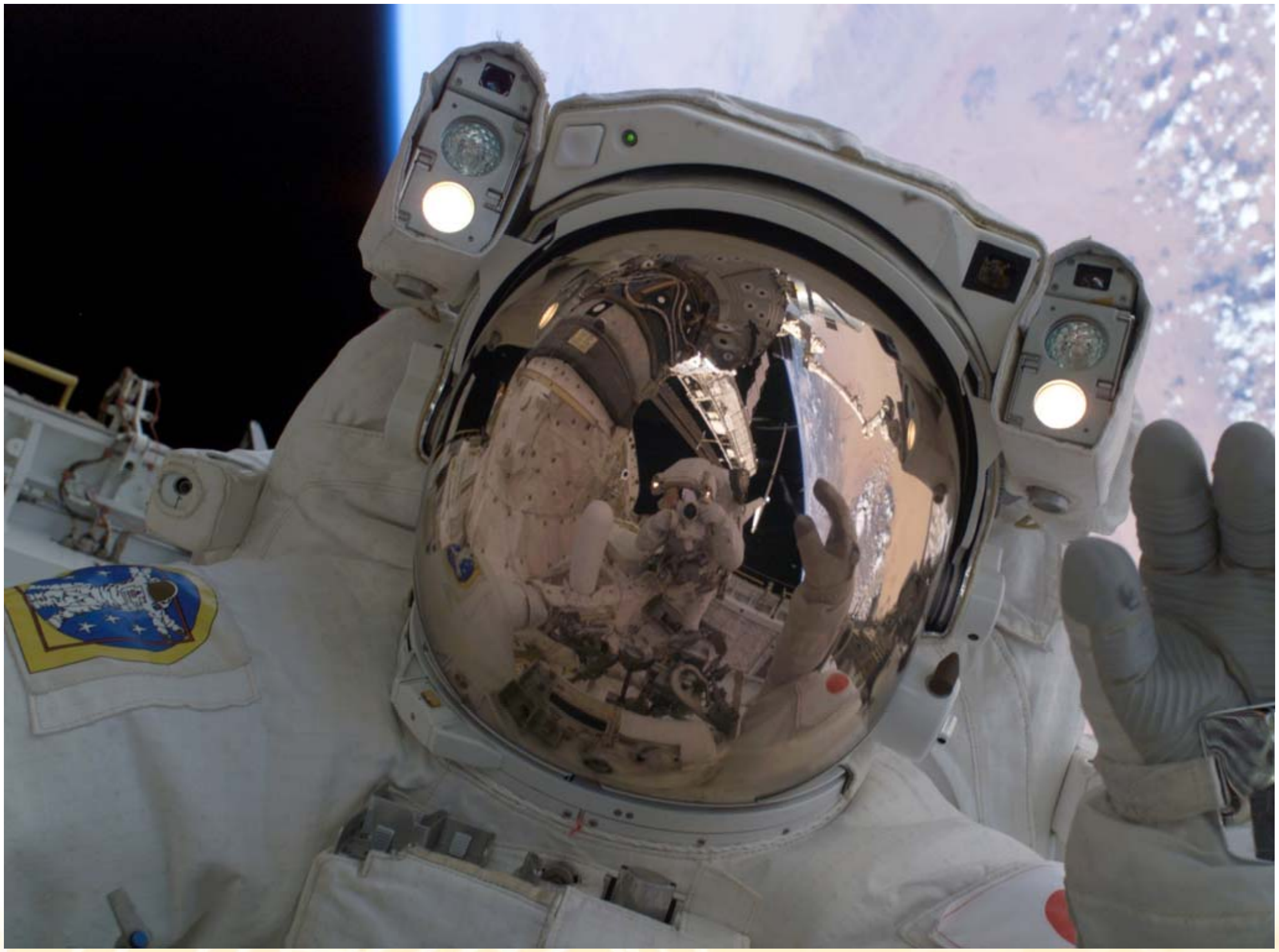


Organizations



NASA's Johnson Space Center

Astronaut Corp



The NASA Astronaut Corps

- →**Part of the JSC Flight Operations Directorate**
- →**330 Total**
- →**Current Active Astronauts**
  - – 57 total
  - – 44 males
  - – 13 females
  - – Average age mid 40's
    - • Mid 30's at Selection
- →**8 ASCANS selected 2013**

Dr. Peggy Whitson, Commander Expedition 51

Military/Civilian Status

Active Astronaut Corps:

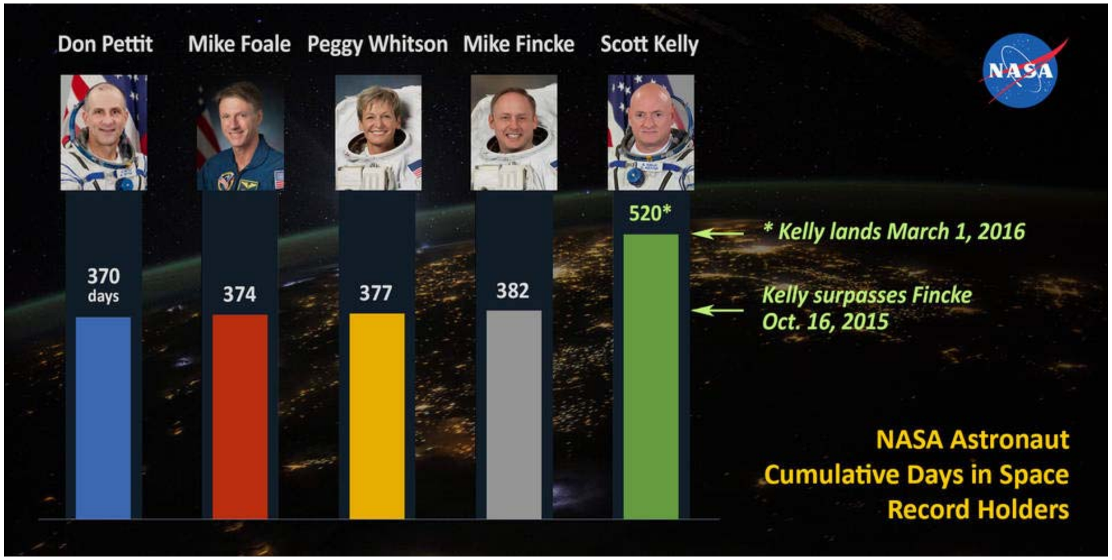
(as of Sept 2012)

Military Branch	M	F	Grand Total
Civilian	9	13	**22**
USA	5		**5**
USAF	13	1	**14**
USCG	1		**1**
USMC	4		**4**
USN	6	1	**7**

Retired/Deceased Astronaut Corps:

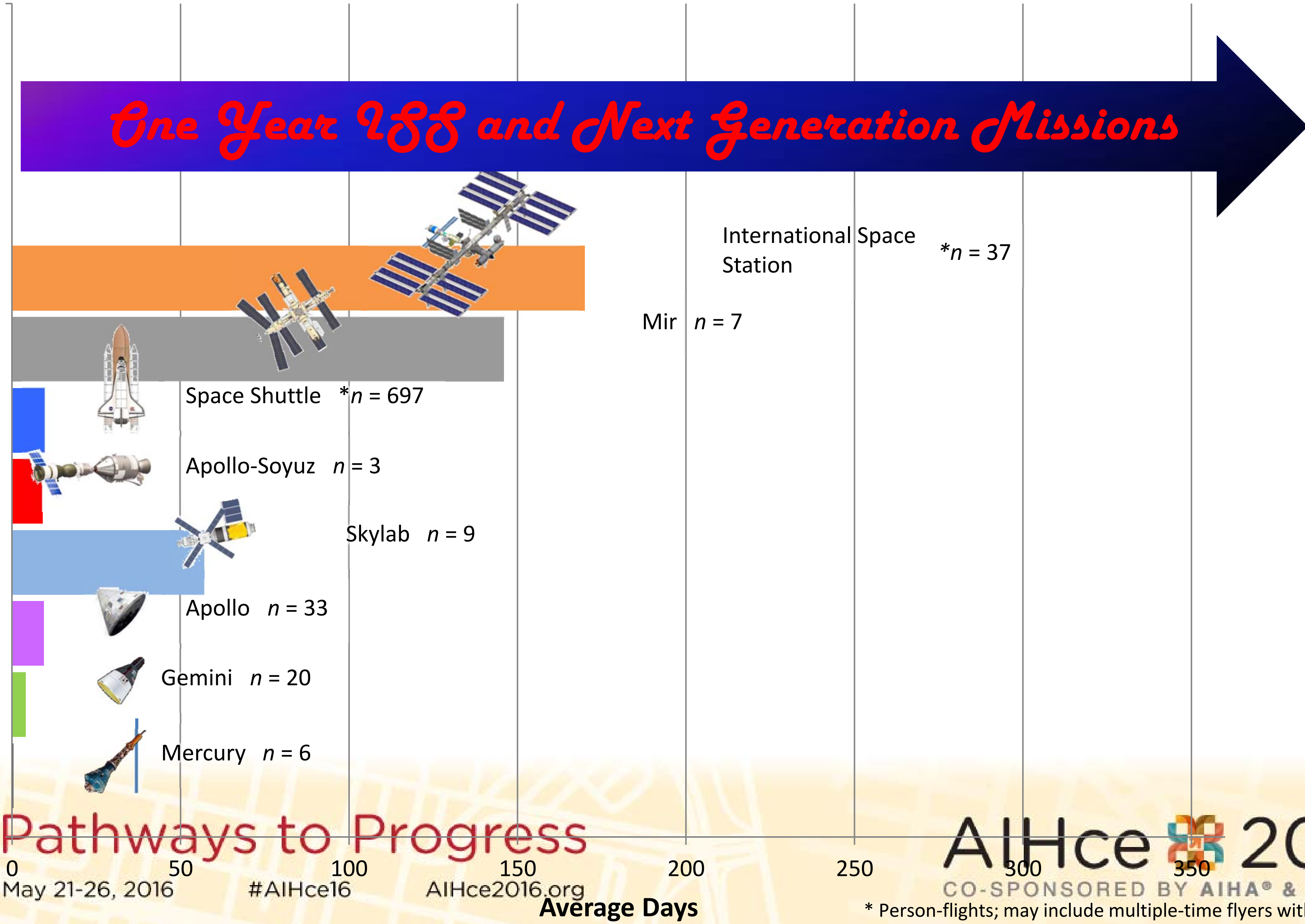
(as of Sept 2012)

Military Branch	M	F	Grand Total
Civilian	63	23	88
USA	11	1	12
USAF	81	4	85
USCG	1		1
USMC	22		22
USN	82	7	89


Don Pettit
Mike Foale
Peggy Whitson
Mike Fincke
Scott Kelly
NASA
370
days
374
377
382
520*
* Kelly lands March 1, 2016
Kelly surpasses Fincke
Oct. 16, 2015
NASA Astronaut
Cumulative Days in Space
Record Holders


2013 ASCANS
NASA
XXI

NASA Human Space Flight



* Person-flights; may include multiple-time flyers within program

General Demographic Data

Program	Avg. Duration (days)	Age at First Launch (yrs)			Count	Gender	
		Minimum	Average	Maximum			Female
Mercury	0.37	35	37.33	40	6	6	0
Gemini	4.6	32	35.80	42	20*	20	0
Apollo	9.5	33	38.48	47	33*	33	0
ASTP	9	44	46.33	51	3	3	0
Skylab	57	37	40.44	43	9	9	0
Shuttle	10	32	40.98	77	714*	607	108
NASA-Mir	146	40	46.57	54	7	6	1
ISS	166	37	46.57	54	39*	9	30

*** Person-flights; may include multiple-time flyers within program**

Early Programs

Astronaut Surveillance

- Longitudinal Surveillance of Astronaut Health (LSAH) I 1959-1989
- Longitudinal/Lifetime Surveillance of Astronaut Health LSAH II 1992-2009
- AOHP 2012- NASA Astronaut Occupational Surveillance Program, Lifetime Surveillance of Astronaut Health

Longitudinal Study of Astronaut Health

LSAH

- Phase 1
- Phase 2
- Workforce controls for comparison
- Low Statistical Power
- No Consent

LSAH Challenges

- **Standard issues with space biomedical research**
  - Small n, competing priorities in flight, lack of consistent data, etc.
- **Healthy Worker Effect: observation that employed populations tend to have a lower mortality experience than the general population.**
  - Likely exacerbated in extremely fit worker populations such as military, firefighters, and the astronaut corps
    - Rigorous selection criteria
    - Specialized medical care provided by NASA
      - Frequent, more comprehensive screenings than those available to the public
      - Incentives for health maintenance not available to the general public
    - Educational level
- **Further illustrates the need for an appropriate control population**

The end of the Shuttle Program

ISS Flight

ULF7

STS-135
Atlantis

Launched
July 8, 2011

Landed
July 21, 2011

13 days

- Christopher J. Ferguson
- Douglas G. Hurley
- Sandra H. Magnus
- Rex J. Walheim

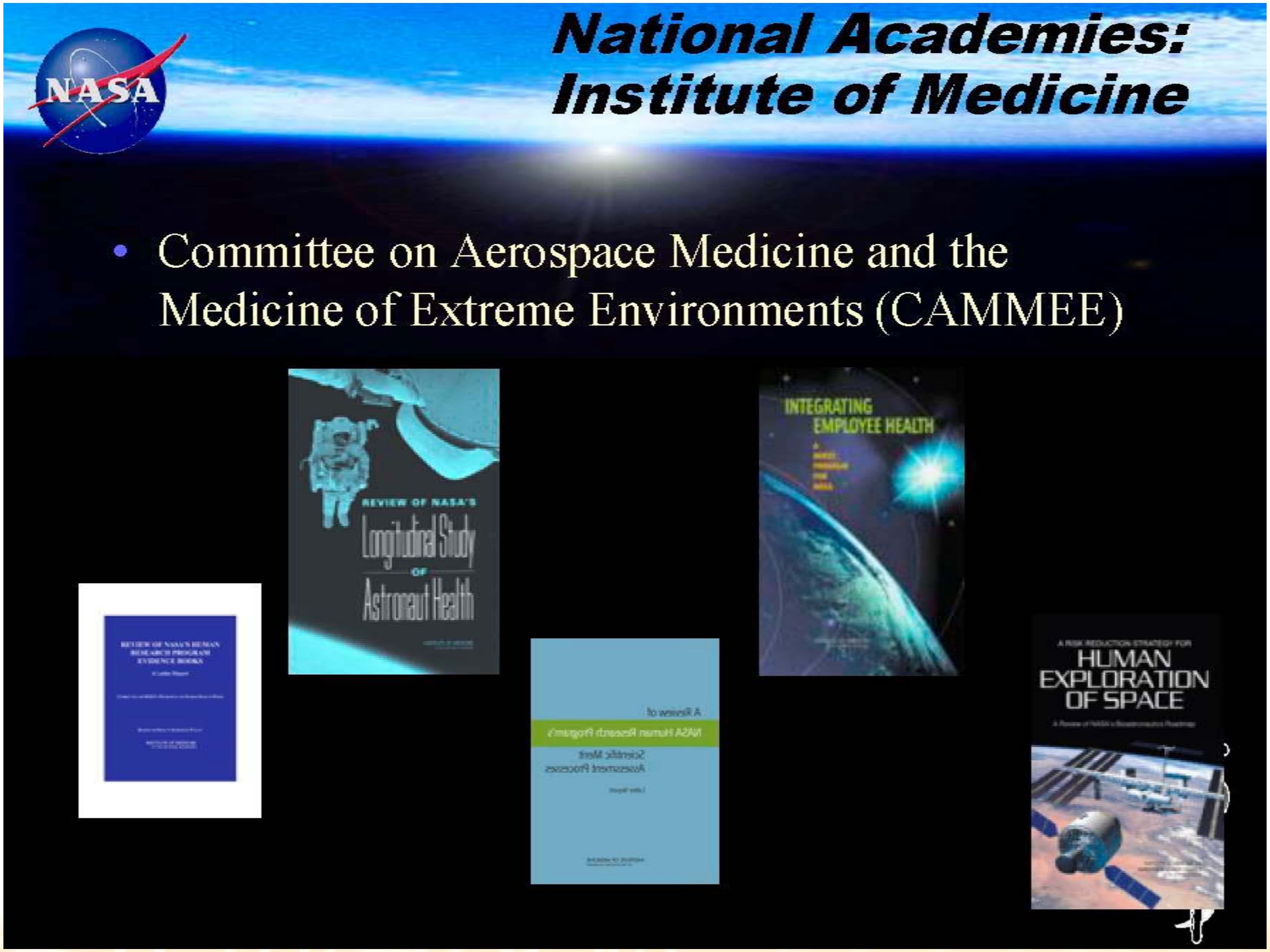
Time for Change NEW LSAH

→**For Human Spaceflight, NASA acts as;**

- NORA
- NIOSH
- OSHA
- Employer

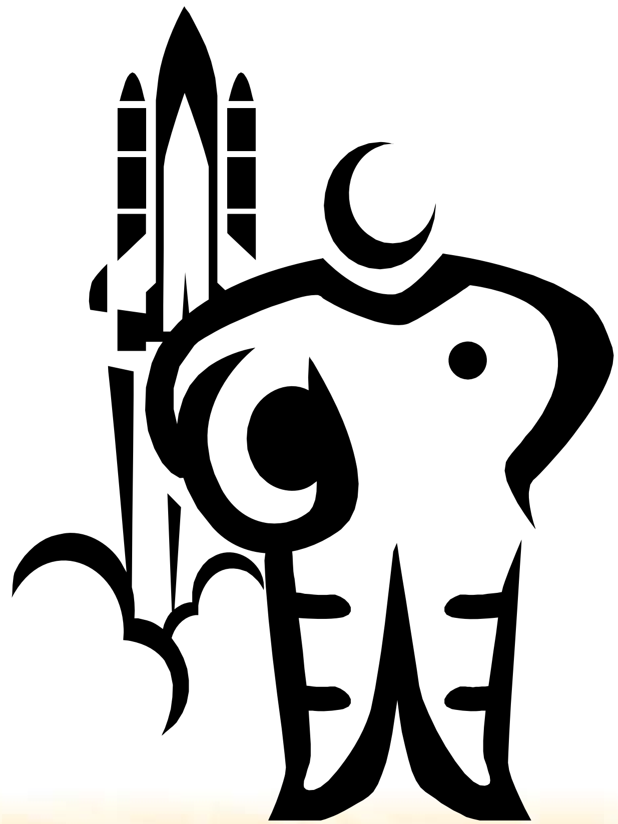
For the astronauts

External Program Reviews



Institute of Medicine Recommendations for Human Spaceflight

1. Must serve two sometimes conflicting goals of research and occupational surveillance...
2. No comparison group can meet every goal or need, it should be individualized...
3. Increase the quality and quantity of preventive care to increase the data...
4. NASA should assume responsibility for the lifelong health care of its active and former astronauts.



Additional Drivers for an Astronaut Occupational Surveillance Program

→ Legal obligation

– US government regulations to protect Federal workers from occupation-related hazards (OSHA 29CFR 1960, 29CFR 1910)

→ Ethical obligation to protect our Astronauts workforce

– Space related medical outcomes may manifest beyond current workers compensation statutes.

Why Change Now?

- Spaceflight paradigm shift- Shuttle Retirement, ISS construction completed and into full operations
- ISS, Emphasis on long duration habitation
- External Reviews and findings of NASA Astronaut Health and Human Research programs
- Integration of evolving medical evidence base into requirements development (vehicles, design reference missions, spacesuits, habitats) for exploration missions
- How does astronaut surveillance compare to what we have to do for JSC employees, how is it different???

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What is the Astronaut Occupational Health Surveillance Program (AOHP)?

- AOHP is a comprehensive program to monitor health outcomes due to the health risks of workplace exposures and develop strategies to best protect the astronaut.

- The modified strategy is more in line with traditional occupational surveillance with additional considerations for the unique environment.

Astronaut Occupational Health Program

Astronaut Occupational Health Program:
Primary responsibility for policy and decision-making, recommendations for requirements/standards/causation determination

Astronaut Medical Services:
Primary responsibility for implementing all elements of astronaut 'clinical' care from selection through retirement.

Lifetime Surveillance of Astronaut Health:
Primary responsibility for data integrity and management, and building and disseminating clinical evidence base.

Occupational Health Management:
Integration??
Primary responsibility for integration within and external to Occ HL, such as HRP, ISSPO, other elements of HEOMD

AOHP Goals

- Goal 1: Develop and Provide a Comprehensive Annual Medical Exam for each LSAH Participant
- Goal 2: Conduct Occupational Surveillance
- Goal 3: Improve Communication, Data Accessibility, Integrity and Storage
- Goal 4: Support Operational and Health Care Analyses
- Goal 5: Support NASA Research Objectives

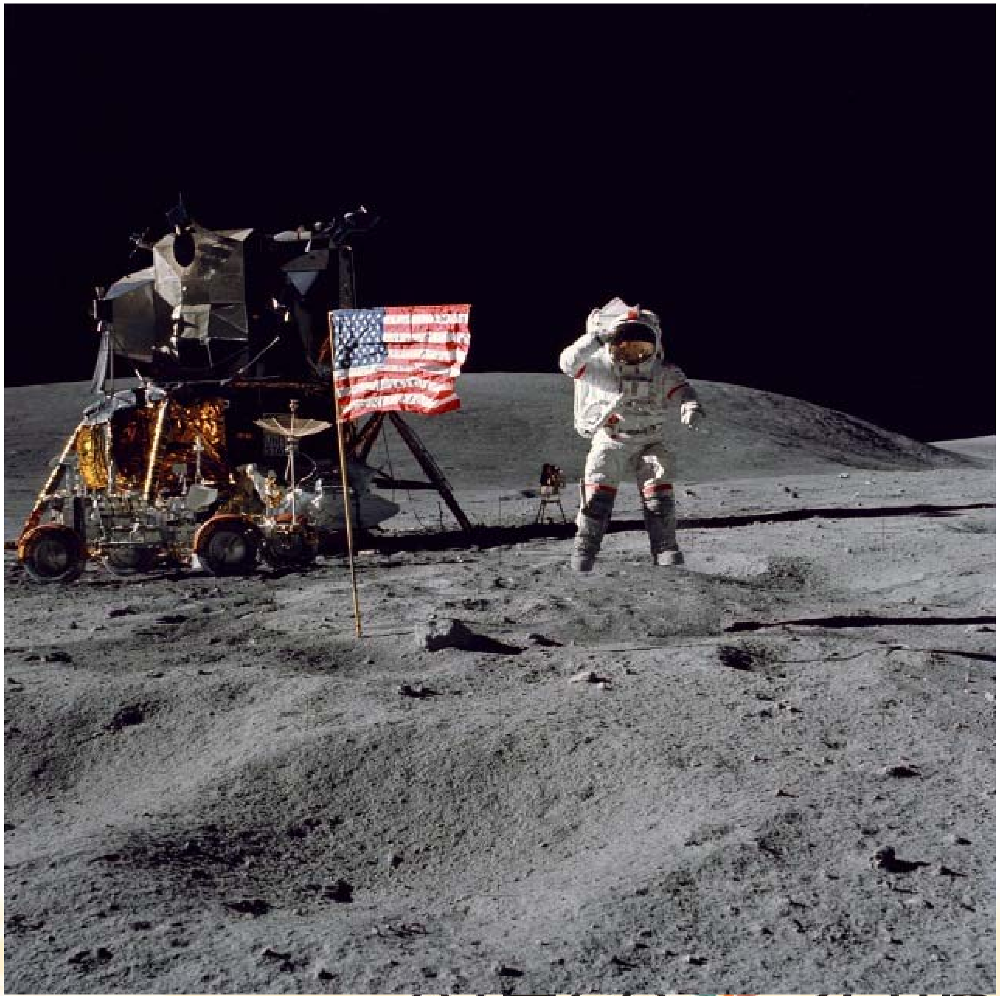
Healthcare/Exposures

Astronaut Occupational Health Program

- Benchmarked off of similar programs in DoD and the Department of Energy
- Allows insight into long-term sequelae from exposures in the workplace
- Presented Draft Model to NIOSH

Occupational Surveillance for Astronauts

- Meets Ethical and Moral obligation
- Increases data available to research
- Identifies and prevents exposure related disease
- Allows feedback into spacecraft design
- Allows NASA to follow long term health impacts



Similar Exposure Groups SEG

Following the fairly standardized process well known in the industrial environment, the astronauts are considered an SEG. We monitor them as a group, then as specific individuals, based on exposures and other factors, throughout their “NASA” career.

NASA JSC Human Spaceflight Risks

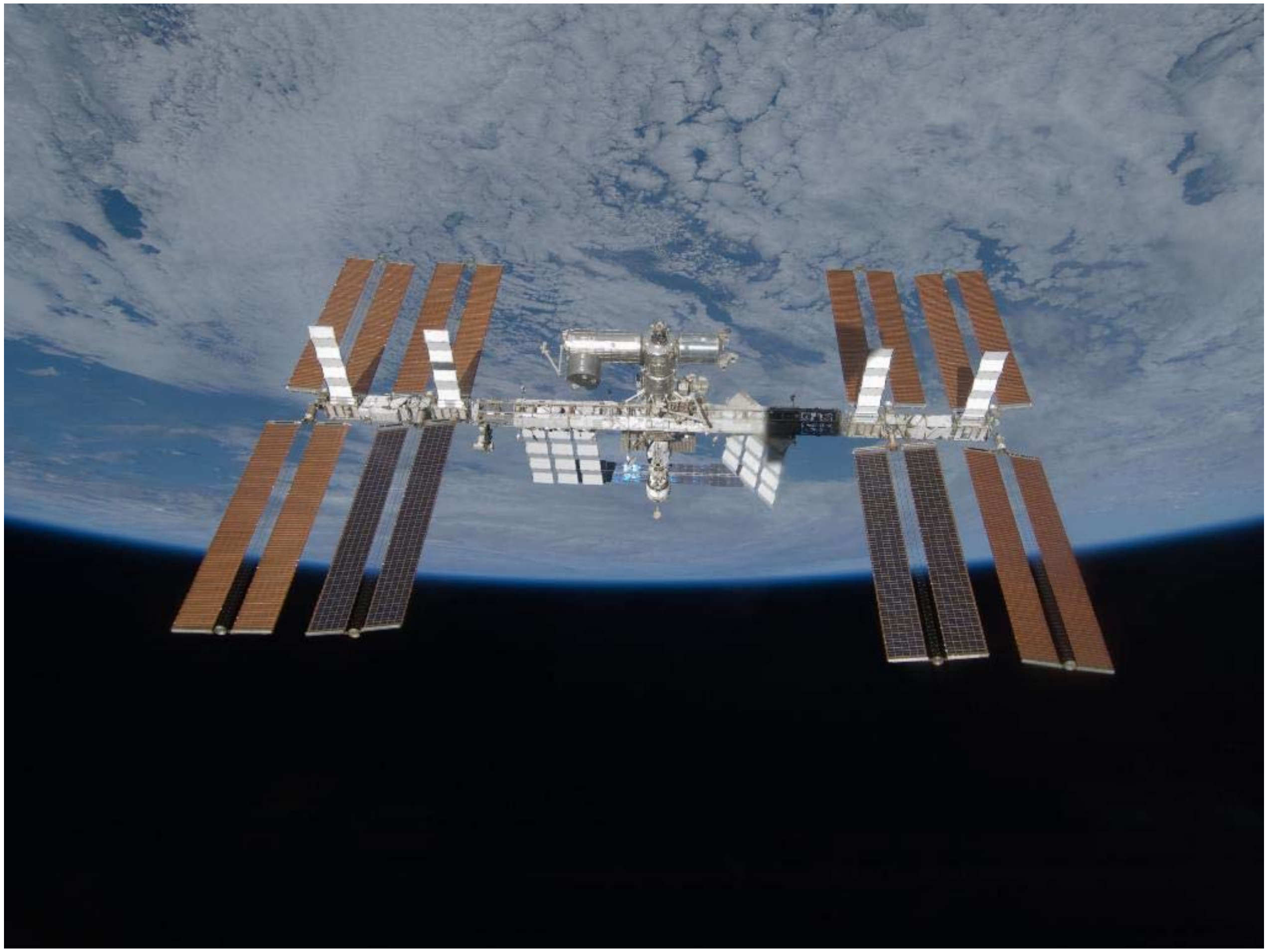
Human Systems Risk Board HSRB

HMTA Integrated Human System Risk Summary

Show Likelihood vs Consequence Scales

DRM Categories Details	In Mission Risk - Operations						Post Mission Risk - Long Term Health					
Human Spaceflight Risks	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Visit/ Habitation	Deep Space Journey/ Habitation	Planetary Visit/ Habitation	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Visit/ Habitation	Deep Space Journey/ Habitation	Planetary Visit/ Habitation
	6 Months	1 Year	1 Month	1 Year	1 Year	3 Years	6 Months	1 Year	1 Month	1 Year	1 Year	3 Years
Renal Stone Formation	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
Inflight Medical Conditions	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation
Cardiac Rhythm Problems	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Requires Mitigation	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring
Cognitive or Behavioral Conditions	Accepted with Monitoring	Requires Mitigation	Accepted with Monitoring	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation
Inadequate Food and Nutrition	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted / Optimize	Requires Mitigation
Bone Fracture	Accepted / Standard Refinement	Accepted / Standard Refinement	Accepted / Low Probability	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Accepted / Standard Refinement	Accepted / Standard Refinement	Accepted / Low Probability	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize
Psychosocial Adaptation within a Team	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted with Monitoring
Inadequate Human-System Interaction Design	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Standard Refinement, May Require Mitigation	Standard Refinement, May Require Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
Hypobaric Hypoxia	Requires Mitigation / Data	Requires Mitigation / Data	Accepted with Monitoring	Requires Mitigation / Data	Requires Mitigation / Data	Requires Mitigation / Data	Requires Mitigation / Data	Requires Mitigation / Data	Accepted	Requires Mitigation / Data	Requires Mitigation / Data	Requires Mitigation / Data
Sleep Loss	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
Toxic Exposure	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted	Accepted	Accepted	Accepted	Accepted with Monitoring	Accepted with Monitoring
Altered Immune Response	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
Host-Microorganism Interactions	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
Reduced Aerobic Capacity	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
Reduced Muscle Mass, Strength	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
Sensorimotor Alterations	Accepted / Standard Refinement	Accepted / Standard Refinement	Accepted / Standard Refinement	Requires Mitigation	Requires Mitigation	Requires Mitigation	Accepted	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
Electrical Shock	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired	Accepted / Retired
Hearing Loss Related to Spaceflight	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring	Accepted with Monitoring
Injury from Sunlight Exposure	Accepted / Low Probability	Accepted / Low Probability	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted / Optimize	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
Urinary Retention	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted
Back Pain	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	N/A	N/A	N/A	N/A	N/A	N/A
Celestial Dust Exposure	N/A	N/A	TBD	Accepted	TBD	TBD	N/A	N/A	TBD	Accepted	TBD	TBD
Intervertebral Disc Damage	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Unpredicted Effects of Medication	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

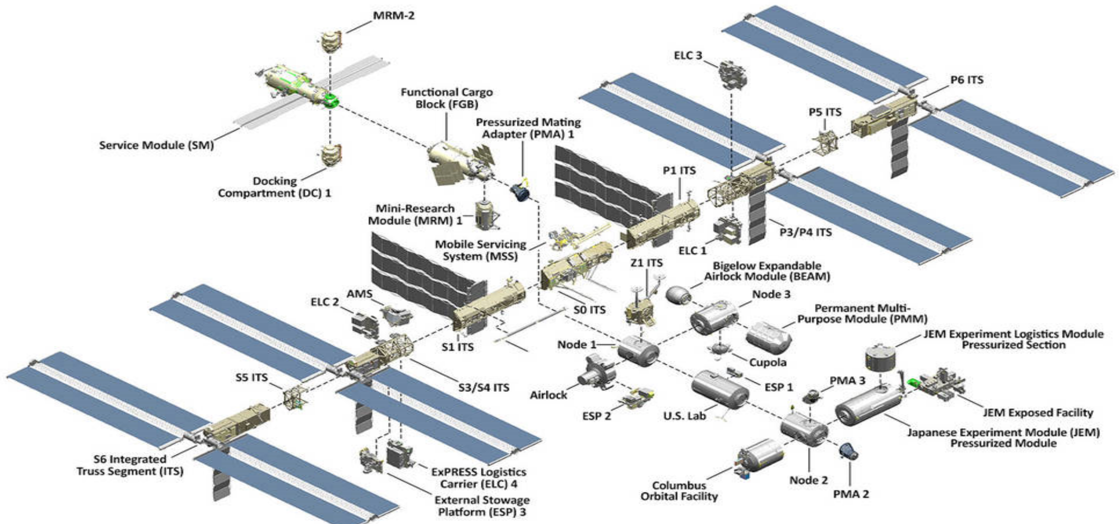
The Work Environment



Terrestrial
Aircraft Operations

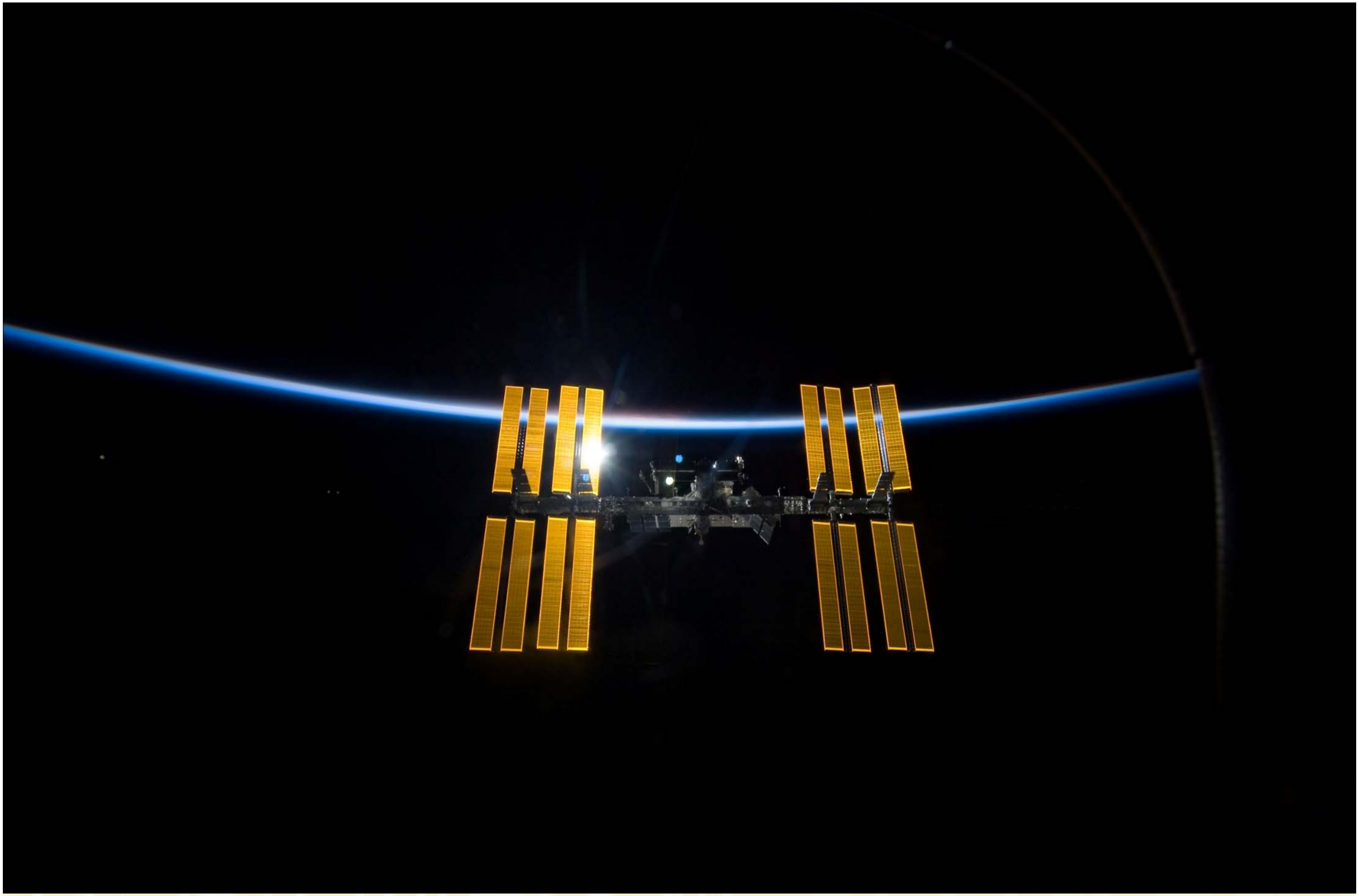
Terrestrial
Neutral Buoyancy Lab

Terrestrial
Extreme Environments



International Space Station

- Module Length: 167.3 feet (51 meters)
- Truss Length: 357.5 feet (109 meters)
- Solar Array Length: 239.4 feet (73 meters)
- Mass: 924,739 pounds (419,455 kilograms)
- Habitable Volume: 13,696 cubic feet (388 cubic meters)
- Pressurized Volume: 32,333 cubic feet (916 cubic meters)
- Power Generation: 8 solar arrays = 84 kilowatts
- SS is larger than a six-bedroom house.
- ISS has an internal pressurized volume of 32,333 cubic feet, or equal that of a Boeing 747.
- More than 115 space flights were conducted. five different types of launch vehicles, over the course of the station's construction.
- More than 100 telephone-booth-sized rack facilities can be in the ISS for operating the spacecraft systems and research experiments.
- The ISS is almost four times as large as the Russian space station Mir and about five times as large as the U.S. Skylab.
- In the International Space Station's U.S. segment alone, 1.5 million lines of flight software code run on 44 computers communicating via 100 data networks transferring 400,000 signals
- The ISS manages 20 times as many signals as the space shuttle.
- U.S. control computers have 1.5 gigabytes of total storage, compared to modern PCs, which have ~500 gigabyte hard drives.
- The entire 55-foot robot arm assembly is capable of lifting 220,000 pounds, which is the weight of a space shuttle orbiter.



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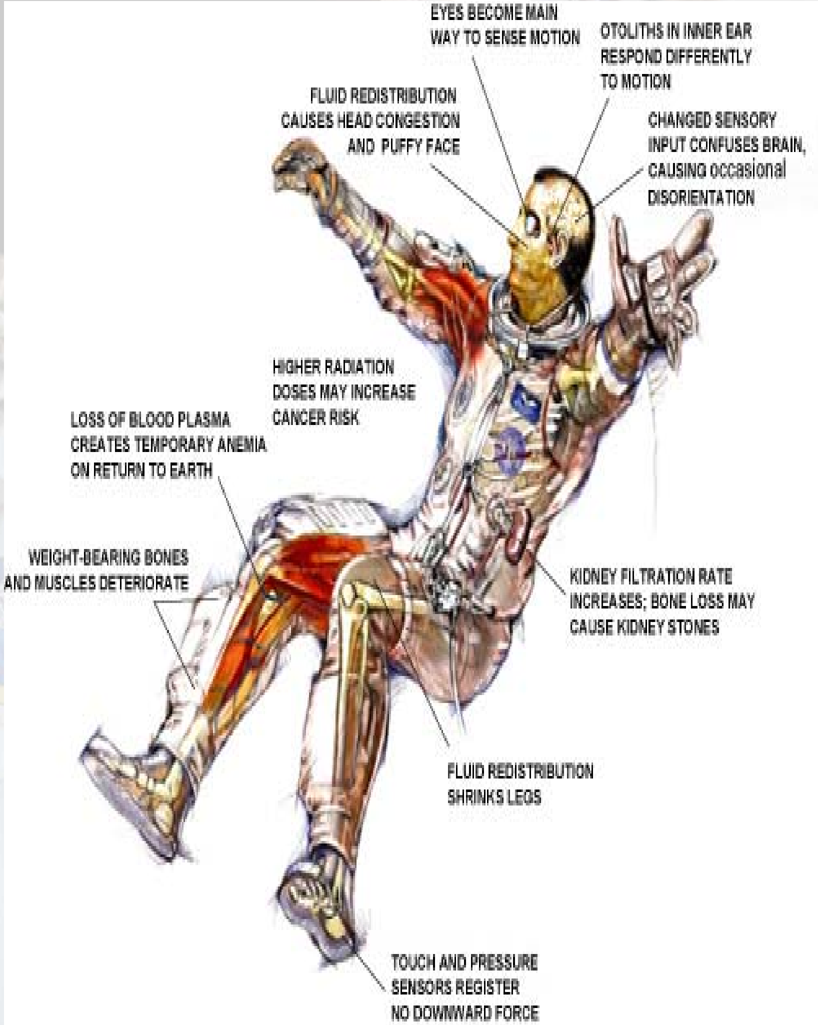
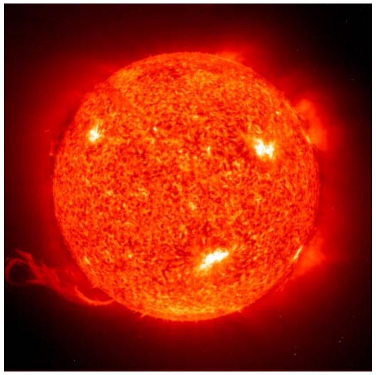
Occupational Hazards in Space



From Scientific American

- Microgravity
- Space Adaptation Syndrome
- Circadian Rhythm Disruption
- Radiation of the Space Variety
- Behavioral Health
- Noise
- Chemicals/Carbon Dioxide
- Lasers
- Rocket propellants
- Biological hazards from mice experiment

Extended Weightlessness

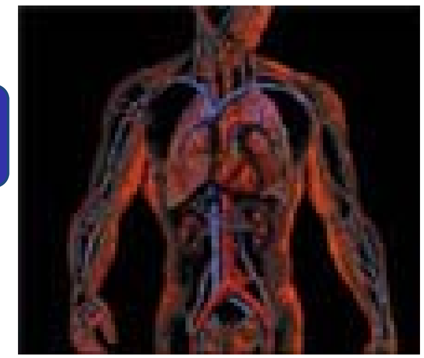


Radiation

Neurovestibular

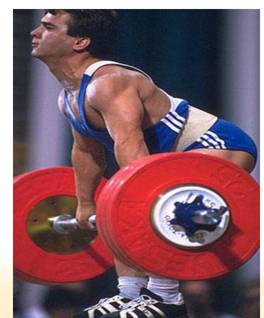
Bone

Cardiovascular



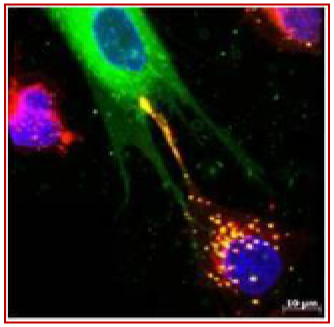
Behavior & performance

Muscle



NASA Health Standards for Human Spaceflight

- NASA STD-3001 Vol. 1: NASA Space Flight Human System Standard - Volume 1: Crew Health
  - *4.2.3 Fitness-for-Duty Aerobic Capacity Standard*
  - *4.2.4 Fitness-for-Duty Sensorimotor Standard*
  - *4.2.5 Fitness-for-Duty Behavioral Health and Cognition Standard*
  - *4.2.6 Fitness-for-Duty Hematology and Immunology Standard*
  - *4.2.7 Permissible Outcome Limit for Nutrition Standard*
  - *4.2.8 Permissible Outcome Limit for Muscle Strength Standard*
  - *4.2.9 Permissible Outcome Limit for Microgravity-Induced Bone Mineral Loss Performance Standard (Baseline with Measured Tscore)*
  - *4.2.10 Space Permissible Exposure Limit for Space Flight Radiation Exposure Standard*



Cell fusion after exposure to Simulated Space Radiation

HUMAN RESEARCH PROGRAM

- Analogs
- ISS Medical Projects
- Behavioral Health & Performance
- Exploration Medical
- Human Health Countermeasures
- Space Human Factors
- Space Radiation

Microgravity Adaptation

Relative to terrestrial normal, the returning de-conditioned, microgravity-adapted crew has:

→ •Hypovolemia –12% to 15% less blood volume (like dehydration)

→ •Anemia –10% to 12% less red blood cells

→ •Neurosensory deconditioning

→ •Aerobic deconditioning –15% to 20% deficit

→ •Decreased strength (postural muscles)

→ •Decreased bone density (postural joints)

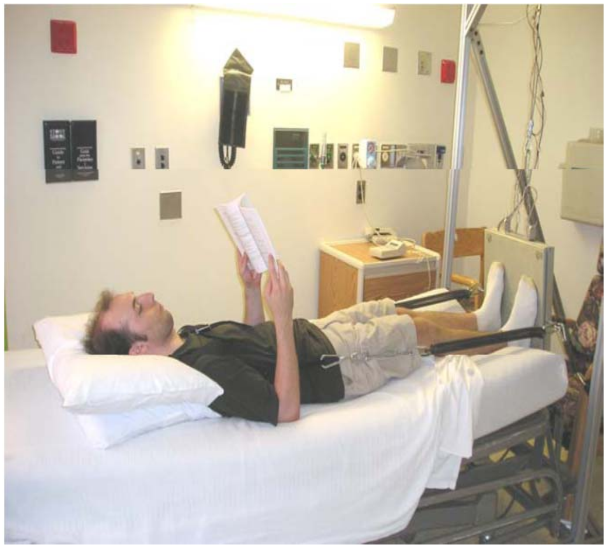
→ •Increased spinal length (about 6%; may affect suit fit)

Microgravity Adaptation

- Space Adaptation Syndrome(SAS)
  - Typically experienced in microgravity during first 2-3 days of spaceflight.
  - Nausea, Vomiting, Visual Illusions, Spatial Disorientation, Pallor, Fatigue, Malaise, Cold Sweat
  - Experienced by significant % of crews
- Entry Adaptation Syndrome (EAS)
  - Response to transitioning from microgravity back to 1G
  - Inverse of SAS
  - Similar symptomology and manifestations contribute to dehydration and orthostatic intolerance
  - Experienced by similar percentage of returning crews

Countermeasures

Research



Operational

Behavior and Performance

→**Occurrence**
- All subjected to factors that affect
  - Psychological well-being
  - Interactions with other crewmembers, families, and ground personnel
  - Performance of duties

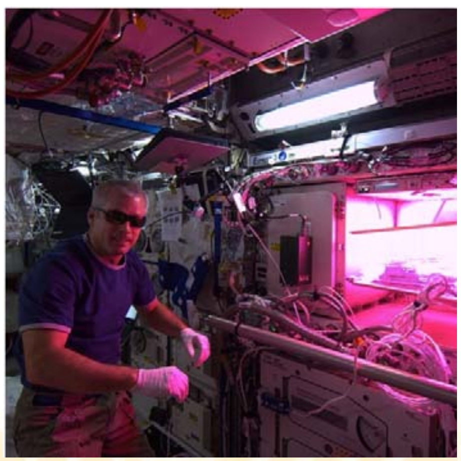
→**Due to**
- Mission design
- Events (9/11; holidays)
- Spacecraft environment
- Close quarters

→**Consequences – changes to**
- Interpersonal environment
- Safety and productively
- Team problem solving
- Decision making
- Communication

Habitability & Environmental Factors


ISS009E29027

Nutrition



Occurrence
- All crewmembers to varying degrees, more severe in long-duration missions

Due to
- Changes in sense of taste
- Limited food choices (currently ~10 day rotation)
- Scarce fresh fruits/vegetables

Consequences
- Decreased calories eaten and decreased vitamin/mineral intake
- Performance decrements?
- Immune, bone, other system impacts
- Decreased muscle mass
- Weight loss / dehydration
- Electrolyte disturbances

Countermeasures?
- Prevention
- In-flight nutrition questionnaires, pre/in/post-flight tracking
- Vitamins, supplements

Vehicle Surveillance Capability

Environmental Health System -

- Acoustics: Area Sound Level Meters
- Carbon Dioxide Monitoring
- Compound Specific Analyzers:
  - Oxygen
  - Combustion Products
- Toxicological 'Grab' Air Sampling
- Microbial Air & Surface Sampling
- Total Organic Carbon Analyzer
- Water Quality Monitoring
- Active and Passive Radiation Monitoring
- Combustion Products Analyzer
- Formaldehyde Monitoring

Vehicle Systems –

- Atmosphere Control and Supply System (ACS)
- Atmosphere Revitalization System (ARS)
- Internal Thermal Control System (ITCS)
- Passive Thermal Control System (PTCS)
- Regenerative Environmental Control and Life Support System (Regen ECLSS)

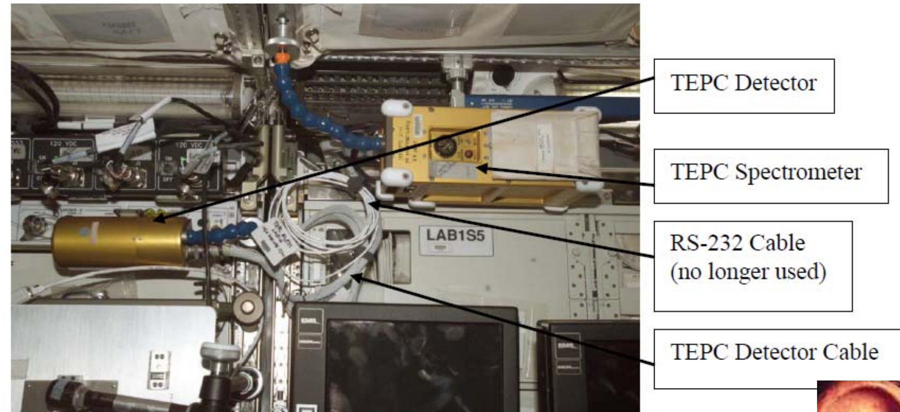
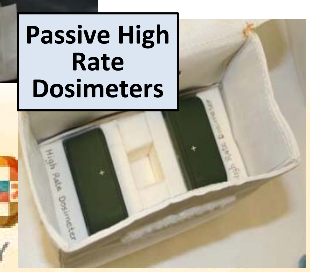
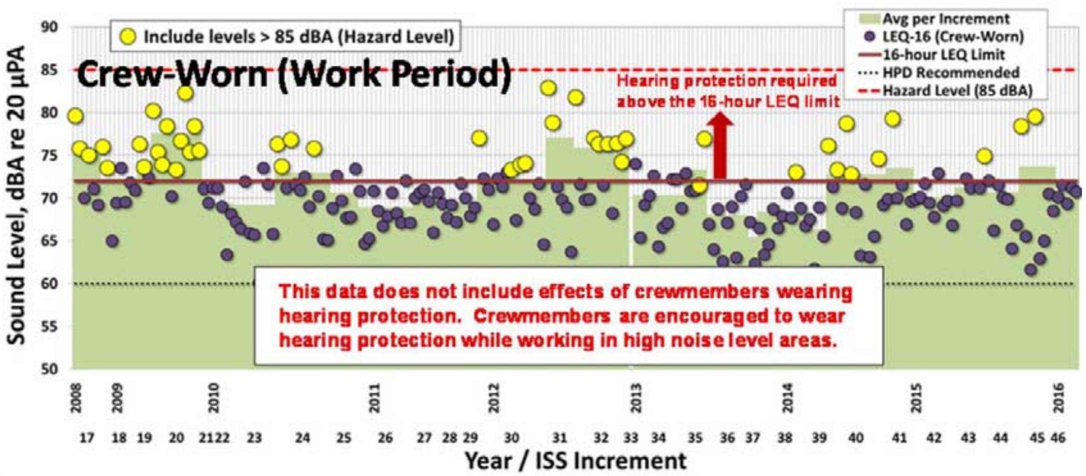
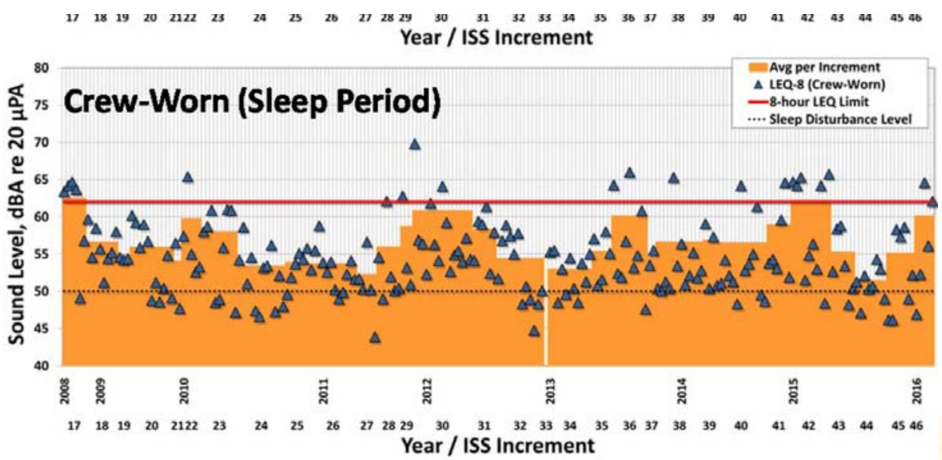


Figure 6. TEPC Spectrometer and Detector deployed in US LAB



Hearing Conservation/Acoustics





ISS Modules' Noise Levels

Module	NC-Level	dBA	SIL(4)*	Survey Date	Normal Level
PMA1	NC 42.7	47.7	40.8 dB	July 31, 2015	NC 43.0
JLP	NC 43.0	50.0	42.8 dB	May 28, 2015	NC 42.0
Airlock	NC 44.7	49.1	40.6 dB	May 28, 2015	NC 48.0
PMM	NC 46.6	50.5	41.4 dB	July 31, 2015	NC 48.0
Cupola	NC 46.9	53.0	43.3 dB	Sept 21, 2015	NC 45.0
Columbus	NC 49.9	53.5	45.7 dB	Apr 1, 2015	NC 43.0
Node 1	NC 51.7	55.1	47.6 dB	July 31, 2015	NC 49.0
JPM	NC 52.1	55.2	47.3 dB	Mar 29, 2016	NC 48.0
DC1	NC 53.8	58.6	51.3 dB	Apr 1, 2015	NC 61.0
Node 3 w/UPA DA ON	NC 56.8	61.1	53.3 dB	Sept 15, 2014	NC 56.0
Node 3 w/UPA DA OFF	NC 56.8	60.9	51.2 dB	Sept 21, 2015	NC 55.0
FGB	NC 57.1	62.2	53.6 dB	Mar 29, 2016	NC 58.0
US Lab	NC 57.5	60.1	52.4 dB	Mar 29, 2016	NC 52.0
MRM1	NC 58.6	62.9	54.6 dB	Sept 21, 2015	NC 65.0
MRM2	NC 59.9	64.4	57.6 dB	July 31, 2015	NC 62.0
SM	NC 60.4	64.7	56.6 dB	Mar 29, 2016	NC 60.0
Node 2	NC 60.5	62.8	52.2 dB	Mar 29, 2016	NC 49.0

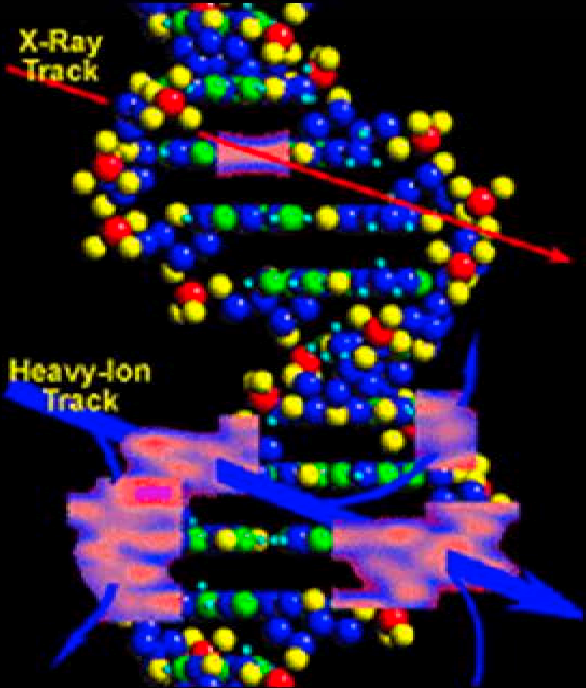
Year / ISS Increment

ISS Sleep Stations' Noise Levels

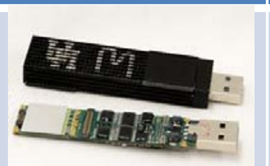
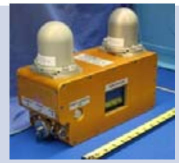
Sleep Station	NC-Level	dBA	SIL(4)	Survey Date	Fan Speed
Deck CQ	NC-43.7	48.8 dBA	36.2 dB	Mar 29, 2016	High
Stbd CQ	NC-46.1	49.9 dBA	37.6 dB	Mar 29, 2016	High
Ovhd CQ	NC-48.1	51.8 dBA	39.5 dB	Mar 29, 2016	High
Stbd kayuta	NC-50.4	54.7 dBA	41.8 dB	Mar 29, 2016	
Port CQ	NC-51.8	54.4 dBA	41.1 dB	Mar 29, 2016	High
Port kayuta*	NC-64.4	65.5 dBA	56.0 dB	Mar 29, 2016	

Space Radiation

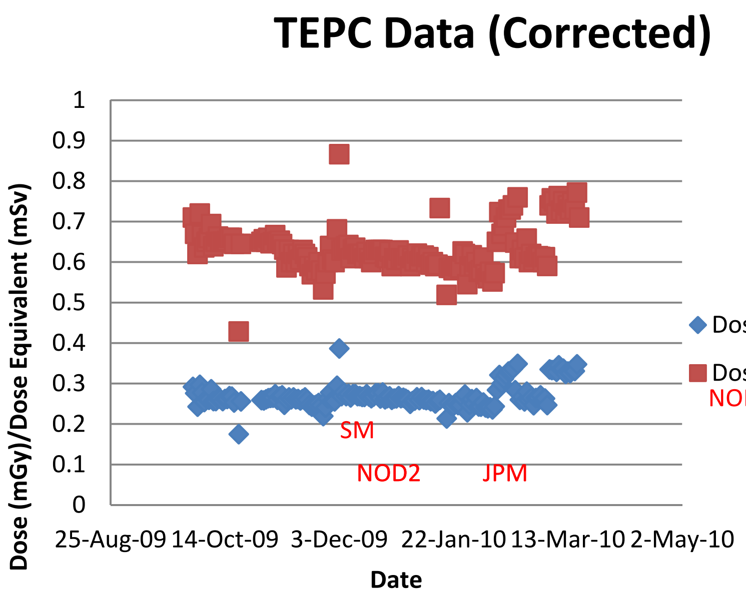
- **Galactic Cosmic Rays (GCR):**
  - highly penetrating protons and heavy ions of extra-solar origin
  - large amounts of secondary radiation
  - largest doses occur during minimum solar activity in an 11-year solar cycle
- **Solar Particle Events (SPE):**
  - medium to high-energy protons
  - occur during maximum solar activity

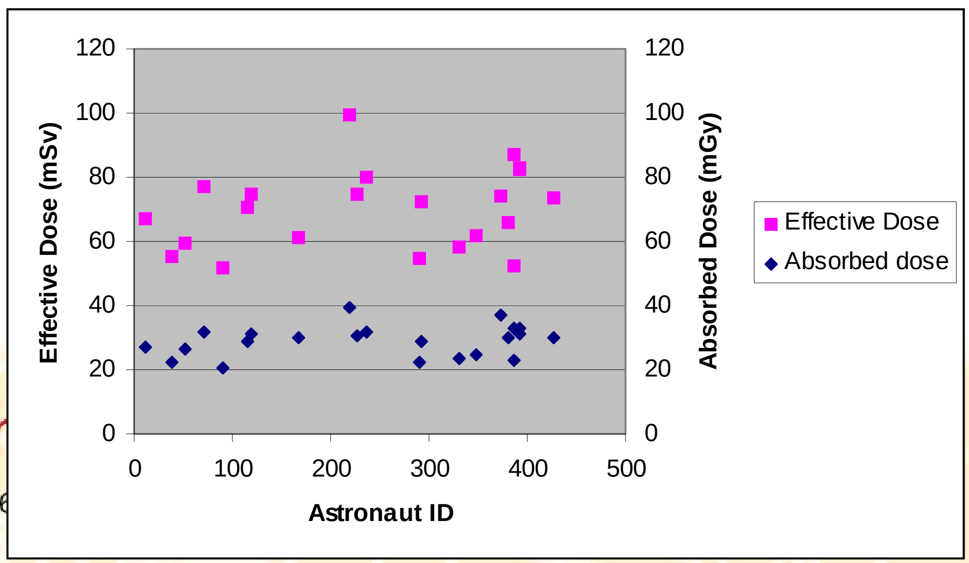


Radiation Monitoring Instruments

	REM Radiation Environmental Monitor (SDTO)	TEPC Tissue Equivalent Proportional Counter	IV-TEPC Intravehicular Tissue Equivalent Proportional Counter	RAD Radiation Assessment Detector	EV-CPDS Extravehicular Charge Particle Directional Spectrometer
TIME-RESOLVED RADIATION HARDWARE					
NASA PROGRAMS	ISS Orion EFT-1 (as BIRD)	ISS Space Shuttle	ISS	ISS	ISS (outside)
IN-ORBIT STATUS	Active (1) US Lab; (1) COL; (2) JPM; (1) Cupola. ISS Survey instrument	Active SM-P327 Fixed location	Channel 2: Enabled; In Acquire ISS Survey instrument	To be launched on SpaceX-8 ISS Survey instrument	EV3: Active, S0 Truss (aft) Fixed location
DETECTOR TYPE	Small, low power, active Pixel detector (Timepix) 256 x 256 pixels	Cylindrical Tissue equivalent	Spherical Tissue equivalent Low and high gain detectors	Charged Particle Silicon Detector (CPD) Fast Neutron Detector (FND)	Silicon Detectors
DIRECTIONALITY	Omni-directional	Omni-directional	Omni-directional	Directional	Directional
MEASUREMENT CAPABILITY PROTONS & CHARGED PARTICLES	Linear energy spectra 0.1-1000 keV/µm GCR/SAA discrimination	Lineal energy spectra 0.4-1000 keV/µm GCR/SAA discrimination	Lineal energy spectra 0.4-1000 keV/µm GCR/SAA discrimination	Differential Flux and Energy Spectra $Z < 3$, 30 – 200 MeV/n $3 \leq Z \leq 26$, 100 – 200 MeV/n	Energy spectra for $Z < 4$ Proton spectrum up to ~120MeV He spectrum ~300MeV/n
MEASUREMENT CAPABILITY NEUTRONS	N/A	N/A	N/A	Energy Spectra 0.5 – 80 MeV	N/A
DOSIMETRY	Particle flux, Energy Spectra, Dose & Dose Equivalent	Dose & Dose equivalent	Dose & Dose Equivalent	Particle flux, Event Rates, Dose & Dose Equivalent	Dose rate & Cumulative Dose

In-Flight Active Monitoring





TEPC located at SM panel327

- Record of radiation doses are used to document occupational exposure.
- Characterization of the radiation environment is used for updating exposure records for risk assessments.

Table 4-1. ***Example Career Effective Dose Limits in Units of milli-Sievert (mSv) for 1-year Missions and Average Life-loss for an Exposure-induced Death for Radiation Carcinogensis (1 mSv = 0.1 rem)***

	E(mSv) for 3% REID (Ave. Life Loss per Death, yr)	
Age, yr	**Males**	**Females**
25	520 (15.7)	370 (15.9)
30	620 (15.4)	470 (15.7)
35	720 (15.0)	550 (15.3)
40	800 (14.2)	620 (14.7)
45	950 (13.5)	750 (14.0)
50	1,150 (12.5)	920 (13.2)
55	1,470 (11.5)	1,120 (12.2)

Human Health and Performance
Risks of Space Exploration Missions

Evidence reviewed by the NASA Human Research Program

Table 5-1. ***Dose Limits (in mGy-Eq or mGy) for Non-cancer Radiation Effects (BFO Refers to the Blood-forming Organs and CNS to the Central Nervous System)***

Organ	30-day limit	1-year limit	Career
Lens*	1,000 mGy-Eq	2,000 mGy-Eq	4,000 mGy-Eq
Skin	1,500 mGy-Eq	3,000 mGy-Eq	6,000 mGy-Eq
BFO	250 mGy-Eq	500 mGy-Eq	Not applicable
Heart**	250 mGy-Eq	500 mGy-Eq	1,000 mGy-Eq
CNS***	500 mGy-Eq	1,000 mGy-Eq	1,500 mGy-Eq
CNS*** ($Z \geq 10$)	–	100 mGy	250 mGy

*Lens limits are intended to prevent early (<5 years) severe cataracts (e.g., from an SPE). An additional cataract risk exists at lower doses from cosmic rays for subclinical cataracts, which may progress to severe types after long latency (>5 years) and are not preventable by existing mitigation measures; they are deemed an acceptable risk to the program, however.

**Heart doses calculated as average over heart muscle and adjacent arteries.

***CNS limits should be calculated at the hippocampus.

Human Health and Performance
Risks of Space Exploration Missions

Evidence reviewed by the NASA Human Research Program

Spaceflight Chemical Exposure Standards

Spacecraft Maximum Allowable Concentrations for Airborne Contaminants

Toxicology Group
Environmental Factors Office
Habitability and Environmental Factors Division
Space Life Sciences Directorate

Spacecraft Water Exposure Guidelines (SWEGs)

Toxicology Group
Environmental Factors Office
Habitability and Environmental Factors Division
Space Life Sciences Directorate

SMACs (Spacecraft Maximum Allowable Concentrations)

POTENTIAL EXPOSURE DURATION

Chemical	1 hr		24 hr		7 d		30 d		180 d		1000 d	
	ppm	(mg/m³)	ppm	(mg/m³)	ppm	(mg/m³)	ppm	(mg/m³)	ppm	(mg/m³)	ppm	(mg/m³)
C3-C8 Aliphatic Saturated Aldehydes	45	(varies)	45	(varies)	4.5	(varies)	4.5	(varies)	4.5	(varies)	4.5	(varies)
Synonyms:	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
NRC Vol. #: 5 CAS #: various; Year SMAC was Set/ Reviewed: 2008; *Remarks:*	Mucosa	Irritation	Mucosa	Irritation	Nasal Cavity	Injury	Liver; Nasal Cavity	Hepatotoxicity; Injury	Liver; Nasal Cavity	Hepatotoxicity; Injury	Nasal Cavity	Injury
Ammonia	30	(20)	20	(14)	3	(2)	3	(2)	3	(2)	3	(2)
Synonyms:	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*	*Organ*	*Effect*
NRC Vol. #: 5 CAS #: 7664-41-7; Year SMAC was Set/ Reviewed: 2008; *Remarks:* Ceiling values	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation	Eye	Irritation

Archival Water Sample Collection Packets

- 4 archive water samples (500 mL) collected prior to vehicle returns
- Allows for comprehensive assessment of water quality

ISS Total Organic Carbon Analyzer (TOCA)

- TOCA measures total organic carbon (TOC) and total inorganic carbon (TIC) in a water sample but does not identify individual contaminants.
- **Uses non-dispersive infrared detector to measure CO2 generated during oxidation of organic contaminants.**
- **U.S. potability limit for TOC < 3.0 mg/L.**
- **TOC concentrations are typically < 0.3 mg/L.**

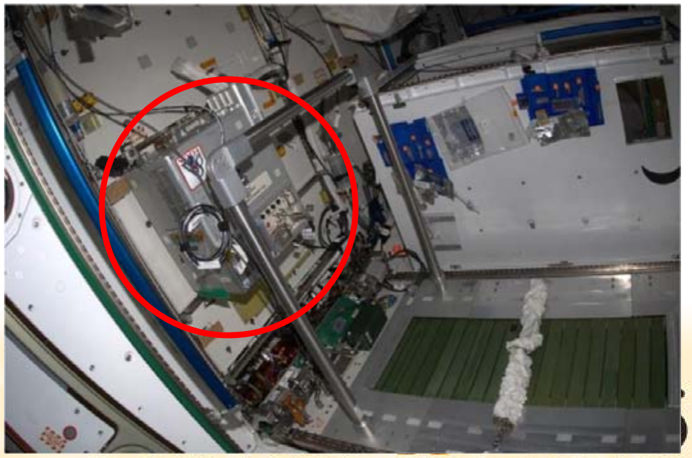
Analysis Schedule:

- Weekly samples from WPA product tank via TOCA hose
- Monthly samples from the Potable Water Dispenser (PWD) collected in sample bags

TOCA PFU2

TOCA Hose

TOCA Bag



Colorimetric Water Quality Monitor Kit (CWQMK)

- Provides the capability to measure ionic silver (Ag^+), molecular iodine (I_2), and total iodine (sum of I^-, I_2, and I_3^-) concentrations in water samples on the ISS.
  - Ionic silver – biocide used in RS water systems
  - Molecular iodine – biocide used in US water recovery system
  - Total iodine – monitored at points of crew consumption (medical requirement)
- Monitoring Frequency:
  - Total iodine concentration in US potable water measured quarterly in ambient samples from PWD.
  - Biocide concentrations can be measured to support contingency operations.

Carbon Dioxide Monitor (CDM)

- Commercial unit
- 6 % upper limit
- 18 h battery life (pump)
- Water & particle filter
- Robust/stable device that uses non-dispersive infrared detector

Formaldehyde Badges

- Formaldehyde Monitoring Kit (FMK)
- Formaldehyde trapped in badge matrix by diffusion
- Typical exposure time is 48 h (in pairs)
- Formaldehyde eluted from badge on the ground and analyzed by spectrophotometry
- Limitation: Sufficient face velocity of air required for best results

Compound Specific Analyzer – Combustion Products (CSA-CP)

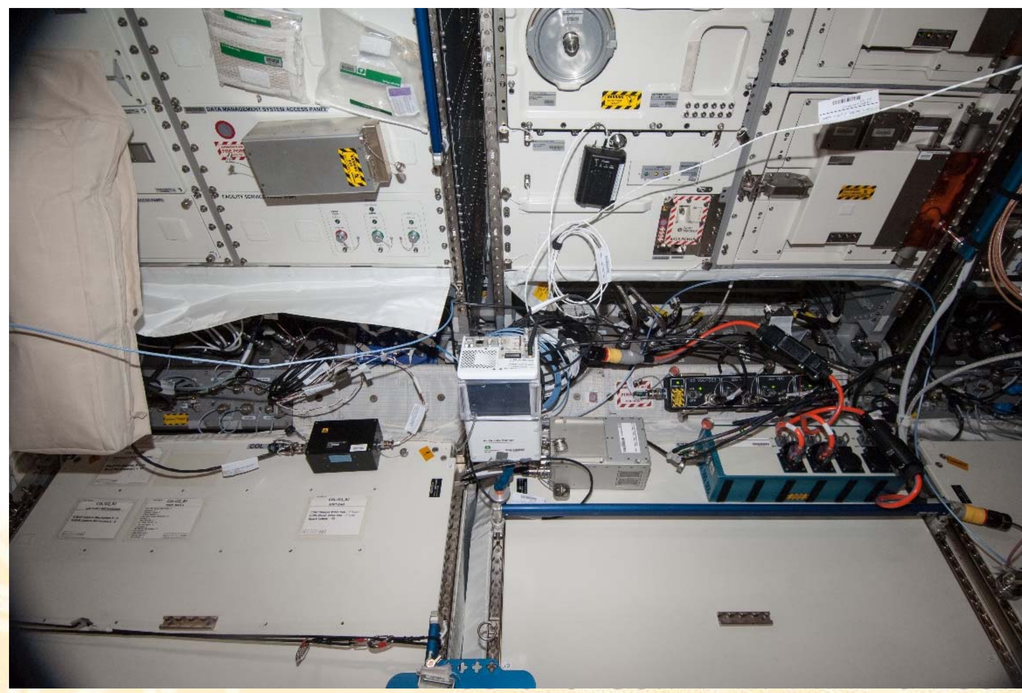
- Commercial unit with electrochemical sensors
- Measures:
  - Carbon Monoxide
  - Hydrogen Chloride
  - Hydrogen Cyanide
  - Oxygen sensors have been removed from current units.
- Post-fire cleanup monitoring
- Mask-doff criteria
- Can be used to investigate sources of combustion products using pump/probe attachment
- Can be zero calibrated inflight

Archival Air Samples

- Grab Samples Canisters (GSCs) evacuated and doped on the ground
- Sample collected in <5 seconds (by opening valve)
- 2 samples collected every 45 days
- Returned and analyzed at JSC by GC/FID and GC/MS
- Benefit: Track 100's of compounds
- Limitation: Reactive compounds are lost

Air Quality Monitor (AQM)

- Periodic measurement of volatile organic compounds in-flight
- Gas Chromatograph-Differential Mobility Spectrometer
- Automated run sequence every ~73 hrs
- 3 year operational life
- Operated in pairs (different GC columns)
- Capable of monitoring 22 target analytes.



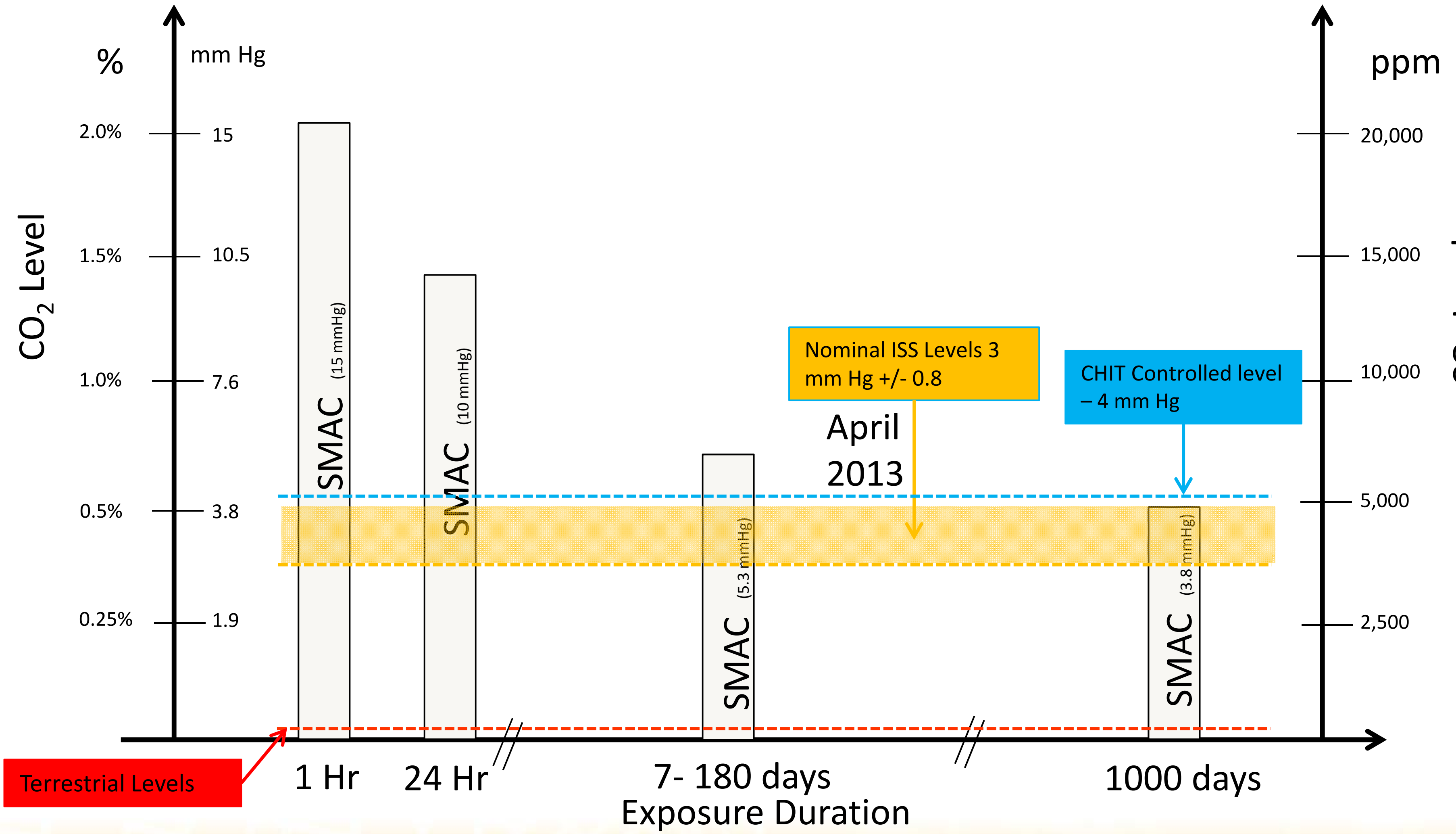
AQM Target Compounds

AQM 1 (2218 - 624 column)	AQM 2 (2221 - DB5 column)
Methanol	Acetaldehyde
Acetone	Ethanol
Hexane	Dichloromethane
1,2-Dichloroethane	Trimethylsilanol
Hexanal	2-Butanone
Acrolein	Ethyl acetate
Isopropanol	n-Butanol
Benzene	
Toluene	**Toluene**
o-Xylene	**o-Xylene**
m-/p-Xylene	**m-/p-Xylene**
Hexamethylcyclotrisiloxane	**Hexamethylcyclotrisiloxane**
Octamethylcyclotetrasiloxane	**Octamethylcyclotetrasiloxane**
Decamethylcyclopentasiloxane	**Decamethylcyclopentasiloxane**

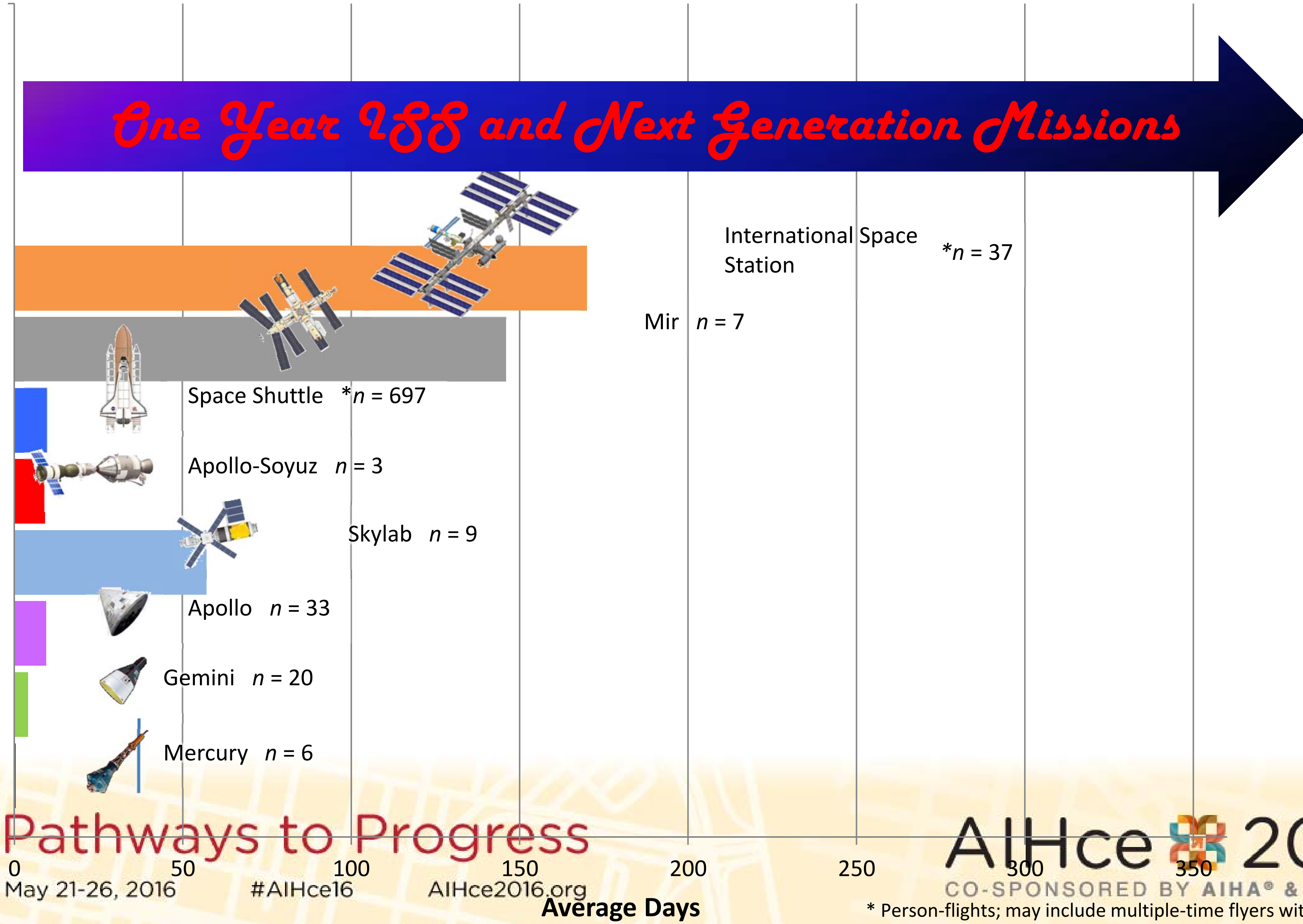
Bolded compounds measured by both units

CO_2 Exposures – Acute, Transient, Chronic

Spacecraft Maximum Allowable Concentrations (**SMAC**) and **CHIT** Implemented Levels



NASA Human Space Flight



* Person-flights; may include multiple-time flyers within program

Extra Vehicular Activity


Thank You
Additional Thanks to some other collegues ;
Daniel Gazda,
Dick Danielson,
Eddie Semones
Lots of Others