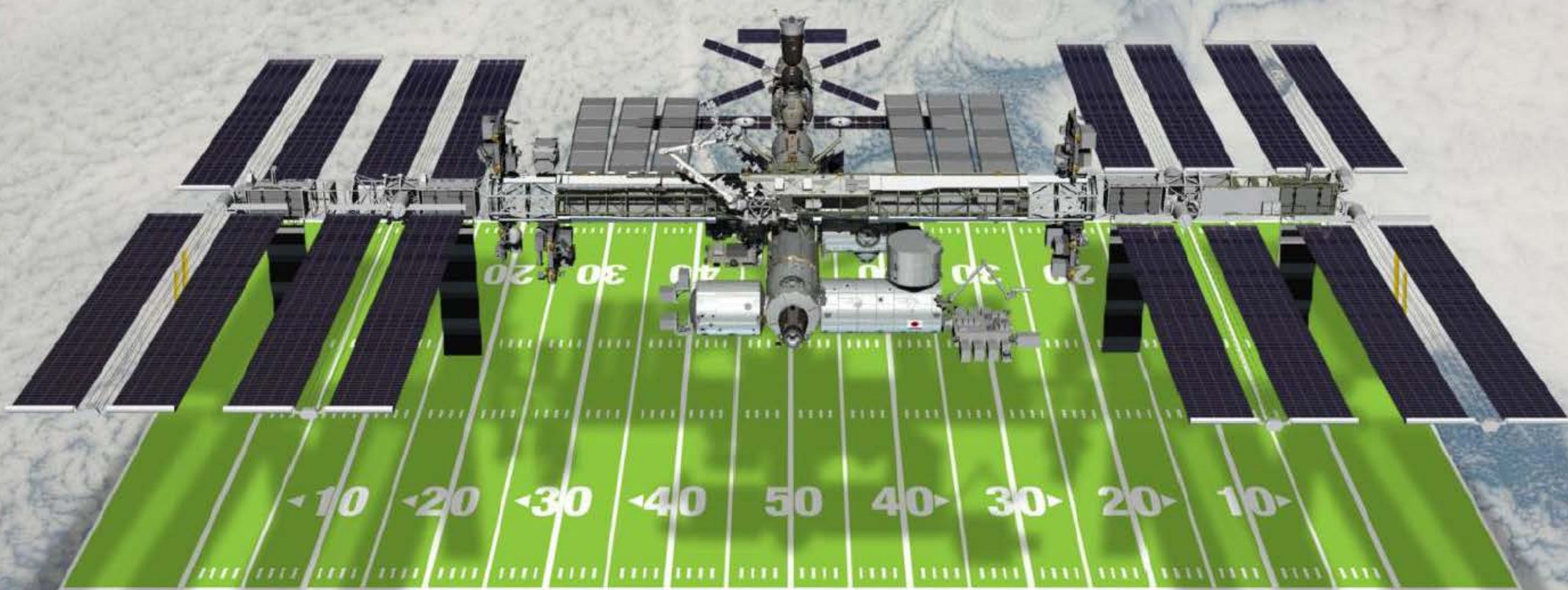
International Space Station Status
And a Look Forward From NASA's Perspective

Annual Association of Space Explorers Congress
October 2016
Joe Acaba, NASA Astronaut

International Space Station



Spacecraft Mass: ~925,000 lb (~419,000 kg)

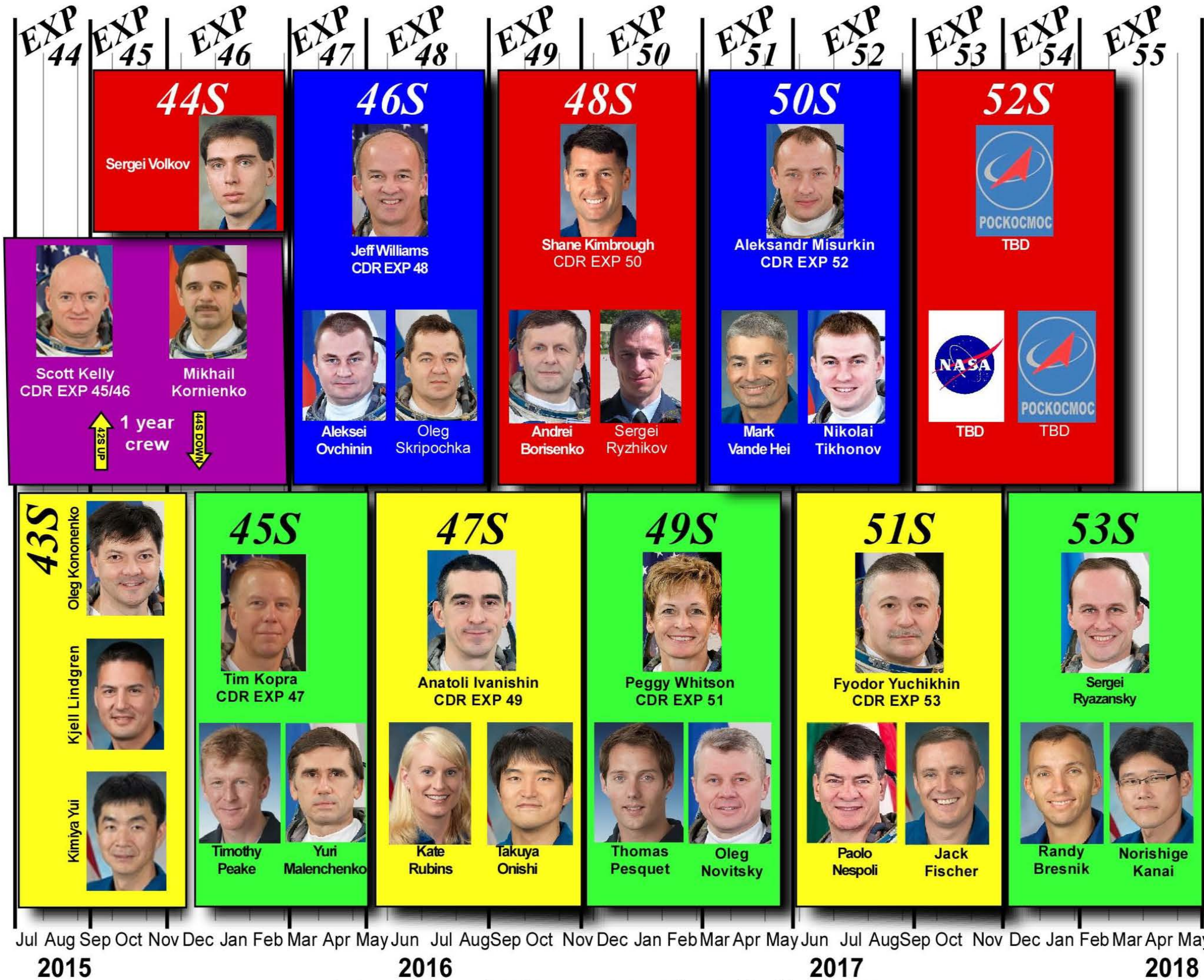
Spacecraft Pressurized Volume: 32,333 ft^3 (915 m^3)

Altitude: ~260 miles (~415 km) Inclination: 51.6°

Velocity: 17,500 mph (28,200 kph)

Science Capability: Laboratories from four international space agencies – US, Europe, Japan, and Russia.

Proposed ISS Crewmember & Flight Surgeon Assignments as of 9/14/15



to be used for planning purposes only - subject to change

- Systems Update
- Operations and Habitability
- Extra Vehicular Activity
- Research
- Exploration

Motion Control System

The biggest update for MCS is the migration of several activities to US control instead of RS control. In the past year we have performed the following activities on US control.

- Progress undock from SM Aft on CMG momentum management (used 0 kg of prop)
- Soyuz undock from MRM-1 and MRM-2 on CMG attitude hold (used less than 1 kg of prop for each undock)
- RS Solar Array Efficiency Test on CMG momentum management (used 0 kg of prop)
- Soyuz thruster test on CMG momentum management (used 0 kg of prop)
- Progress prop purge from SM Aft on CMG momentum management (used 0 kg of prop)
- Progress prop purge from DC-Nadir on CMG attitude hold (used less than 2 kg of prop)

All of these activities used to be done exclusively on RS control. By moving to US control, hundreds of kilograms of prop can be saved per year. With the reduction of Progress flights from 4 per year to 3 per year, this is especially important.

CRONUS

Two Major Software Transitions

X2R14 was completed in October 2015 and included updating the software on 14 MDMs, both Ku Comm Units (KCU), as well as all of the PCS.

- included the capability to perform dual berth cargo visiting vehicles
- an update to the flight software to pave the way for USCV from a C&DH perspective.

X2 PMPV R5 was completed in July 2016 and updated the software to 8 different MDMs (namely the Power Management (PM) and Photovoltaic (PV) Control Units).

- The new software in this update included the algorithms that will manage the new Lithium Ion batteries that will be installed during the HTV-6 mission.

Installation and RF Testing of Common Communications for Visiting Vehicles (C2V2)

C2V2 – the primary communication device between ISS and the USCV – was installed in early 2016. In April of 2016

Installation of the External High Definition Cameras (EHDC)

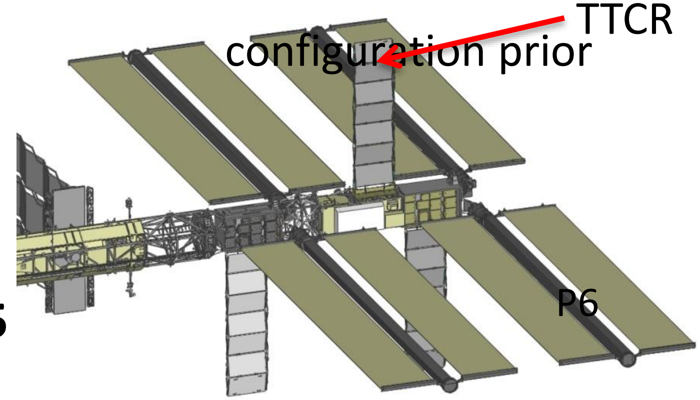
- The camera assemblies are completely commercial off the shelf products (Nikon D4s with some controllers and network gear in a pressurized box)
- Aim to provide some higher resolution images of Earth than the current external video cameras and will assist in surveys of ISS.

Mission Control Center (MCC) Upgrade

- FOD completed a five-year project to redesign and modernize the MCC for NASA's Human Spaceflight Programs in early 2016.
- The upgrade modernized the telemetry distribution and command systems in the MCC, improving telemetry and analysis tools and providing more flexible access to telemetry to allow greater flexibility to issue resolution teams.
- The MCC has undertaken change of this magnitude several times in the 60 years since the MCC was created to support the Gemini and Apollo missions.
- The original MCC team defined the control center concept and much of the architecture and electronics system was designed, developed, and constructed in-house.
- The Flight Operations Directorate is now able to use the advances in data center technology made throughout the information management industry to use commercially-available command and control tools, reducing the long-term cost of MCC operation.
- The upgraded MCC supports ISS operations today, and is positioned to provide future programs (e.g., NASA's Commercial Crew Partners and Exploration Missions) industry-leading technology to support increasingly flexible and efficient mission execution.

SPARTAN

- Trailing Thermal Control Radiator (TTCR)
  - US EVA 20 configured PVTCS 2B to flow through EETCS and the TTCR to troubleshoot PVTCS 2B slow leak.
    - Following large leak in May 2013, PFCS 2B determined to be source of leak.
  - As part of the RTOC EVA executed on 11/6/15
    - PVTCS 2B returned to a nominal PVTCS configuration
    - TTCR Retraction was performed, but crew were unable to cinch in place due to EVA contingency.
    - TTCR was redeployed into a safe configuration prior to EVA completion.



  - **TTCR successfully retracted on GMT 2016/245**

In addition, SPARTAN is supporting the program in the long term assessment of power availability for ISS.

With the addition of modules, higher traffic of visiting vehicles, new crewed vehicles and payloads, power will be one of the most challenging issues we will face.

Solar Arrays are not getting any younger which means that we will have to look at options to minimize impacts to ISS utilization. Things that we are looking at:

Better understanding of current and upcoming system loads, power requirements (tied to the RISE effort above).

Re-distributing loads at the MBSU level. Basically re-wiring the MBSU to better balance loads across all channels.

Taking more advantage of higher load capacity of parallel DDCU sets.

New Operations

- Lithium-Ion Batteries launching on HTV-6
  - Ni-Hydrogen batteries are aging
  - Lithium Ion although not expected to increase power capacity of ISS, better performance should alleviate load management in the long term
  - Two EVAs required with the help of robotics, and up to 6 EVAs if robotic operations are unsuccessful
  - 16 days of operations starting the day before HTV Capture for the nominal plan
    - SPCH for each Channel
    - Discharging 3 Battery sets per channel
    - ROBO Operations per channel
    - One EVA per channel

ECLSS: CO2

Resources:

- 2 CDRAs
- Vozdukh
- Amine Swingbed
- 20 US LiOH Cans

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, Amine Swingbed

Carbon Dioxide (CO2)

New CO2 Management Strategy:

Integrated Ops: Both USOS and Russian Segments

Ground will plan to manage the USOS 24-Hr average PPCO2 at **3.0** mm Hg or below with nominal CO2 scrubbing configuration.

Nominal CO2 scrubbing configuration: Vozdukh in Mode 4, Lab IMV bypass duct installed, 1 CDRA configured for Max efficiency.

Split Atmosphere Ops:

If degraded performance is noticed.

For performing diagnostics on the root cause of the increase of CO2.

CO2 Symptom Scale:

Terrestrial normal: 0.4 +/- 0.3 mmHg

ISS:

2.0 crew notices the difference

>3.0 crew definitely notices, "micro-fatigue", sleep is affected, performance is degraded

Future Work

<u>Need to develop more robust and capable hardware to maintain CO2 at low levels</u>:
Redesigning Valves to minimize breakdowns.
Increase flow rate
New Sorbent Beds

<u>Innovative operational solutions</u>
Personal CO2 Monitors
Exploration Tech Demos: Full scale demo on ISS in 2021/2022 (4 crew at 2 mmHg); early demo early 2018.
ESA Life Support Rack (HTV-7)

Operations,
and Habitability

Galley Rack Outfitting Timeline

Updated: August 2016

COMPLETED:

- Sep 2015: Remove NOD1P4 ZSR, install Galley Rack [HVT-5].
  - 4 Stowage Lockers, 2 Stowage Volumes.
- Oct 2015: Install N1, Lab Mod Kits.
- Apr 2016: New HUNCH Galley Table [OA-6].

REMAINING:

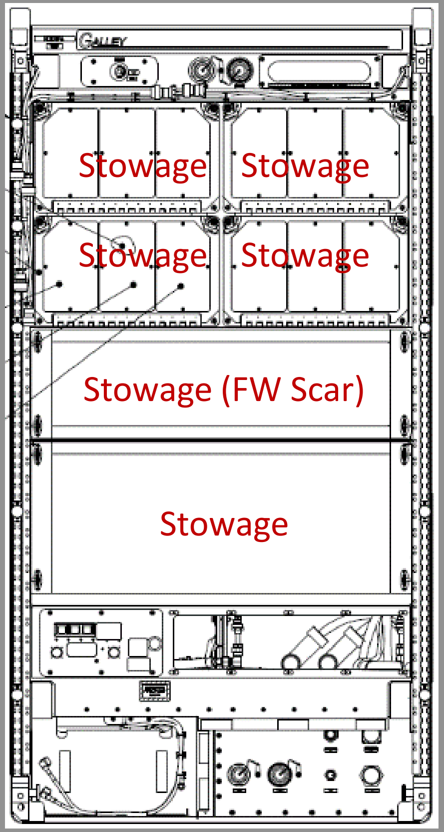
- To be scheduled: Install N2 120-VDC power cable.
- To be scheduled: Install N1 Galley Mod Kit:
  - MDM data, MTL, Potable Water, UOP Pwr.
- Dec 2016: Galley Control Panel, Power Supply [HTV-6].
  - Install existing Food Warmer, Ethernet Switch.
  - Swap 4 Stowage Lockers with existing MERLINS, PWD from Lab.

RESULT:

- Outfitting complete: Dec 2016

OTHER UPGRADES:

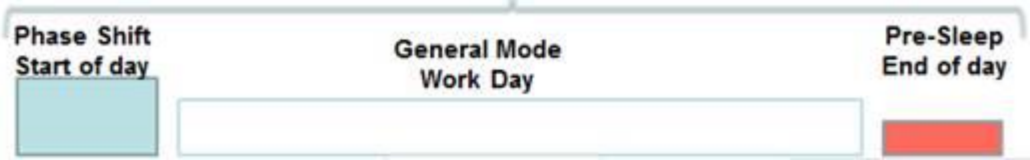
- New Galley Food Warmers: Jan 2017 [OA-7], Feb 2017 [SpX-11]



Lighting

- The SSLA project is a result of the ISS Vehicle Office's effort to replace the existing GLA Station lighting system. Currently ISS is outfitted with 85 Possible GLA locations. The inventory of GLA spares will expire by the last quarter of 2017. The first set of SSLAs will arrive on ISS in 2016.

- The Crew Quarters and Node 2 will be outfitted first then the remainder of Station will be replaced by attrition as they fail.

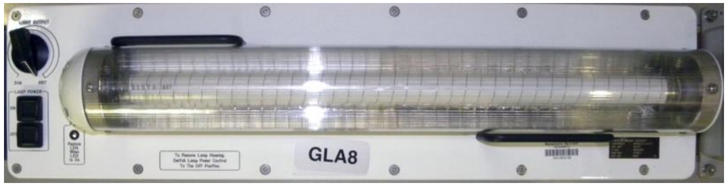


Pioneering LED Research

- The Solid-State Lighting Module (SSLM), is a Station Development Test Objective (SDTO) sponsored by the National Aeronautics and Space Administration (NASA) to demonstrate the advantages of Light-Emitting Diode (LED) lighting systems within the spacecraft environment.

Operational Differences

GLA



SSLA

Dimming Control	Knob/Dial	Touch Sensitive Up/Down Buttons (Duration of touch affect intensity)
Unit On/Off Control	Pushbutton Switch (Separate on/off function)	Touch Sensitive Multi-Mode Buttons (No physical detent, Touch “on,” Touch “off”)
Color of Light	4000 Kelvin Corrected Color Temperature	6500, 4500, & 2700 Kelvin Corrected Color Temperatures
Spectrum of Light	Classic Fluorescent Spectrum	Broad Spectrum with peaks in the blue, green, and red visible wavelength region
System On/Off Control	SRCA on/off will switch system of lights on/off	SRCA on/off will switch system of lights through different color temperature modes
Indicators	The GLA lamp is the indication the system is working.	One indicator for “Max Bright” and three indicators for the different color modes

Stowage on ISS

- Currently, ISS stowage is divided between all the different IPs.
  - There are share consumables and office supplies but most hardware is stowed within each partner's module.
- Stowage space on ISS is calculated by "Cargo Transfer Bag Equivalent", based on the size of the bags used.
  - 1 CTBE = 10" x 17" x 10"
  - 1.86 ft^3
  - 0.05 m^3
- ISS has ~2350 CTBE – equivalent to a normal 2 car garage, packed floor to ceiling.
  - NASA has ~1700 CTBE but is losing 262 CTBE in the coming years

Stowage on ISS

- Several new racks are being launched for new science experiments and new systems racks, which will replace stowage racks. All IPs will need to reduce their hardware onboard to reduce stowage levels.
  - In the future, we may need to share stowage locations for hardware that all IPs share.
    - Ex: Hardware for the Waste Hygiene Rack (ie. toilet)
  - Russian has been borrowing most of the stowage space in the FGB from NASA until MLM launches. NASA may need to reclaim that space.
  - New US commercial crew vehicles will be using vehicle ports that had been used as a secondary purpose for stowage.

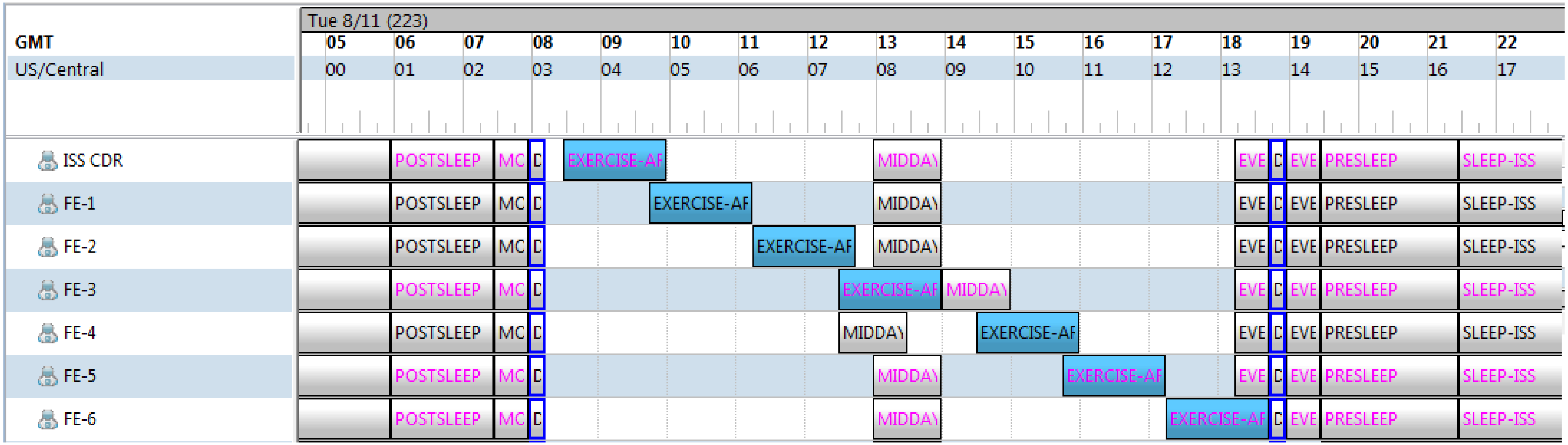
PMM (NASA Stowage Module)

NOD2 Vehicle Hatch Ports

Vehicle ports were being used as stowage locations when US crew vehicles were not using them. Once US commercial crew vehicles start flying, these areas will have to be clear of stowage.

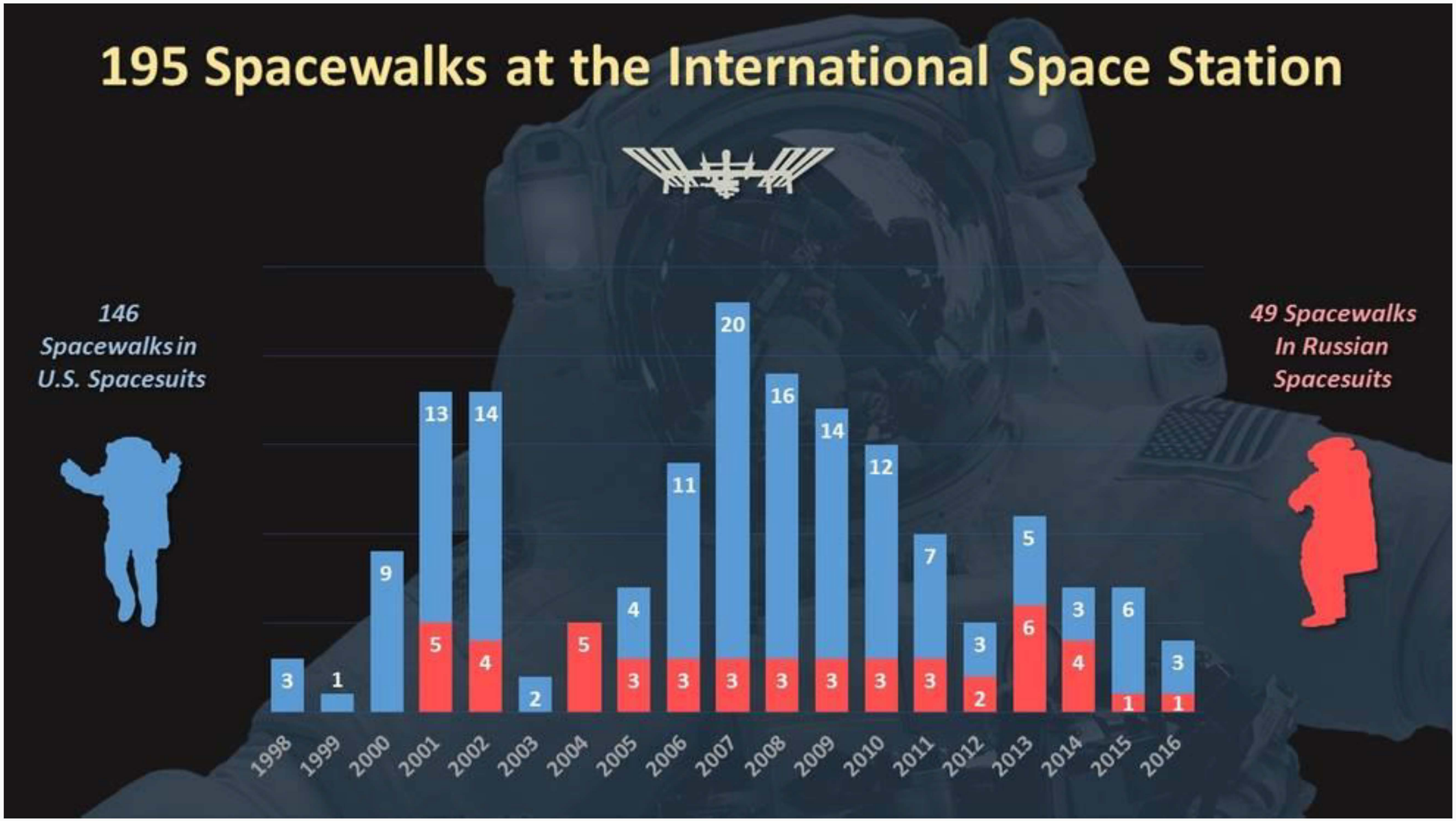
Exercise

- During USCV handovers, will be 7 USOS crew on board
  - **How to schedule all Resistive Exercise (RE)? (1.5 hours x 6 days x per crewmember)**
  - **How to accommodate Russian crew with RE.**
    - **Current Russian RE sessions on ARED are per ISS Program agreement and not ground prescribed.**
- 7 RE sessions x 1.5 hrs/session = **10.5 hrs**
  - Equivalent to typical length of crew day
  - More RE sessions = less timeline flexibility
  - **Creates unavoidable conflicts with rules regarding timing of exercise & meals**
    - 6 hr btw meals
    - 1 hr btw Postsleep and Exercise; 1:15 btw Midday Meal and Exercise
- Mitigations
  - **Shorten RE session duration (exercise requirements discussions ongoing)**
  - **Allow RE workout overlap (discussions ongoing) - 30 mins currently allowed, but not practiced**
  - **One less crewmember gets RE for a day (last resort)**
  - **Fly additional RE hardware to ISS. (This has additional challenges: location, Isolation, etc)**



Potential Option: 15 min overlap on <u>one side only</u> - 7 REs/day

Extra Vehicular Activity


195 Spacewalks at the International Space Station
146 Spacewalks in U.S. Spacesuits
49 Spacewalks In Russian Spacesuits
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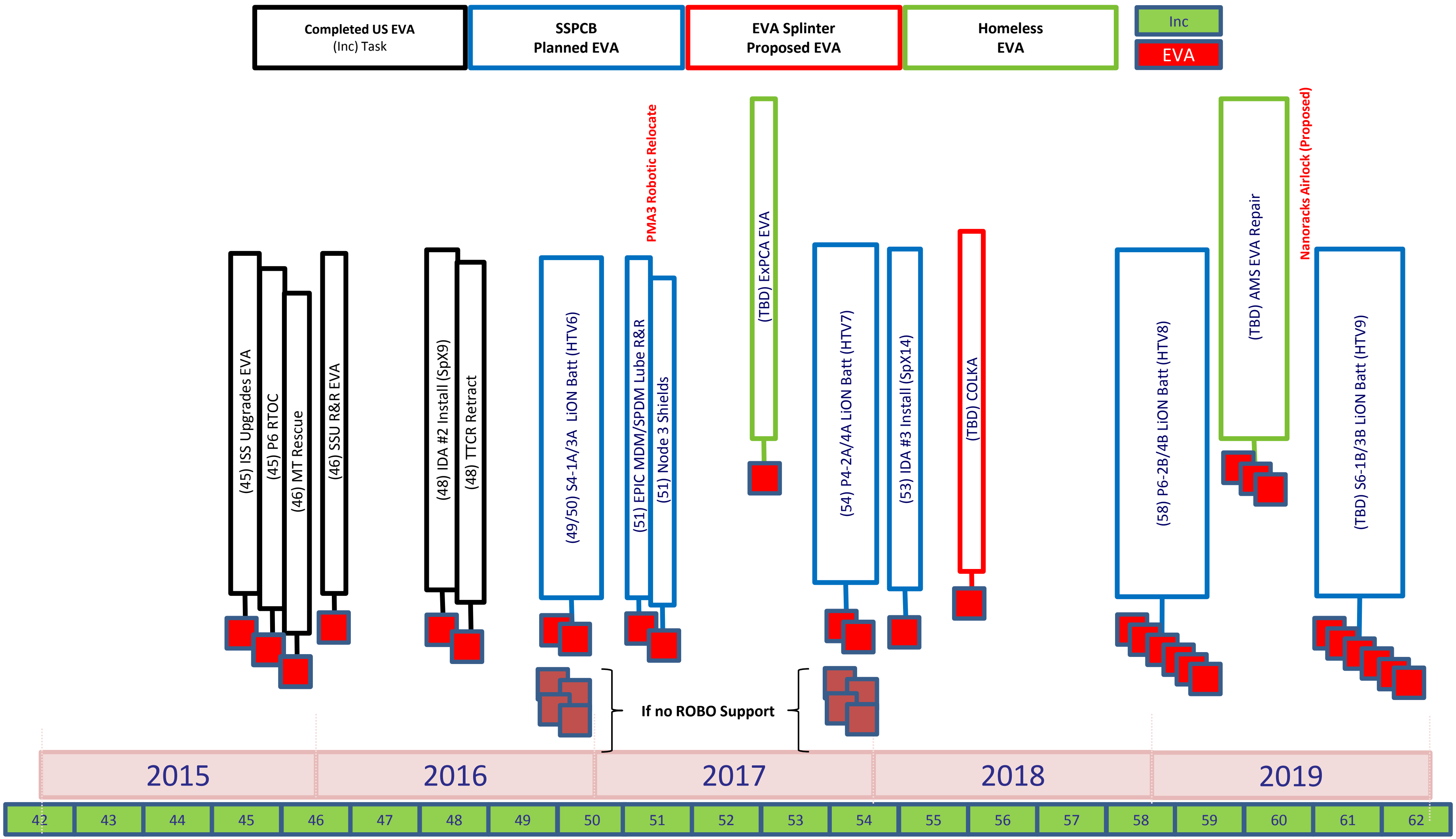
EVA Long Range Plan

Updated (09/07/16)



EVA Suit Technology Development

Development Objectives

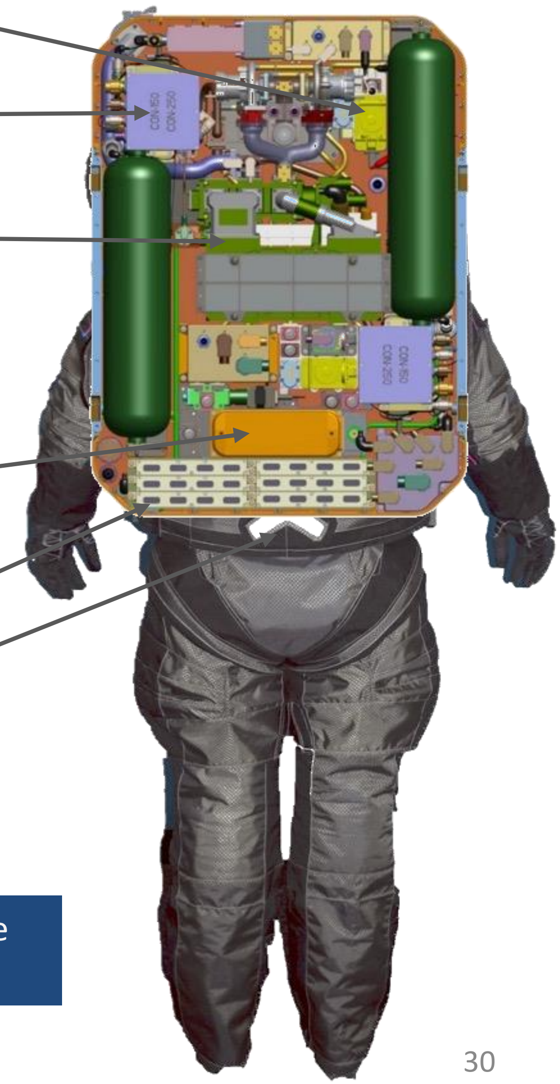
- To mature technologies and capabilities that will enable future EVA exploration systems for any of the proposed design reference missions
  - Incorporating lessons learned from 30+ years of EMU operations
  - Designing for the different environments of the potential destinations
  - Developing hardware that enables scientific exploration and supports the operational concepts of the potential destinations

- To produce real cost, performance, and reliability data through building and testing high-fidelity systems

- To systematically develop EVA technologies and systems to assist in closing gaps for an integrated humans to Mars mission in the 2030s

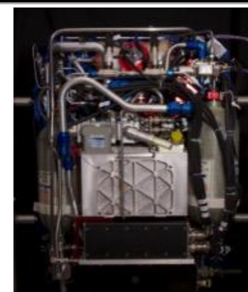
NASA Exploration EMU Reference Architecture

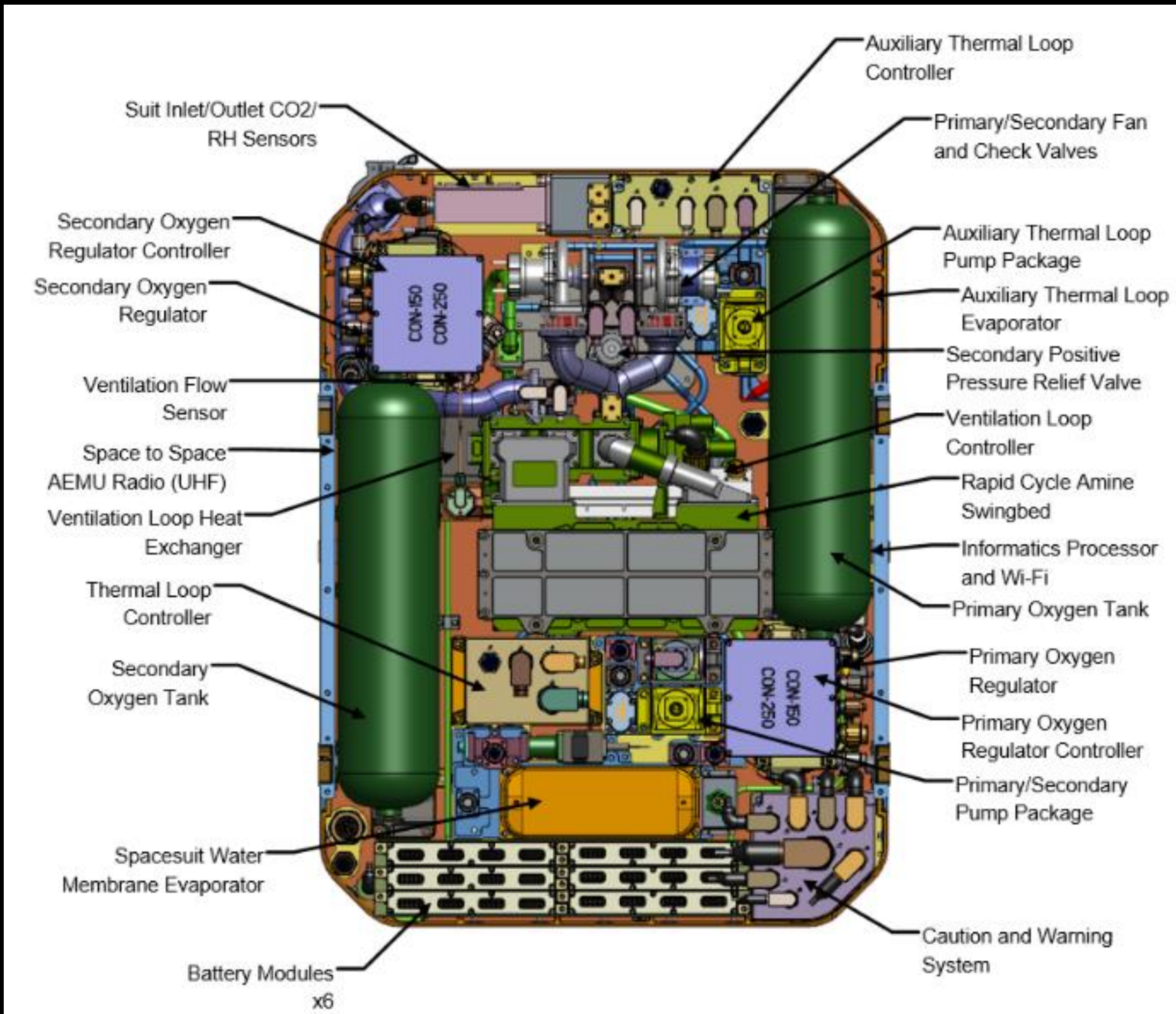
- High Speed Data Comm.
- 1 Hr. Emergency Return
- HD Video and Lights
- 4.3 – 8.2 psi Variable Pressure
- Informatics Display and Control
- Amine CO2 Removal Tech
- Integrated Communications (No Snoopy Cap)
- Enhanced Upper Mobility
- Membrane Evaporation Cooling (SWME)
- Automated Suit Checkout
- Modular/ORU PLSS Design
- Rear Entry Ingress/Egress
- Planetary Mobility

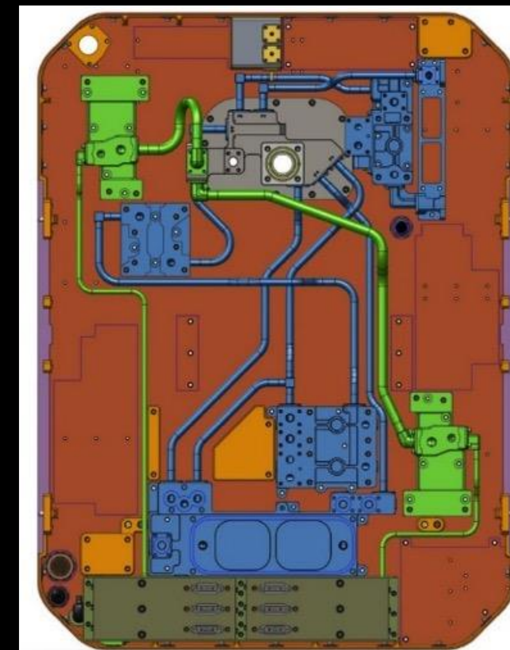


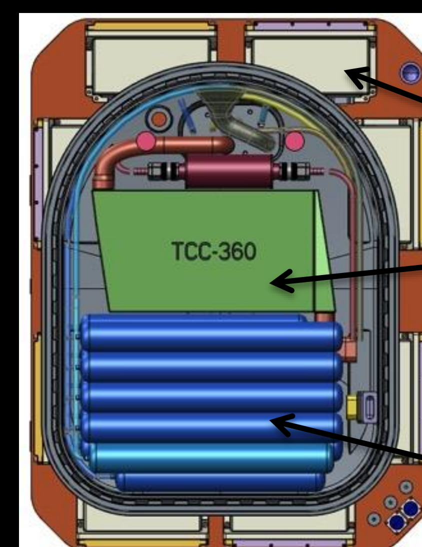
Conceptual only – Not all features displayed have completed full design assessment

Portable Life Support System Technology Development

	COMPLETE	COMPLETE	FY16/17/18
	PLSS 1.0 (Breadboard)	**PLSS 2.0 (Packaged GN2)**	**PLSS 2.5 (xPLSS) (Flight prototype)**
			
Purpose:	• Schematic validation with models • Component pneumo-hydraulic integration	• Packaged lab unit • System level performance	• Flight design without paperwork (GN2/Air only) • Integrated system performance
Hardware:	• Prototype: RCA, Fan, SWME, POR, SOR • Balance COTS/Instruments	• 2nd gen prototypes: RCA, SWME, POR, SOR • 1st gen prototypes: remainder	• 3rd gen prototypes; RCA, SWME, POR, SOR • 2nd gen prototypes: remainder
Testing:	• 8 simulated EVA transient profiles • 397 hrs of full PLSS operation • 595 hrs of SWME/thermal loop operation	• Pre-Installation Acceptance (PIA) test against system spec • 19 psia air human-in-the-loop testing with the Mark III spacesuit (2hr EVAs) • 25 EVAs, failure simulations, integration tests at vacuum	• PIA test against system spec • 100 unmanned EVAs in vacuum • Unmanned thermal vacuum testing • Pressurized launch vibe testing • EMI Testing • Static Magnetics Testing


Auxiliary Thermal Loop Controller
Suit Inlet/Outlet CO2/ RH Sensors
Primary/Secondary Fan and Check Valves
Secondary Oxygen Regulator Controller
Auxiliary Thermal Loop Pump Package
Secondary Oxygen Regulator
Auxiliary Thermal Loop Evaporator
CON-150
CON-250
Secondary Positive Pressure Relief Valve
Ventilation Flow Sensor
Ventilation Loop Controller
Space to Space AEMU Radio (UHF)
Rapid Cycle Amine Swingbed
Ventilation Loop Heat Exchanger
Informatics Processor and Wi-Fi
Thermal Loop Controller
Primary Oxygen Tank
Secondary Oxygen Tank
Primary Oxygen Regulator
Primary Oxygen Regulator Controller
Primary/Secondary Pump Package
Spacesuit Water Membrane Evaporator
Caution and Warning System
Battery Modules x6




TCC-360

Pressure Garment Technology Development

2005 — CxP — **2010** — ETDD/ETDP — **2012** — AES/GCD — **2016**

MK III 1992

WEI 1998

REI 2006

- Exploration mission tradestudy support via timeline analysis and end-to-end analog testing with pressurized suits, robotic assistants, and mid-fidelity vehicles/habitats
- Exploration pressure garment requirements development
    - Suit fit and strength analysis
    - Extensive multi-suit mobility studies
    - Suited joint torque
    - Dust/dirt protection and mitigation
    - Suit mass and center of gravity

Z-1 2011

- Mobility demonstrator
- First prototype compatible with delta pressure suitport don/doff evaluations
- Optimized for larger crew population

Z-2 2016

- Highest fidelity planetary prototype since Apollo
- Rated for 100% oxygen environments
- Certified for testing in the NBL
- Optimized for smaller crew population

Z-2 Design Features

Hybrid Composite Hatch (Carbon/S-Glass/AL)

Integrated Comm. Systems

Ti Waist Bearing w/1.75” Integral Sizing Ring

Composite Brief

2 Bearing Toroidal Convolute Soft Hip

Ankle Bearing

Gen 2 Adjustable Walking Boot

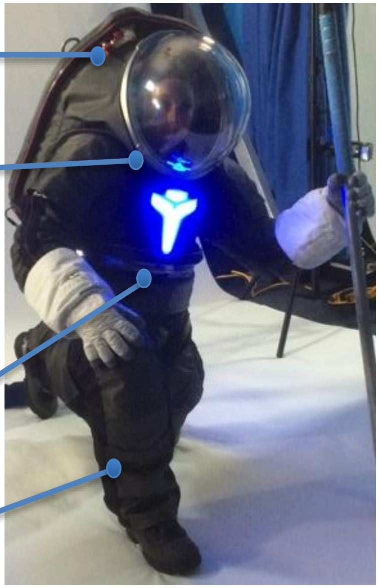
Removable SIP (not shown)

13x11 Elliptical Hemispherical Helmet

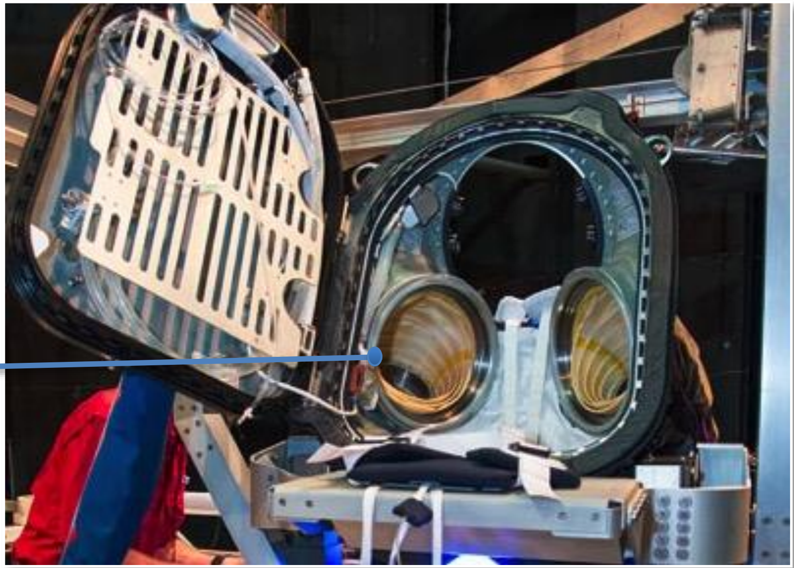
2 Bearing Rolling Convolute Shoulder

RC Waist Joint

EMU Style Acme Thread FAR



Composite HUT (Carbon/S-Glass) (1” Vernier Sizing)



Energy Mobility Testing

- Goal: Evaluate suited mobility at the system level by measuring metabolic cost of functional tasks in different space suits
  - Alternative to traditional approach to defining mobility
- Approach: Performed testing with 6 subjects and 3 suits (Mark III, REI, Demonstrator) and measured rate of CO_2 production
- Results: Statistically relevant differences between similar suit architectures performing functional tasks exist
  - Method shows great promise to be robust and reliable, but needs continued refinement

Walking Full body Side Step Stair Climbing Upper body

Research


ISS Research Highlights
National Aeronautics and Space Administration

Five major Earth benefits themes

Human Health

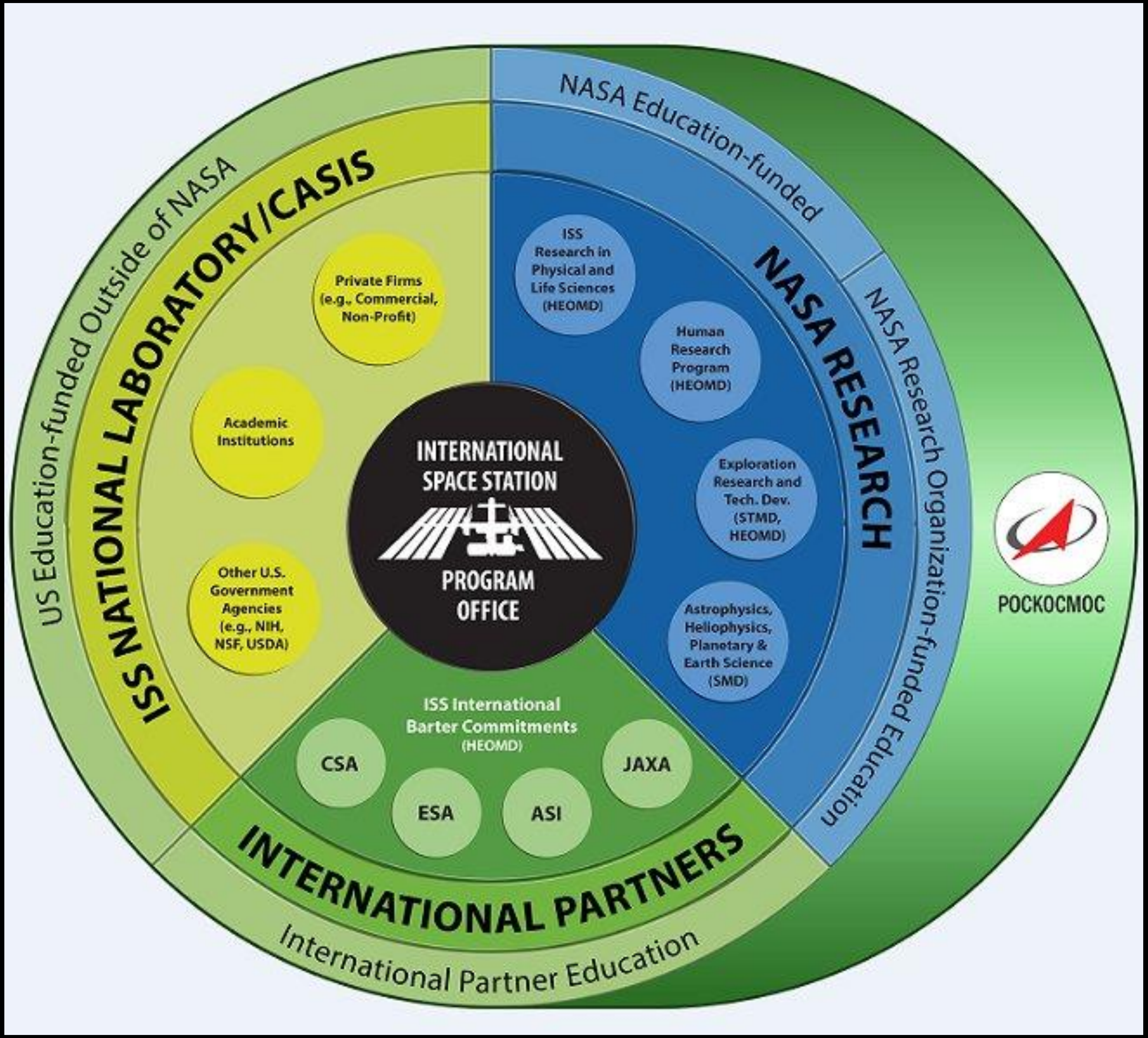
Earth Observation and Disaster Response

Innovative Technology

Global Education

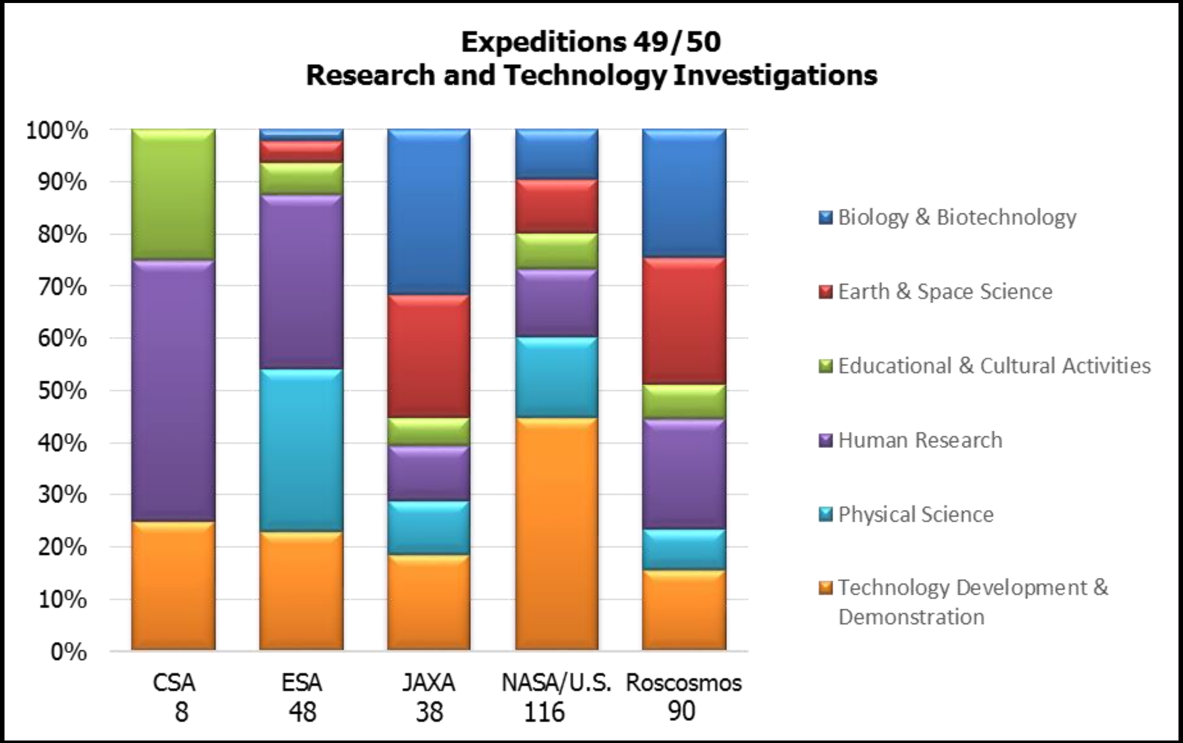
Economic Development of Space

Source: ISS Program Scientist


INTERNATIONAL SPACE STATION
PROGRAM OFFICE
ISS NATIONAL LABORATORY/CASIS
Private Firms (e.g., Commercial, Non-Profit)
Academic Institutions
Other U.S. Government Agencies (e.g., NIH, NSF, USDA)
US Education-funded Outside of NASA
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 Education-funded
NASA Research Organization-funded Education
INTERNATIONAL PARTNERS
ISS International Barter Commitments (HEOMD)
CSA
ESA
ASI
JAXA
International Partner Education
РОСКОСМОС

ISS Research Statistics
Number of Investigations for 49/50: 300

- 116 NASA/U.S.-led investigations
- 184 International-led investigations
- 84 New investigations
  - 2 CSA
  - 11 ESA
  - 9 JAXA
  - 56 NASA/U.S.
  - 6 Roscosmos (Preliminary Data)
- Over 800 Investigators represented
- Over 1300 scientific results publications (Exp 0 – present)

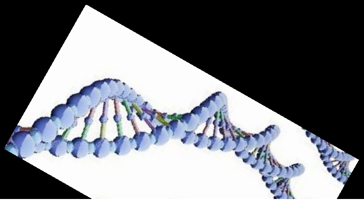


Estimated Number of Investigations Expedition 0-50: 2275*

Working data as of July 31, 2016

***Pending Post Increment Adjustments**

Featured Investigations: Technology Development and Demonstration



Biomolecule Sequencer

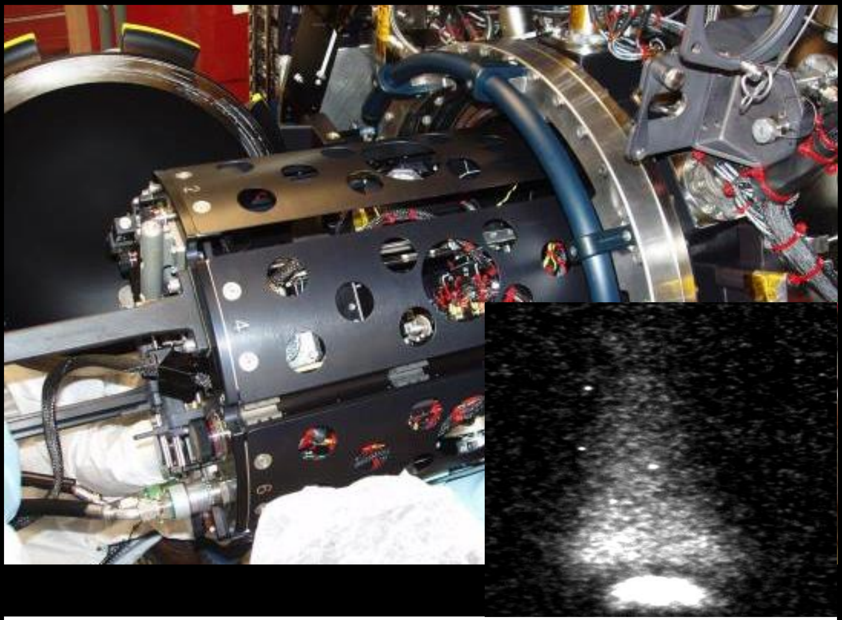
- The Biomolecule Sequencer investigation seeks to demonstrate, for the first time, that DNA sequencing is feasible in an orbiting spacecraft. A space-based DNA sequencer could identify microbes, diagnose diseases and understand crew member health, and potentially help detect DNA-based life elsewhere in the solar system.

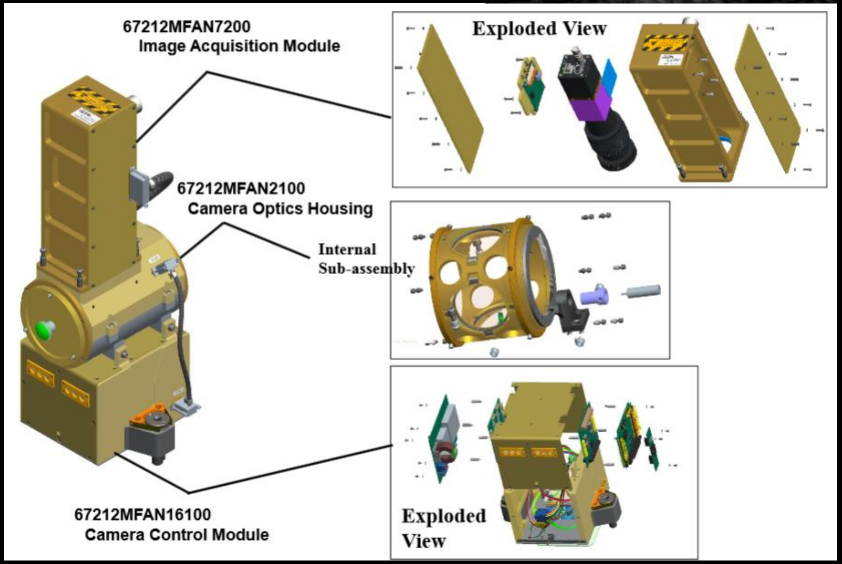
- Biomolecule Sequencer runs started August 26th with Kate Rubins performing the first activation.
- Upcoming NASA Sciencecast will focus on why we are testing the capability in space.

Biomolecule Sequencer Live Demo

Featured ISS Investigation:

Combustion Research: Cool Flames Investigation



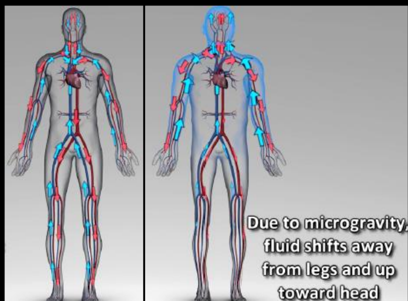


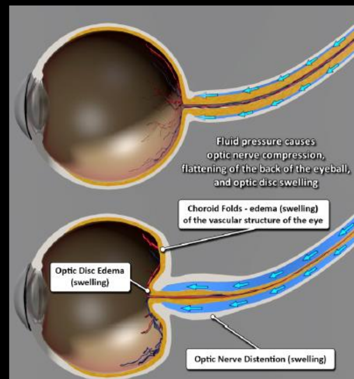
Multi-user Droplet Combustion Apparatus (MDCA) is being upgraded to support the award winning CFI experiment.

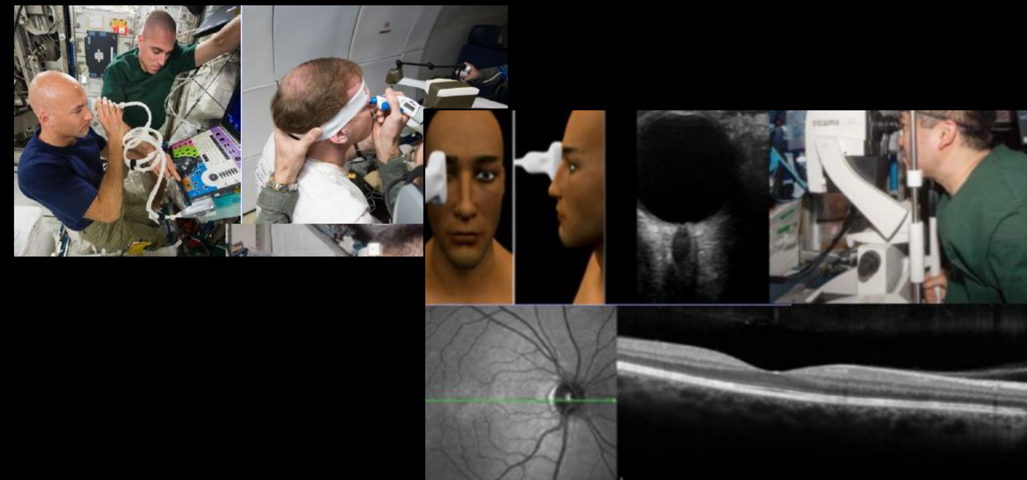
Upgraded hardware includes:

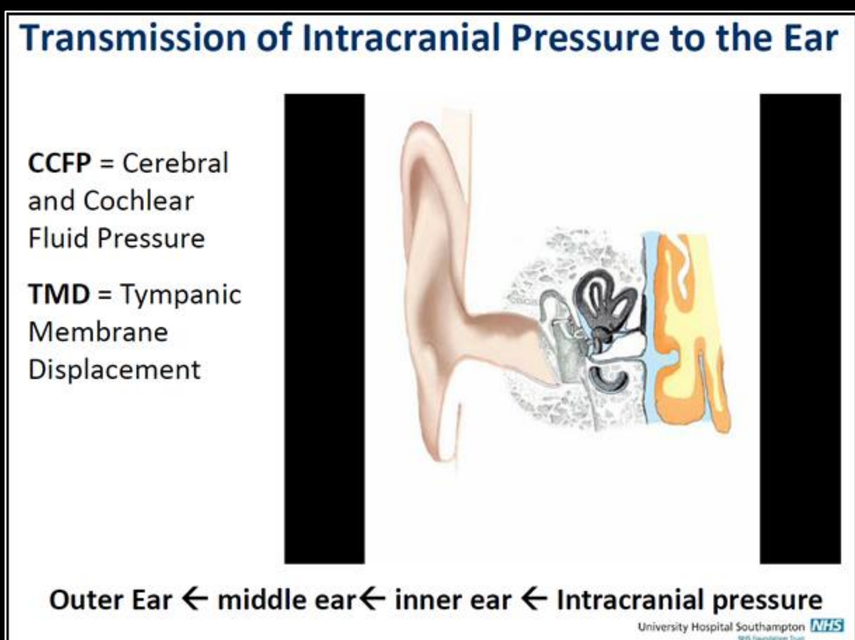
- A new MDCA radiometer array that automatically adjusts signal gain based on flame intensity
- New CIR camera with integrated light intensifier and rotating filter barrel
- New gigabit Ethernet enabled Image Processing and Storage Unit.
- The new hardware will be launched on OA-5 in Fall 2016, and is expected to be integrated into the CIR by the end of the calendar year.

Relation of the CCFP to the Fluid Shifts Experiment









ISS Research Resources (public)

ISS Research & Technology
http://www.nasa.gov/iss-science/

@ISS_Research

ISS Research Blog "A Lab Aloft"
http://go.usa.gov/atI

ISS Research Explorer App
(Apple App Store and Google Play)

Benefits: www.nasa.gov/stationbenefits

One-Year Mission | The Research (7 Areas of Focus)

1. Functional - These investigations examined the changes in crew member performance of functional tasks after 12 months in a low-gravity environment: Field Test and Functional Task Test.

2. Behavioral Health - These investigations examined psychological effects of long-duration spaceflight on crew members by conducting cognition tests, neuromapping studies, sleep monitoring, journaling analyses and a reaction self-test.

3. Visual Impairment - These investigations will examine ocular health and the body's response to fluid shifts in a weightless environment. This includes examining techniques to measure intracranial pressure.

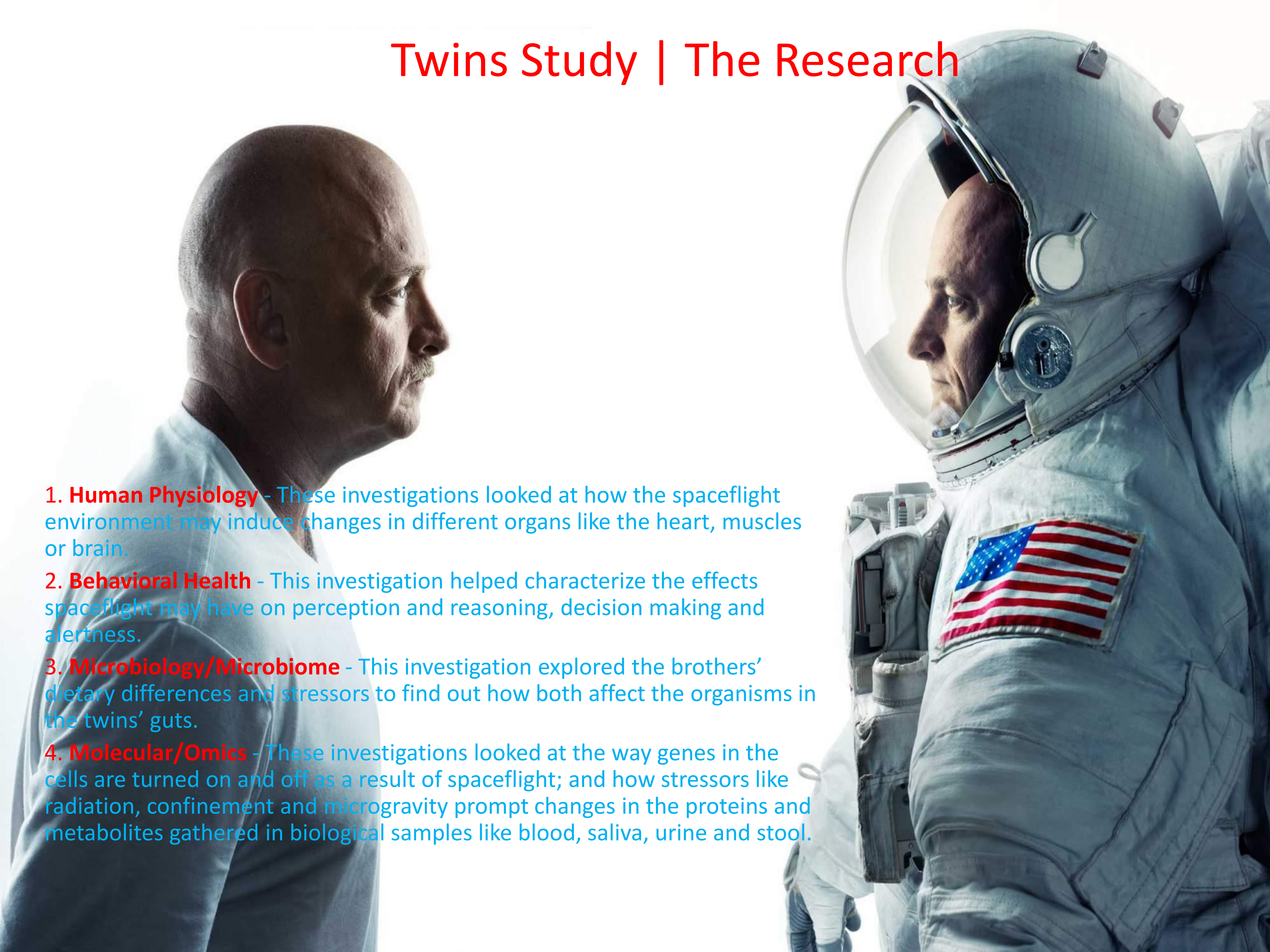
4. Metabolic - These investigations examined integrated immune, salivary markers, biochemical profiles and the relationship between biological markers of oxidative and inflammatory stress and the risk for atherosclerosis in a long-duration, weightless environment. An integrated immune monitoring strategy also will be validated.

5. Physical Performance - These investigations examined exercise capability with a focus on physical performance of bone, muscle and the cardiovascular system over time in a weightless environment: Sprint Study and Hip QCT Study.

6. Microbial - These investigations examined changes in the microbiome of crewmembers.

7. Human Factors - These investigations examined how astronauts interact with their environment aboard the International Space Station focusing on fine motor performance, habitability, and training retention.

Twins Study | The Research



1. **Human Physiology** - These investigations looked at how the spaceflight environment may induce changes in different organs like the heart, muscles or brain.
2. **Behavioral Health** - This investigation helped characterize the effects spaceflight may have on perception and reasoning, decision making and alertness.
3. **Microbiology/Microbiome** - This investigation explored the brothers' dietary differences and stressors to find out how both affect the organisms in the twins' guts.
4. **Molecular/Omics** - These investigations looked at the way genes in the cells are turned on and off as a result of spaceflight; and how stressors like radiation, confinement and microgravity prompt changes in the proteins and metabolites gathered in biological samples like blood, saliva, urine and stool.

One-Year Mission | The Results

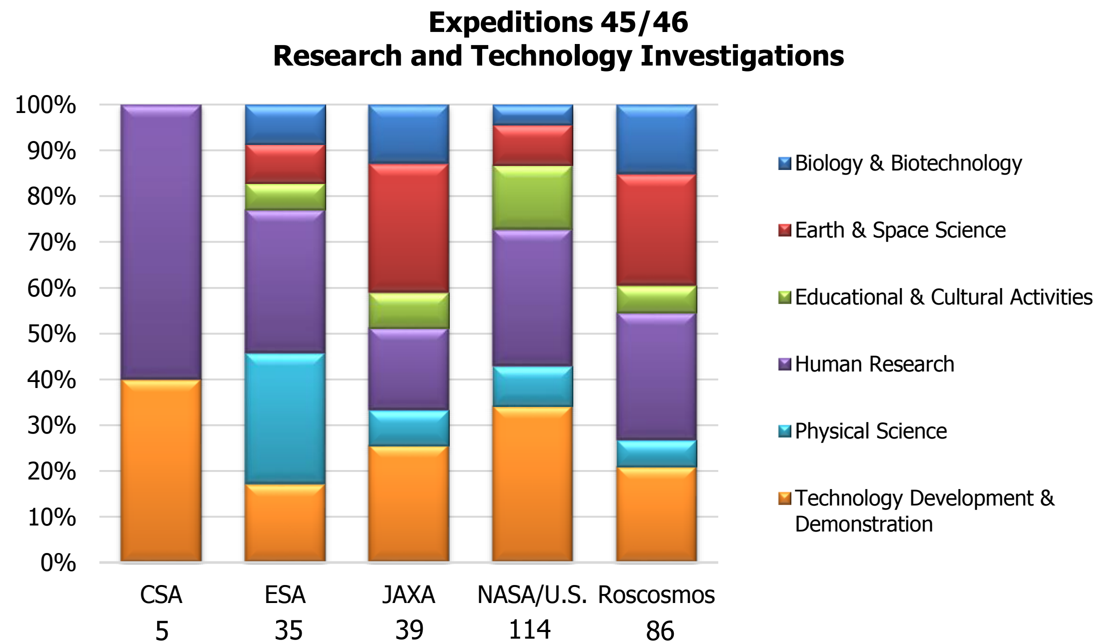
ISS Research Statistics

Working data as of March 31, 2016

Number of Investigations for 45/46: 279

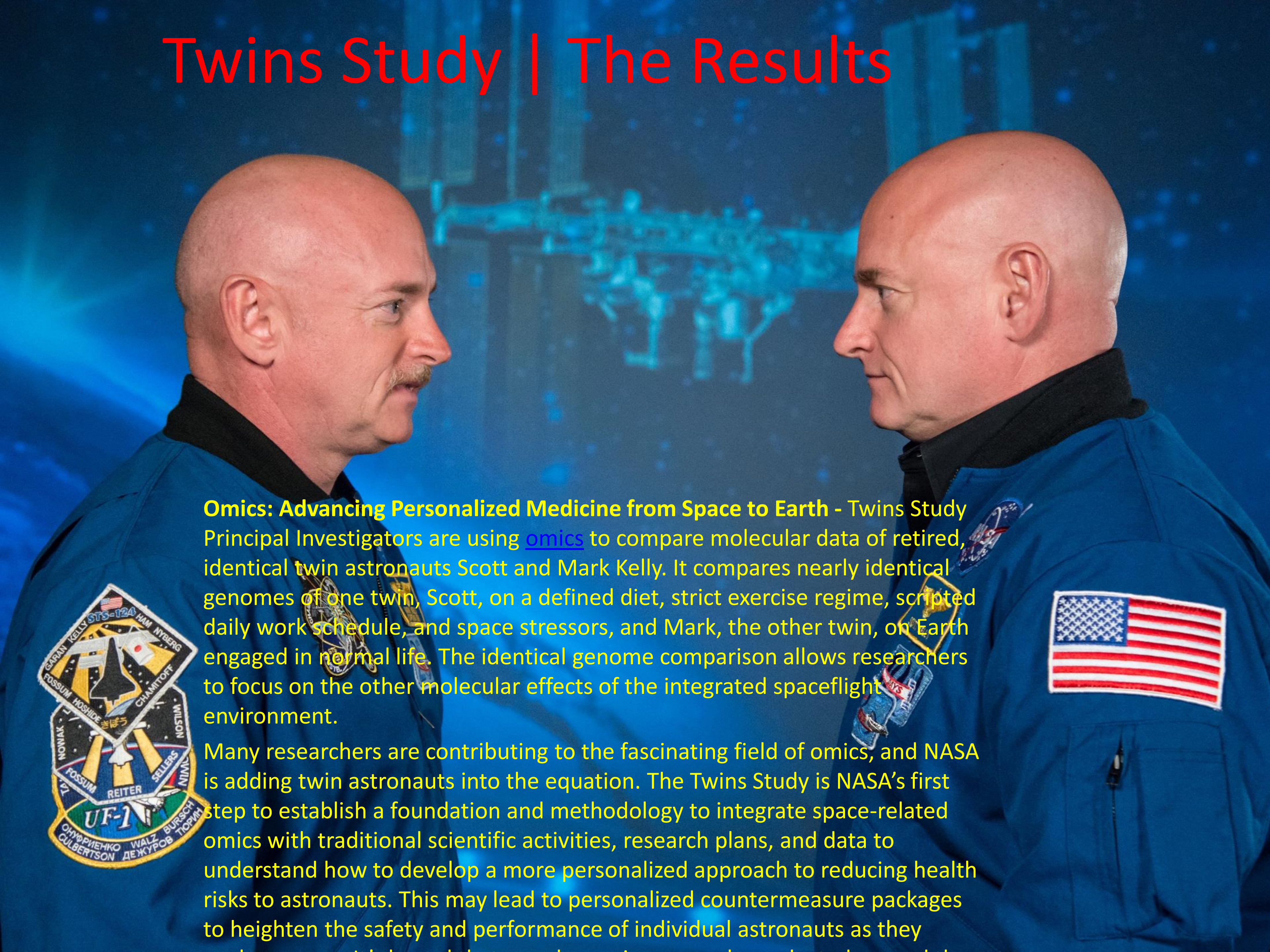
- 114 NASA/U.S.-led investigations
- 165 International-led investigations
- 35 New investigations
  - 1 CSA
  - 4 ESA
  - 4 JAXA
  - 25 NASA/U.S.
  - 1 Roscosmos *(preliminary data)*

- Over 800 Investigators represented
- Over 1300 scientific results publications (Exp 0 – present)



Estimated Number of Investigations Expeditions 0-46: 2095*

Twins Study | The Results



Omics: Advancing Personalized Medicine from Space to Earth - Twins Study Principal Investigators are using [omics] to compare molecular data of retired, identical twin astronauts Scott and Mark Kelly. It compares nearly identical genomes of one twin, Scott, on a defined diet, strict exercise regime, scripted daily work schedule, and space stressors, and Mark, the other twin, on Earth engaged in normal life. The identical genome comparison allows researchers to focus on the other molecular effects of the integrated spaceflight environment.

Many researchers are contributing to the fascinating field of omics, and NASA is adding twin astronauts into the equation. The Twins Study is NASA's first step to establish a foundation and methodology to integrate space-related omics with traditional scientific activities, research plans, and data to understand how to develop a more personalized approach to reducing health risks to astronauts. This may lead to personalized countermeasure packages to heighten the safety and performance of individual astronauts as they

Research Highlights

Plant Gravity Sensing-3

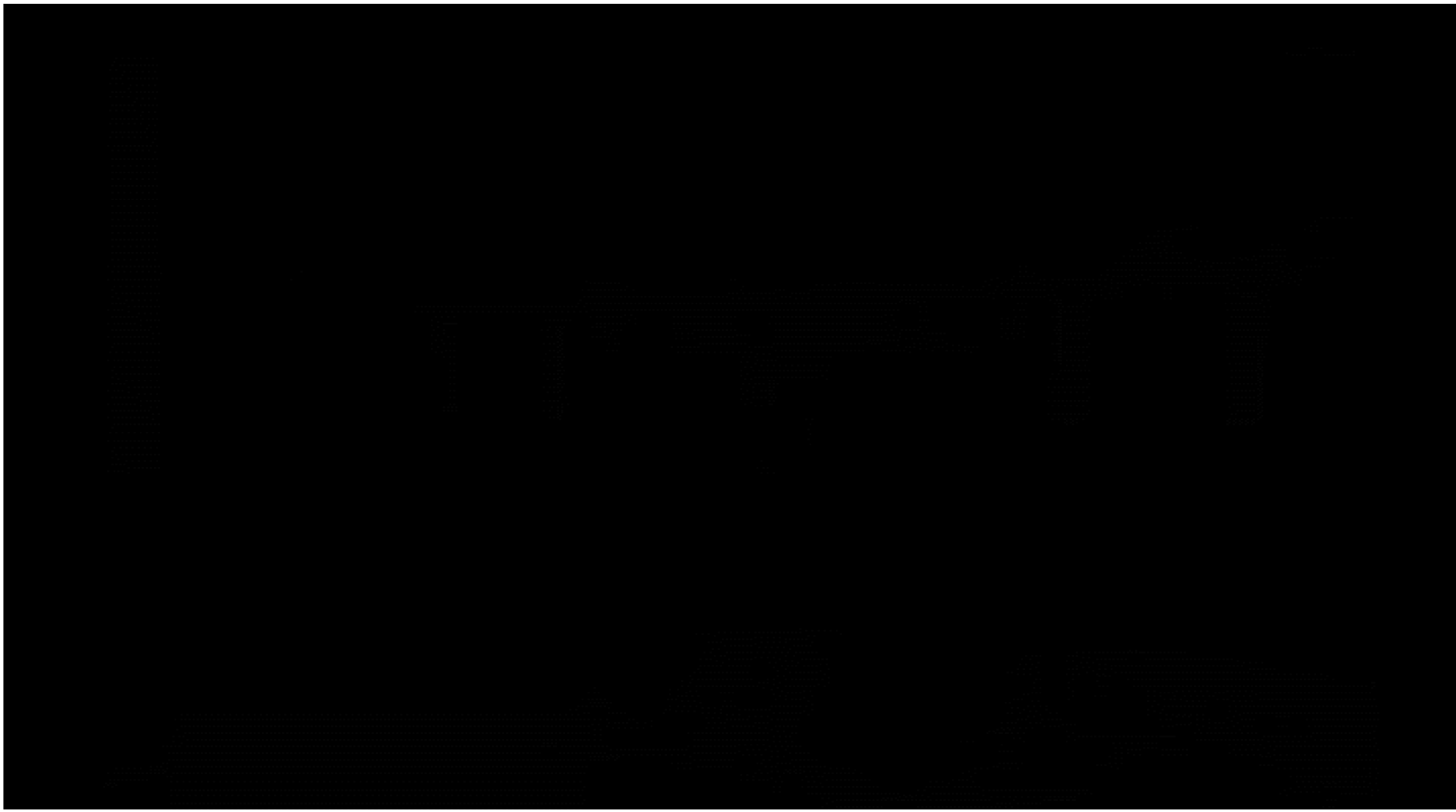
Space Applications

- Future missions to asteroids, Mars, or to deep space require astronauts to grow food
- Changes in gravity affect how plants grow, and could affect how many crops they can yield
- Understanding the molecular mechanisms that control plants' gravity response can help scientists develop new ways to grow plants in space
- Plant genes could be controlled to respond to increased or decreased gravity conditions, so that plants grow in a manner similar to how they would grow on Earth

Earth Applications

- Plant Gravity Sensing studies the genetic expression and other molecular changes involved in how plants respond to gravity
- Understanding the genetic expression process and other molecular changes could lead to new plant varieties that grow in different ways
- For instance, plants that respond quickly to gravitational sensing could recover more quickly after collapsing in floods or high winds
- In a broader sense, understanding the mechanisms of gravity sensing could lead to new research pathways or treatments for muscle atrophy, bone density loss and other gravity-dependent disorders

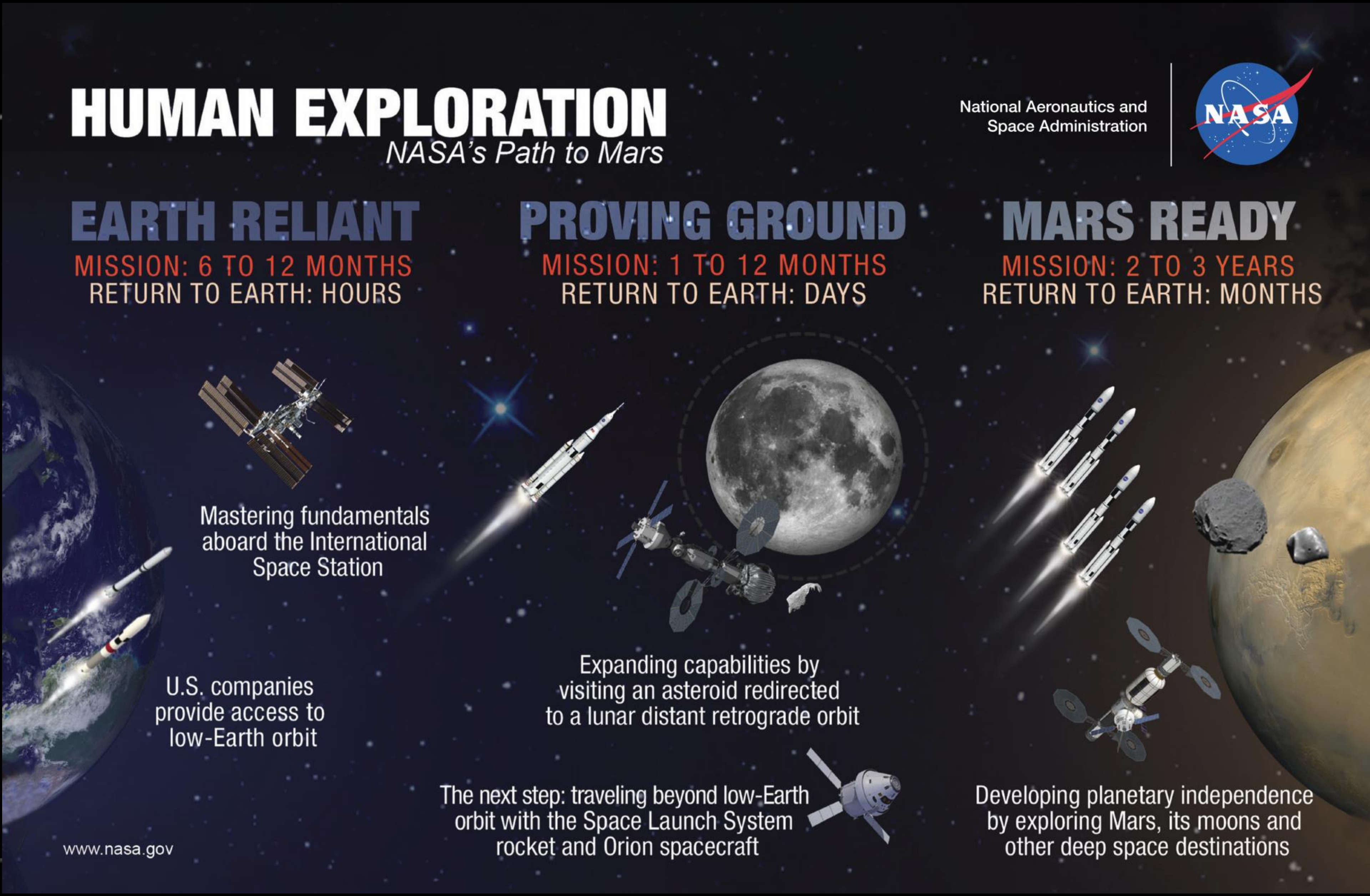
Preparing for Exploration



National Aeronautics and
Space Administration

Commercial Crew Program
2016 Updates

The Next Steps in U.S. Space Transportation


HUMAN EXPLORATION
NASA's Path to Mars
National Aeronautics and
Space Administration
NASA
EARTH RELIANT
MISSION: 6 TO 12 MONTHS
RETURN TO EARTH: HOURS
PROVING GROUND
MISSION: 1 TO 12 MONTHS
RETURN TO EARTH: DAYS
MARS READY
MISSION: 2 TO 3 YEARS
RETURN TO EARTH: MONTHS
Mastering fundamentals aboard the International Space Station
U.S. companies provide access to low-Earth orbit
Expanding capabilities by visiting an asteroid redirected to a lunar distant retrograde orbit
The next step: traveling beyond low-Earth orbit with the Space Launch System rocket and Orion spacecraft
Developing planetary independence by exploring Mars, its moons and other deep space destinations
www.nasa.gov

Current and Future Human Spaceflight

2016: (present day)

- International Space Station (6 crew)
- Soyuz 4 launches/year
- ISS Resupply with International Partners (Progress, HTV)
- ISS Resupply with Commercial Resupply Contract (Space-X and Orbital Sciences)

~2017 -2018

- International Space Station (6+ Crew)
- Soyuz 2 launches /year
- Commercial Crew ~2 launches/year
- ISS Resupply with International Partners (Progress, HTV)
- ISS Resupply with Commercial Resupply Contract (new contract including SpaceX, Sierra Nevada and ATK/Orbital)
- Orion Exploration Mission-1 (uncrewed, Circumlunar)

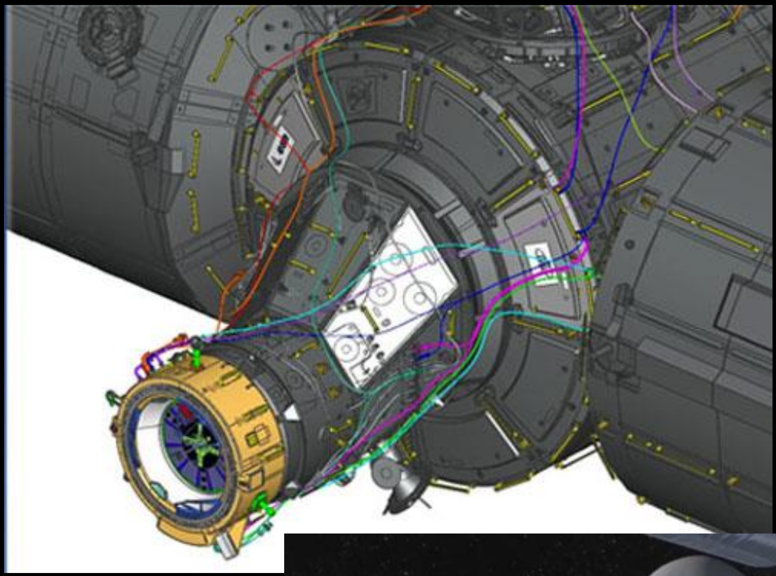
~2021

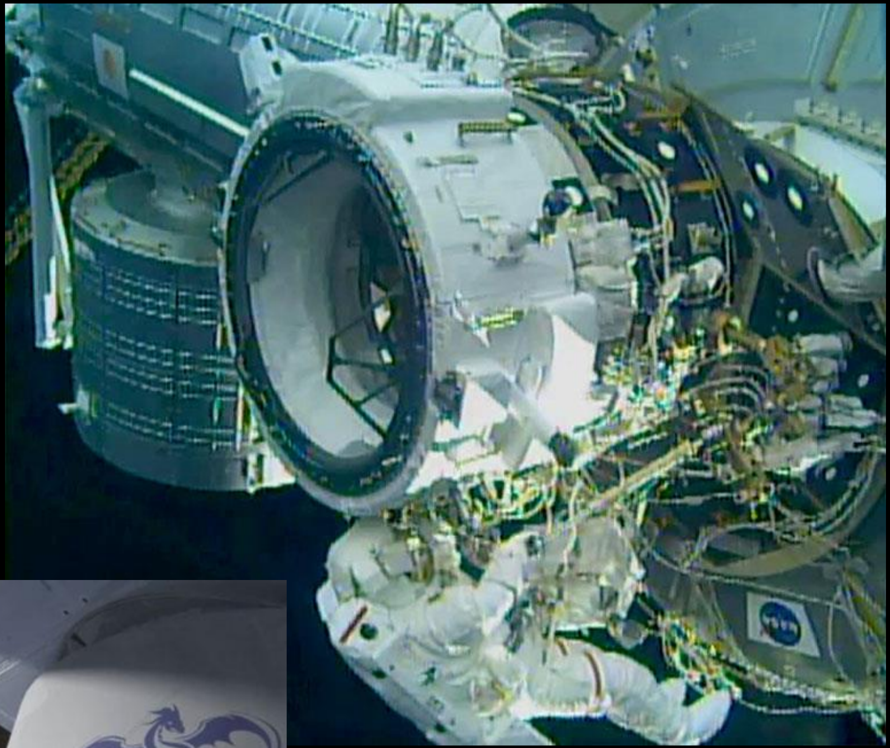
- International Space Station (6+ Crew)
- Soyuz 2 launches /year
- Commercial Crew ~2 launches/year
- ISS Resupply with International Partners (Progress, HTV)
- ISS Resupply with Commercial Resupply Contract (new contract including SpaceX, Sierra Nevada and ATK/Orbital)
- Orion Exploration Mission-2 (crewed, Lunar orbit)

NASA COMMERCIAL CREW

National Aeronautics and Space Administration

Getting the International Space Station Ready





Boeing: CST-100 "Starliner"/ Atlas V

2016- Starliner Update *(since last ASE Congress)*

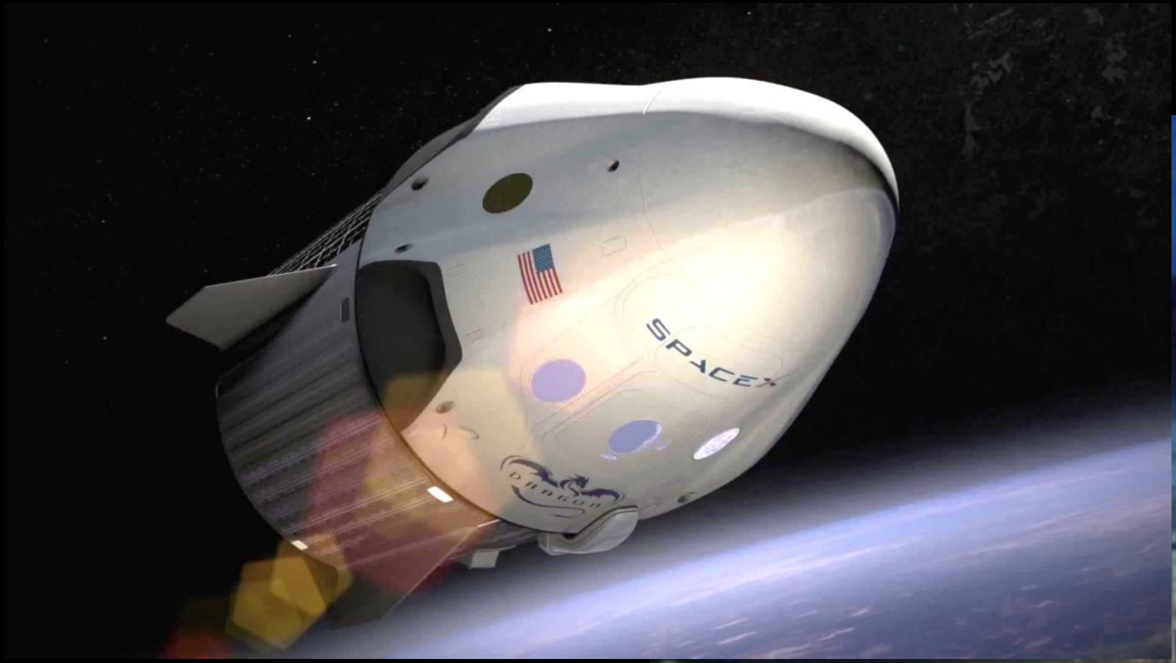
Testing and Construction in Progress

<u>Including…</u>

1) Crew Access Arm Added to Atlas Launch Pad

2) Starliner Tested for Ground-Landing Conditions

Space X: Dragon / Falcon 9



2016- Dragon Update (since last ASE Congress)

2016- A year of plusses and minuses

1) SpaceX Conducts Successful Crew Dragon Parachute System Test

2) SpaceX Rocket and Satellite Destroyed in Launch Pad Explosion


"These distinguished, veteran astronauts are blazing a new trail, a trail that will one day land them in the history books and Americans on the surface of Mars."
– Charles Bolden, NASA Administrator
LAUNCH AMERICA
COMMERCIAL CREW TRANSPORTATION
Bob Behnken
Eric Boe
Doug Hurley
Suni Williams

Questions?