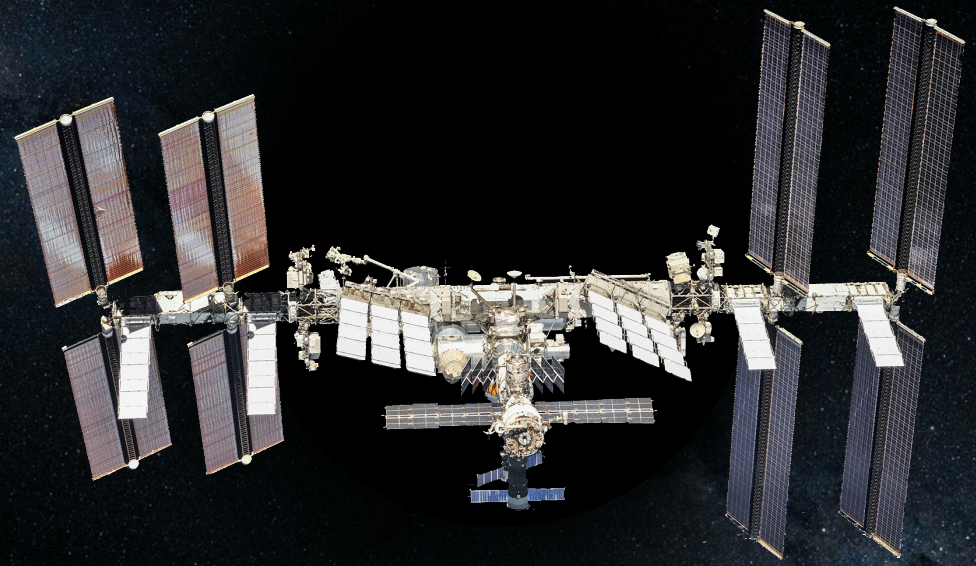
National Aeronautics and Space Administration



International Space Station Status

Robyn Gatens
International Space Station Director
Space Operations Missions Directorate
May 2023

Agenda

- ISS Increment Overview
- ISS Operational Status
- Utilization Highlights
- ISS Extension and Transition

ISS Mission Goals – The Decade of Results

Enable Deep Space Exploration

Validate Exploration Technologies and Reduce Human Health Risks

23 NASA tech demos initiated since 2018
~20 human health risks continuing to be characterized and countermeasures developed

Over **500** payloads have flown through the ISS National Lab; **75%** from the **commercial** sector
$1.8 billion of capital raised by startups post-flight
20 In-Space Production Applications Awards to date
1 Private Astronaut Mission

Foster Commercial Space Industry

In partnership with Commercial LEO Office

Incubate in-space manufacturing, support commercial LEO facilities and customers

Conduct Research to Benefit Humanity

Life-saving medical research & applications, understanding climate change, sharing discoveries with all

~3,400 investigations
~4,400 investigators represented
Over **2,450** scientific results publications
~3.5 million images of Earth captured

Involves **100,000+** people at **500** contractor facilities in **37** U.S. states and **16** countries
>3 million student activities in 2022
18 million people follow social media accounts

Inspire Humankind

Broaden reach of space benefits, engage public, create diverse future STEM workforce

Enable International Collaboration

Maintain & expand international partnerships, set norms & standards

~more than 2000 international-led investigations through Expedition 69
111 countries/areas with ISS research and education participation
1st ISS increment UAE astronaut

>22 years continuous presence in space
>260 cargo and crew missions to ISS

Provide National Human Space Flight Infrastructure

Ensure continuous human presence in LEO - no gap; provide destination for crew & cargo transportation

ISS Increment Overview

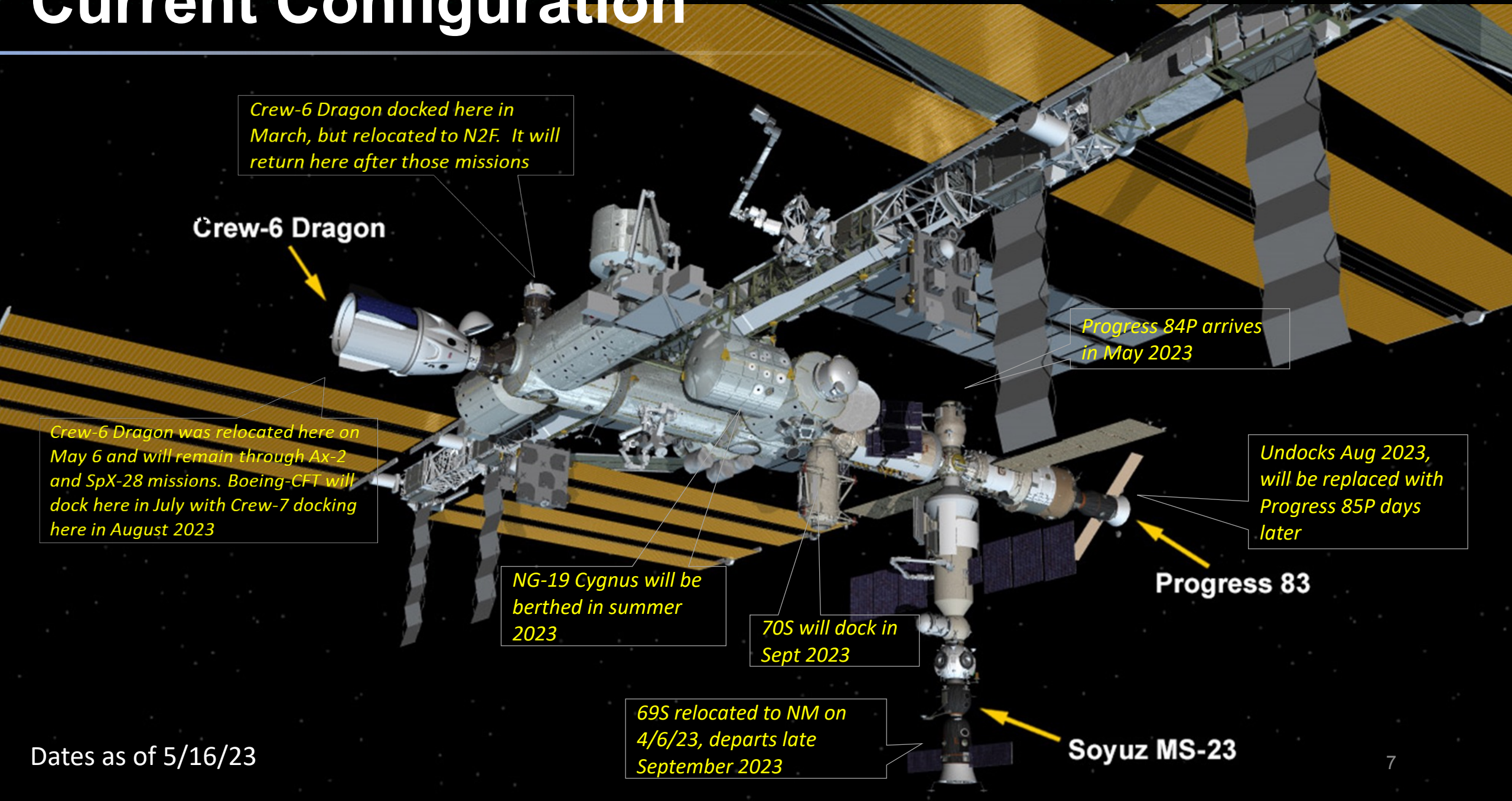
Increment 69 Overview

- Soyuz 69S Launch/Dock (uncrewed)
- SpaceX-Crew6 Launch/Dock
- SpaceX-Crew5 Undock/Splashdown
- SpaceX CRS-27 Launch/Dock
- Soyuz 68S Undock (uncrewed)
- SpaceX CRS-27 Undock/Splashdown
- RS EVA 56-60 (potentially five spacewalks)
- US EVA 86-89 (potentially four spacewalks)
- Axiom-2 Private Astronaut Mission (PAM)
- Progress 84P Launch/Dock
- SpaceX CRS-28 Launch/Dock
- Northrop Grumman CRS-19 Launch/Capture
- Boeing Crew Flight Test (Boe-CFT) Mission
- SpaceX-Crew7 Launch/Dock
- Progress 85P Launch/Dock
- Progress 83P Undock
- SpaceX-Crew6 Undock
- Soyuz 70S Launch/Dock
- Soyuz 69S Undock

Flight Engineers Frank Rubio from NASA, Dmitri Petelin from Roscosmos, Sultan Alneyadi from UAE (United Arab Emirates), Woody Hoburg from NASA, Stephen Bowen from NASA, Andrey Fedyaev from Roscosmos, and Commander Sergey Prokopyev from Roscosmos.

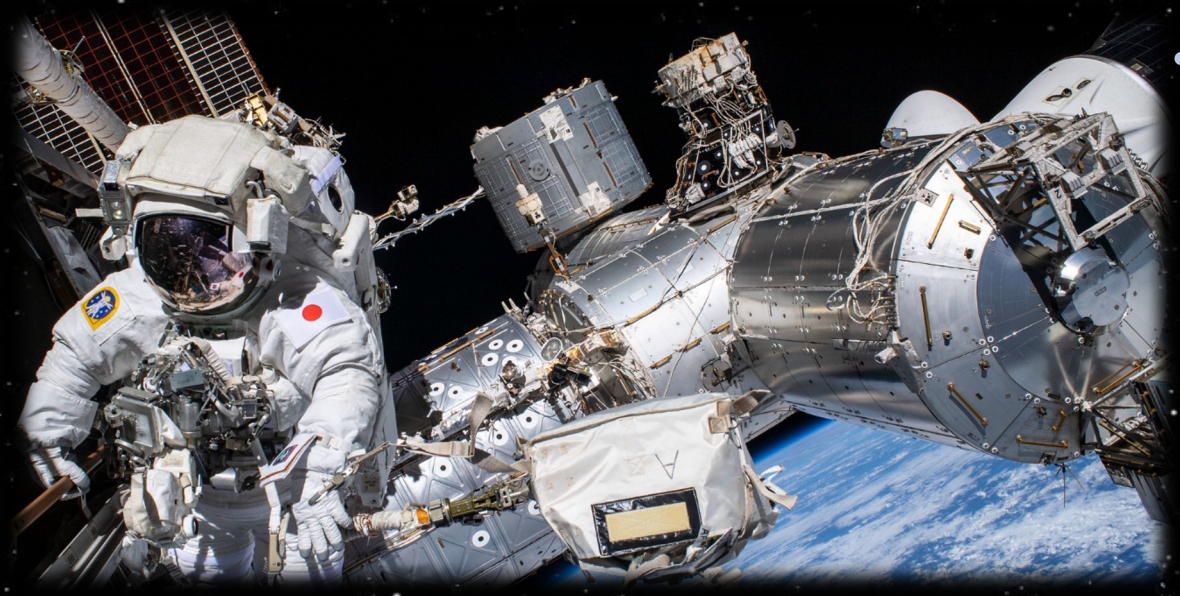
ISS Operational Status

Current Configuration



Dates as of 5/16/23

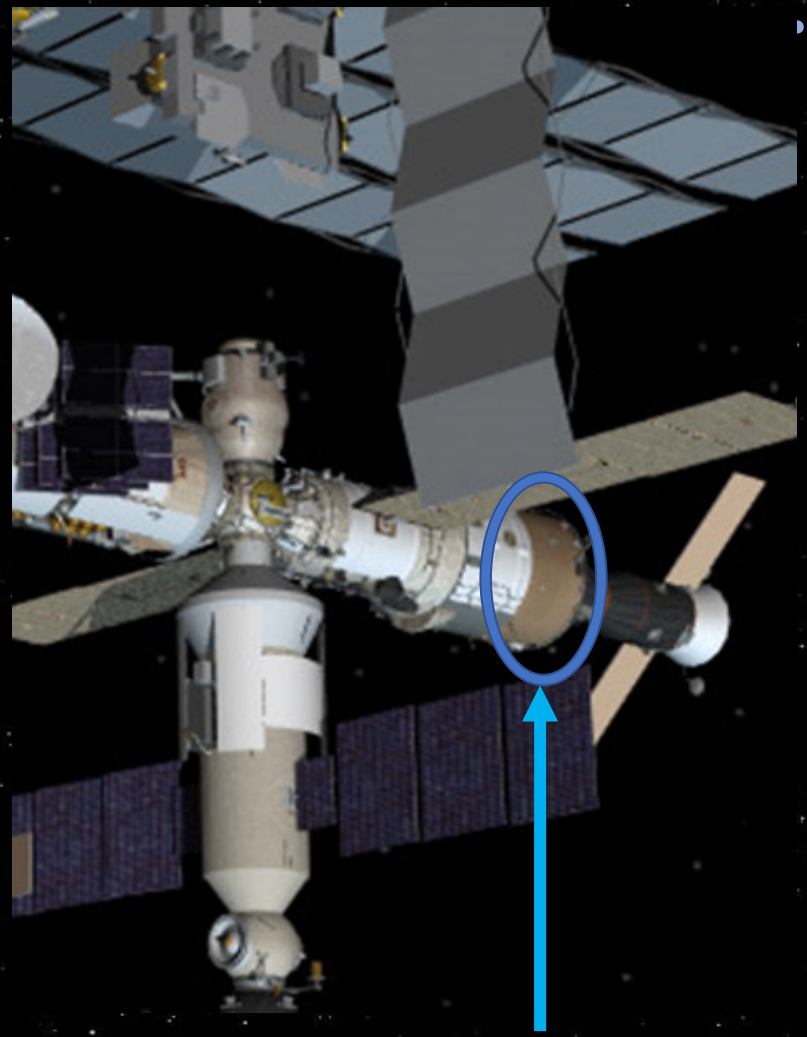
Recent/Upcoming Spacewalks (EVAs)



- **RS EVAs – April through July 2023**
  - RS EVA #56 – Russian radiator transfer by European Robotic Arm (ERA) – *complete*
  - RS EVA #57 – Russian airlock transfer by ERA – *complete*
  - RS EVA #58 – Russian radiator deploy - *complete*
  - RS EVA #59 – Equipment R&R / SM Inspection
  - RS EVA #60 – Portable workstation transfer from MRM-1 to MLM by the ERA. MMOD shielding.

- **U.S. EVA – S-Band Radio Frequency Group (RFG) Retrieval** – *4/28/23*
  - EV crew attempted to remove the RFG from the degraded S-band Assembly (SASA) for return and refurbishment, but encountered seized bolt. Repaired unit will eventually be launched to improve our SASA sparing posture on-orbit.
  - First spacewalk for UAE astronaut, Sultan Alneyadi and the eighth for NASA's Stephen Bowen
- **U.S. EVAs – iROSA Install 1A and 1B**
  - Two separate EVAs that will take place this summer following launch of IROSA's on SpX-28.
  - Primary objective to install the new 1A and 1B iROSAs onto the Mod Kits that were installed on previous EVAs between Nov '22 and Feb '23.

ISS Significant Items of Interest



ISS Atmosphere Leak Location
(Aft end of Service Module)

- **Atmosphere Leak**
  - Identified atmosphere leakage increase in September 2019. The leak presents no immediate danger to the crew, or vehicle, at its current state. Multiple measures in work to identify the source(s) of the leak from the PrK section of the Russian Service Module (SM).
  - Kapton tape applied to the PrK pressure shell and labeled for tracking purposes. Two cracks have been permanently repaired with no issues. Strain gauge data is being collected for events of interest. Thus far, all strains measured to date are low and in-family with predictions.
  - In the near term, that section of the SM will be isolated appropriately to minimize consumables loss.
  - Current leak ~0.9 lbm/day
  - PrK hatch closed when access not required
  - Roscosmos team / crew continue to search for leaks and provide samples/data to the ground team for inspection.

ISS Significant Items of Interest

- **End-of-life Deorbit Planning**
  - NASA released draft RFP for a U.S. ISS deorbit capability on May 4, 2023.
- **Soyuz 68S/Progress 82P Coolant Leaks**
  - Investigations ongoing
- **Science Demand**
  - Demand for internal and external ISS payload space, as well as upmass resources has been increasing.
  - Delays in cargo vehicles have exacerbated the challenge
  - Agency established a new prioritization process for NASA utilization
    - Sponsors will receive a minimum allocation of 70% of their request
    - Remaining 30% will be allocated based on a rotating order of sponsor (e.g. HRP, tech demo, BPS)
    - New scheme allows for each sponsor to plan for their highest priorities while allowing flexibility for atypical increment resource impacts (such as AMS upgrade planned for 2025)

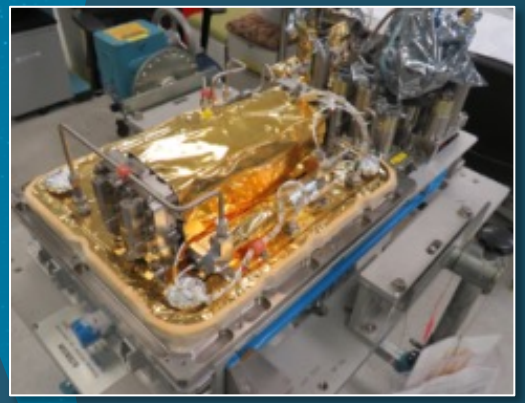
Utilization Summary

Exploration Capabilities Development Technology Demonstrations: FY23 Hardware

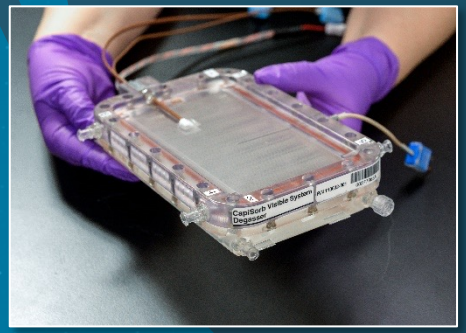
Life Support

- CapiSorb Visible System: Investigation Complete
- Upgraded Water Processor Assembly (WPA) Catalytic Reactor Re-fly: SpX-28
- Urine Processor Assy (UPA) Purge Pump and Separator Assy (PPSA): Delivered, install in work
- Exploration Potable Water Dispenser (xPWD): NG-19

Exploration Potable Water Dispenser



WPA Catalytic Reactor



CapiSorb Visible System

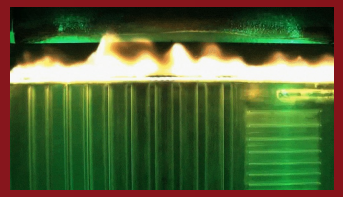
Environmental Monitoring

Spacecraft Atmosphere Monitor TDU1

- Spacecraft Atmosphere Monitor (SAM) Technology Demonstration Unit 2: TBD

Fire Safety

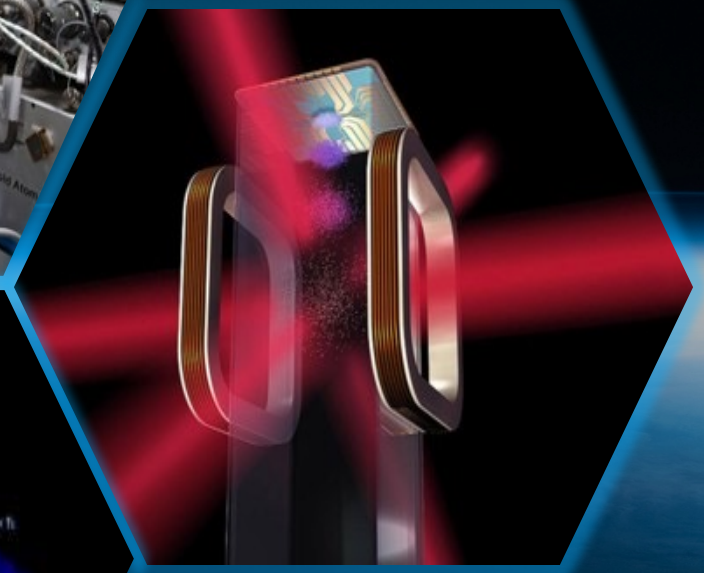
Saffire-VI: NG-19

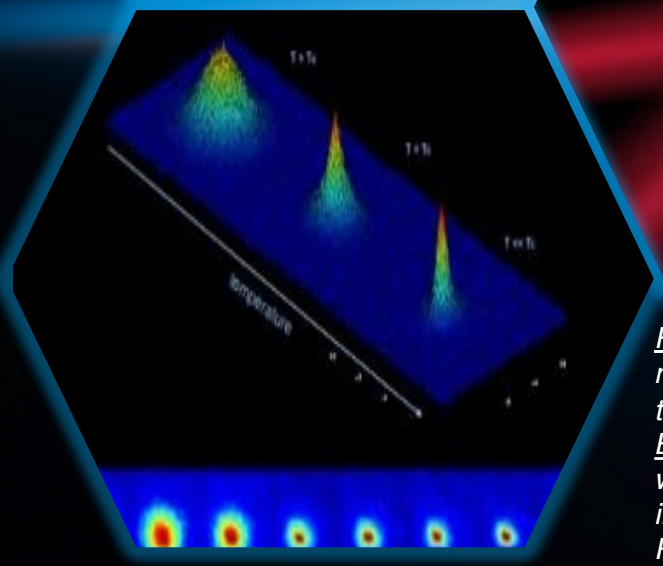


PMMA burning on Saffire V

Cold Atom Lab Creates Fifth State of Matter

Top Left: An in-orbit repair and replacement of a critical microwave frequency driver (using an AR headset) by NASA astronaut Megan McArthur in 2021 enabled the effort to produce two species of BEC—potassium and rubidium.





Right: Artist's concept of a magneto-optical trap and atom chip to be used by CAL
Bottom left: False-color images which show the formation of BECs in the CAL prototype at NASA's Jet Propulsion Laboratory (JPL) as the temperature gets progressively closer to absolute zero

OVERVIEW

NASA's CAL is the first quantum science laboratory in Earth orbit. CAL lowers the atomic temperature to create a gel-like fifth state of matter called Bose-Einstein Condensates (BECs). BECs move slowly and enable exploration of fundamental behaviors and properties of atoms. With the weightlessness of the space station, BECs can float, allowing for longer observing times compared to the vacuum environment required on Earth.

RESULTS

Research completed in CAL has demonstrated the capability to move BECs with accuracy and study interactions between different atoms, paving the way for future high-precision measurements. An upgrade to CAL science module will enable the next experiments on ISS to enhance space-based quantum sensing.

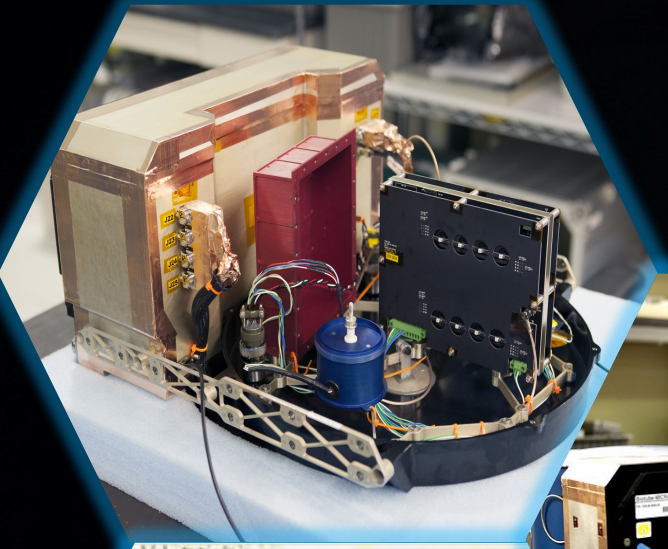
IMPACT

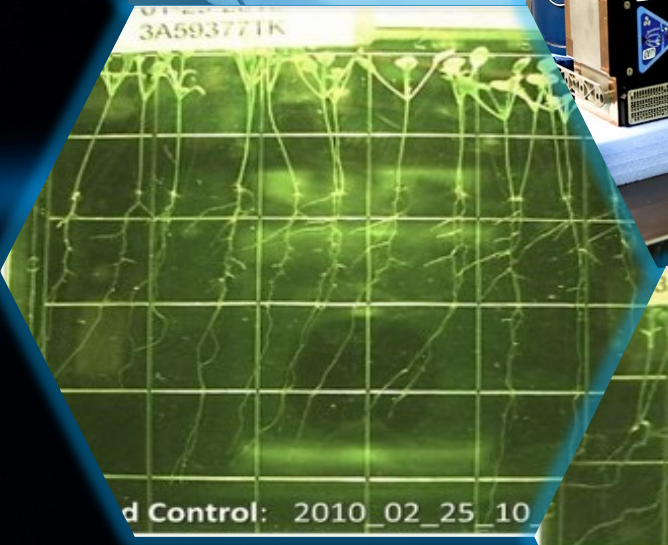
Results from CAL greatly enhance Earth-based capabilities to improve the sensitivity of quantum sensors and enhance quantum-based communication, computation and sensing in space and on Earth.

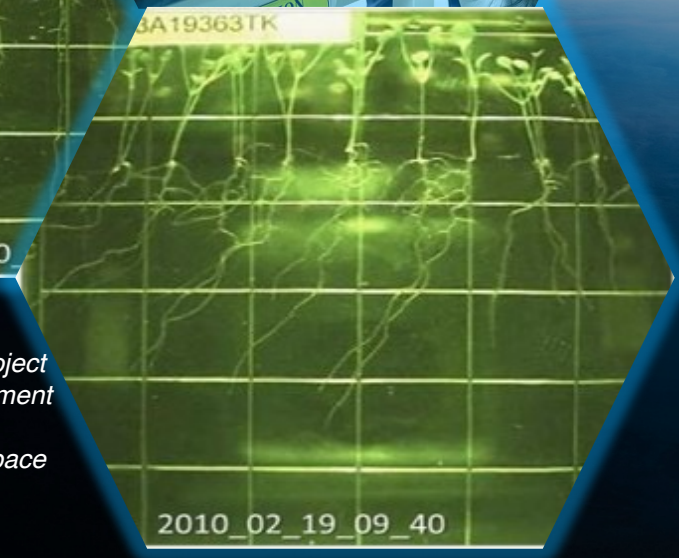
Benefits:

How Gravity Guides Plant Growth

Biotube-MICRO Study







Top left photo: Biotube-Micro instrument
Top right photo: QinetiQ North America Project Manager Carole Miller preparing the instrument with mechanical engineer Allison Caron
Bottom photo: Plant growth on Earth vs. Space
Credits: NASA

OVERVIEW

The Biotube-MICRO will help scientists understand how gravity guides plants into growing correctly. It will apply a magnetic field to induce root curvature and direct plant growth in space with the goal of measuring changes in growth rate, directionality and gene expression.

RESULTS

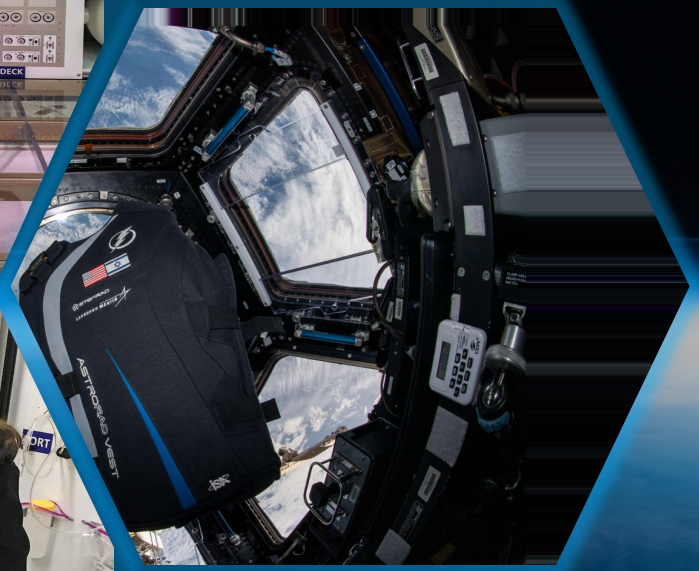
Comparison of ground and space results showed genetic alterations appeared to be mainly caused by the plants' perception of weightlessness, which prompted changes to metabolism.

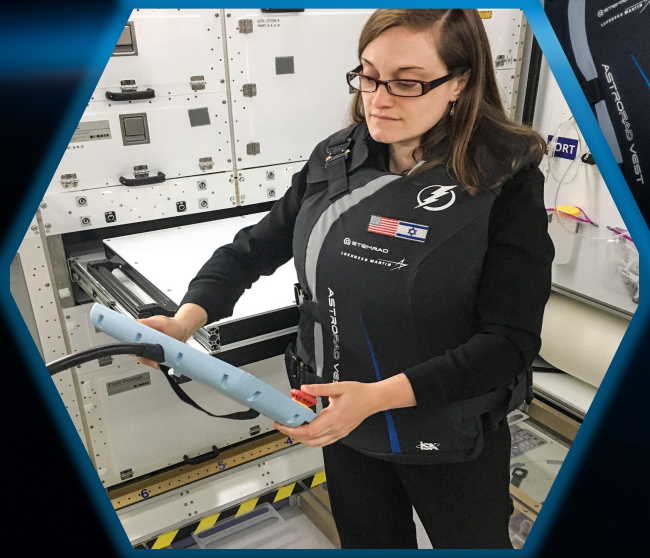
IMPACT

A better understanding of the processes that impact plant growth could help direct the growth of future food crops in space and improve plant production on Earth.

Benefits:

Vest Protects Astronauts from Radiation in Space





Top left: The AstroRad Vest undergoes fit testing at the Kennedy Space Center in the Lockheed Martin mockup of the Gateway
Bottom left: Preflight imagery of Astrorad Vest.
Bottom right: The AstroRad Vest in the Cupola module aboard the ISS
Credit: NASA

OVERVIEW

AstroRad is a specialized garment designed to protect astronauts from radiation caused by unpredictable solar particle events. The vest's developers will use astronaut feedback from ergonomic testing to improve design and comfort of the garment.

RESULTS

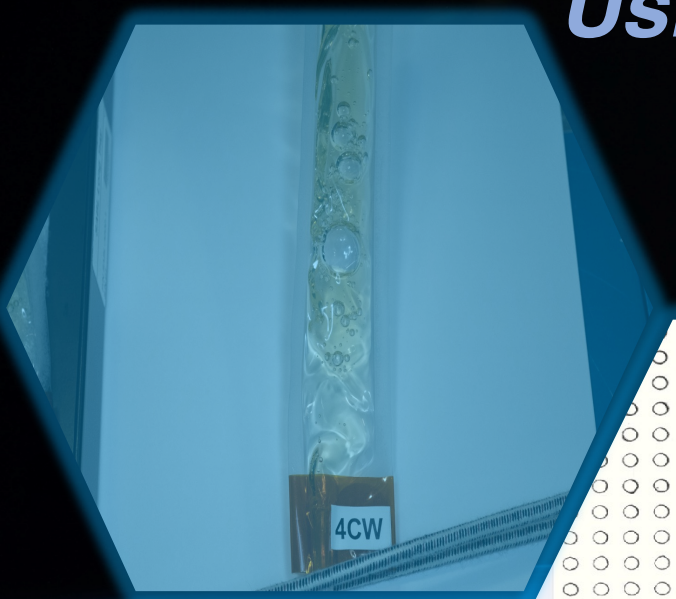
Preliminary data indicates that astronauts were able to complete 75% of tasks related to onboard activities such as cargo operations, eating, housekeeping and sleeping. Feedback on sizing indicates that range of motion was restricted at the hips, shoulders and neck. Sizing can be addressed with minor structural modifications.

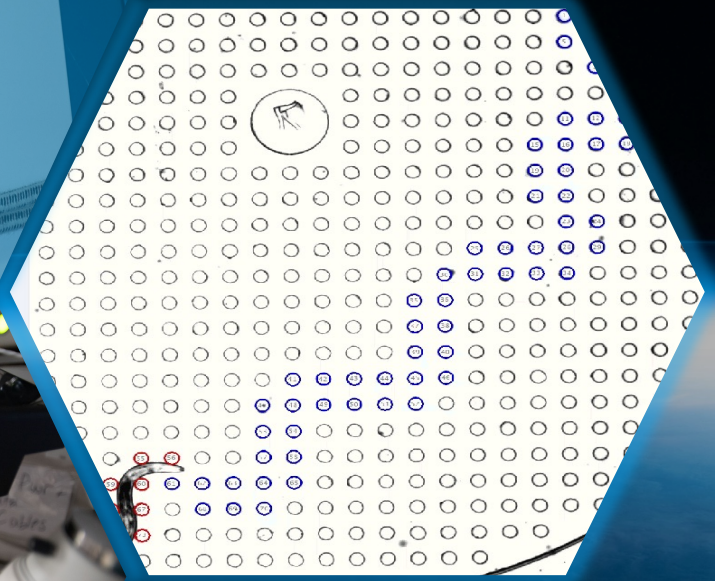
IMPACT

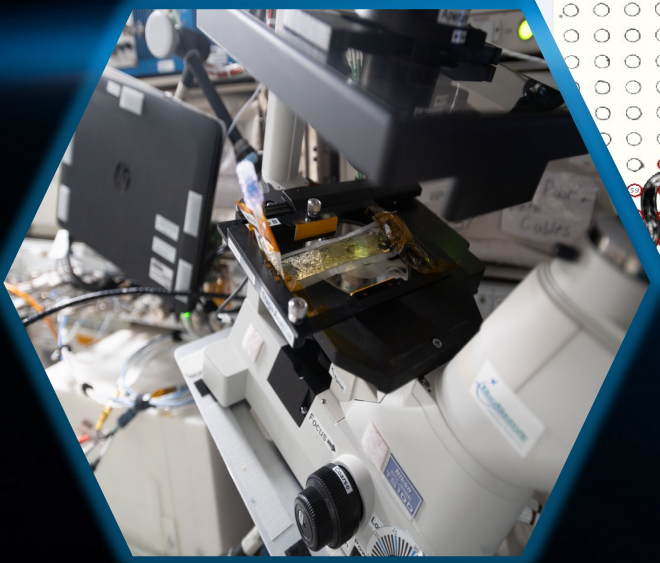
The vest provides personal radiation protection for astronauts beyond low-Earth orbit, reducing the chance of certain types of radiation-induced cancer and other adverse health effects associated with long duration space missions.

Using Worms to Study Muscle Strength in Space

MICRO-16 Study







Top left: View of Micro-16 experiment
Bottom left: View of sample on microscope
Right photo: Animated simulation of a C. elegans moving through a NemaFlex device, developed to enable continuous measurement of worm muscle forces
Credits: NASA

OVERVIEW

A NASA-funded research team developed the NemaFlex chip to measure muscle strength over multiple generations of *C. elegans* (worms) born and raised on the International Space Station (ISS). The body wall of these "worms" are similar to human skeletal muscle,
and therefore useful surrogates for studying microgravity induced changes in muscle physiology. The NemaFlex microfluidic device contains a “forest” of tiny micro-pillars. As the worms crawl through the device, scientists can measure the muscle strength of the worms based on this pillar deflection.

RESULTS

The Micro-16 study successfully demonstrated an updated microfluidic habitat for measurement of muscle strength *C. elegans.* Results showed defects in muscle attachment complexes contributed to a decline in muscle strength. Additionally, altered gene expression was observed in this *C. elegans* model.

IMPACT

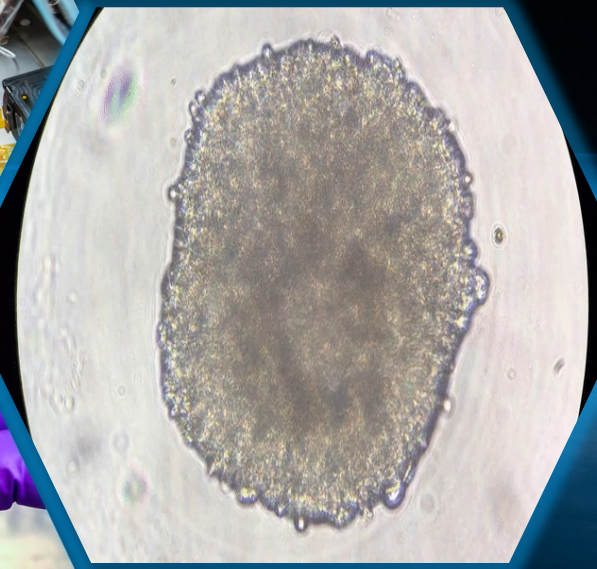
Loss of muscle mass and strength in astronauts remains a crew health issue and could be limiting for future space and lunar exploration. This study provides a better understanding of how changes in gene expression in space are linked to muscle function. This may support muscle atrophy research in space and clinical populations on Earth.

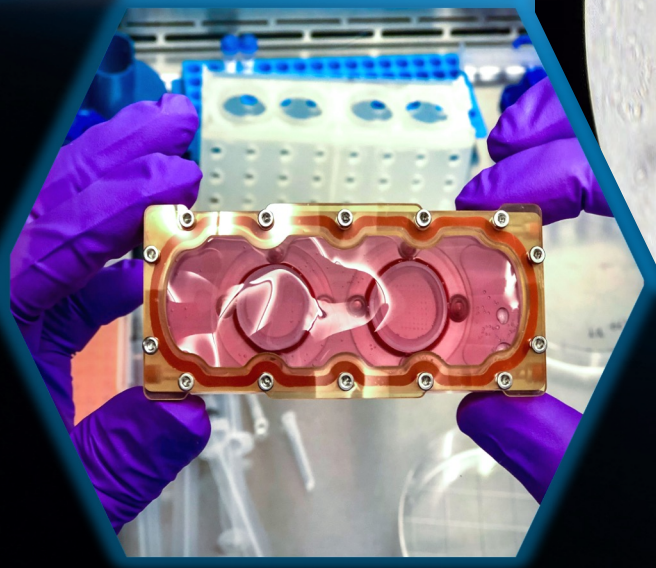
Benefits:

Effects of Microgravity on the Heart

Cardinal Heart 2.0 Experiment

Top Left: NASA astronaut Kate Rubins works inside the Life Sciences Glovebox (LSG) to change the Media in a Tissue Chamber for the Cardinal Heart experiment.





Bottom left: A pre-flight image of a BioCell that contains 162 beating cardiac spheroids. Credit: NASA Right: A pre-flight image of a beating cardiac spheroid. Credit: Stanford Cardiovascular Institute

OVERVIEW

Microgravity exposure causes significant changes in heart cell function that could lead to long-term damage or cardiac muscle atrophy. Cardinal Heart 2.0 tests whether clinically approved drugs can help prevent changes in heart cell function and gene expression that occur during spaceflight.

RESULTS

Results from the first Cardinal Heart investigation suggested exposure to long-term spaceflight causes changes to the heart. Cardinal Heart 2.0 flew on SpX-27, results pending.

IMPACT

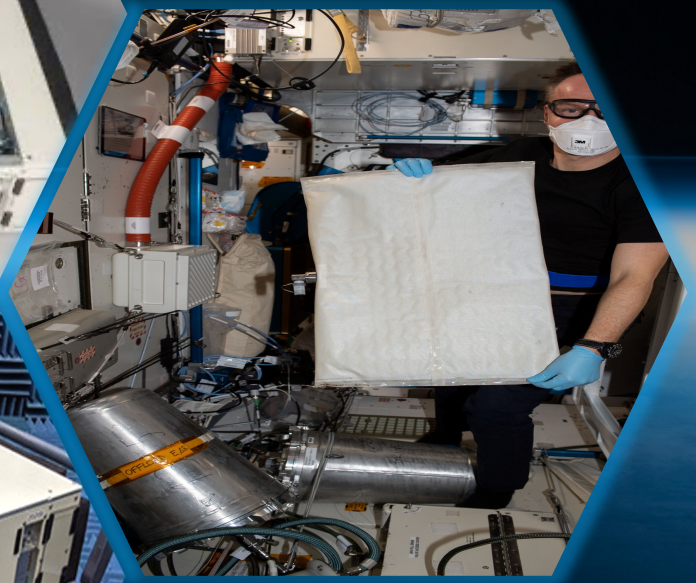
This research could help identify microgravity-induced changes in cardiac cells and their possible harmful effects. Results could support the development of effective drug combinations to improve the health of astronauts and patients on Earth.

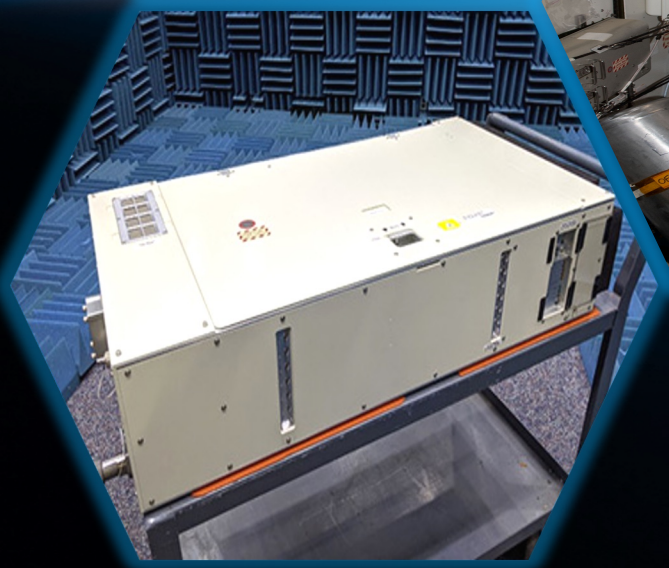
Benefits:

*** ISS NATIONAL LAB ** NATIONAL INSTITUTES OF HEALTH (NIH)**

Brine Processor Assembly Increases Water Recovery

Top Left: Brine Processor's dual membrane bladder works to recover additional water from urine brine. Credit: NASA





Bottom left: Brine Processor Assembly undergoing testing on the ground Credit: Paragon Space Development Corporation Right: Astronaut Matthias Maurer working on the BPA in the ISS. Credit: NASA

OVERVIEW

The Brine Processor Assembly (BPA) demonstrates technology to improve the efficiency of water recycling for deep space exploration missions. A water recovery system for exploration is needed that is capable of increased water recovery and demonstrated to be highly robust to limit consumables and required maintenance.

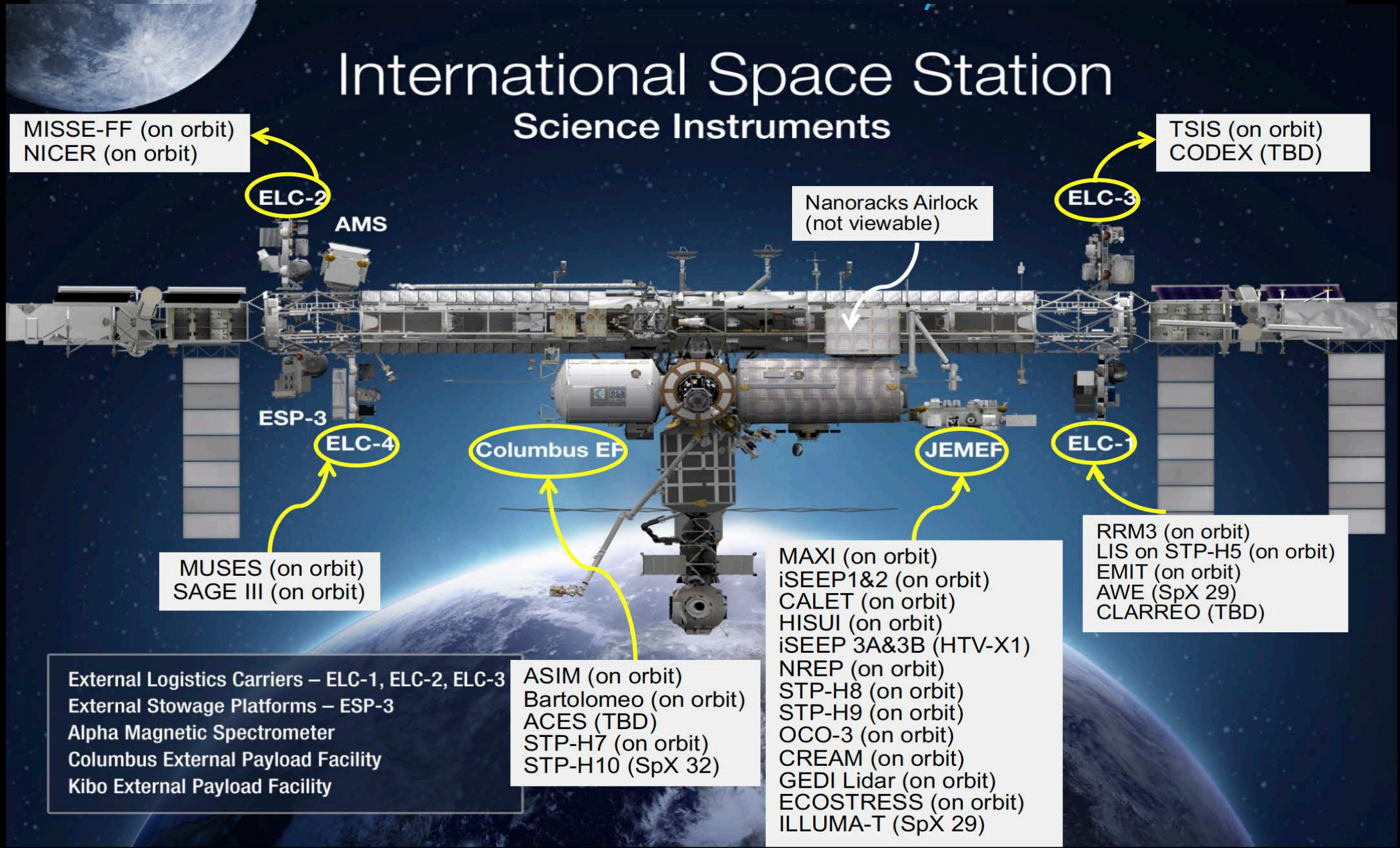
RESULTS

With the addition of the BPA, the exploration water revitalization system on the ISS has successfully demonstrated the exploration goal of recovering 98% of water.

IMPACT

This successful demonstration proves NASA is on track to develop the technology to prepare for deep space exploration missions.

Current and Future External Payloads



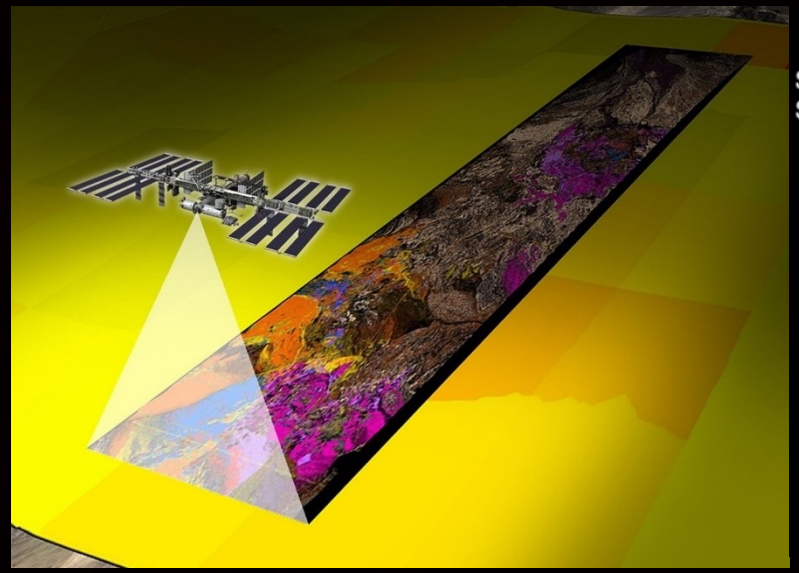
EMIT

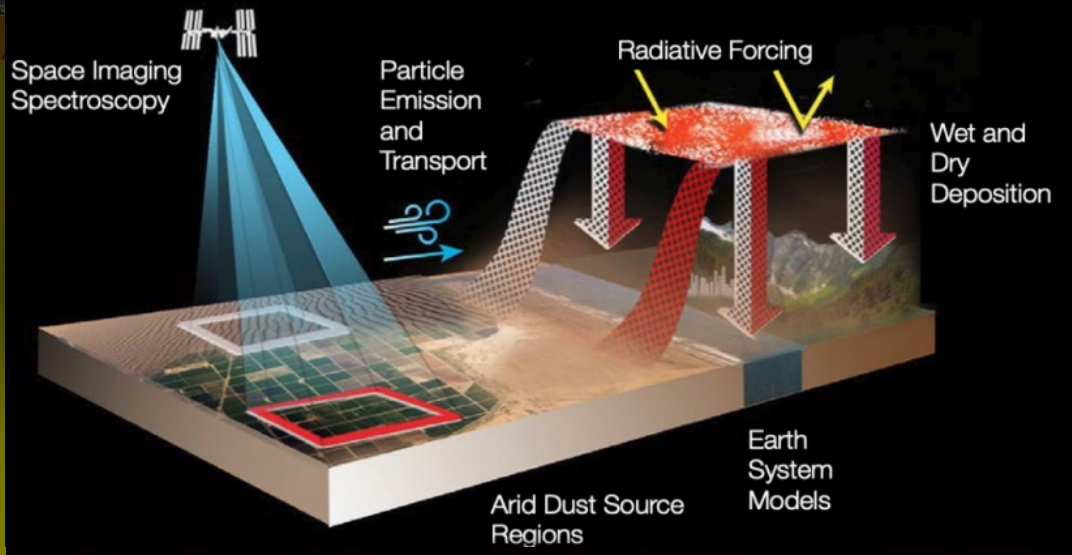
Earth Surface Mineral Dust Source Investigation

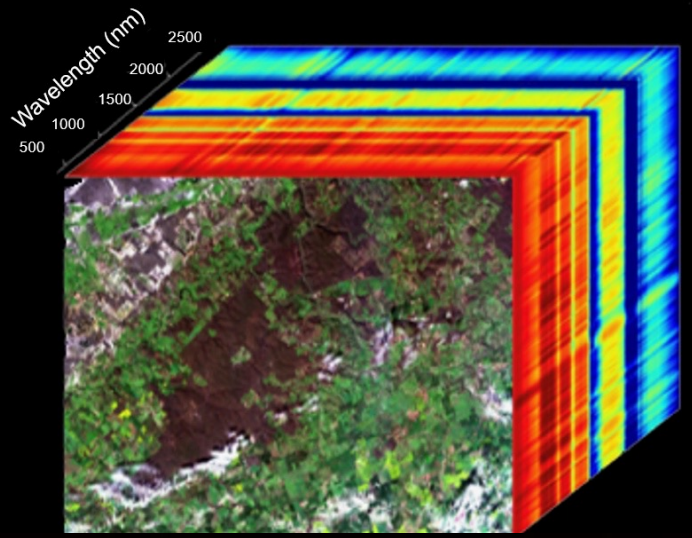
EMIT was developed by NASA JPL and works by measuring the hundreds of wavelengths of light reflected from materials on Earth. Materials reflect different wavelengths of light to produce a spectral fingerprint. The data EMIT collects will help scientists study the role of airborne dust particles in heating and cooling Earth's atmosphere on global and regional scales.

Results: (Fig 3)

- The front image shows a mix of materials in western Australia, including exposed soil (brown), vegetation (dark green), agricultural fields (light green), river, and clouds.
- The rainbow colors are the wavelengths of light (spectral fingerprints), from corresponding spots in the front image.







ISS Research Statistics

Working Data as of April 30, 2023

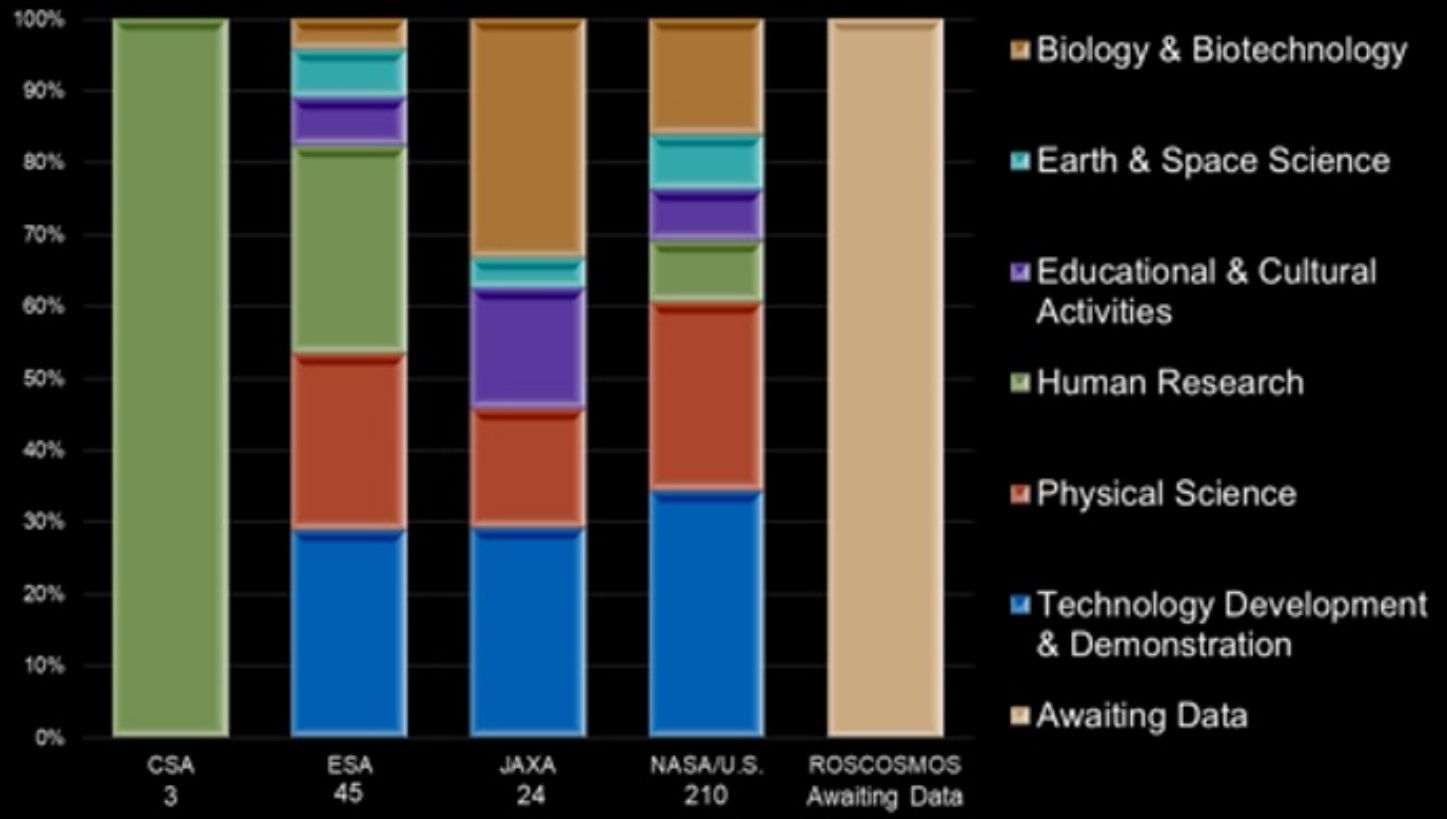
Current Investigations for 69: 282

- 210 NASA/U.S.-led investigations
- 72 International-led investigations
- 79 New Investigations
  - 0 CSA
  - 6 ESA
  - 2 JAXA
  - 71 NASA/US

MCB Approved Statistics Exp. 0-62

- 3040 Investigations
- 4418 Investigators Represented
- 109 Countries/Areas with ISS Research and Education Participation
- Over 3219 Scientific Results Publications (Dec 1998 – April 2023)

Estimated Number of Investigations Expedition 0-69: 3486*



Estimated Number of Investigations Expedition 0-69: 3704* *Pending Post Increment Adjustments

*Pending Post Increment Adjustments

Education on Station

Over the past 20 years, 2.8 million U.S. students in primary and secondary school have designed, launched, operated, or used data from the more than 800 student experiments launched to the ISS as part of these programs.

STEMonstrations

Story Time from Space

Student Downlinks

Earth KAM

HUNCH

High school students United with NASA to Create Hardware

Zero Robotics

Space Station Public Engagements

Even while NASA is flying Artemis missions, ISS provides routine opportunities for student and public engagements like:

Social Media and Film Engagements

- Spot The Station
- Video series like Down to Earth
- Netflix/Discovery documentaries
- CineSpace

NASA & HOUSTON CINEMA ARTS SOCIETY PRESENT

CINESPACE

NASA IMAGERY - YOUR VISION

Interactive mission coverage (launches, dockings, spacewalks, and landings broadcast on NASA TV, NASA app, and social media accounts)

ISS National Lab Status (CASIS)

- **CASIS met or exceeded all target metrics in FY22**
- **Staff Changes and Updates**
  - Betsy Cantwell stepped down as board chair, replaced by Dave Radzanowski
  - Ray Lugo named permanent CASIS CEO and Director
  - Francisco Cordova joined as Chief Operating Officer
  - Robbie Hampton awarded NASA Silver Achievement Medal
- **Continuing to see more demand than resources available**
- **Planning ISS R&D conference July 31st – August 3rd at Hyatt Regency in Seattle Washington**
- **Increased CASIS funding which will in part go toward high impact "Big Idea" awards. Multiplier on CASIS grant funding 4:1**
- **National Laboratory in LEO**
  - ISS working on formal action from National Space Council to develop strategy for future National Lab in LEO
  - OTPS study complete, reviewed potential 6 models and will release concurrently with National Space Council response
    - Bottom Line: no one model fits, must use best attributes from multiple models
  - OSTP released RFI on national strategy for microgravity research and development and collected over 80 responses – overwhelmingly agreed the government should continue to sponsor a national lab in LEO
  - OSTP released the National LEO Research and Development Strategy in March defining strategy policy objectives throughout the government

ISS Extension and Transition

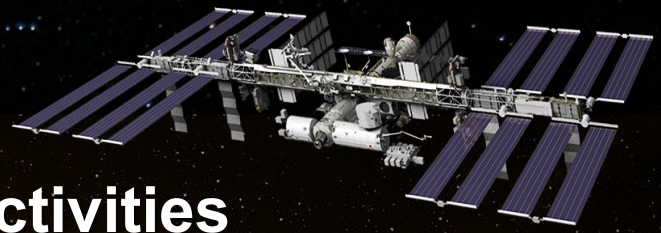
ISS Extension Status

- The ISS International Partners have all completed governmental approval to continue ISS operations beyond 2024.
  - Canada, Europe, and Japan have all announced their decision to continue ISS operations with the United States through 2030.
  - Roscosmos has announced governmental approval to continue ISS operations through 2028.

International Partner ISS Transition Working Group

- All USOS International Partner agencies have indicated a desire to continue ISS-like research and development operations in LEO beyond the ISS
  - Includes crew opportunities, human research, technology demonstrations, basic and applied science, and more
  - Working to define specific utilization activities
- NASA is working to define potential partnership goals and models for cooperation onboard U.S. CLDs.
  - (NASA policy decisions presented in CSD presentation)
- All ISS Partners are working to establish planning milestones and standard interfaces
  - Developing “flexible science” that can work on ISS or a CLD

Transition Activities



Category	Current Activities	Policies
International Partners	- ISS International Partner Transition Working Group	- Partnership goals in LEO - Framework and mechanism options
NASA Demand/Forecast	Updated forecast from 2019 sent out on RFI, responses being compiled	Science prioritization through ISS EOL, define critical activities and utilization transition details for ISS to CLDs
National Lab	- NSpC action to NASA for LEO NL strategy - OSTP LEO Science & Technology interagency working group & release of National LEO R&D Strategy	- Scope of NASA sponsorship of non-NASA users on CLD's (OGA's, commercial startups, STEM) - Recommended model - Stepwise transition plan including potential legislative changes
ISS End of Life Planning	- US Deorbit Vehicle Procurement - Facility transition planning	- No gap in LEO with ISS operations through 2030
Whole of Govt/Regulatory	- NSpC chairing In-space Authorization & Supervision Policy (IASP) Sub-Interagency Space Policy Committee	- The U.S. requires a new or a new in-space authorization and supervision regulatory framework for novel space activities

Resources

National Aeronautics and Space Administration

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