International Space Station

Overview

Research and On-Orbit Facilities

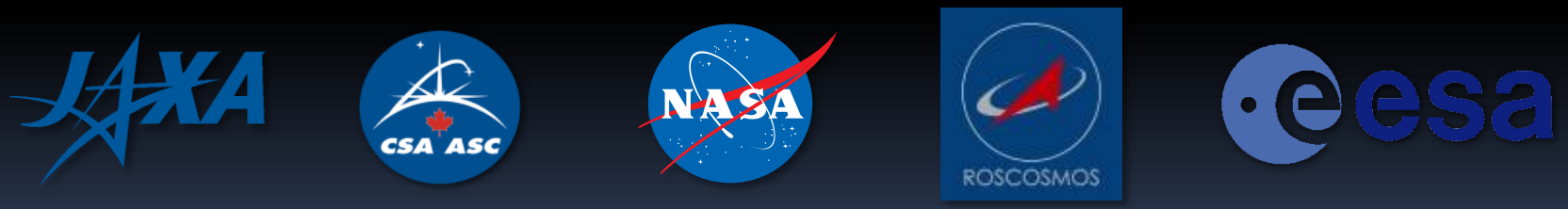
Non-Partner Participation

Rod Jones
NASA ISS Payloads Office
February 2011

International Space Station

Created by a partnership of 5 space agencies representing 15 countries

10 years and over 30 missions to assemble



International Space Station Unique Features

- Robust, continuous, sustainable microgravity platform
- Continuous human presence in space
- Access to the ultra high vacuum of space
- 30kw steady state power for payloads
- Unique altitude for observation and testing
- Payload to orbit and return capability

Why Microgravity Research?

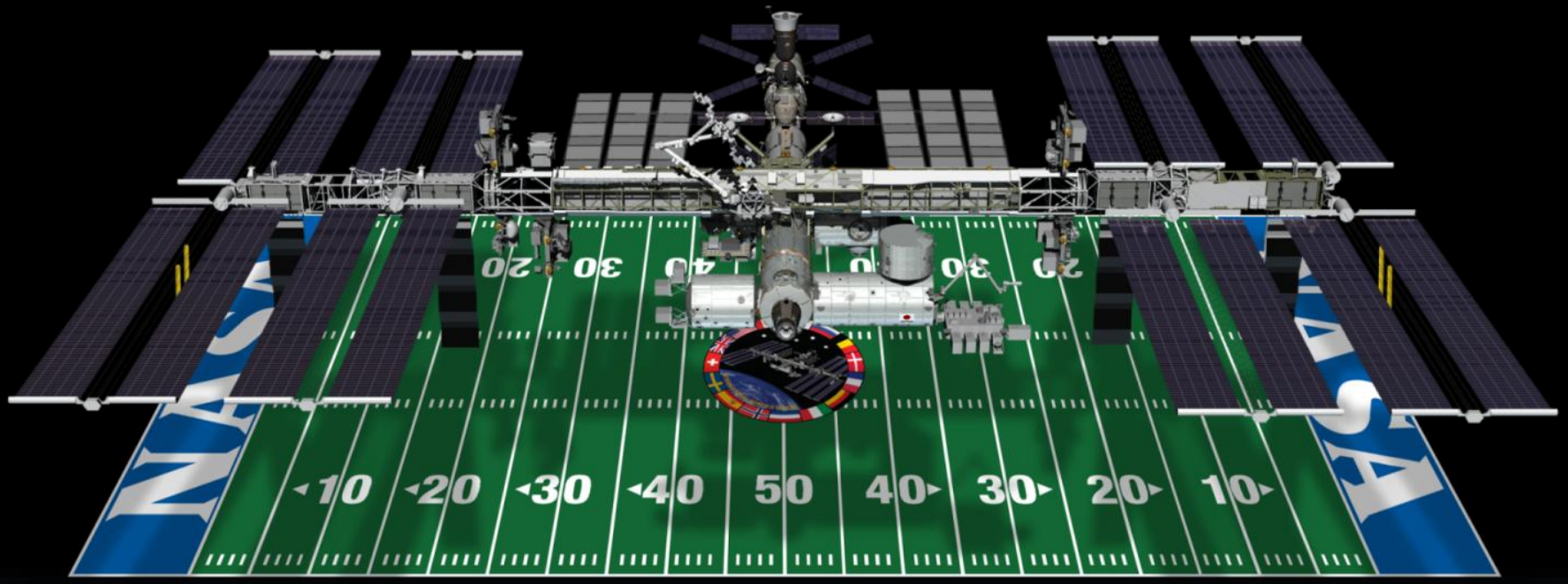
A candle flame in Earth's gravity (left) and microgravity (right) showing the difference in the processes of combustion in microgravity

- Gravity is a constant force on Earth
- It cannot be completely controlled or removed in experiments
- It dominates and masks other forces in processes
- The ISS provides a laboratory environment to control this force

International Space Station Key Features

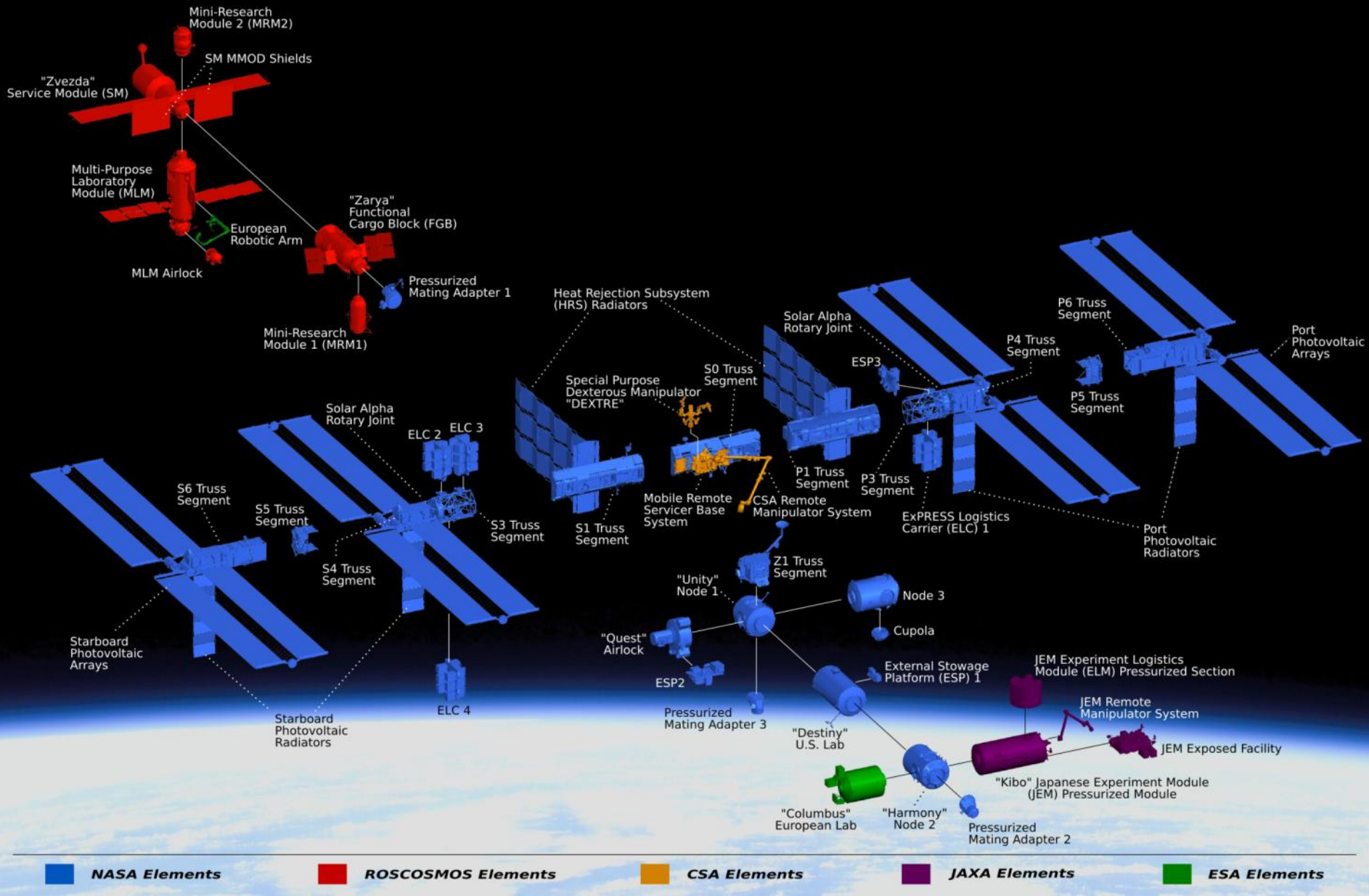
- Supports both external and internal research
- Automated, human, and robotic operated research
- Exposure to the thermosphere
- Nearly continuous data and communication link to anywhere in the world
- Modularity and maintainability built into the design ensures mission life, allows life extension, vehicle evolution and technology upgrades

International Space Station Facts



Spacecraft Mass: +800,000 lb (+362,874 kg)
Velocity: 17,500 mph (28,200 kph)
Altitude: 220 miles above Earth
Power: 80 kW continuous

A collaboration of 5 space agencies



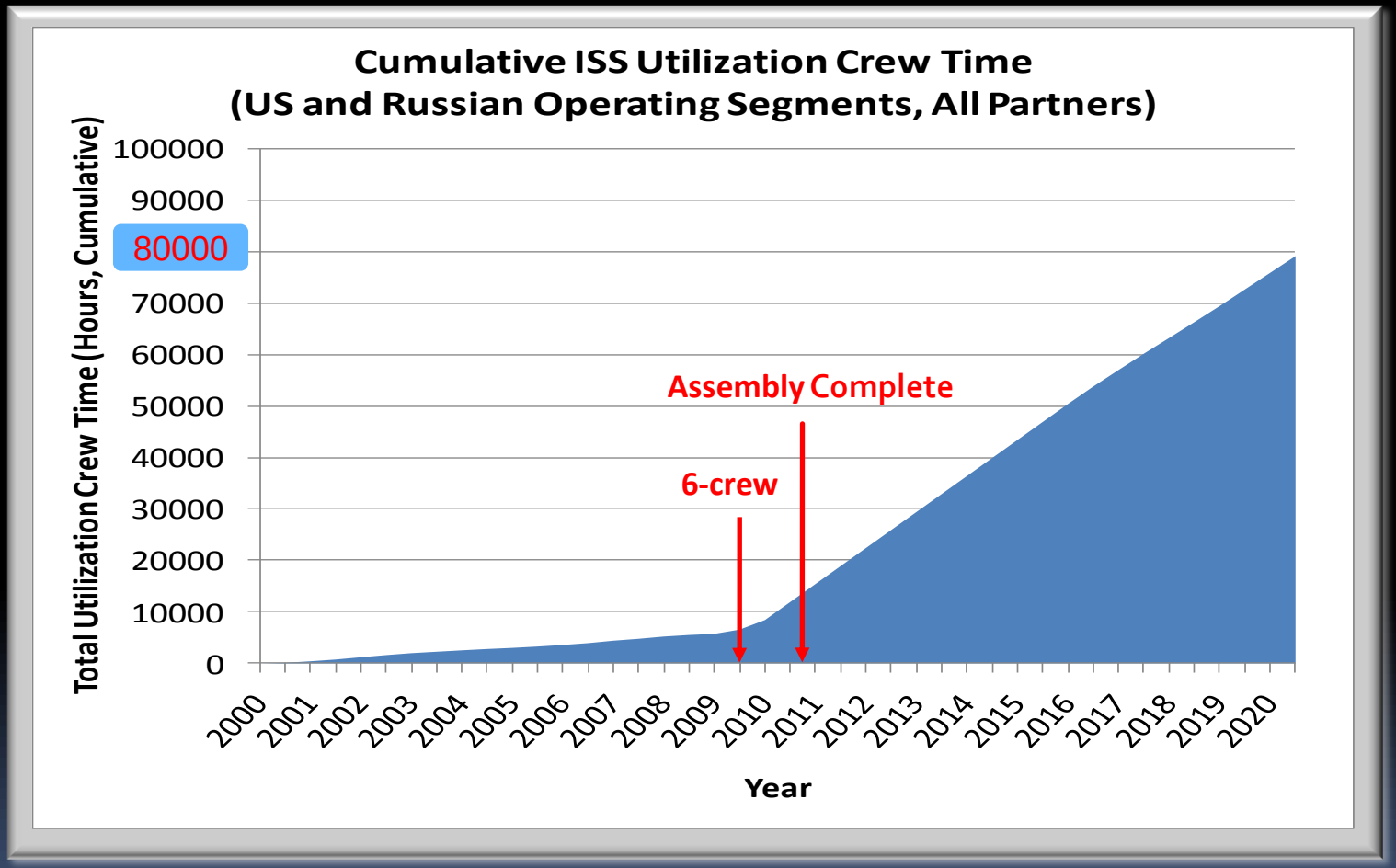
Research Resources on ISS

Biology and Biotechnology, Earth and Space Science, Educational Activities, Human Research, Physical & Material Sciences, Technology Demonstration

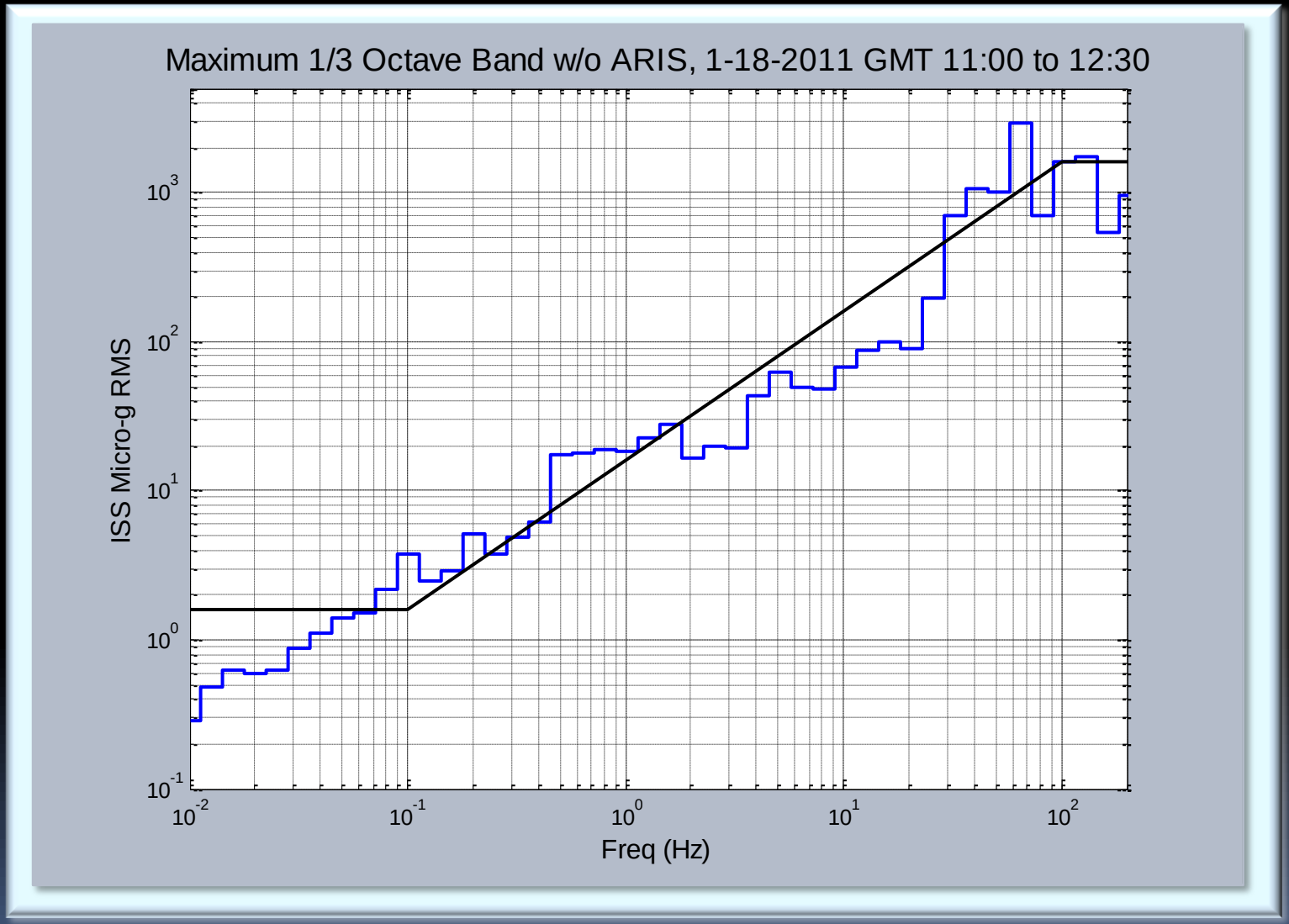
On Orbit Payload Resources

Power	30kw average
Air to Ground Data	~37.5 Mbps of video (3 lines of video at 12.5 Mbps each)
	~8 Mbps of MRDL data (Science return)
	~5 Mbps for payload still imagery downlink
	~20 Mbps utilized for payload data recorded over LOS
Internal Payload Racks	13 NASA Lab
	11 ESA Lab
	10 JAXA Lab
External Sites	8 NASA Truss ELC Platform Sites
	10 JAXA Platform Sites
	4 ESA Platform Sites
Crew time	35 hrs per week (average)

Human Operated Research



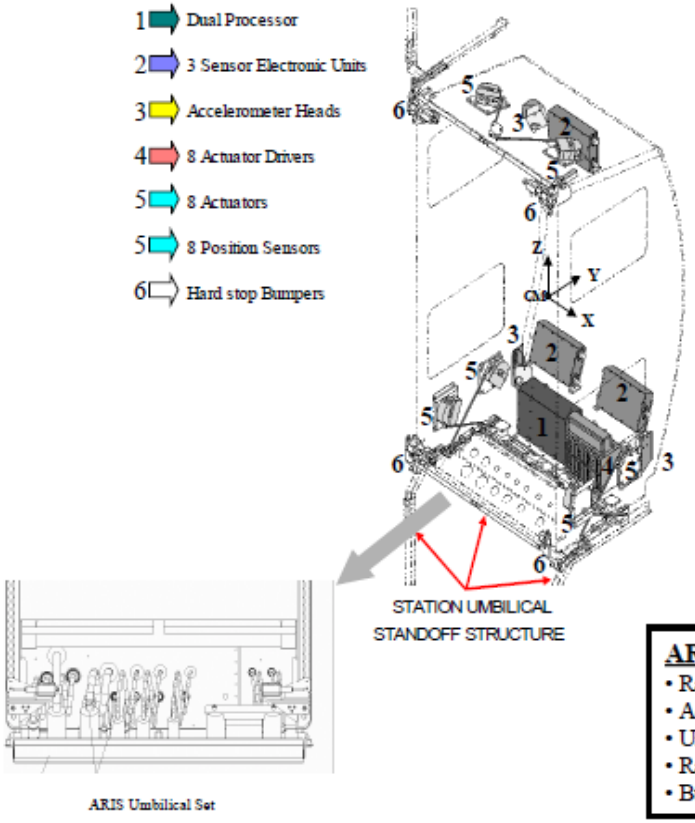
Internal Microgravity Environment



On-board sensors monitor perturbations to the microgravity state
Maximum over 1.5 hours, SARJ Rotating, 6 crew

Microgravity Environment

Active Rack Isolation System



ARIS Umbilical Set

- ARIS is the primary rack-level ISS vibration isolation system.
- ARIS umbilical system allows Station resources (power, low temperature water etc.) to be passed to the rack.
- Three triaxial accelerometer heads sense rack acceleration.
- Eight voice coil actuator driven pushrods used for actuation.
- Eight position sensors integrated in actuator housing.

ARIS Active Isolation Mode Control Architecture

- Low Bandwidth Position Loop (< 0.01 Hz):
  Rack Centering
- Higher Frequency Acceleration Loop (< 7 Hz):
  Active Vibration Isolation
- Antibump Outer Loop:
  Accelerate/Decelerate rack if bumping is imminent.

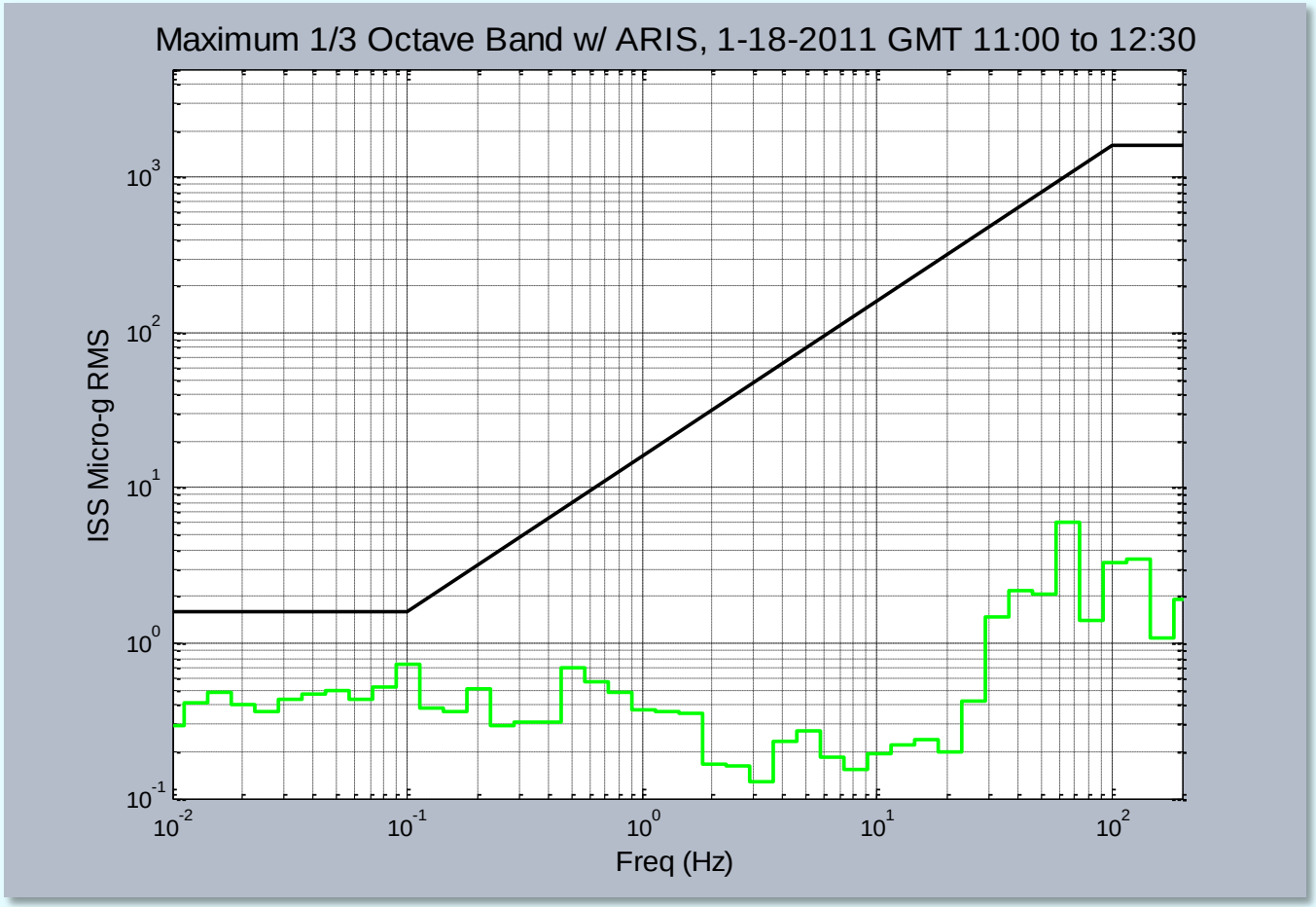
ARIS Modeling

- Rack Mass and Umbilical Stiffness Modeling
- Actuator Dynamics Modeling
- Umbilical Dynamics Modeling
- Rack Structural Dynamic Modeling
- Bumper Models

ARIS Qualification Test/Verification Analysis Technical Review; 1/11&1/12; Houston

Internal Microgravity Environment

Rack with ARIS active



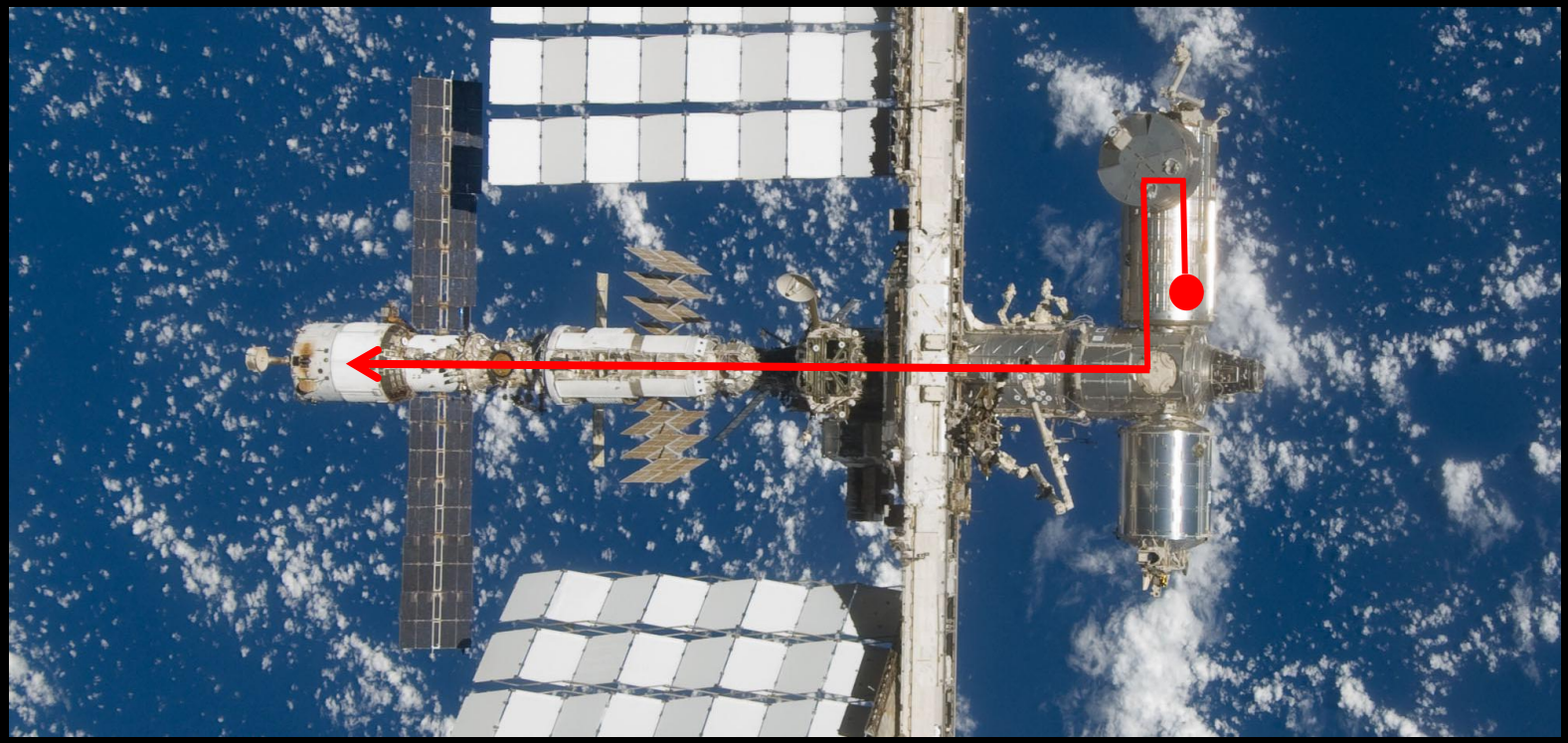
Active Rack Isolation System is effective even during crew exercise

Internal Research Accommodations

Architecture based on Modular racks

Modularity = maintainable, reconfigurable, interchangeable between ESA, JAXA, NASA

ISS Fly through from the JAXA module to the Russian Service Module



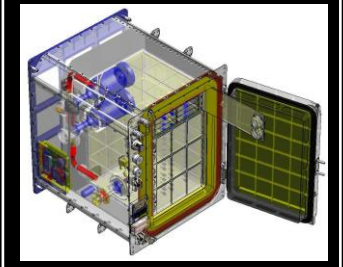
Research Facilities and Capabilities

Multi Purpose Research Facilities
Physical & Material Sciences
Biology and Biotechnology
Human Research
Earth and Space Science
Technology Test Beds
Robotics
Communication and Ground Control
Transportation

Minus Eighty-degree Laboratory Freezer for ISS (MELFI)

Provides thermal conditioning at +4°C, -26°C and -80°C for sample (blood, urine, tissue, etc) preservation
3 Units on-orbit

Cold Stowage Accommodations

	MELFI	MERLIN	GLACIER	Single and Double Cold bag with ICEPAC's
				
Transport	No	Yes	Yes	Yes
Power	Yes	Yes	Yes	No
On-orbit temperature (ºC)	+4, -26, -80	+45 to -20	+4 to -185	N/A
Transport temperature (ºC)	N/A	+45 to -5	+4 to -160	+4 to -32
Useable volume (L)	175	19	30	6.8/18.7
External volume	1 rack	1 MLE	2 MLE	0.5/1 MLE

Material Science Glove Box

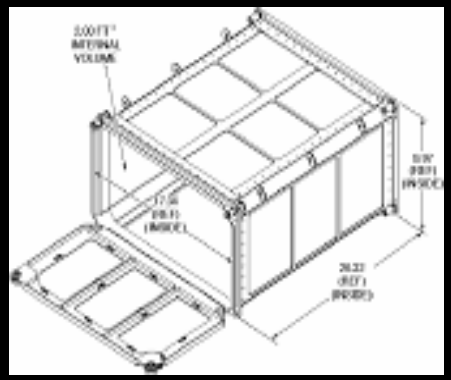
Provides a safe environment for research with liquids, combustion, and hazardous materials

Being modified to support Biology and Bio-technology

ExPRESS Racks

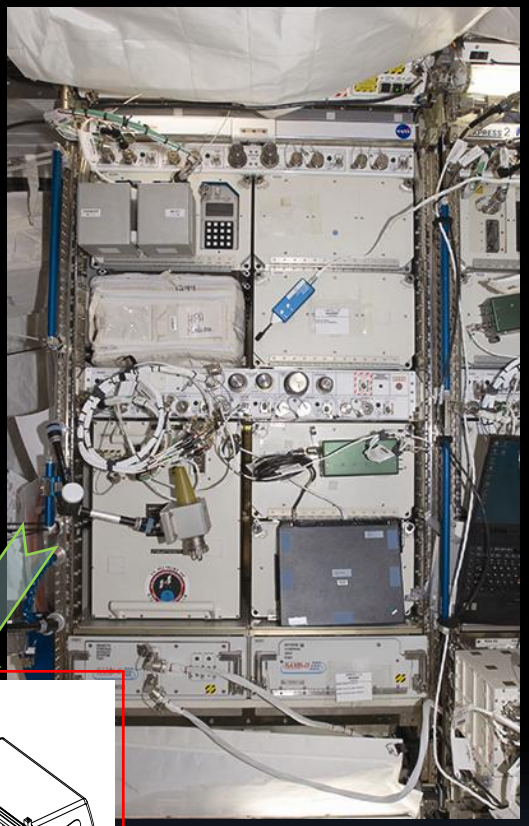
(Expedite the Processing of Experiments for Space Station)

Middeck Locker



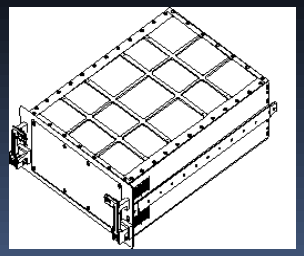
Features
- 4 rear captive fastener attachments
- Friction hinge
- Dual door locks
- Installation tool guides on 4 corners
- Weight – 12 lbs

Sub Rack size payload capability with standard utilities such as power, data, cooling and gases



ExPRESS Rack

International Sub rack Interface Standard Drawer



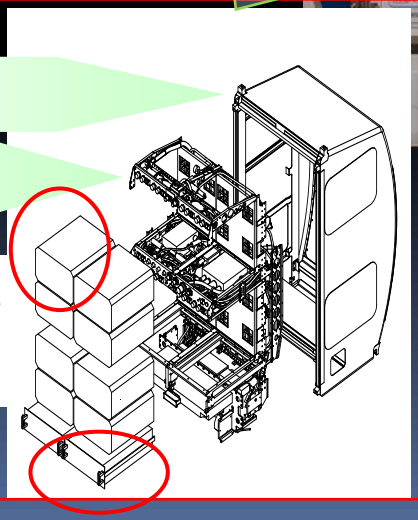
Features
- 4 PU (Panel Unit)
- Blind Connectors
- Locking Handles
- Weight – 27 lbs
- Rated to at least 37 lbs

EXPRESS 8/2 Configuration

International Standard Payload Rack

Secondary Structure & Subsystems

8/2 Payload Configuration (8 Middeck Lockers, 2 Powered ISIS Drawers)

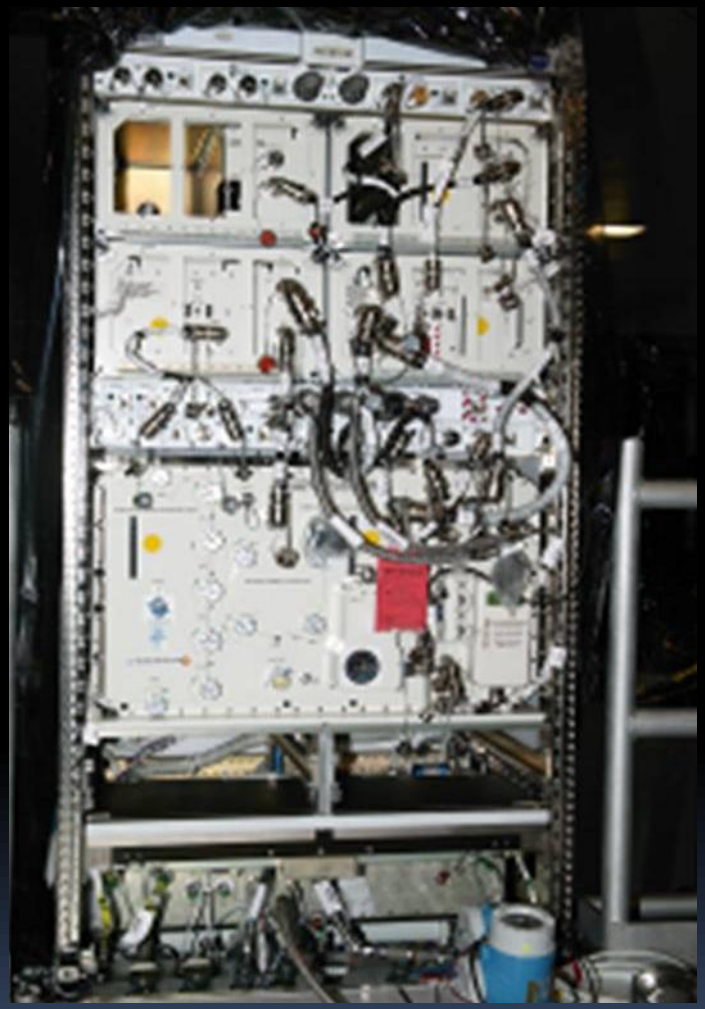


ExPRESS Rack Resources

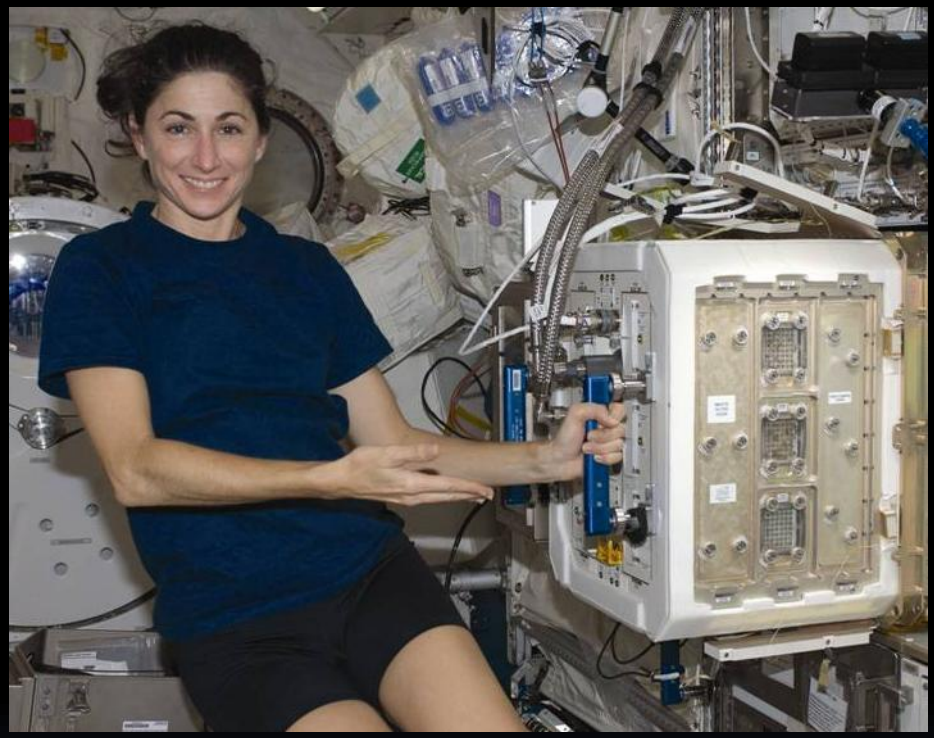
(*Expedite the Processing of Experiments for Space Station)*

System	Middeck Locker Locations	ISIS Drawer Locations	Rack-Level Accommodation
Structural	72 lbs. within cg constraints	64 lbs. within cg constraints	8 Mid deck Lockers 2 ISIS Drawers (4 Panel Unit)
Power	28 Vdc, 0 – 500 W	28 Vdc, 0 – 500 W	2000 Watts 28Vdc power
Air Cooling	≤ 200 Watts	<100 Watts	1200 Watts
Thermal Control System Water Cooling	500 Watts (2 positions per rack)	500 Watts (2 positions per rack)	2 positions per rack
Command and Data Handling	RS422 Analog Ethernet 5 Vdc Discrete	RS422 Analog Ethernet 5 Vdc Discrete	RS422 Analog Ethernet 5 Vdc Discrete
Video	NTSC/RS170A	NTSC/RS170A	NTSC/RS170A
Vacuum Exhaust System	1 payload interface per rack	1 payload interface per rack	1 payload interface per rack
Nitrogen	1 payload interface per rack	1 payload interface per rack	1 payload interface per rack

ExPRESS Sub Rack Payloads



Space Dynamically Responding Ultrasound Matrix System (SpaceDRUMS)



ASI Mouse Drawer System (MDS)

Supported 6 mice on orbit for 90 days

ExPRESS Sub Rack Payloads

ABRS
Advanced Biological Research System

Two growth chambers; each chamber is a closed system capable of independently controlling temperature, illumination, and atmospheric composition to grow a variety of biological organisms.

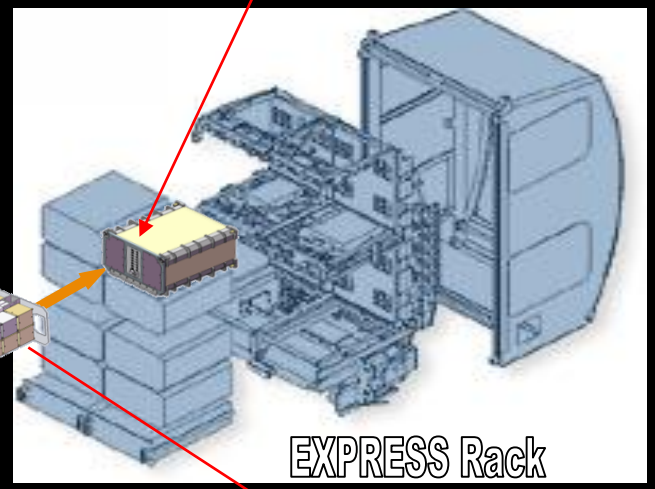
Cube Lab Sub-locker Payload

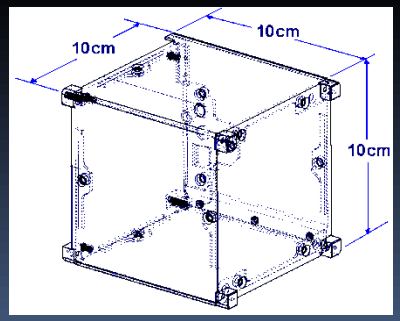
SCIENCE TEAM: NANORACKS, LLC

RESEARCH OBJECTIVES:

Cube Lab is a multipurpose research facility consisting of CubeSat platform experiment modules (Cube Lab Modules) and Cube Lab Frames. Three Cube Lab Frames are being installed as EXPRESS Rack inserts to supply power and USB data transfer capability for Cube Lab Modules on ISS. The Frames are made to house up to 16 standard-sized Cube Lab Modules (1 CU size = 10cmx10cmx10cm).

Each Cube Lab Module has different educational or industrial researcher(s). Each Module plugged into a Frame can provide USB data file transfer capability if an experiment requires it. The transfer is conducted with the Module plugged-into a Frame and use of a temporary Cube Lab Data Cable connection between the FRAME and an EXPRESS Laptop Computer. The Modules also come in multiples of the 1CU size: 4 CU = 40cmx10cmx10cm and 8 CU= 40cmx10cmx20cm.



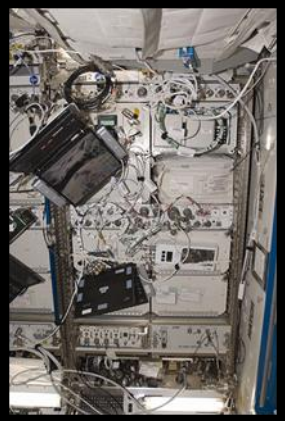


Cube Lab Module

Cube Lab Frame

ExPRESS Racks

ExPRESS 1
US Lab



ExPRESS 2
US Lab

ExPRESS 3
Columbus

ExPRESS 4
JEM

ExPRESS 5
JEM

ExPRESS 6
US Lab

ExPRESS 7
US Lab

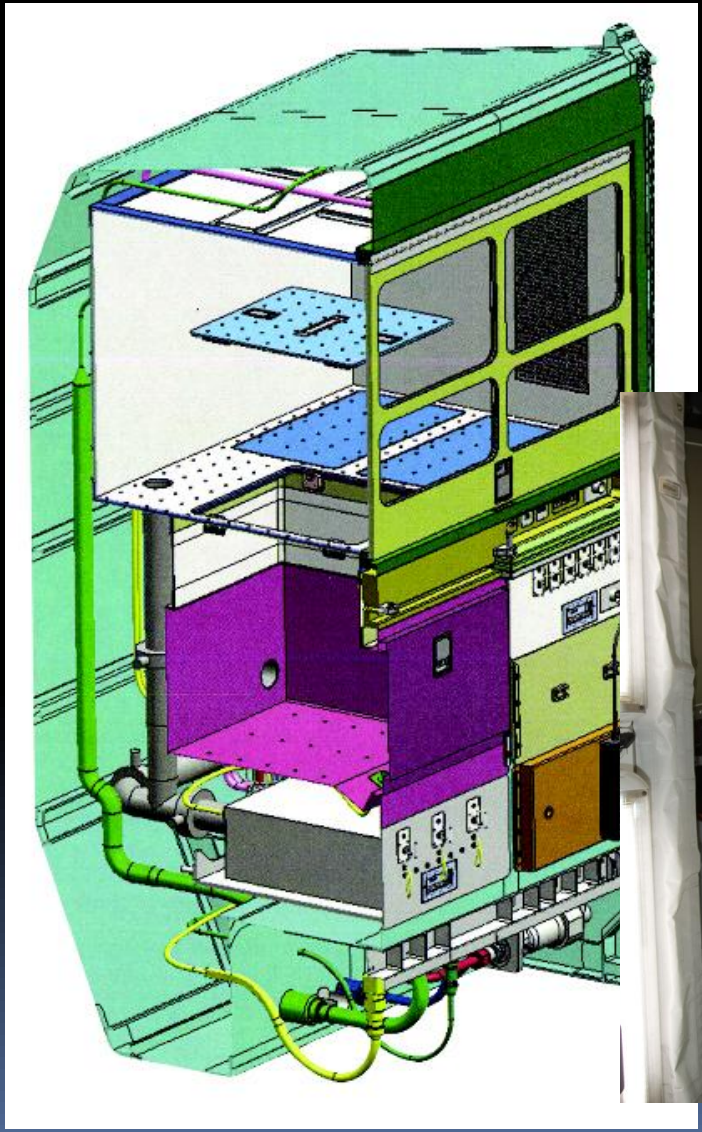
ExPRESS 8
US Lab
Launching on ULF-5

European Drawer Rack *(EDR)*

A multidiscipline facility to support up to seven experiment modules. Each module has its own cooling, power, data, communications, vacuum, venting and nitrogen supply.

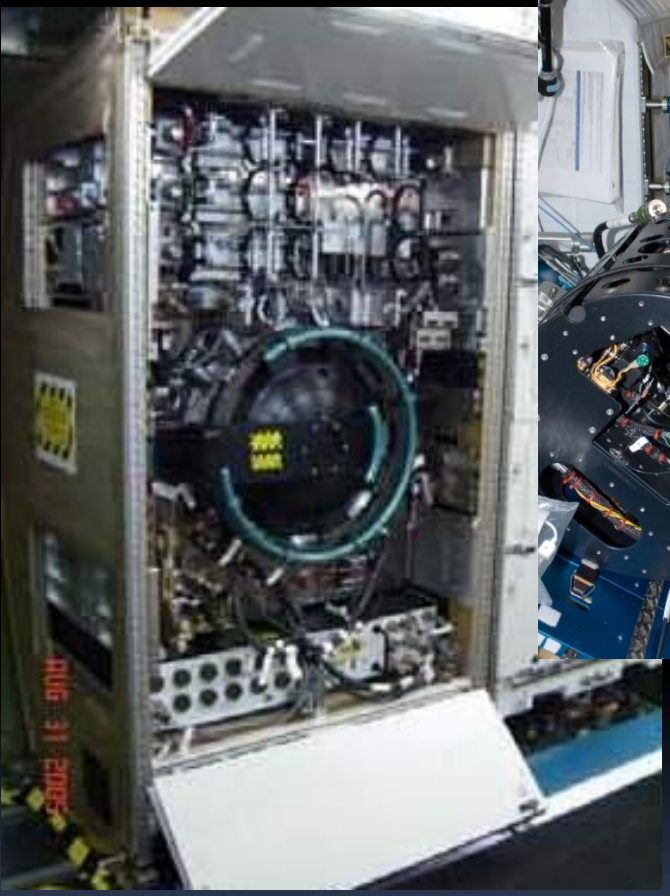
Multipurpose Small Payload Rack

(MSPR)

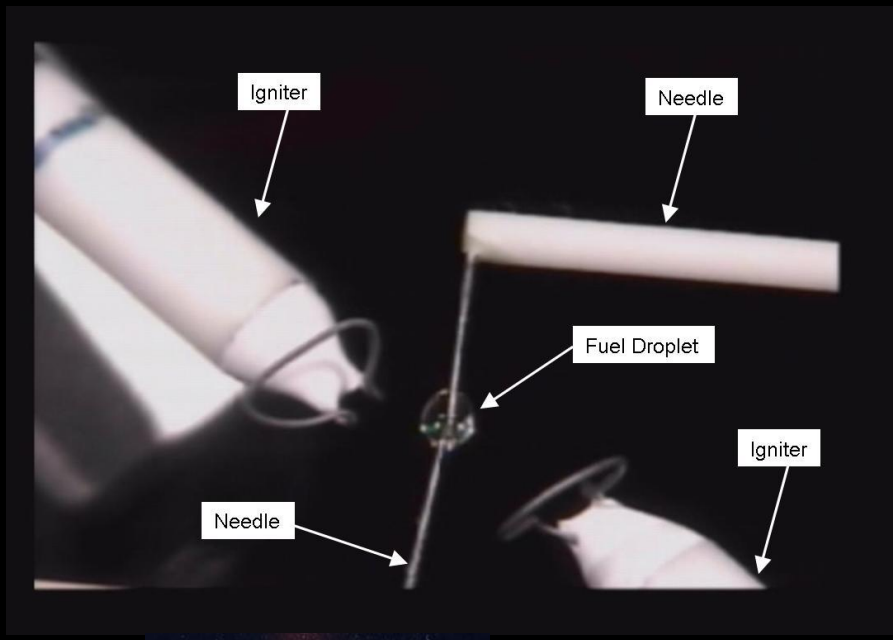


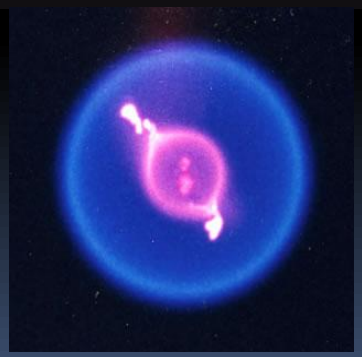
A multidiscipline facility that provides two workspaces and one work bench and can hold equipment, supplies power and enables communication and video.
MSPR just arrived on orbit aboard HTV2.
A second rack is planned for HTV5.

Combustion Integrated Rack *(CIR)*



Facility used to perform sustained, systematic combustion experiments in microgravity





Sample during combustion

Materials Science Research Rack-1

(MSRR-1)

ESA Provides the furnace ‘s and sample cartridges

NASA Provides the rack and on-orbit space

Solidification and Quenching Furnace in the ESA Material Science Laboratory (MSL)

MICAST = Microstructure Formation in Casting of Technical Alloys under Diffusive and Magnetically Controlled Convective Conditions
Studies formation of microstructures during casting of technical alloys

Investigations selected from both agencies

Ryutai Fluids Experiment Rack

A multipurpose rack system that supports various fluid physic experiments. It consists of four sub rack facilities:
Fluid Physics Experiment
Solution Crystallization Observation
Protein Crystallization Research
Image Processing Unit

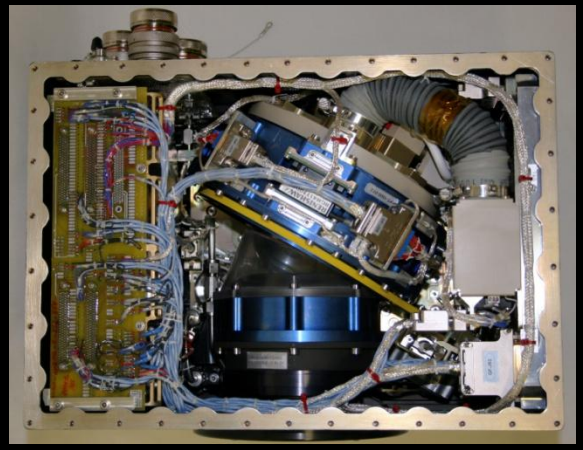
Fluids Integrated Rack *(FIR)*

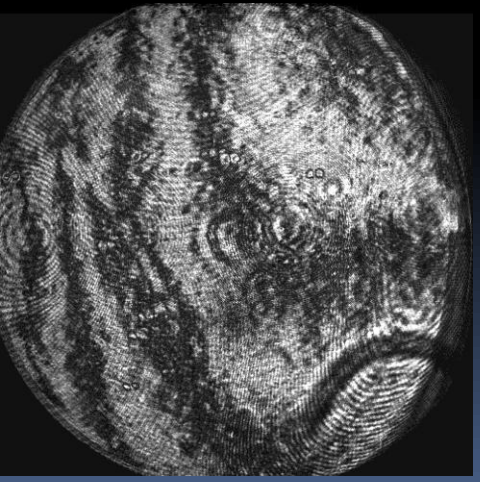
A fluid physics research facility designed to accommodate a wide variety of microgravity experiments dedicated to fluid physics research, with Light Microscope Module

Fluid Science Laboratory *(FSL)*

Multi user facility for conducting fluid physics research in microgravity

<u>Geoflow</u>
Simulation of Geophysical Fluid Flow Under Microgravity



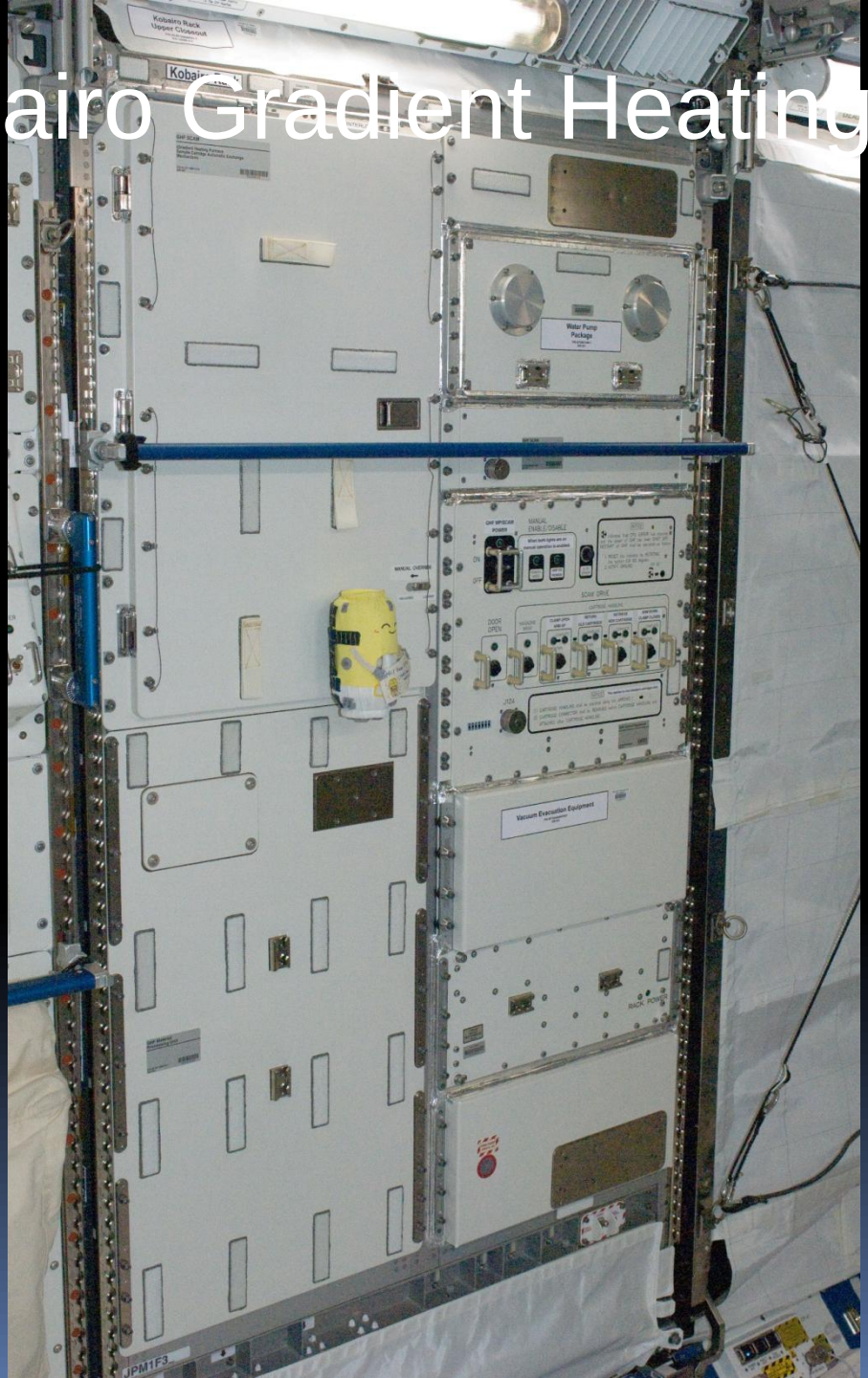


This interferogram is used to calculate the temperature field analyzing the "bulls-eye" (fringe) patterns. Geoflow studies thermally driven rotating fluids which can be used in modeling the convection of the Earth. Image courtesy of ESA

Saibo Experiment Rack

A multipurpose Biological Research payload rack system that sustains life science experiment units and supplies resources to them.
It contains a clean bench, glove box with microscope incubators and centrifuge.

Kobairo Gradient Heating Furnace



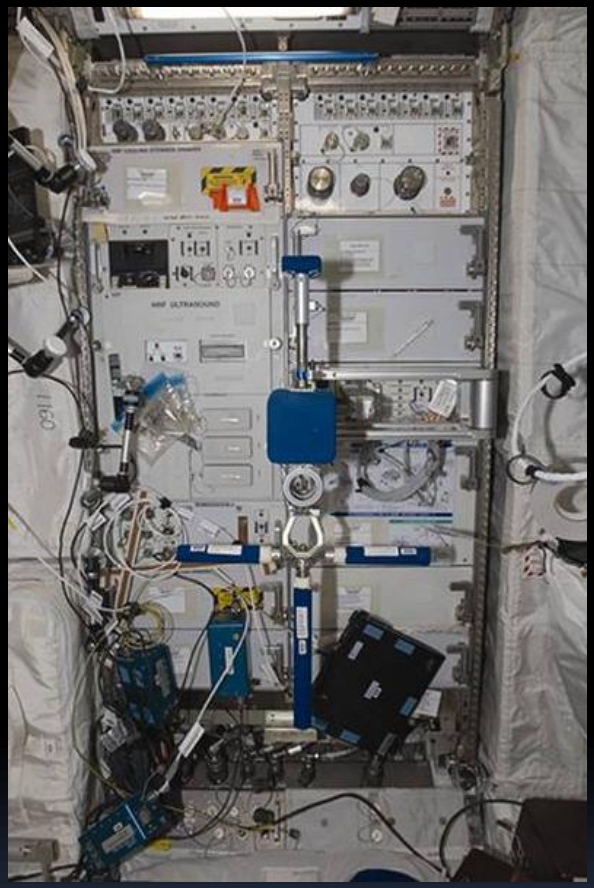
An electrical furnace used for generating high-quality crystals from melting material.
It consists of a vacuum chamber and three independently movable heaters.
Kobairo just arrived on orbit aboard HTV2.

Biological Experiment Laboratory *(BioLab)*

Used to perform space biology experiments on micro-organisms, cells, tissue cultures, small plants, and small invertebrates.

It includes a incubator with microscope, spectrophotometer, and two centrifuges, glove box and two cooler/freezer units.

Human Research Facility *(HRF)*



HRF-1 Rack

HRF-2 Rack

Ultrasound

2 Human Research Facility (HRF) Racks - Biomedical investigations, including ultrasound, body mass measurement, metabolic gas analysis, pulmonary monitoring, ambulatory blood pressure measurement, Holter monitor, and experiment unique hardware

European Physiology Module *(EPM)*

Designed for investigating the effects of microgravity on short-term and long-duration space flights on the human body and includes equipment for studies in neuroscience, cardiovascular, bone, muscle physiology and metabolic processes.

Exercise Device's

Russian Treadmill

CEVIS
Cycle Ergometer with
Vibration Isolation System

COLBERT
Combined Operational
Load Bearing Exercise
Treadmill

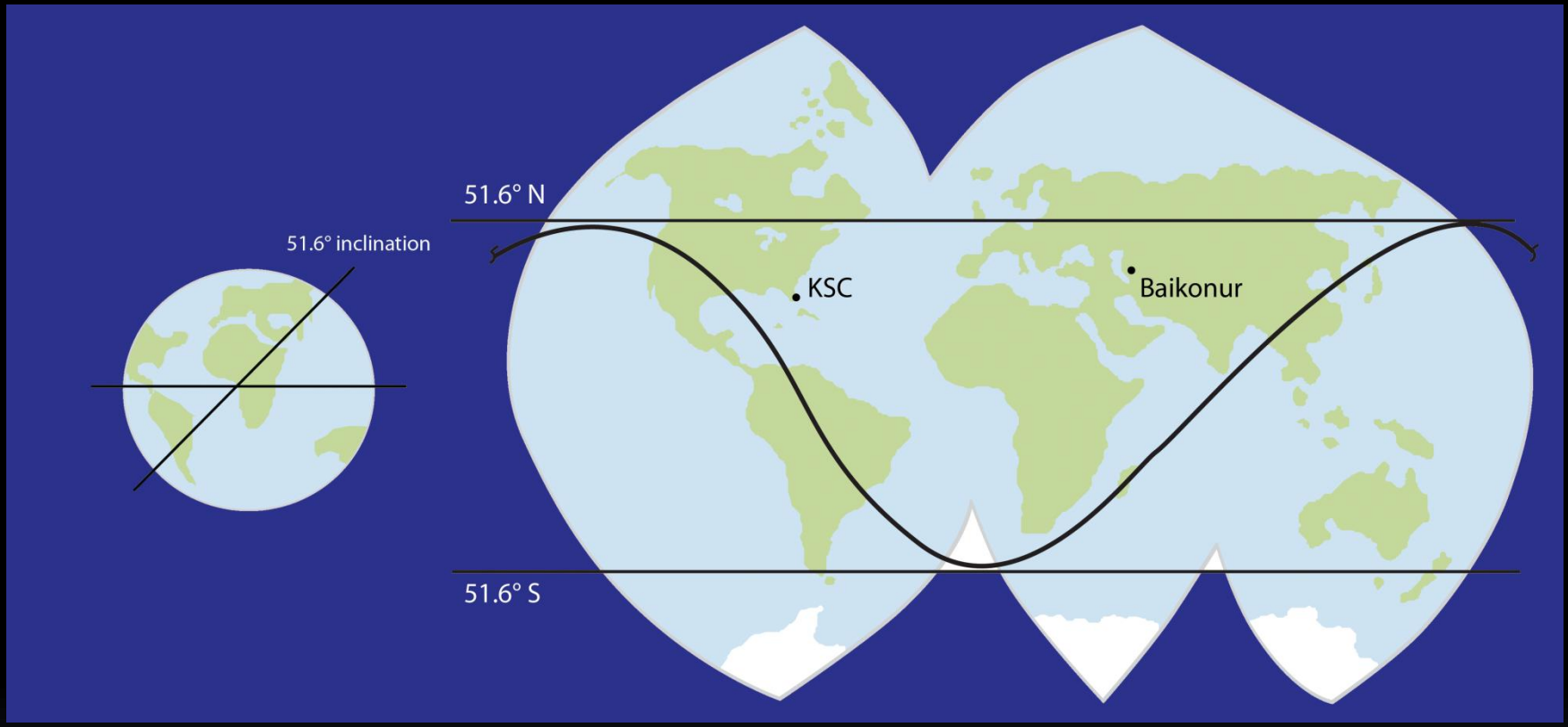
Russian
Cycle Ergometer

ARED
Advanced Resistance
Exercise Device

Earth and Space Science

- Space, Earth surface and Limb views
- External and Internal Payload sites
- Observation of transient atmospheric phenomena
- Planetary science sensor test beds

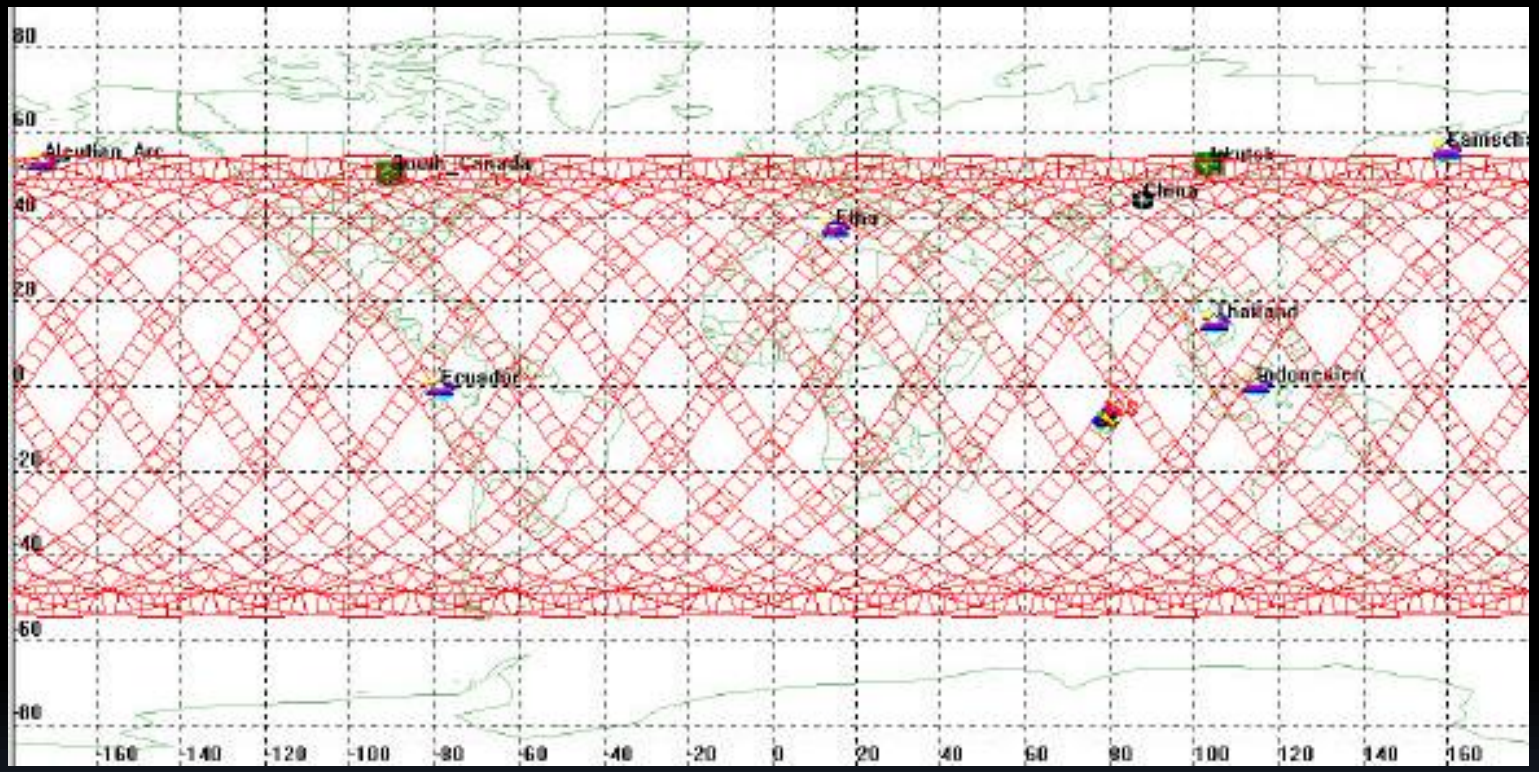
ISS as a Platform for Earth Science



All geographic locations between 51.6 North and South latitude can be observed NADIR pointing

Provides coverage of 85% of the Earth's surface and 95% of the world's populated landmass every 1-3 days

ISS as a Platform for Earth Science



ISS coverage in 24 hrs for a 70°-swath optical payload. (Courtesy of ESA)

Processing lighting (changes with subsequent passes)

Well-suited for test bed concepts with hardware change out and upgrades

ISS as a Observation Platform

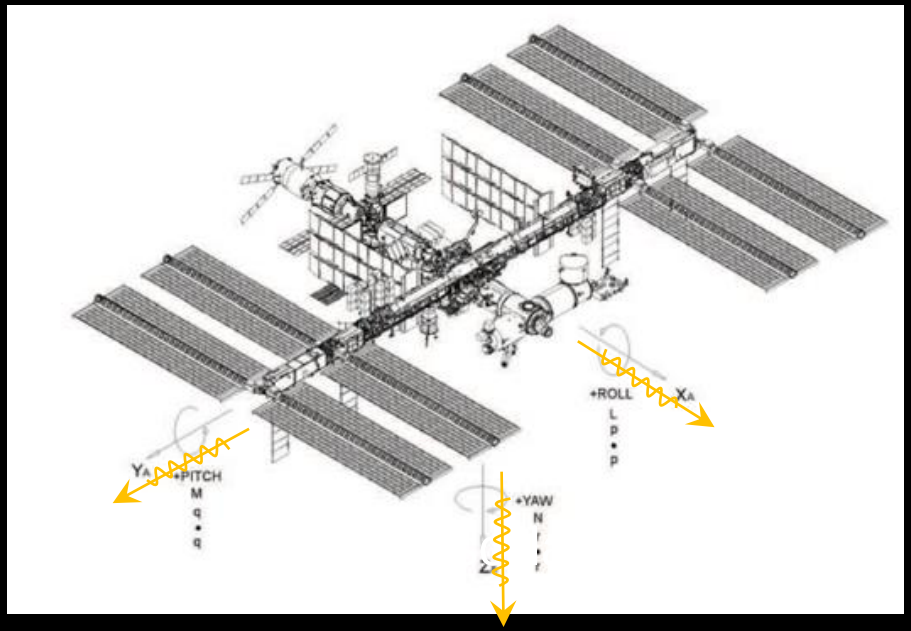
Torque Equilibrium Attitude (TEA) and Wobble Oscillation Description

For Stage configurations in the foreseeable future, the predicted TEA ranges are:

Roll: -1.0 ~ +3.0 deg

Pitch: -7.0 ~ +2.0 deg

Yaw: -15 ~ +15 deg.



Momentum Manager Controller Peak to Peak Attitude Wobble Oscillation

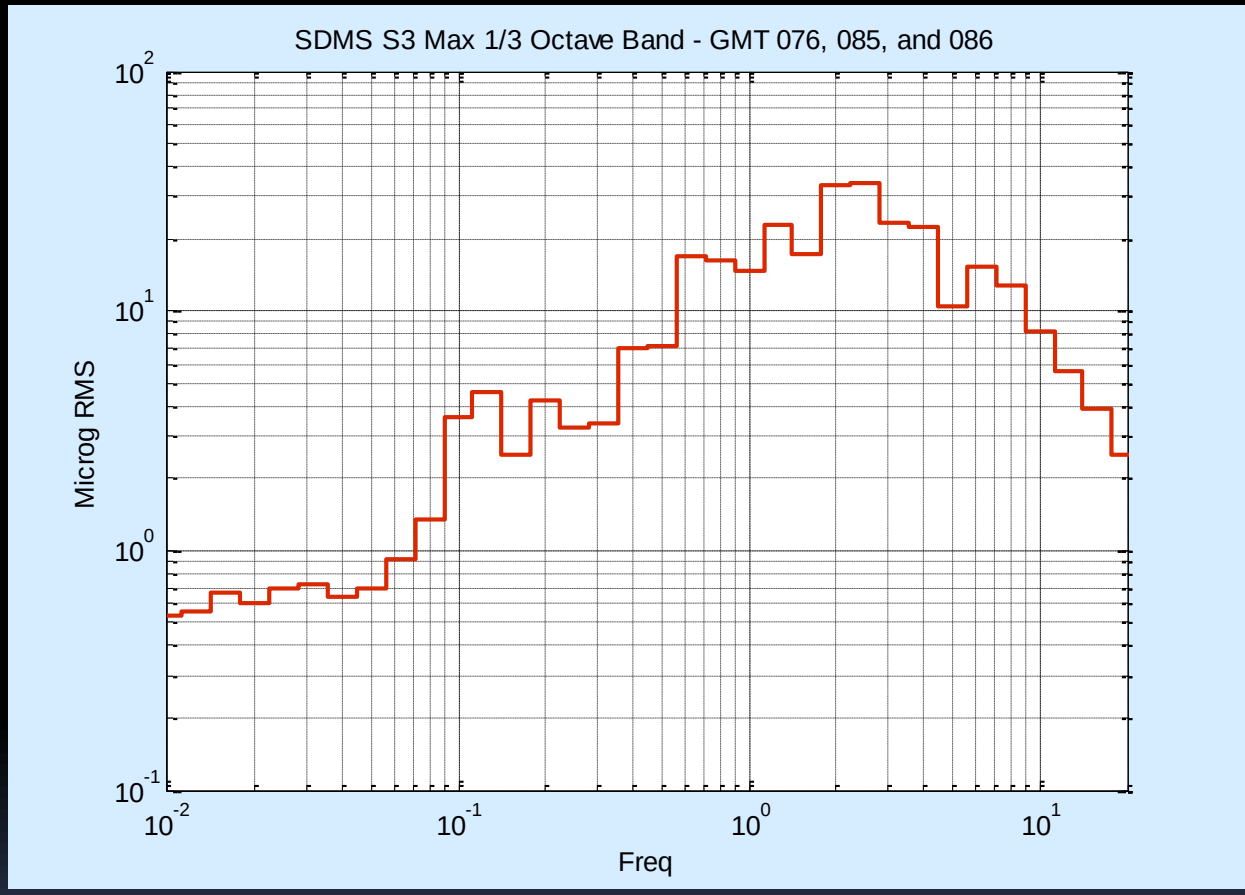
Performance Descriptions	Peak to Peak Attitude Oscillations Per Orbit			Peak Attitude Variation from Steady-State Orbit-Average Attitude		
	Roll (X) (deg)	Pitch (Y) (deg)	Yaw (Z) (deg)	Roll (X) (deg)	Pitch (Y) (deg)	Yaw (Z) (deg)
Non-Micro-Gravity (Assembly Stages) Non-Propulsive (Momentum Manager) Attitude Control Performance Requirement	10.0	10.0	10.0	+/- 5	+/- 5	+/- 5
Micro-Gravity (Assembly Complete) Non-Propulsive (Momentum Manager) Attitude Control Performance Requirement	7.0	7.0	7.0	+/- 3.5	+/- 3.5	+/- 3.5
Typical Steady-State Performance of **Minimum** *CMG momentum oscillation* Momentum Manager Controller	1.6	1.6	2.0	+/- 0.8	+/- 0.8	+/- 1
Typical Steady-State Performance of **Minimum** *Attitude oscillation* Momentum Manager Controller	1.6	0.4	0.2	+/- 0.8	+/- 0.2	+/- 0.1
Typical Steady-State Performance of **Minimum** *CMG momentum & Attitude oscillation* **Blended** Momentum Manager Controller	1.6	0.7	1.2	+/- 0.8	+/- 0.35	+/- 0.6

ISS External Vibratory Environment

for External Payload Pointing Instrument

Data measured on ISS S3 truss

- ISS quiescent mode = No thruster firings, dockings, EVA, or robotics operations
- Typical response, not worst case
- Snapshot of 3 10-minute data takes
- All data taken on March 16, 26, and 27, Stbd SARJ Rotating, exercise, 3 crew.



Data provided by Boeing, June 2010

ULF-4 analysis concluded peak ELC rotations on the order of 0.03 degrees during quiescent mode

Windows on the Earth

Service Module Window
40-cm diameter
NADIR view

Window Observation Research Facility

(WORF)

US Laboratory Window
50-cm diameter
Telescope-quality optical glass
NADIR view

WORF Rack

Facility to support visual and multispectral remote sensing using Lab Optical Window

Crew Earth Observation

Targets of opportunity are uplinked each day to the crew based on that days orbital track

Human disasters

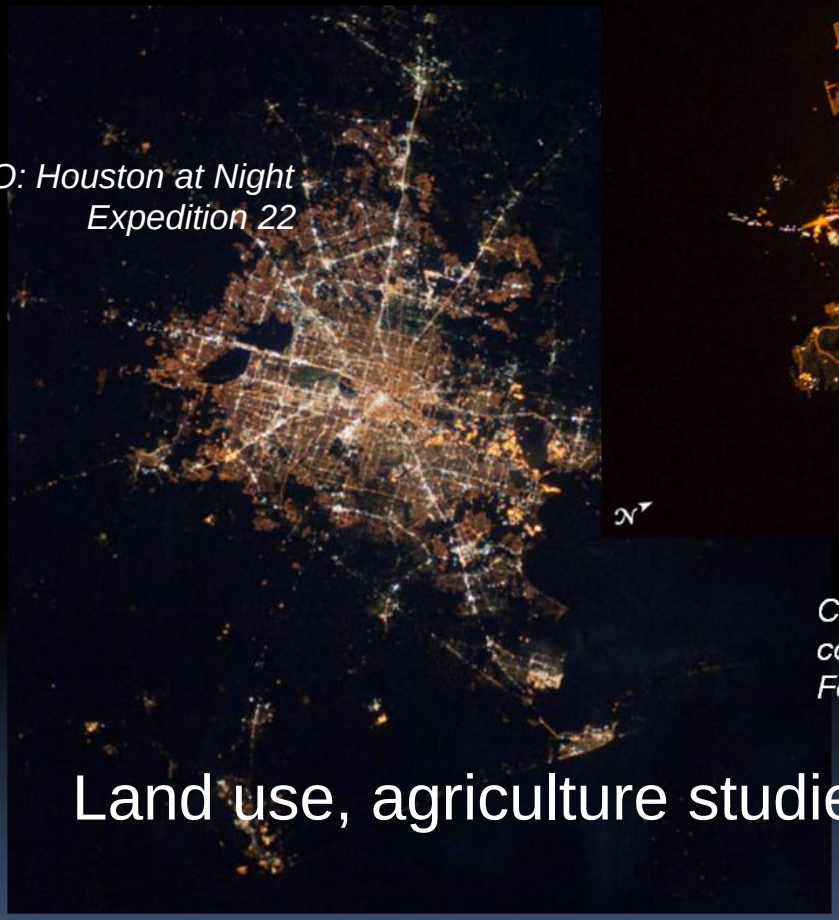
Gulf of Mexico Oil Spill, 4 May 2010, ISS023-E-32397

Crew Earth Observation

Geologic phenomena

Sarychev Peak, Kuril Islands, ISS020-E-9048, 12 June 2009

Crew Earth Observation
(CEO)



CEO: Houston at Night
Expedition 22

CEO: Las Vegas at night. Visible are the Las Vegas Strip, seen in contrast with McCarran Airport. Frenchman Mountain and Nellis Air Force Base are dark against the rectilinear grid of the city.

Land use, agriculture studies and urban growth

Cupola

Bay window in space

80-cm diameter top window

6 side windows

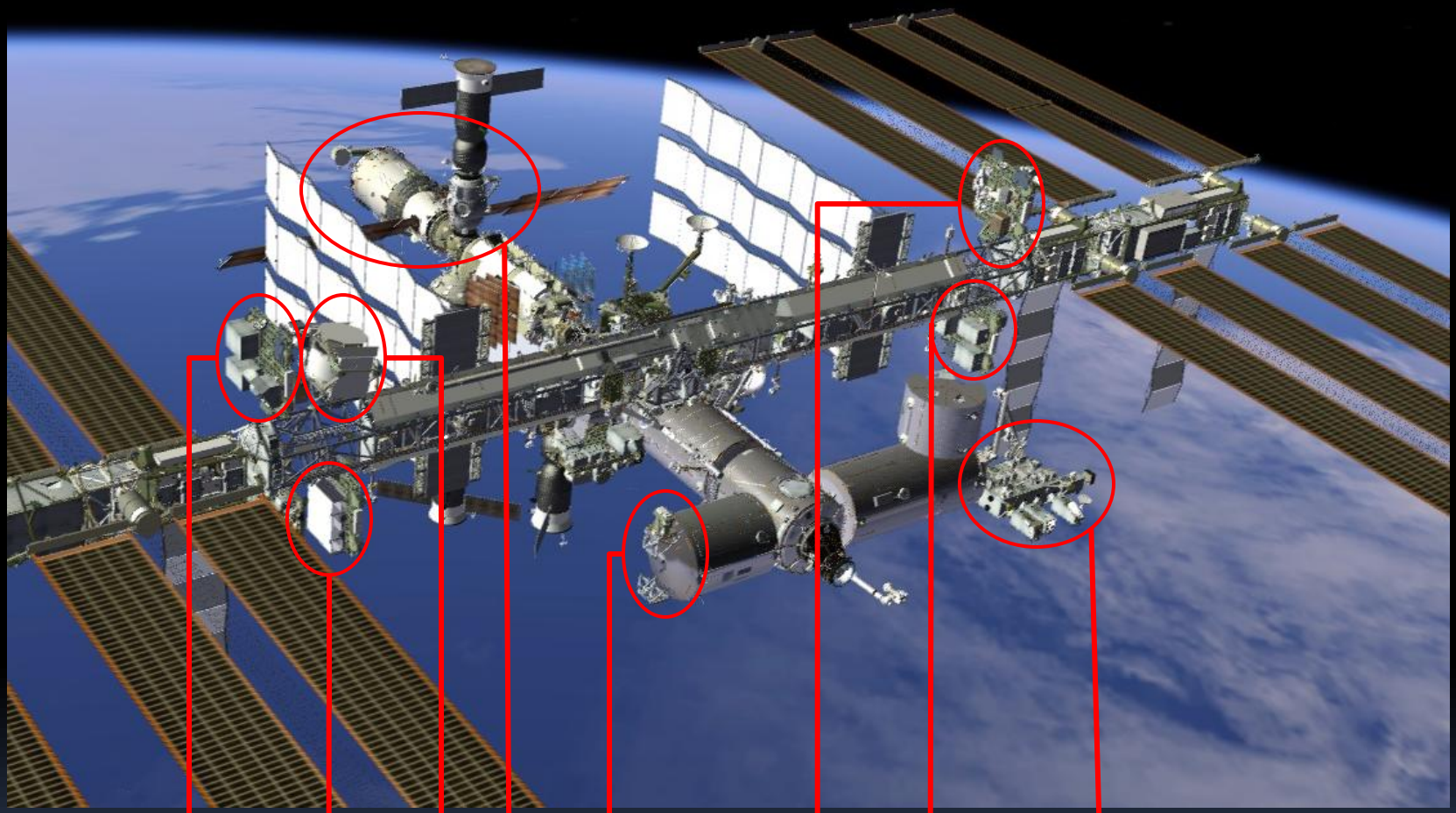
Cupola

Situational Awareness
Inspection
Robotic work station

Cupola

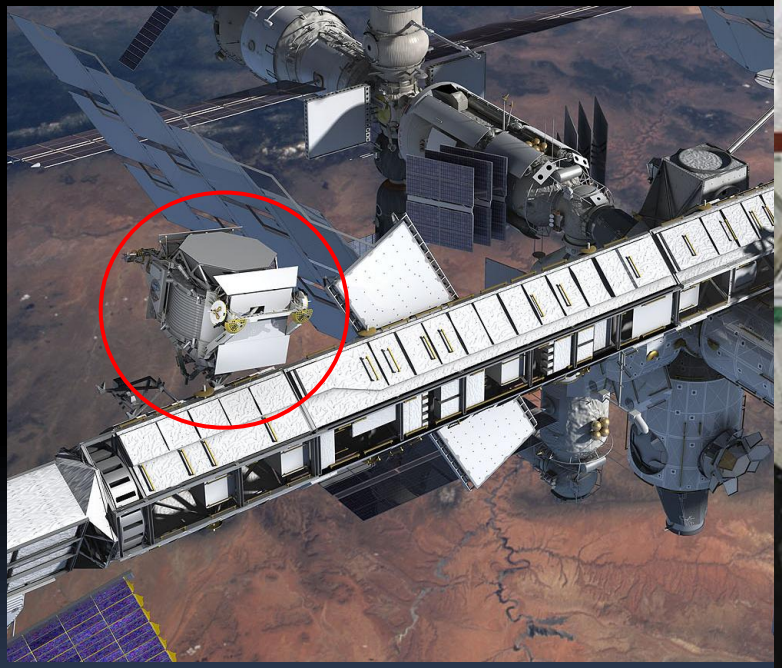
Crew Earth Observation

External Payload Attach Site's



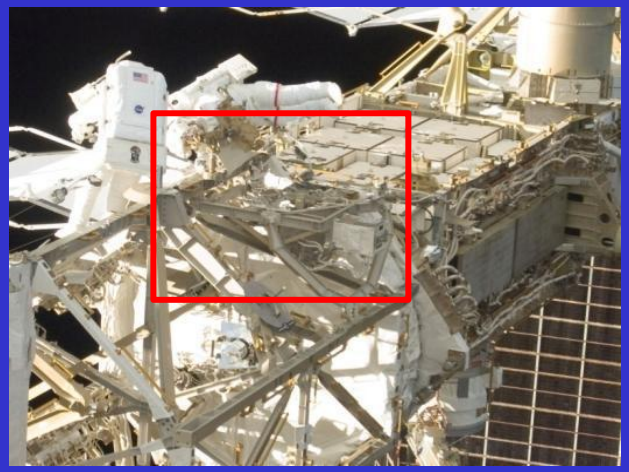
Alpha Magnetic Spectrometer (AMS)

Cosmic Ray detector
Collaboration of DOE and xxx
Truss mounted payload



External Research Accommodations

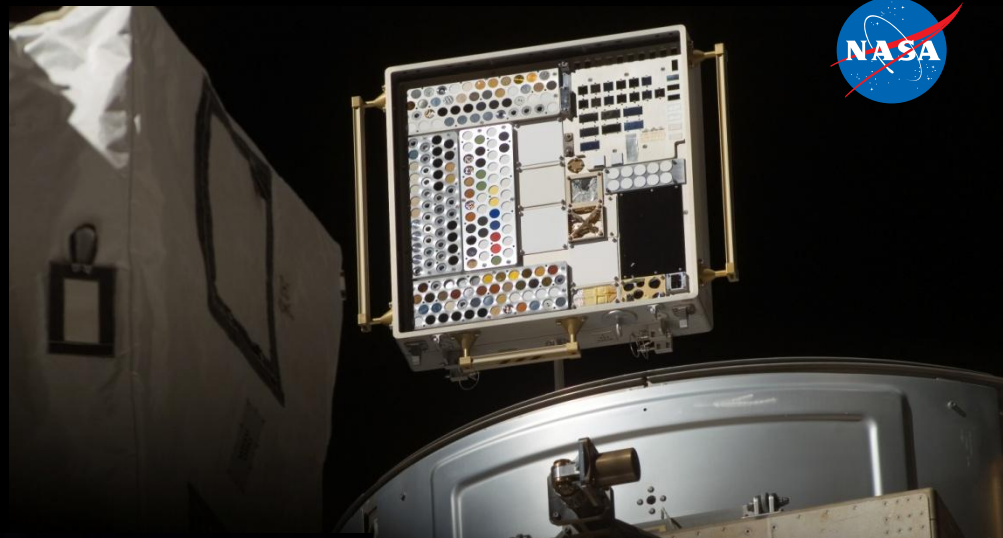
Common Attachment System (CAS) Site

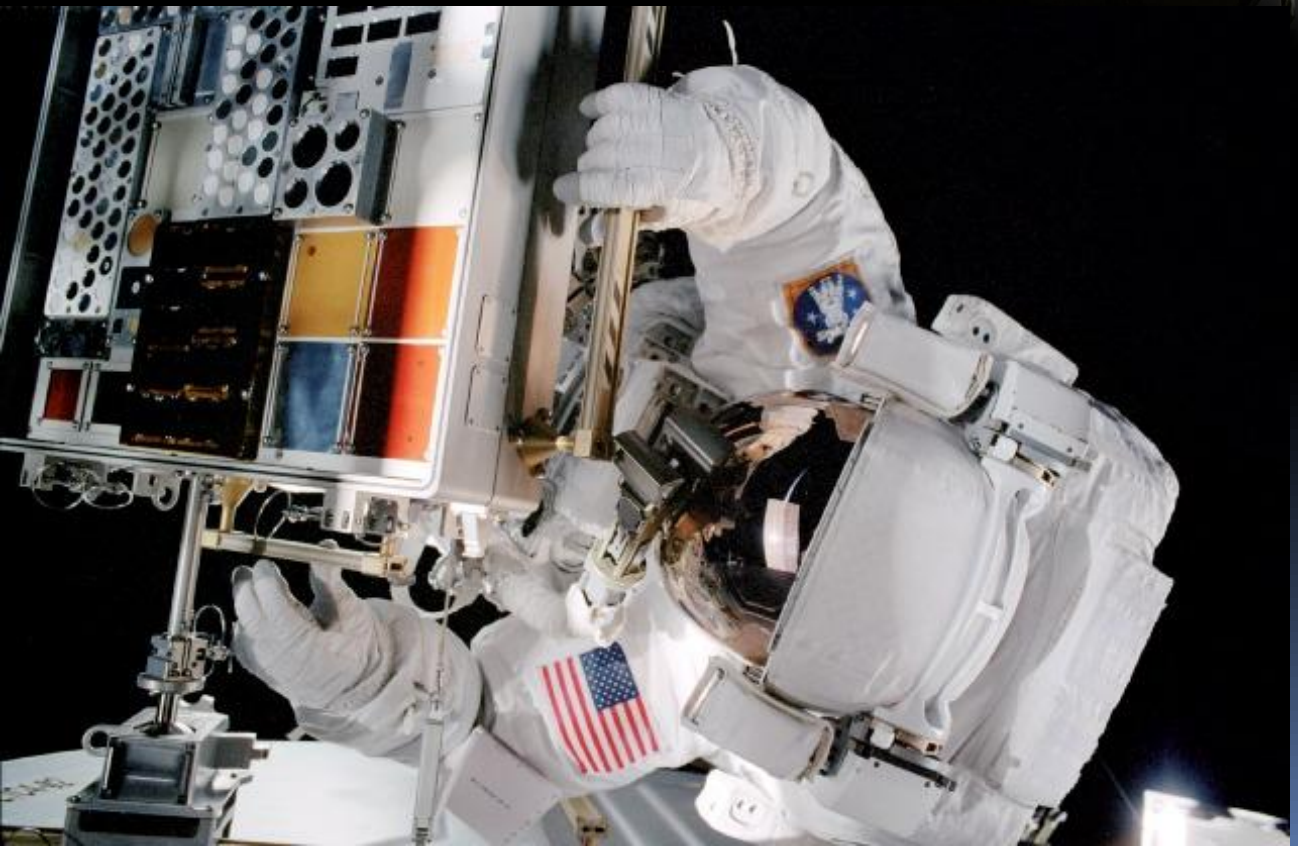


Mass capacity	1360 - 8618 kg (3000 - 19000 lb)
Power	3 kW each on two lines (primary, auxiliary)
Thermal	Passive
Low-rate data	1 Mbps (MIL-STD-1553)
High-rate data	100 Mbps (shared)
Sites available to NASA	6 sites

Materials Research

Materials International Space Station Experiment (MISSE)



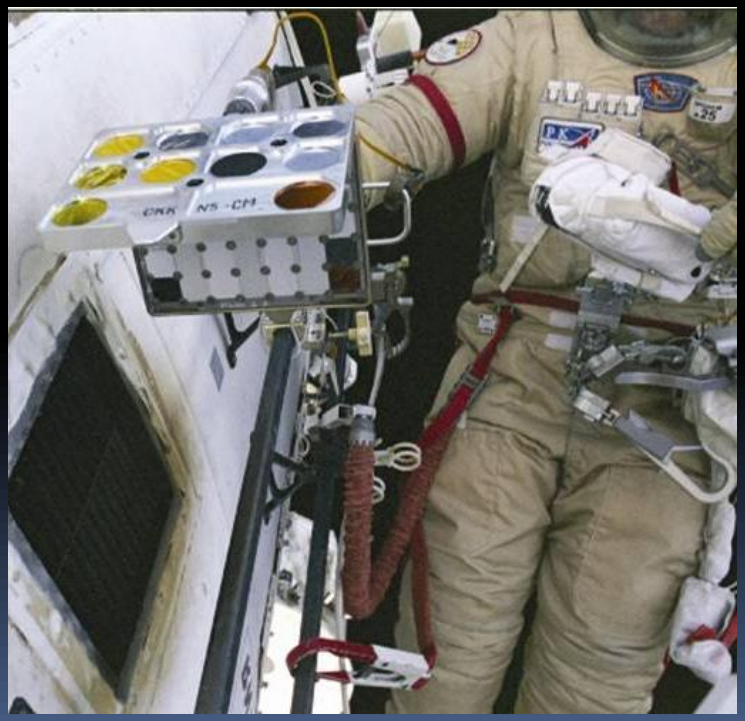


Deployed outside it is a test bed for materials and coatings attached to the outside of the International Space Station being evaluated for the effects of atomic oxygen, ultraviolet, direct sunlight, radiation and extremes of heat and cold outside

Replaceable Cassette-Container

(SKK or CKK)

Mounted on the outside of the ISS to test materials directly exposed to the harsh environment of space



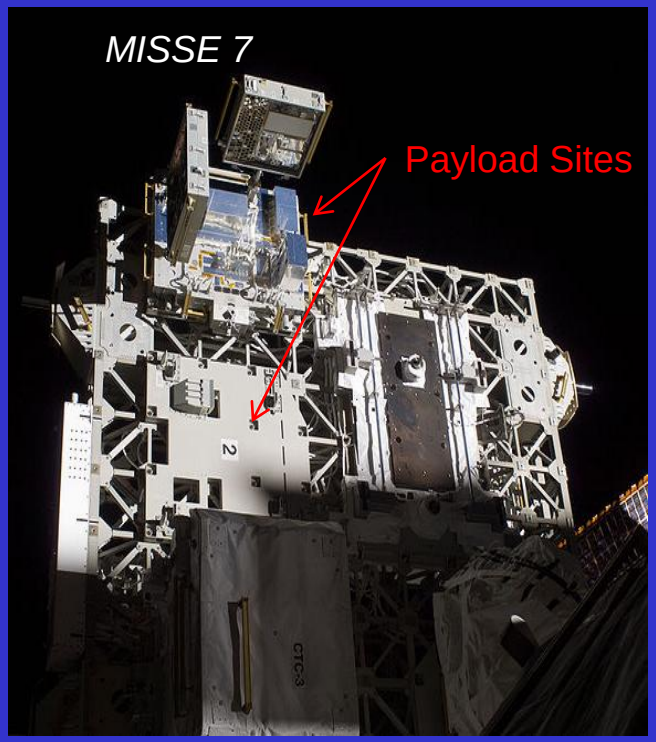
Astro-Biology Research

Exposure Experiment
Expose

Deployed outside of the Zvezda service module it is multi user facility accommodating experiments in photo processing, photo-biology, exobiology and materials research

External Research Accommodations

ExPRESS Logistics Carrier Payload Resources



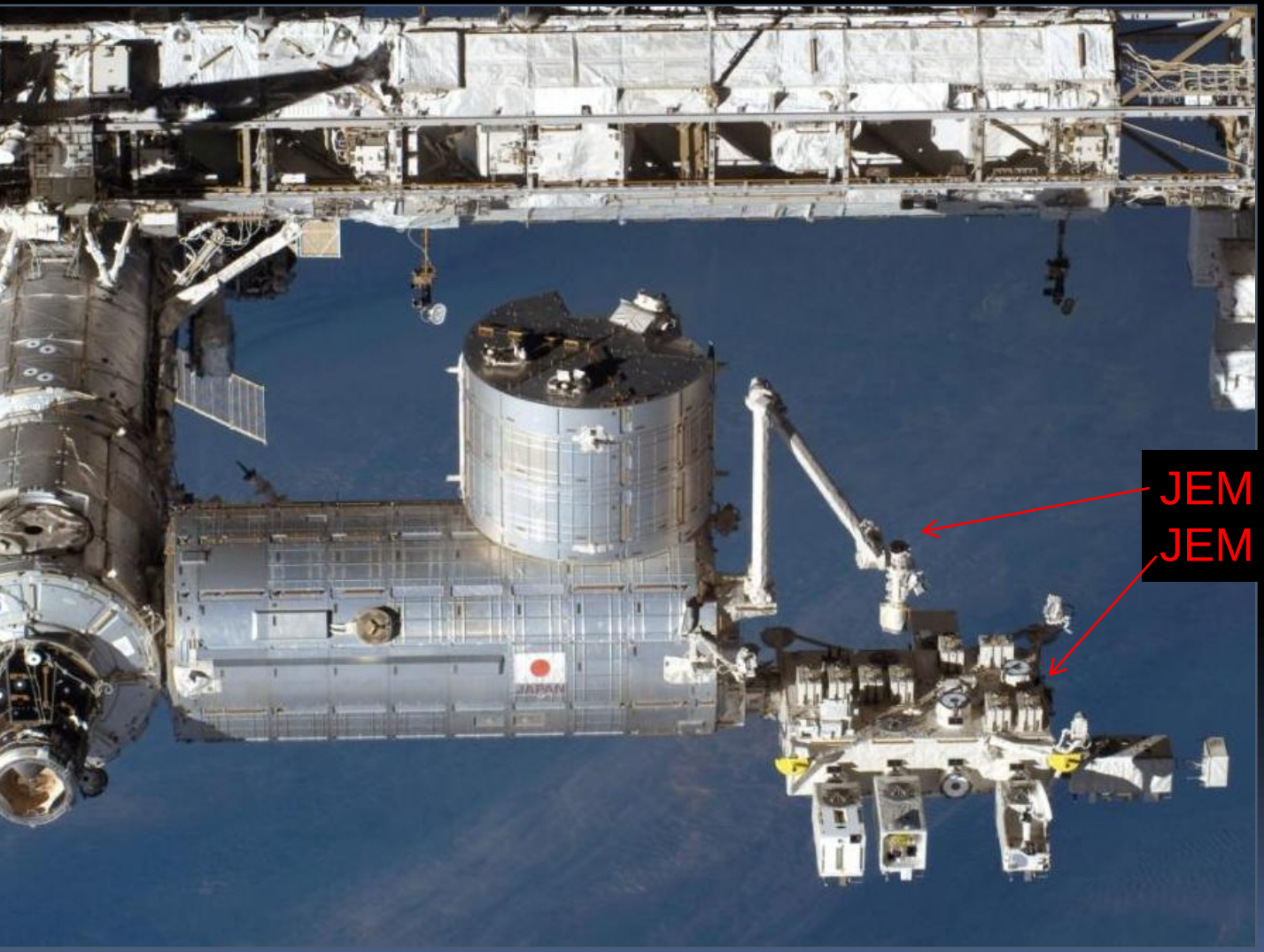
Mass capacity each site	**227 kg (500 lb)**
Volume	**1 m^3**
Power	**750 W, 113 – 126 VDC; 500 W at 28 VDC per adapter**
Thermal	**Active heating, passive cooling**
Low-rate data	**1 Mbps (MIL-STD-1553)**
Medium-rate data	**6 Mbps (shared)**
Sites available per ELC	**2 sites**
Total ELC sites available	**8 sites**

External Research Accommodations

Columbus External Resources

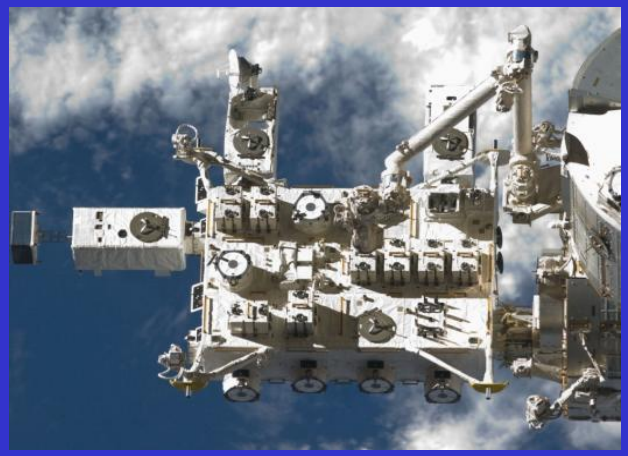
Mass capacity	**230 kg (500 lb)**
Volume	**1 m^3**
Power	**2.5 kW total to carrier (shared)**
Thermal	**Passive**
Low-rate data	**1 Mbps (MIL-STD-1553)**
Medium-rate data	**2 Mbps (shared)**
Sites available	**4 sites**

Japanese Experiment Module - *Kibo*



External Research Accommodations

JEM-EF Resources



Mass capacity	550 kg (1,150 lb) at standard site 2,250 kg (5,550 lb) at large site
Volume	1.5 m^3
Power	3-6 kW, 113 – 126 VDC
Thermal	3-6 kW cooling
Low-rate data	1 Mbps (MIL-STD-1553)
High-rate data	43 Mbps (shared)
Sites available	10 sites

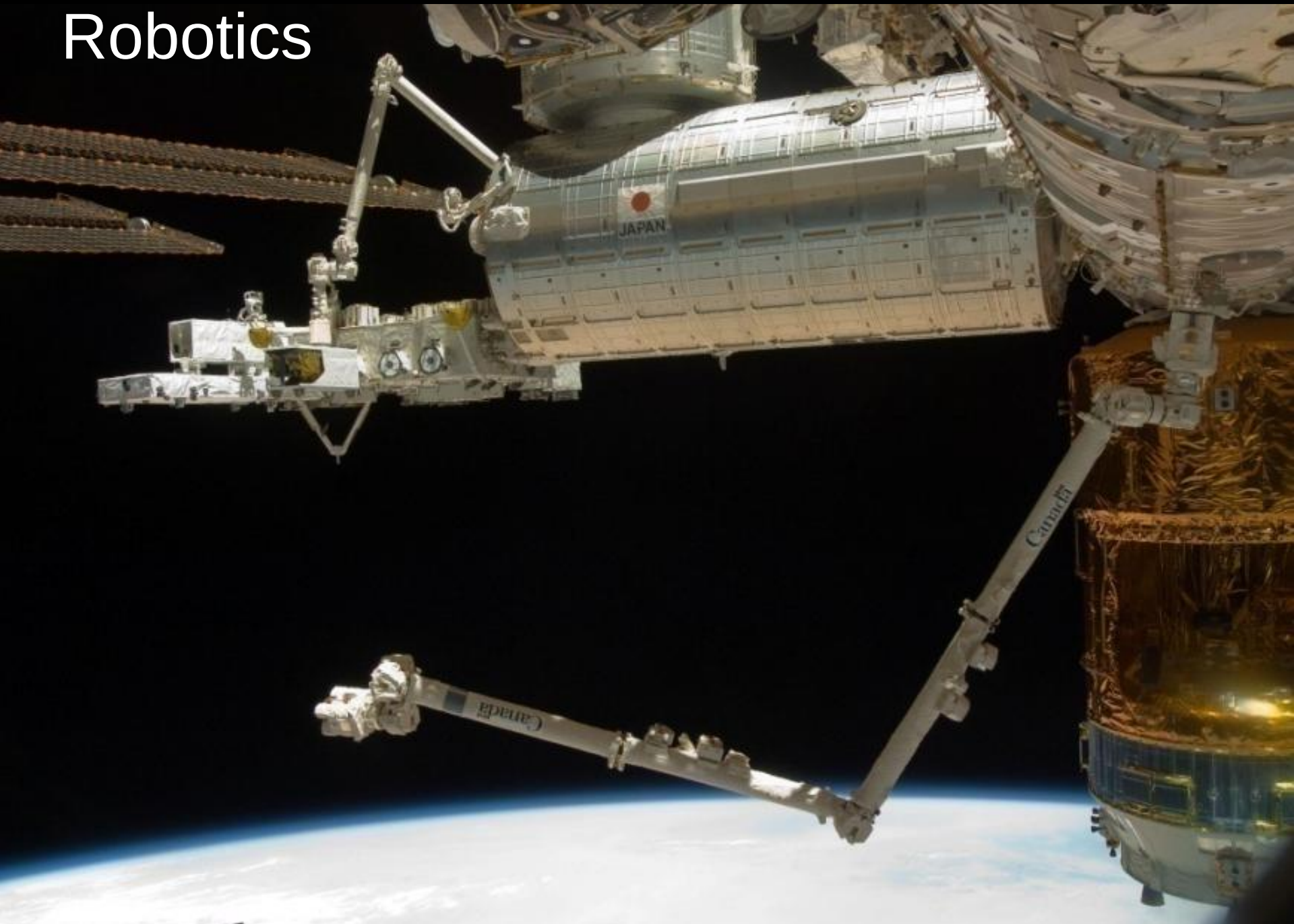
Station to Internal Resources

Power	3, 6, or 12 kW, 114.5 - 126 voltage, direct current (VDC)	
Data	Low Rate	MIL-STD-1553 bus 1 Mbps
	High Rate	100 Mbps
	Ethernet	10 Mbps
	Video	NTSC
Gases	Nitrogen	Flow= 0.1 kg/min minimum; 517-827 kPa, nominal; 1,379 kPa, maximum
	Argon, carbon dioxide, helium	517-768 kPa, nominal; 1,379 kPa, maximum
Cooling Loops	Moderate temperature	16.1 C – 18.3 C
	Flow rate	0 - 45.36 kg/h
	Low temperature	3.3 C – 5.6 C
	Flow rate	233 kg/h
Vacuum	Venting	10^{-3} torr in less than 2 h for single payload of 100 L
	Vacuum resource	10^{-3} torr

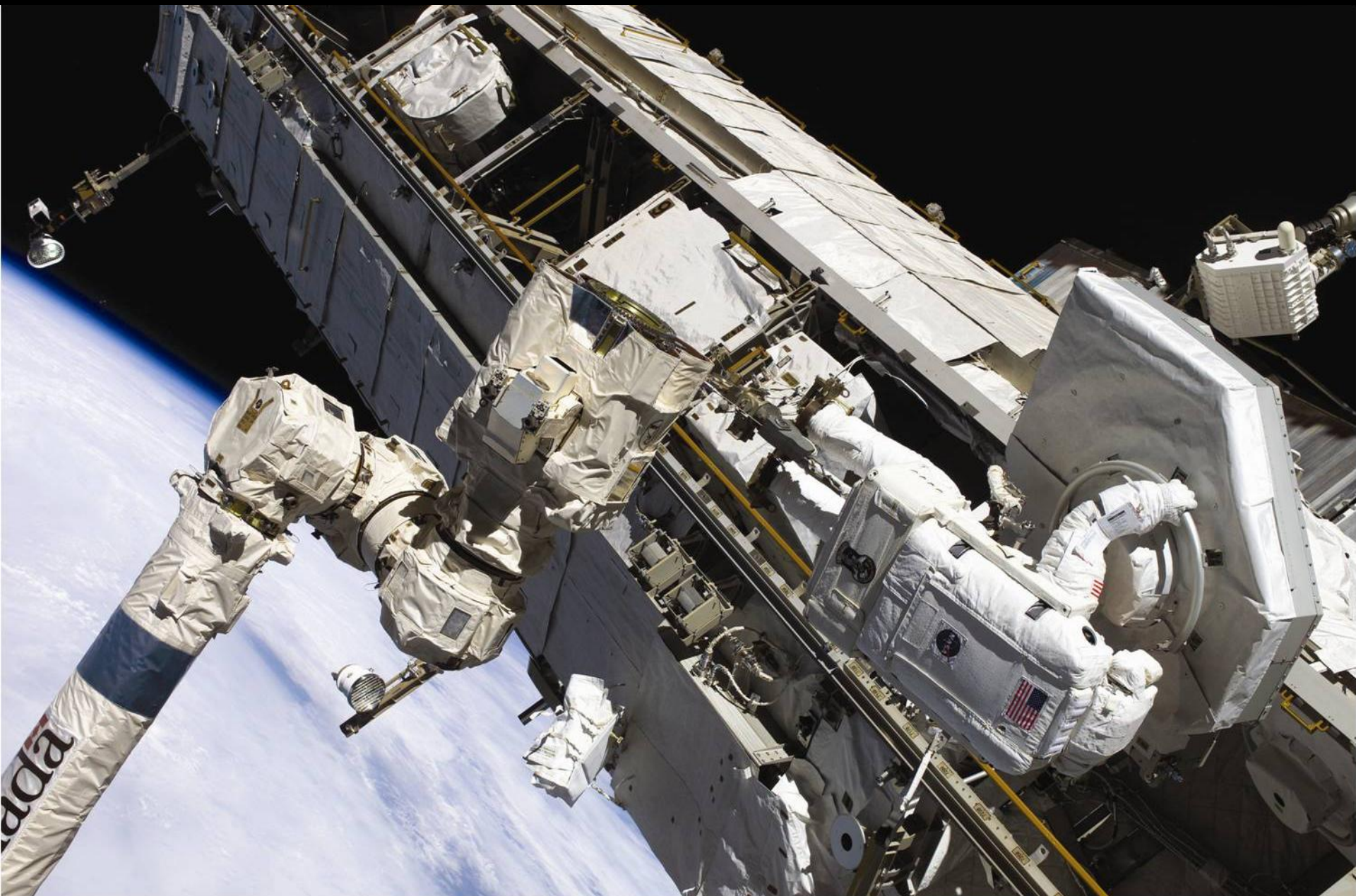
Upgrades In Work

Enhanced Processor and Integrated Communications (EPIC) Project	Phase A will upgrade the three Command and Control (C&C) MDMs and the two Guidance, Navigation, & Control (GN&C) MDMs.
	Phase B will upgrade the two Payload MDMs, and add Ethernet support for the C&C and Payload MDMs.
Air to Ground High Rate Communications System (HRCS) Project	Increase data rates internally and on the RF link 300 Mbps downlink, 7/25 Mbps uplink
	Combine audio and video on orbit
	Provide two way, high quality audio
	Open the door to internet protocol communications
	Open the forward link to multiple users
	Allow for the capability of transmitting & recording HDTV
On Orbit External Wireless High Rate	100 Mbps 2-way Ethernet capability
	1 Mbps 1553 capability
	Up to 4 antennas attached to EVA handrails on US Lab

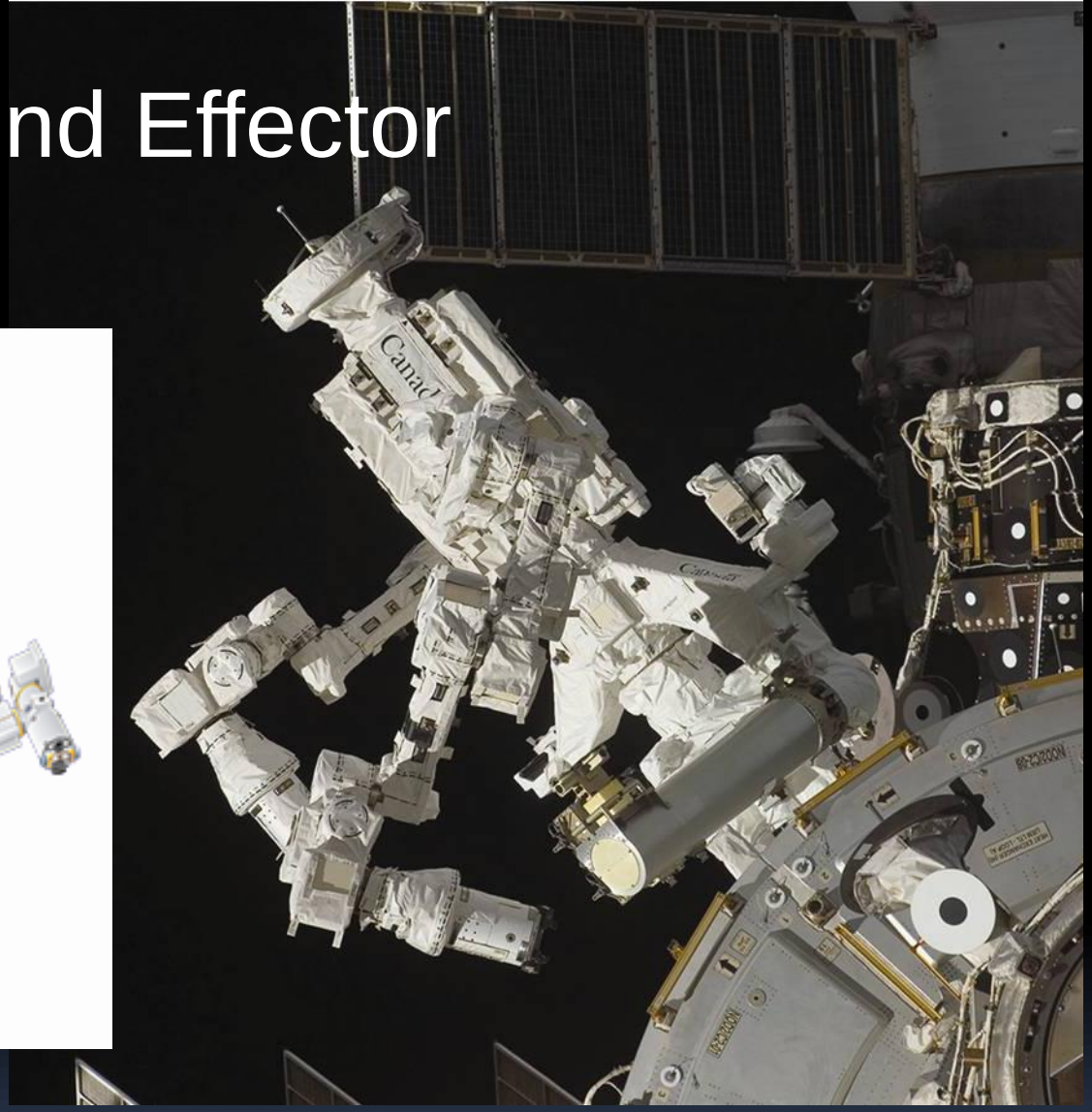
Robotics



Support Assembly and Maintenance

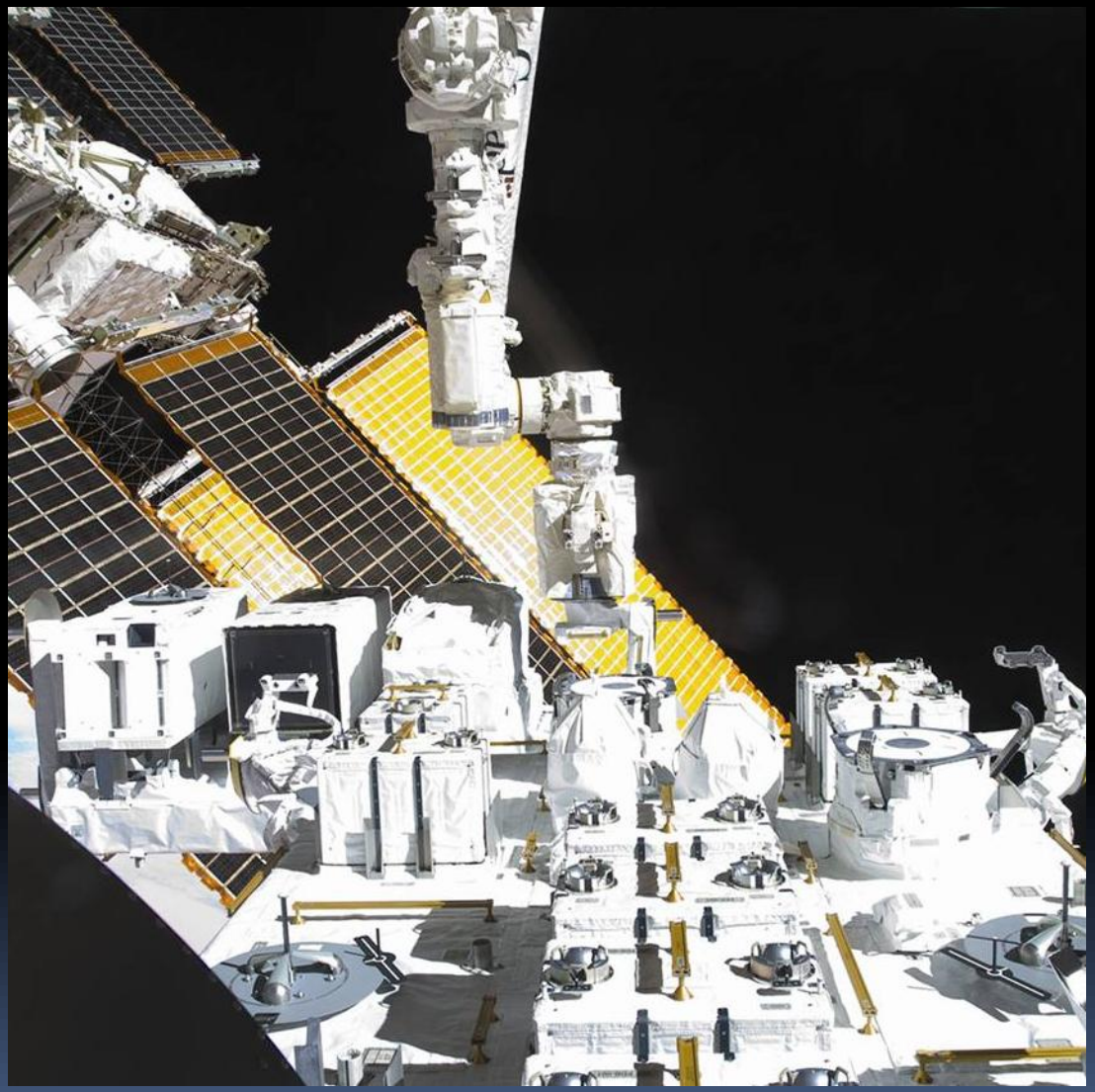


Dexterous End Effector



SSRMS attachment which the ground team or on-orbit crew can use robotically to install, remove and replace payloads and failed components

JEM ARM Payload Support



Communication and Control

ISS Control Centers

CSA-Payloads Telescience Operations Center (PTOC), St. Hubert, Quebec, Canada

Canadian Space Agency Mission Control Center (CSA-MCC), Longueuil, Quebec, Canada

NASA - Payload Operations and Integration Center (POIC), Huntsville, AL

NASA - Mission Control Center (MCC), Houston, TX

ESA ATV - Control Center Toulouse, France

ESA-European User Support Operations Centers:
CADMOS, Toulouse, France
MARS, Naples Italy
MUSC, Cologne, Germany
B-USOC, Brussels, Belgium
E-USOC, Madrid, Spain
N-USOC, Trondheim, Norway
DAMEC, Odense, Denmark
BIOTESC, Zurich, Switzerland
ERASMUS, Noordwijk, The Netherlands

ESA - Columbus Control Center (Col-CC), Oberpfaffenhofen, Germany

HTV Control Center (HTVCC), Tsukuba-shi, Ibaraki, Japan

Japan Experiment Module Mission Control (JEMMC), Tsukuba-shi, Ibaraki, Japan

Roscosmos - Flight Control Center (TsUP), Korolyov, Russia

Roscosmos - Transport Vehicle Control Room, Korolyov, Russia

Near continuous air to ground communication

Payload Operations Integration Center Interfaces

TDRSS

Space Shuttle

ISS

White Sands Complex, New Mexico

Commands, Uplinks, Voice

Vehicle Telemetry, Voice, Video

Payload Ku-band & Vehicle Telemetry

Mission Control Center Houston

Commands, Uplinks

Planning Products, Voice, Ops Mgmt, Other

Payload Ops Control Center Huntsville

US Payload Commands, Uplinks

Payload Ku-band & Ancillary Telemetry

Planning Products, Voice, Ops Mgmt,

Internet

MCCH to International Partner Services

Russia
Europe
Japan
Canada

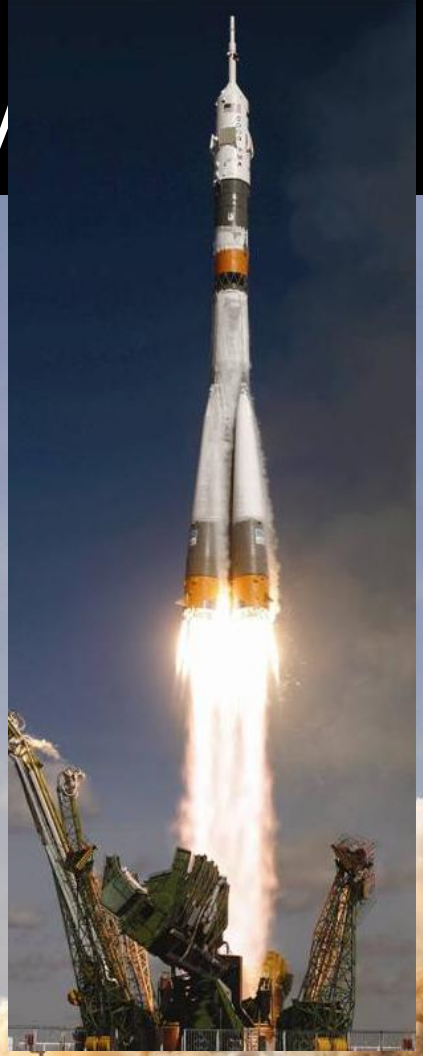
4 International Partner Facilities

GRC
ARC
JSC
MSFC

4 NASA Tele-science Support Centers

+100 Payload TReK User Sites World Wide

Crew and Cargo Capability



Soyuz

Cargo Capacity
3 crew
170 kg ascent

Space Shuttle

Cargo Capacity
5-7 crew
16,000 kg ascent

Cargo Capability

Proton	**Ariane 5**	**HII**	**Falcon 9**	**Taurus II**
Progress	***ATV***	***HTV***	***Dragon***	***Cygnus***

ROSCOSMOS

esa

JAXA

SpaceX

Orbital

An International fleet of space vehicles that delivers propellant, supplies and replenishes science experiments

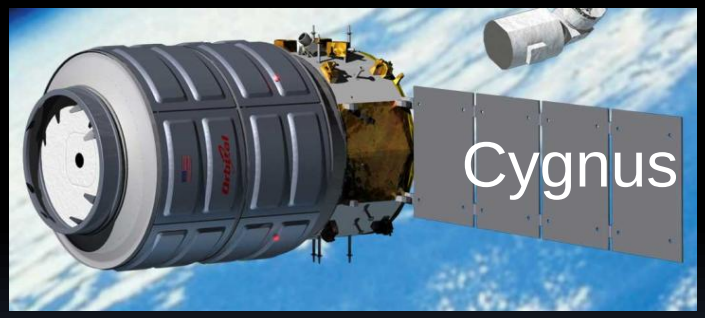
ISS Cargo Vehicles

Progress

Cargo Capacity
2,250 kg

ATV (ESA)

Cargo Capacity
5,500 kg



Cygnus (Orbital)

Cargo Capacity
2,000 kg

Dragon (SpaceX)

Cargo Capacity
3,100 kg ascent

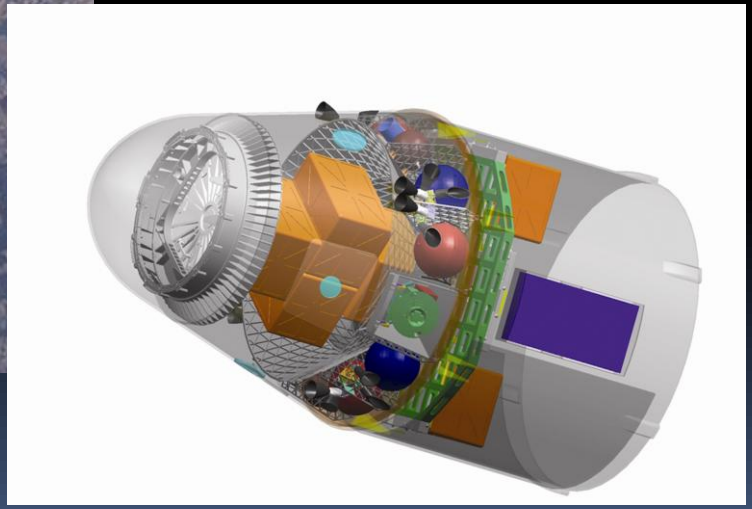
HTV (JAXA)

Cargo Capacity
5,500 kg

Crew and Payload Return Capability

Space Shuttle
5-7 crew
Cargo Capacity
16,000 kg descent

Soyuz
3 crew
Cargo Capacity 50 kg descent



Dragon (SpaceX)
Cargo Capacity
2,500 kg descent

Non-Partner Participation

In 2002, the ISS partnership developed a non-Partner Participation Policy, which governs how non-ISS Partners can participate in the International Space Station

Non-Partners team with one of the 5 ISS Partners (NASA, Roscosmos, the European Space Agency, the Japanese Aerospace Agency, the Canadian Space Agency)

The ISS partnership then reviews the bilateral cooperation for approval

Non-Partners are encouraged to review and contact one of the ISS Partners with their research proposals