An Overview of EXPRESS Rack, Microgravity Science Glovebox, and Sub-rack Facilities for Materials Science Research

Materials LAB Workshop
April 15, 2014

Sean W. Thompson
EXPRESS Rack Project Manager
NASA Marshall Space Flight Center
Sean.thompson@nasa.gov

Lee P. Jordan
MSG Project Manager
NASA Marshall Space Flight Center
Lee.p.jordan@nasa.gov

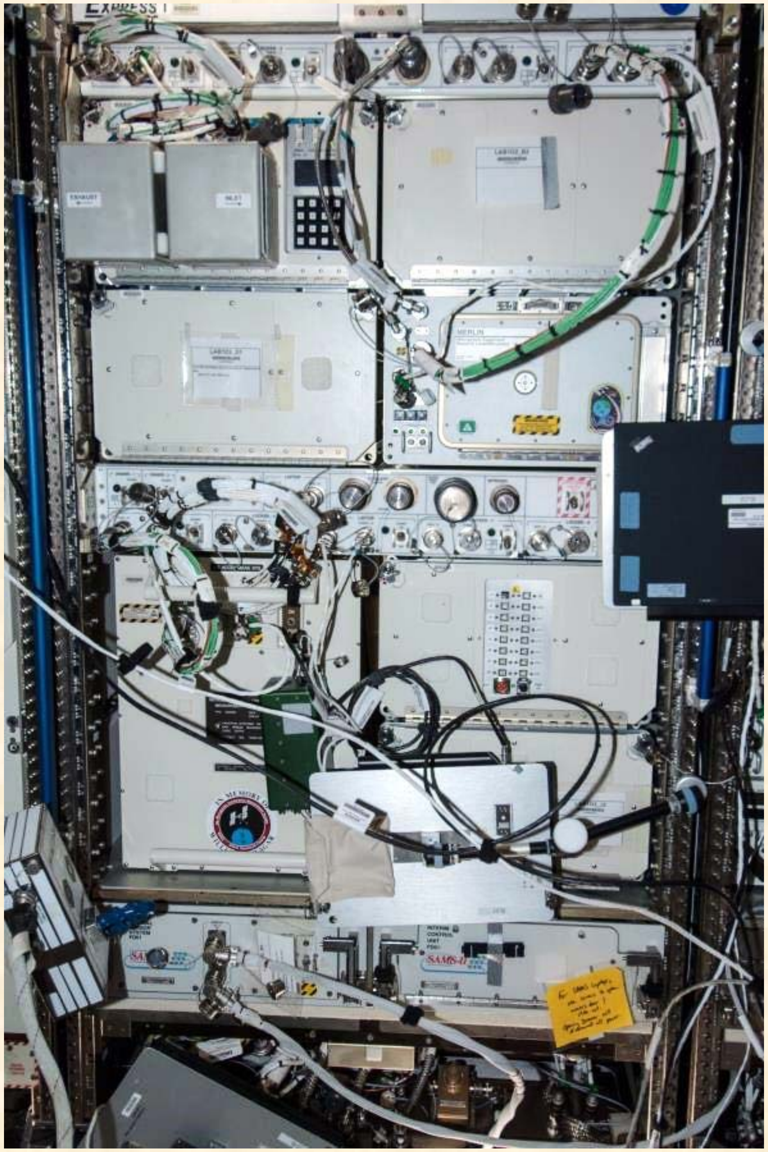
Ginger N. Flores,
MSFC ISS Payloads Office
NASA Marshall Space Flight Center
Ginger.n.flores@nasa.gov

Outline

- Rack Facilities
  - EXPRESS Overview
  - Microgravity Science Glovebox (MSG) Overview
- Sub-rack facilities
  - CSLM, SUBSA, and PFMI Overview

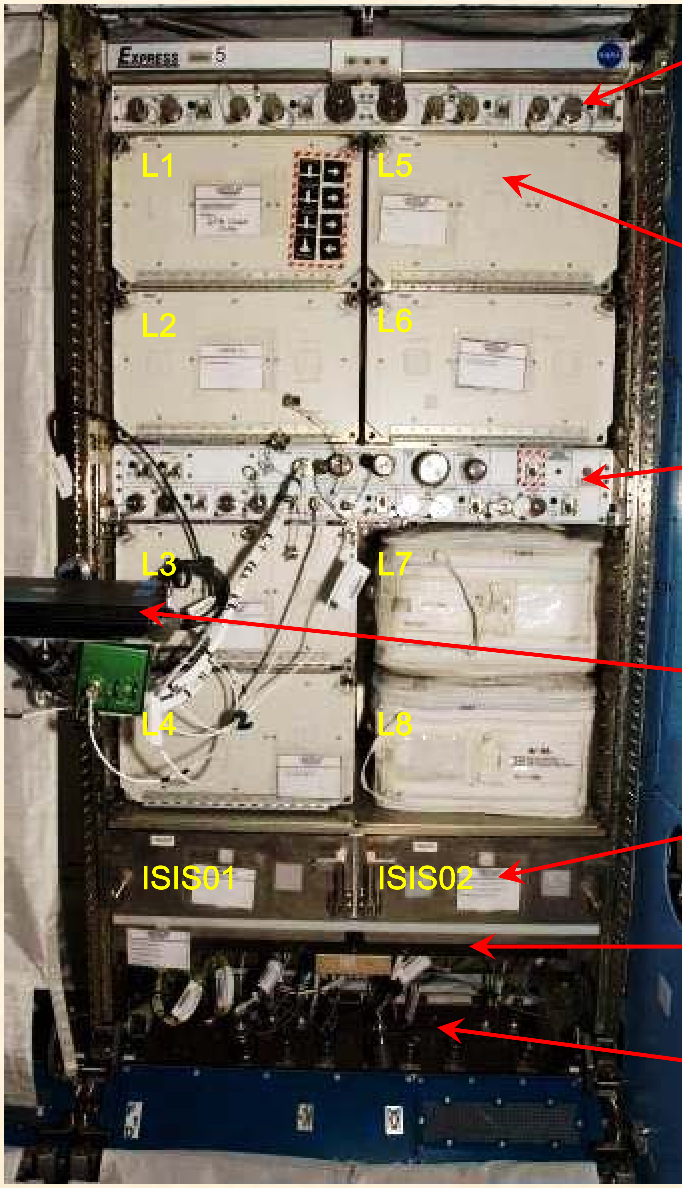
EXPRESS Rack

- **EXpedite the PRocessing of Experiments to Space Station (EXPRESS) Rack** is a multi-use facility which provides standard interfaces and resources for 8 locker-type and 2 drawer-type payloads
- **Payload Interfaces**
  - Power: 28 Vdc
  - Data: Ethernet, RS-422, Analog, Discrete
  - Video: NTSC
  - Cooling: Air (all locations) and Water (2 locations per rack)
  - Vacuum Exhaust (1 location per rack)
  - Nitrogen Supply (1 location per rack)



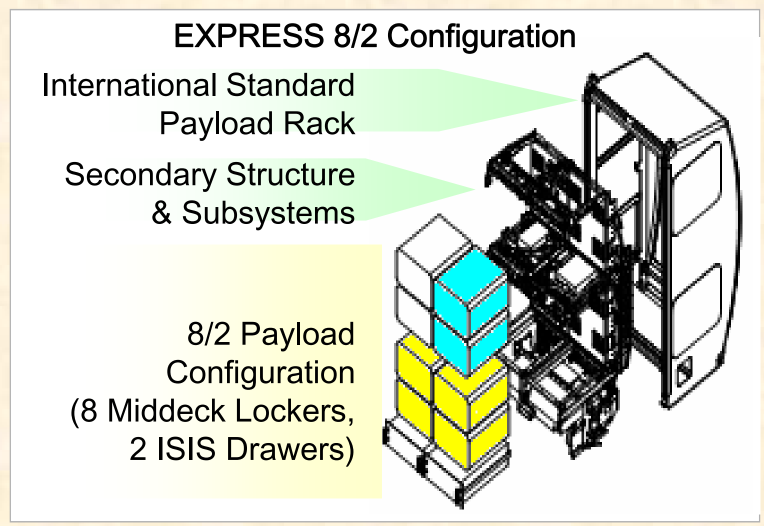
EXPRESS Rack 1, 7/9/13

EXPRESS Rack Front View

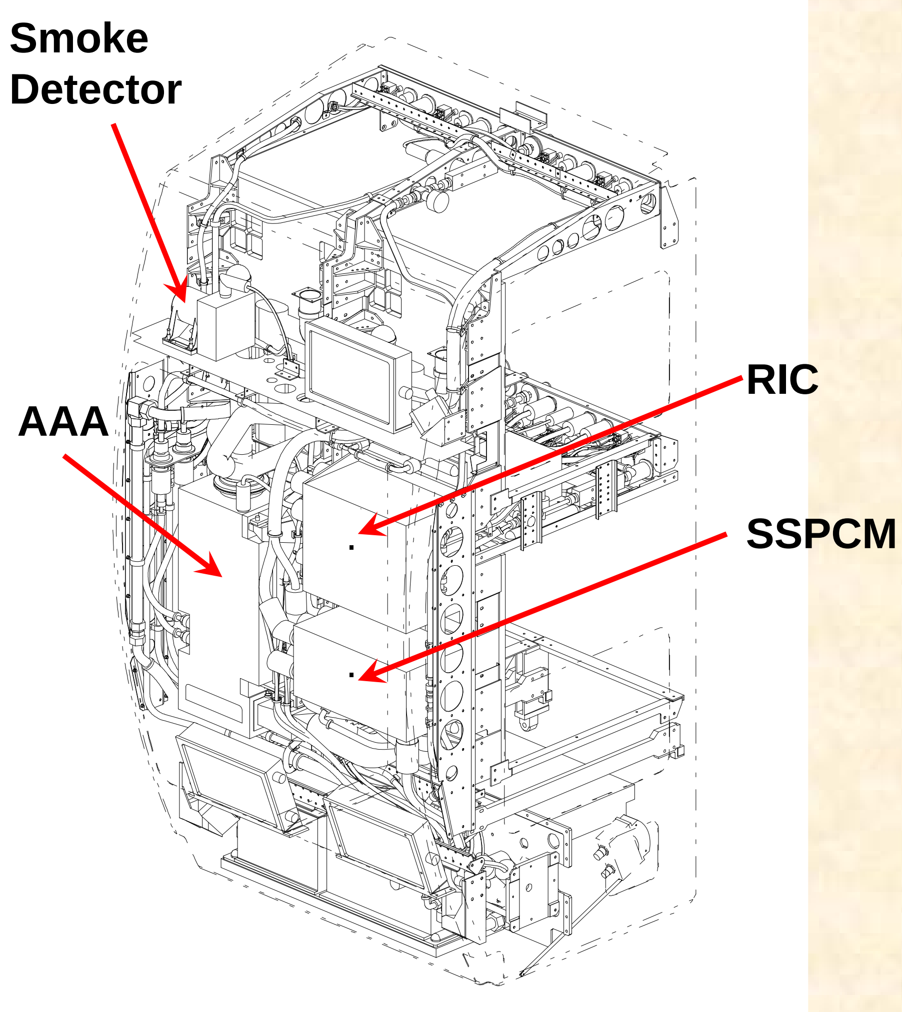


Payload configuration options:

- **Insert into a NASA-provided ISS Locker**
- **Integrate into an International Subrack Interface Standard (ISIS) Drawer**
- **Design single unit to replace 1, 2, or 4 lockers.**



EXPRESS Subsystems



Rear View

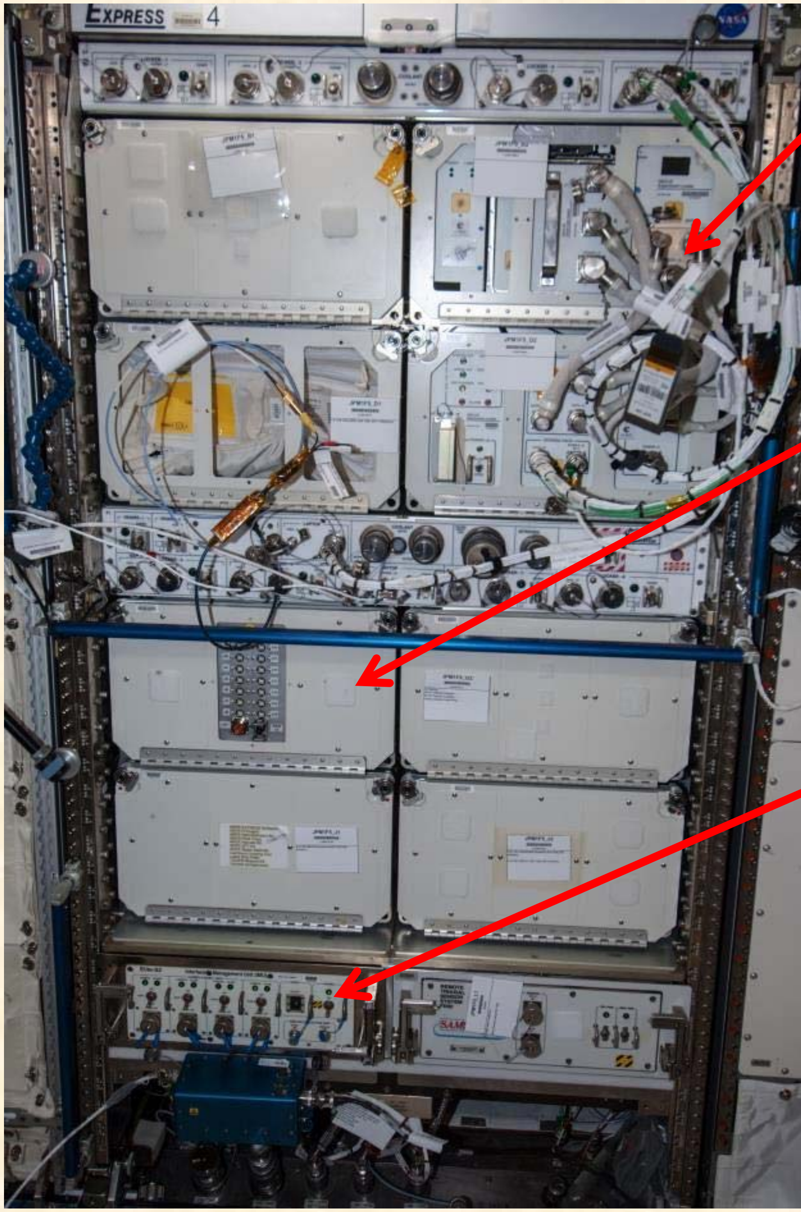
- **RIC: Rack Interface Controller**
  - Provides command and control of rack subsystems and payloads and interfaces with the ISS Payload MDM.
  - Collects health and status from rack subsystems and payloads.
- **SSPCM: Solid State Power Control Module**
  - Receives ISS main power and provides power to rack subsystems and payloads.
  - Provides discrete and analog I/O to payloads and rack subsystems.
- **AAA: Avionics Air Assembly**
  - Provides air cooling to payloads and exchanges heat with the Moderate Temperature Loop.
  - Circulates air for smoke detection

EXPRESS Subsystems

ELC: EXPRESS Laptop Computer

- Dedicated to EXPRESS rack operations
- Crew can view rack displays
- Crew can command rack and payloads
- Payload can have applications installed
- Lenovo T61p
- Windows XP SP2 operating system
    - Upgrade to Windows 7 within 2 years

EXPRESS Rack 4 (Inc 35)



- **DEvice for the study of Critical LIquids and Crystallization (DECLIC)**
  - **Multi-user facility utilized to study transparent media and their phase transitions in microgravity.**
  - **http://www.nasa.gov/mission_pages/station/research/experiments/203.html**
- **NanoRacks Platform 1**
  - **NanoRacks Platforms provide power and data transfer capabilities for NanoRacks Modules, which function as experiment platforms for a wide range of disciplines.**
  - **http://www.nasa.gov/mission_pages/station/research/experiments/829.html**
- **ELaboratore Immagini TElevisive - Space 2 (ELITE-S2)**
  - **Investigates the connection between brain, visualization and motion in the absence of gravity.**
  - **http://www.nasa.gov/mission_pages/station/research/experiments/78.html**

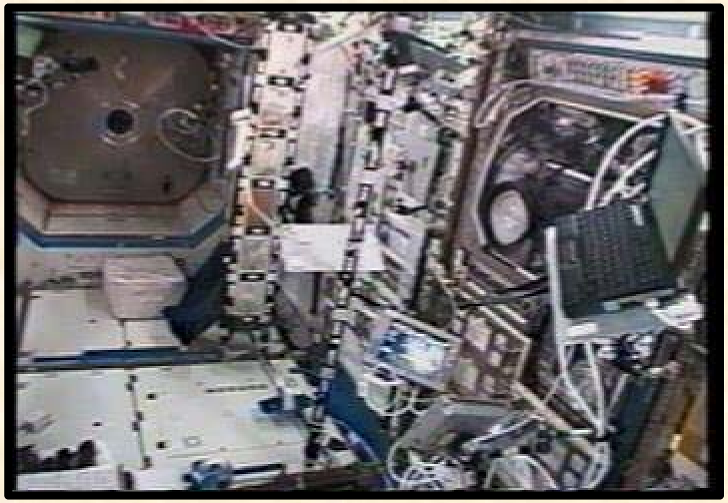
EXPRESS Payload Resources

Resource	Amount per Payload Position	
	Locker	ISIS Drawer
Structural Attachment	Attachment to Rack per IDD •Mass constraint launch vehicle dependent	Attachment to Rack per ISIS Spec •64 lb within cg constraints
Power	5, 10, 15, or 20 Amp at 28 VDC	5, 10, 15, or 20 Amp at 28 VDC
Thermal Control Air	Nominal 150 W (1200 W rack maximum)	Nominal 150 W (1200 W rack maximum)
Thermal Control Water	500 W Heat Rejection per position (2 positions per rack)	500 W Heat Rejection per position (2 positions per rack)
Data	•1 - RS-422 •2 - +/- 5 Vdc Analog •1 - Ethernet •3 - 5 Vdc Discrete (bi-dir)	•1 - RS- 422 •1 - +/- 5 Vdc Analog •1 - Ethernet •2 - 5 Vdc Discrete (bi-dir)
Video	NTSC/RS 170A feed from payload source (Shared)	NTSC/RS 170A feed from payload source (Shared)
Venting	1 payload interface per rack (Shared)	1 payload interface per rack (Shared)
Nitrogen	1 payload interface per rack (Shared, 12 lbm/hr)	1 payload interface per rack (Shared, 12 lbm/hr)

Reference: EXPRESS Rack Payloads Interface Definition Document, SSP 52000-IDD-ERP

Microgravity Science Glovebox (MSG)

- The Microgravity Science Glovebox (MSG) is a double rack facility designed for microgravity investigation handling aboard the International Space Station (ISS).
- The unique design of the facility allows it to accommodate science and technology investigations in a "workbench" type environment



- MSG facility provides an enclosed working area for investigation manipulation and observation in the ISS. Provides two levels of containment via physical barrier, negative pressure, and air filtration .
- The MSG facility is ideally suited to provide quick, relatively inexpensive access to space for Physical Science, Life Science, and Biological Science Investigations.

MSG Facility Hardware Overview

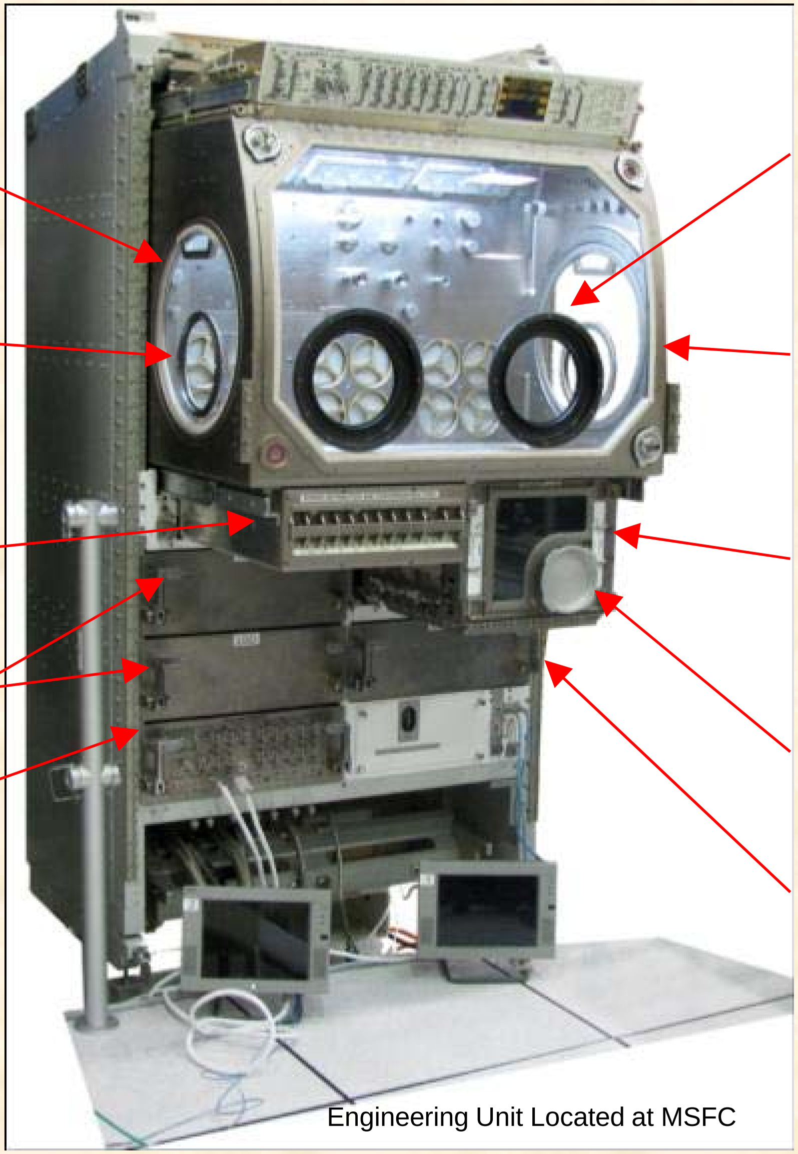
Removable Side Ports
16” diameter on both Left and Right sides for setting up hardware in Work Volume

Glove Ports
Four identical glove ports are located on the left and right side loading ports and the front window

DC Power Switching And Circuit Breakers

Stowage Drawers

Video System Drawer



Engineering Unit Located at MSFC

Front Window Glove Ports
Four 6” diameter glove ports can be fitted with any of three different sized gloves or blanks

Core Facility
Retractable Core Facility includes the Work Volume, Airlock, Power Distribution & Switching Box, and the Command and Monitoring Panel

Airlock
Provides a “Pass Through” for hardware to enter the Work Volume without breaking Containment. The lid of the Air Lock opens up into the floor of the Work Volume

Airlock Glove Port with Blank
A Single 4” diameter glove port can also be fitted with any of three different sized gloves or a blank

Stowage Drawers

Current MSG-Provided Payload Interfaces/Resources

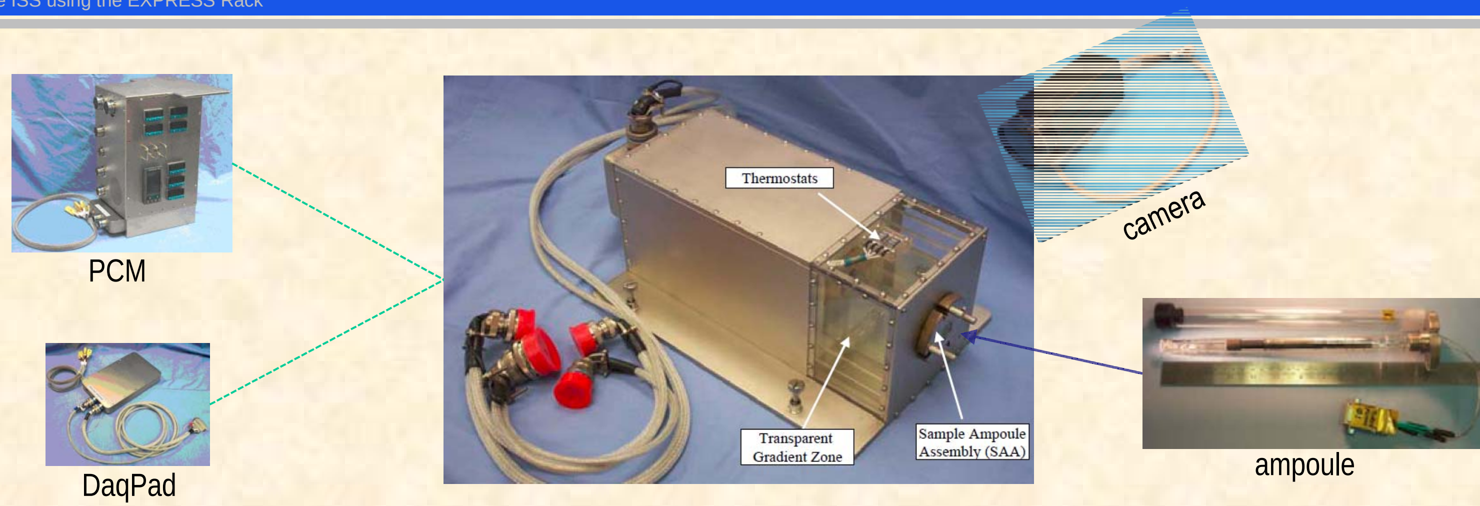
- Work Volume(WV) - Volume
  - 0.255 m^3 = 255 liters
- Work Volume - Dimensions
  - 906mm wide x 637mm high
  - 500mm deep (at the floor)
  - 385mm deep (at the top)
- Maximum size of single piece of equipment in WV (via side access ports)
  - 406mm diameter
- Payload Attachment
  - M6 threaded fasteners in floor, ceiling, & sides
- Power available to investigation
  - +28V DC at useable 7 amps
  - +12V DC at useable 2 amps
  - -12V DC at useable 2 amps
  - +5V DC at useable 4 amps
  - +120V DC at useable 8.3 amps
- Maximum heat dissipation
  - 1000W Total
    - 800W from coldplate
    - 200W from air flow
- General illumination
  - 1000 lux @ 200mm above WV floor
- Video
  - 4 color Hitachi HV-C20 cameras
  - 2 Sony DSRV10 Digital Recorders
  - 2 Sony GV-A500 Analog 8mm Recorders
- Data handling connections
  - Two RS422-to-MSG for investigations
  - One MIL-BUS-1553B-to-MSG for communication via MLC
  - Ethernet LAN 1 and LAN 2 (in US LAB)
  - MSG Laptop Computer (MLC) – IBM T61P
- Filtration
  - 12 HEPA/charcoal/catalyst WV filters
- 1 HEPA/charcoal/catalyst Airlock filter
- Up to Two Levels of Containment
  - Physical barrier of MSG structures, gloves, etc.
  - Negative pressure generated by MSG fans.
- Other resources available
  - Gaseous Nitrogen
  - Vacuum (VRS & VES)

MSG Investigations

Payload Name & Acronym	Sponsoring Organization	Type of Investigation
Combustion Synthesis under Microgravity Conditions (COSMIC)	ESA	Combustion
Microgravity Experiment for the Measurement of Diffusion Coefficients in Crude Oil (DCCO)	ESA	Diffusion
NANOSLAB	ESA	Zeolite Crystal Growth
Protein Microscope for the International Space Station (PromISS-1,2,3, & 4)	ESA	Protein Crystal Growth
ARGES	ESA	Light Bulb Technology
HEAT	ESA	Heat Pipe Technology
Selectable Optical Diagnostics Instrument (SODI)	ESA	Diffusion and Soret Phenomena
Cell Wall/Resist Wall (CWRW)	JAXA	Plant Growth
Coarsening in Solid Liquid Mixtures-2 (CSLM-2)	NASA	Material Science
Investigating the Structure of Paramagnetic Aggregates from Colloidal Emulsions (InSPACE-1,2, &	NASA	Magnetorheological (MR) Fluids
IntraVenous Fluids GENeration and mixing (IV-Gen)	NASA	Human Health
Smoke Aerosol Measurement Experiment (SAME)	NASA	Spacecraft Smoke Detection
Shear History Extensional Rheology Experiment (SHERE)	NASA	Polymer
Smoke Point Coflow Experiment (SPICE)	NASA	Combustion
Critical Velocities in Open Capillary Channels (CCF)	NASA	Fluids
Structure and Liftoff in Combustion Experiment (SLICE)	NASA	Combustion
Burning and Suppression of Solids (BASS)	NASA	Combustion
Boiling eXperiment Facility (BXF)	NASA	Heat Transfer
Pore Formation and Mobility Investigation (PFMI)	NASA	Material Science
Solidification Using a Baffle in Sealed Ampoules (SUBSA)	NASA	Material Science
Rodent Research	NASA	Life Science
3D Printer	NASA	Technology Demonstration
Bioculture Systems	NASA	Life Science
Observation and Analysis of Smectic Islands in Space (OASIS)	NASA	Material Science
Zero Boil-Off Tank (Z-BOT)	NASA	Heat Transfer
Packed Bed Reactor Experiment (PBRD)	NASA	Physical Science
Transparent Alloys	ESA	Material Science

12

Solidification Using a Baffle in Sealed Ampoules



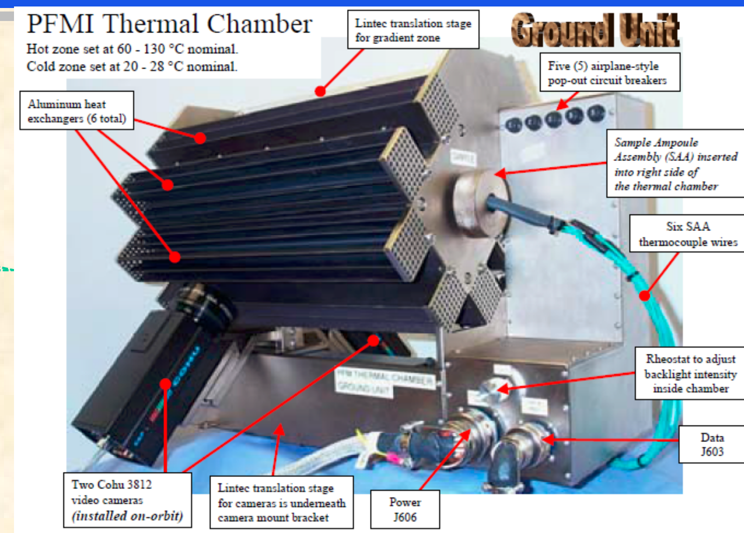
Solidification Using a Baffle in Sealed Ampoules (SUBSA):

- One of the first materials science experiments on the International Space Station (Expedition Five); the first to operate within MSG.
- The SUBSA furnace offers control and visualization of melting and solidification of samples using a transparent furnace, video downlink, and real-time commanding.
- Furnace - Max Temp: 850C; sample size: 30 cm long (12 mm dia); also offers an 8 cm long transparent gradient zone coupled with a Cohu 3812 camera and a quartz ampoule allows for observation and video recording of the solidification process.
- Uses a gradient freeze process (minimum cool down rate of 0.5 C/min, and a stability of +/- 0.15° C)
- SUBSA includes a Process Control Module (PCM) which controls sample processing, and a Data Acquisition Pad (DaqPad) which provides signal conditioning of thermocouple data.
- The SUBSA furnace has processed eight indium antimonide (InSb) samples in the MSG

Pore Formation and Mobility Investigation (PFMI)


PCM

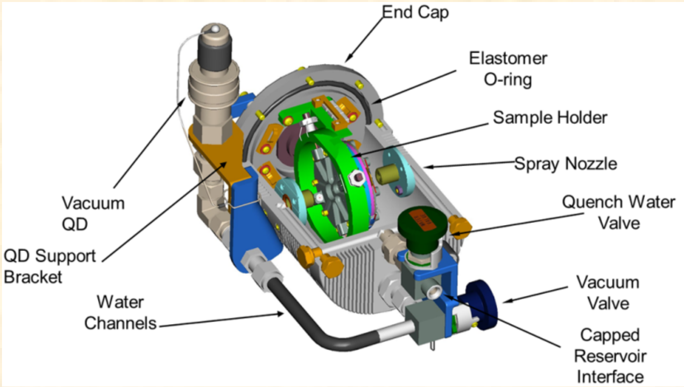

DaqPad

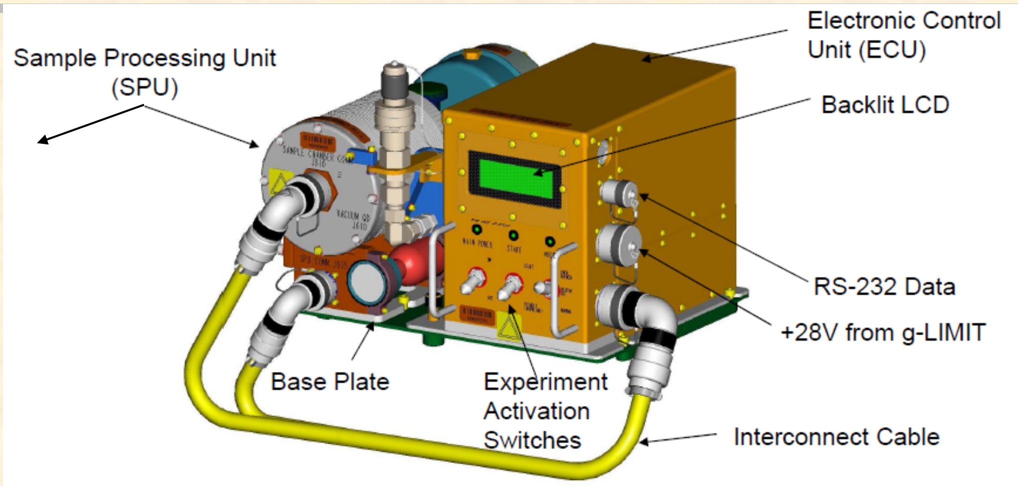


Pore Formation and Mobility Investigation (PFMI):

- *The first observation of sustained dendritic growth in a microgravity environment.*
- PFMI shares control module, data acquisition, and cameras with SUBSA.
- PFMI is a Bridgman type furnace, with a maximum temperature of 130° C and can accommodate a sample 23 cm long and 10 mm in diameter. Two Cohu 3812 cameras mounted 90° apart move on a separate translation system that allows for viewing of the sample in the transparent hot zone and gradient zone independent of the furnace translation rate and direction. Translation rates for both the cameras and furnace can be specified from 0.5 micrometers/sec to 100 micrometers/sec with a stability of +/-5%.
- Designed to study bubbles that can become trapped in metal alloys used to produce jet engine turbine blades and semiconductor crystals for electronic devices.
- Scientists on the ground can watch via video downlink as bubbles form, move and interact in the samples before they cool down and re-solidify.
- Commands from the ground change temperatures, growth rate, and other variables that affect processing. Most importantly bubble size, numbers, and movement can be measured.

Coarsening in Solid Liquid Mixtures (CSLM)





Coarsening in Solid Liquid Mixtures (CSLM):

Objectives: 1) Produce coarsening data, and 2) Investigate the factors controlling the morphology of solid-liquid mixtures during coarsening. Has operated on shuttle & ISS.

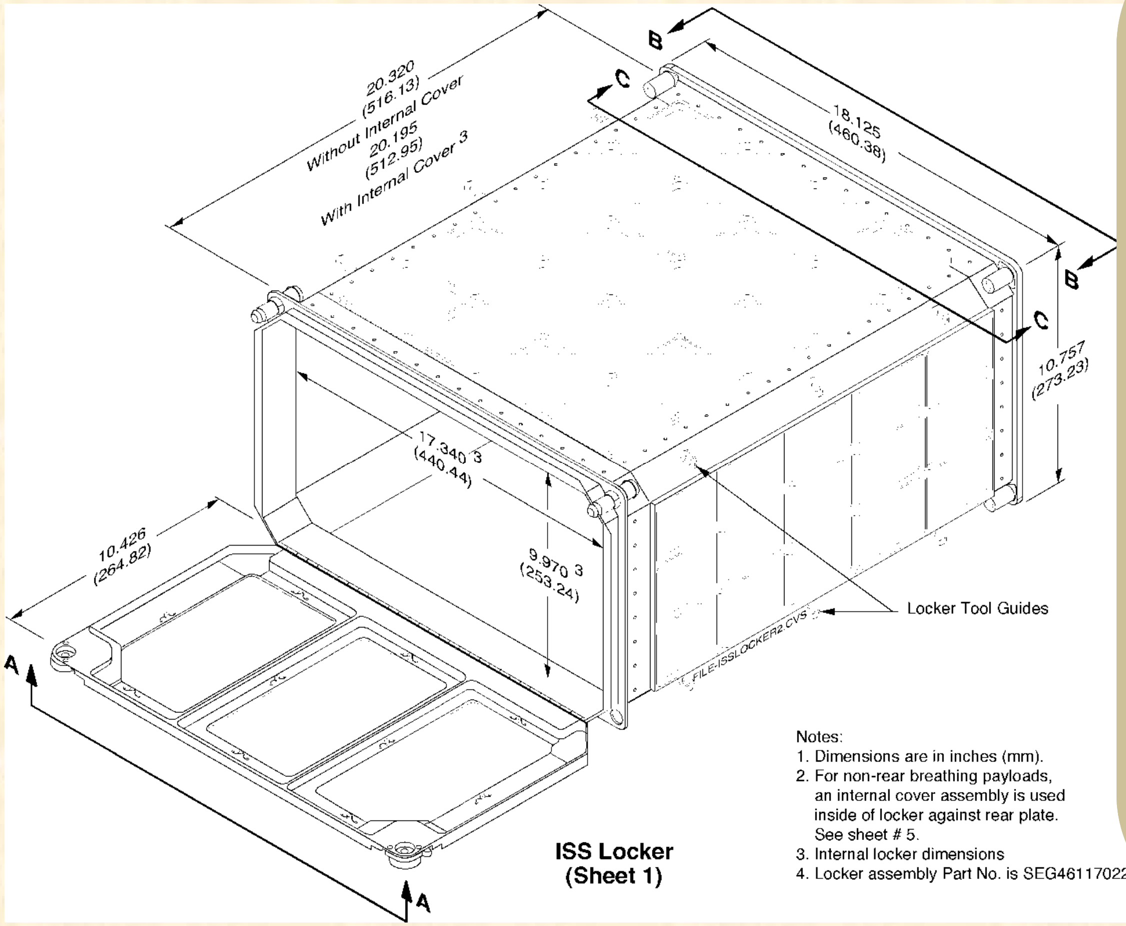
- Vacuum System - To achieve the required level of isothermality, a vacuum level of 0.2 Torr is required. The vacuum is achieved by attaching the Vacuum Exhaust System (VES) to the Sample Processing Unit (SPU.
- Heating System - Two disc resistance heaters and one ring resistance heater are utilized to evenly heat the samples to the desired 185° C. Four RTDs are installed in the Sample Holder to accurately measure the temp of the samples.
- Quench System - When water quench is required, the solenoid valve opens allowing air to pressurize the water in the reservoir. The reservoir burst disc opens and allows water flow through the spray nozzles and onto the Sample Holder clamping plates.
- ECU houses both the Power Distribution System and the Data Acquisition and Control System (STD-80 Bus Based).
- One Sample Processing Unit (SPU) contains 4 samples.
- One ECU can store data from as many as twelve SPUs.

Summary

- These facilities on board ISS have been used for a large body of research in material science, heat transfer, crystal growth, life science, smoke detection and combustion research, plant growth, human health, and technology demonstration
- Process improvements and enhancements continue to improve the accommodations and make the integration and operations process more efficient.
- MSG and EXPRESS are ideal platforms for gravity-dependent phenomena related research. Moreover, ISS provides engineers and scientists a platform for research in an environment similar to the one that spacecraft and crew members will actually experience during space travel and exploration.
- The successful on-orbit operations and versatility of the EXPRESS Racks and MSG has facilitated the operations of many scientific areas, with the promise of continued payload support for years to come.

BACK UP

EXPRESS ISS Locker Details



Features

- 4 rear captive fastener attachments
- Installation tool guides on 4 corners
- Friction hinge
- Dual door locks
- 3 removable panels on door
- Rear internal closeout removed for active payloads
- Internal dimensions (ref)
  - Width 17.340 in.
  - Height 9.970 in.
  - Depth 20.320 in.
- Weight – 13 lbs. empty
- Internal Volume – 2 ft^3

Payloads can either be locker "inserts" or locker "replacements"

EXPRESS Powered Drawer

Features

- Blind-mate connectors
- Locking handles
- Internal dimensions (ref)
    - 15.94 x 5.88 x 23.23 in.
- Weight – 26 lbs empty
- Volume – 1.26 ft^3

NASA provides a powered drawer for ground integration of powered payloads