



# Conducting Research on the International Space Station using the **EXPRESS Rack** Facilities

**29<sup>th</sup> American Society for  
Gravitational and Space Research and  
5<sup>th</sup> International Symposium of  
Physical Sciences in Space  
November, 2013**

*Sean W. Thompson  
EXPRESS Rack Project Manager  
NASA Marshall Space Flight Center  
[sean.thompson@nasa.gov](mailto:sean.thompson@nasa.gov)*

*Robert E. Lake  
EXPRESS Rack Lead Systems Engineer  
NASA Marshall Space Flight Center  
[robert.e.lake@nasa.gov](mailto:robert.e.lake@nasa.gov)*



# EXPRESS Rack



Conducting Research on the ISS using the EXPRESS Rack

- **EXpedite the PProcessing 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)
- **Active Rack Isolation System (ARIS)**
  - Isolates vibration between ISS and EXPRESS



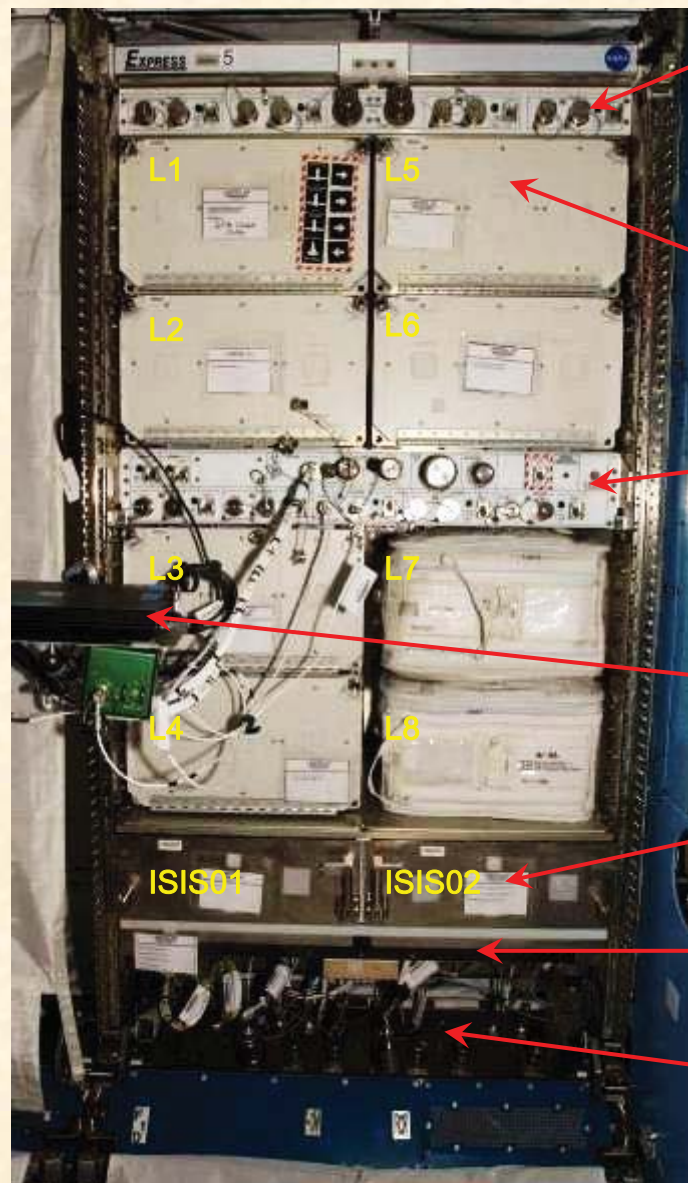
EXPRESS Rack 1, 7/9/13



# EXPRESS Rack Front View



Conducting Research on the ISS using the EXPRESS Rack



Upper Connector Panel

Lockers (8 locations)

Lower Connector Panel

EXPRESS Laptop Computer (ELC)

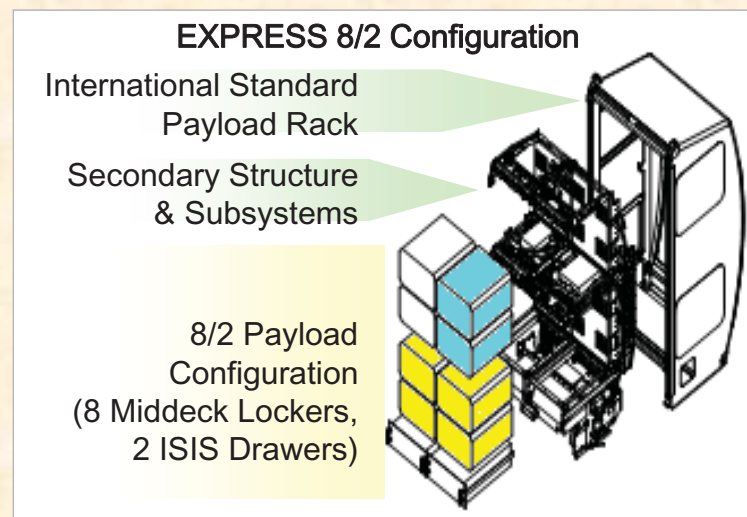
ISIS Drawers (2)

Utility Drawer

Utility Interface Panel

## 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 Racks



Conducting Research on the ISS using the EXPRESS Rack

- 8 flight racks on-orbit (4 ARIS, 4 non-ARIS)
- First launched April 19, 2001
- Trainer Racks at JSC and MSFC to support crew and ground training
- Functional Checkout Unit (FCU) at MSFC to support payload testing

Rack	Location (Lab, Bay)	Launch (Flight, Date)	Sep. 2013 Operating Hrs	Total Operating Hours
EXPRESS Rack #1	US Lab, O2	6A, 4/19/01	720	91,133
EXPRESS Rack #2A	US Lab, O1	6A, 4/19/01	720	59,294
EXPRESS Rack #3A	Columbus, P2	UF2, 6/5/02	717	24,458
EXPRESS Rack #4	JEM, F5	7A.1, 8/10/01	720	86,015
EXPRESS Rack #5	JEM, F1	7A.1, 8/10/01	0	844
EXPRESS Rack #6	US Lab, O4	ULF2, 11/14/08	720	42,659
EXPRESS Rack #7A	US Lab, P2	19A, 4/5/10	0	3,645
EXPRESS Rack #8A	US Lab, P4	ULF5, 2/24/11	720	4,604

**Total: 312,652**

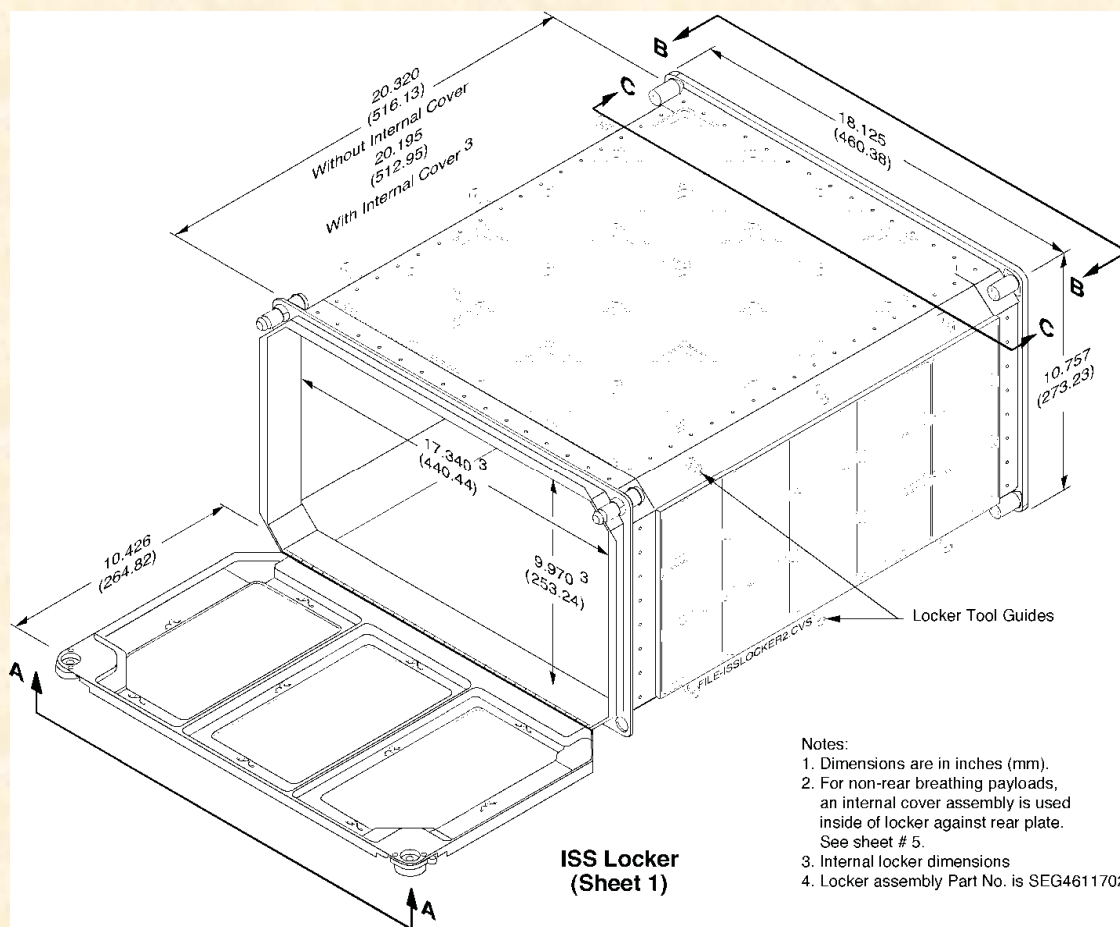
*Operational Hours through 9/30/2013*



# EXPRESS ISS Locker Details



Conducting Research on the ISS using the EXPRESS Rack



## 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<sup>3</sup>

Payloads can either be locker “inserts” or locker “replacements”



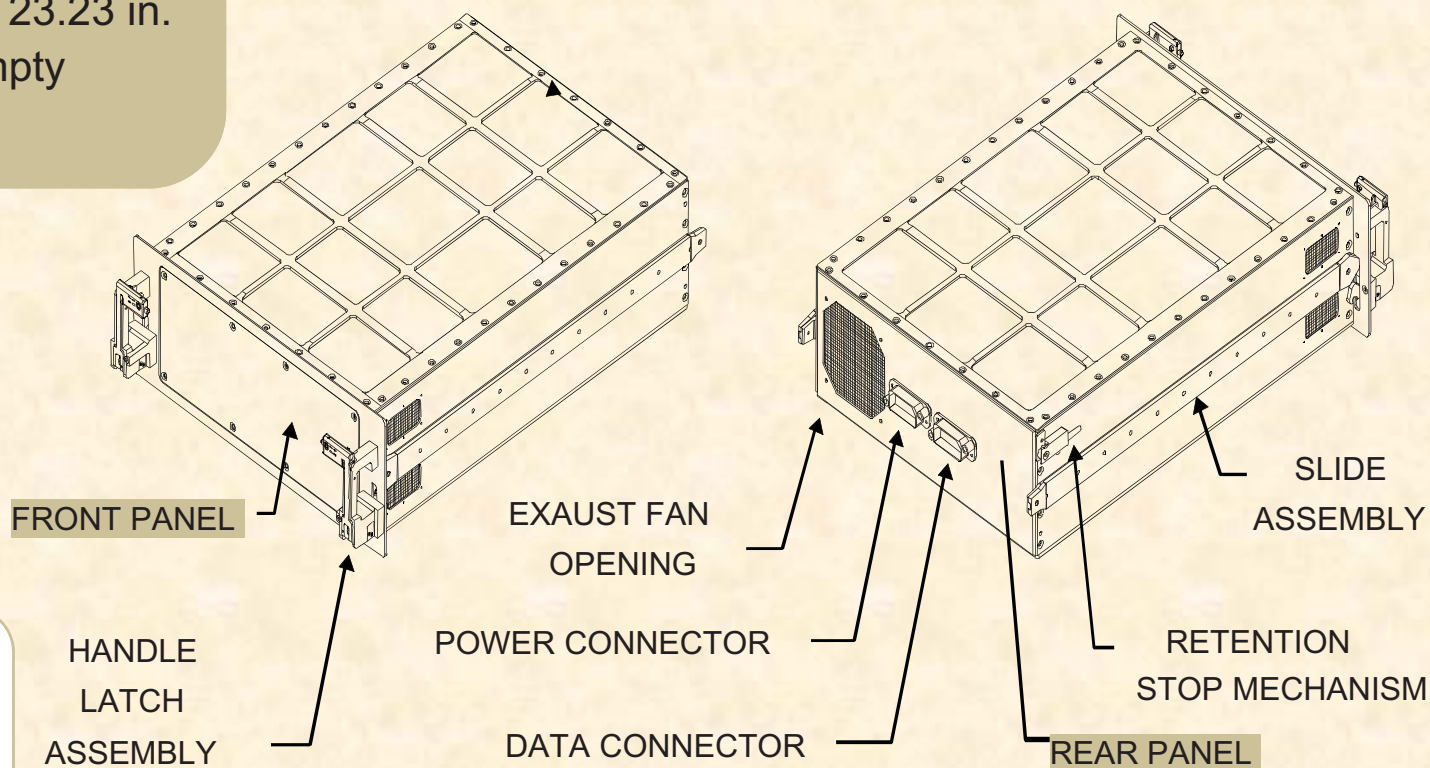
# EXPRESS Powered ISIS Drawer



Conducting Research on the ISS using the EXPRESS Rack

## 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<sup>3</sup>



NASA provides a powered ISIS drawer for ground integration of powered payloads



# EXPRESS Subrack Payload Mounting



Conducting Research on the ISS using the EXPRESS Rack

- Mounting for 8 single ISS lockers (or equivalent) and 2 ISIS drawers
- Subsystem equipment located behind connector panels or mounting plates

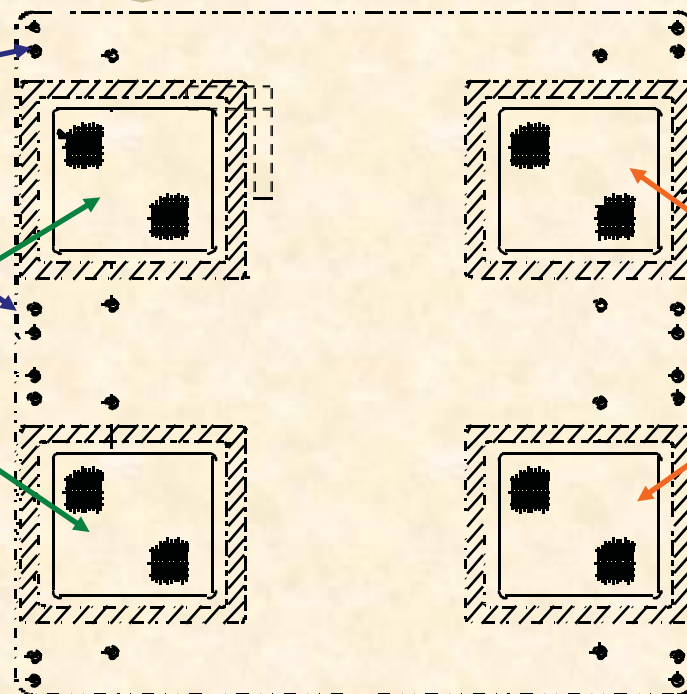


Front View

LOCKER  
PAYLOAD  
MOUNTING  
HOLES

AIR INLET  
(To Payloads)

AIR OUTLET  
(From Payloads)



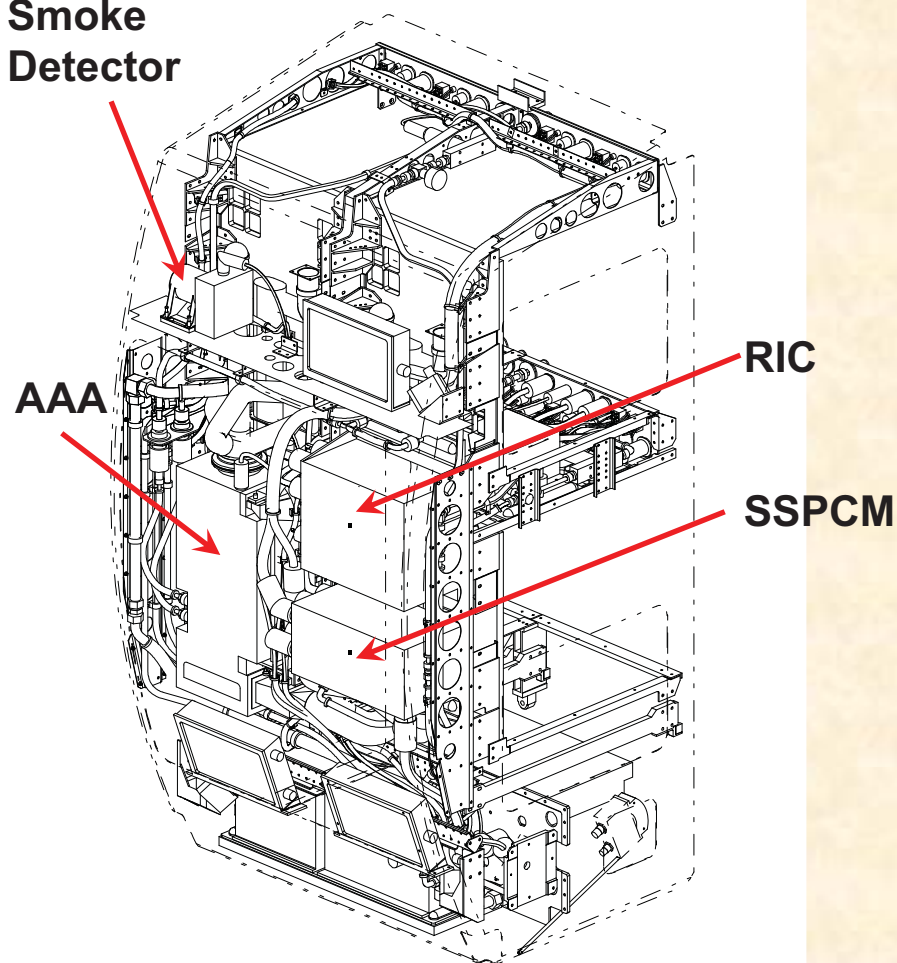


# EXPRESS Subsystems



Conducting Research on the ISS using the EXPRESS Rack

**Smoke  
Detector**



**AAA**

**RIC**

**SSPCM**

**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



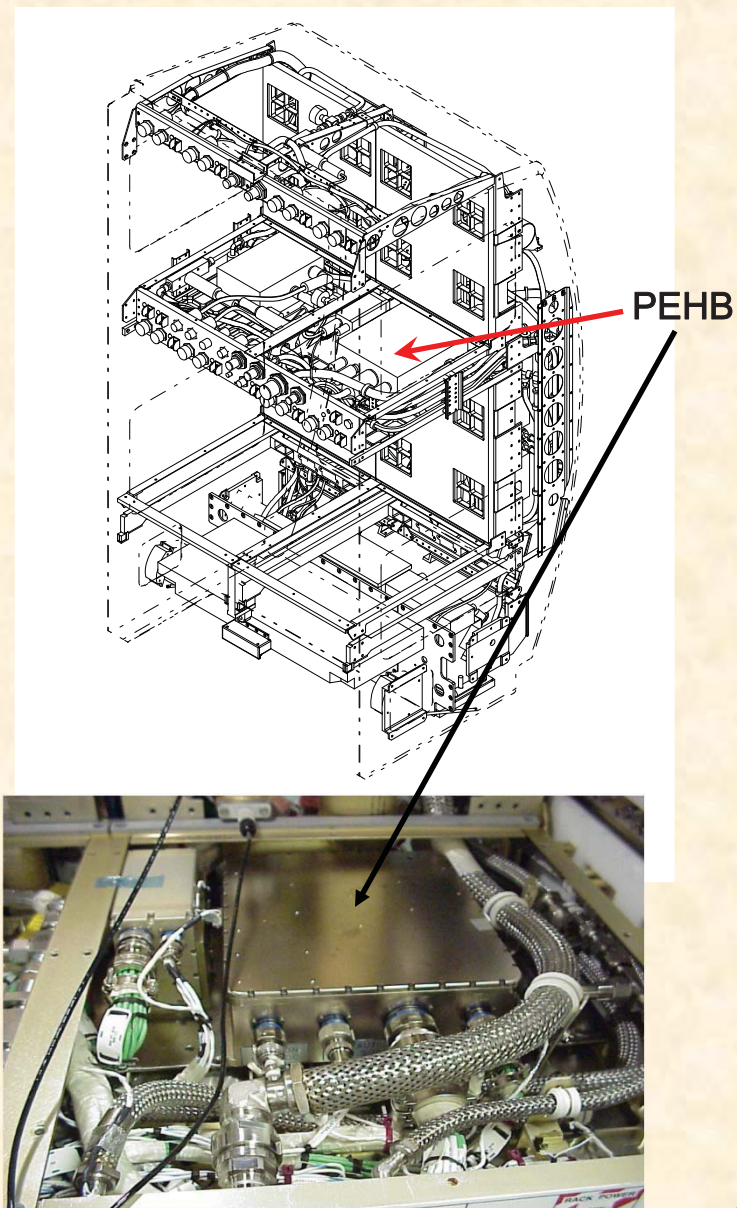


# EXPRESS Subsystems



Conducting Research on the ISS using the EXPRESS Rack

- **PEHB: Payload Ethernet Hub Bridge**
  - Provides primary means of communication between EXPRESS rack, the payloads, and the ISS.
  - Provides 10 Mbps Ethernet data packet transfer between payloads, laptops, and the RIC and provides a bridge to the ISS LANs for telemetry downlink.
  - Command and data interface to EXPRESS laptop.
- **PEHG: Payload Ethernet Hub Gateway**
  - Will replace PEHB in 2015 (est.)
  - 100 Mbps Ethernet





# EXPRESS Subsystems



Conducting Research on the ISS using the EXPRESS Rack

## 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 Subsystems



Conducting Research on the ISS using the EXPRESS Rack

## ➤ Payload Cooling

- Moderate Temperature Loop (MTL)
  - MTL circulates water through rack
  - Payloads have MTL cooling access at the upper and lower connector panels
  - 500 W per payload position x 2 positions per rack
- AAA – “Rear Breather” payloads (1200 W total rack)
- Cabin Heat Load – “Front Breather” payloads (very limited)

## ➤ Thermal Shutdown

- RIC monitors 2 internal sensors that are configured by the PRO (usually a flow sensor and a temperature sensor)
- RIC will shut down all active payloads and rack if both sensors are out of limits

## ➤ Fire Detection System (FDS)

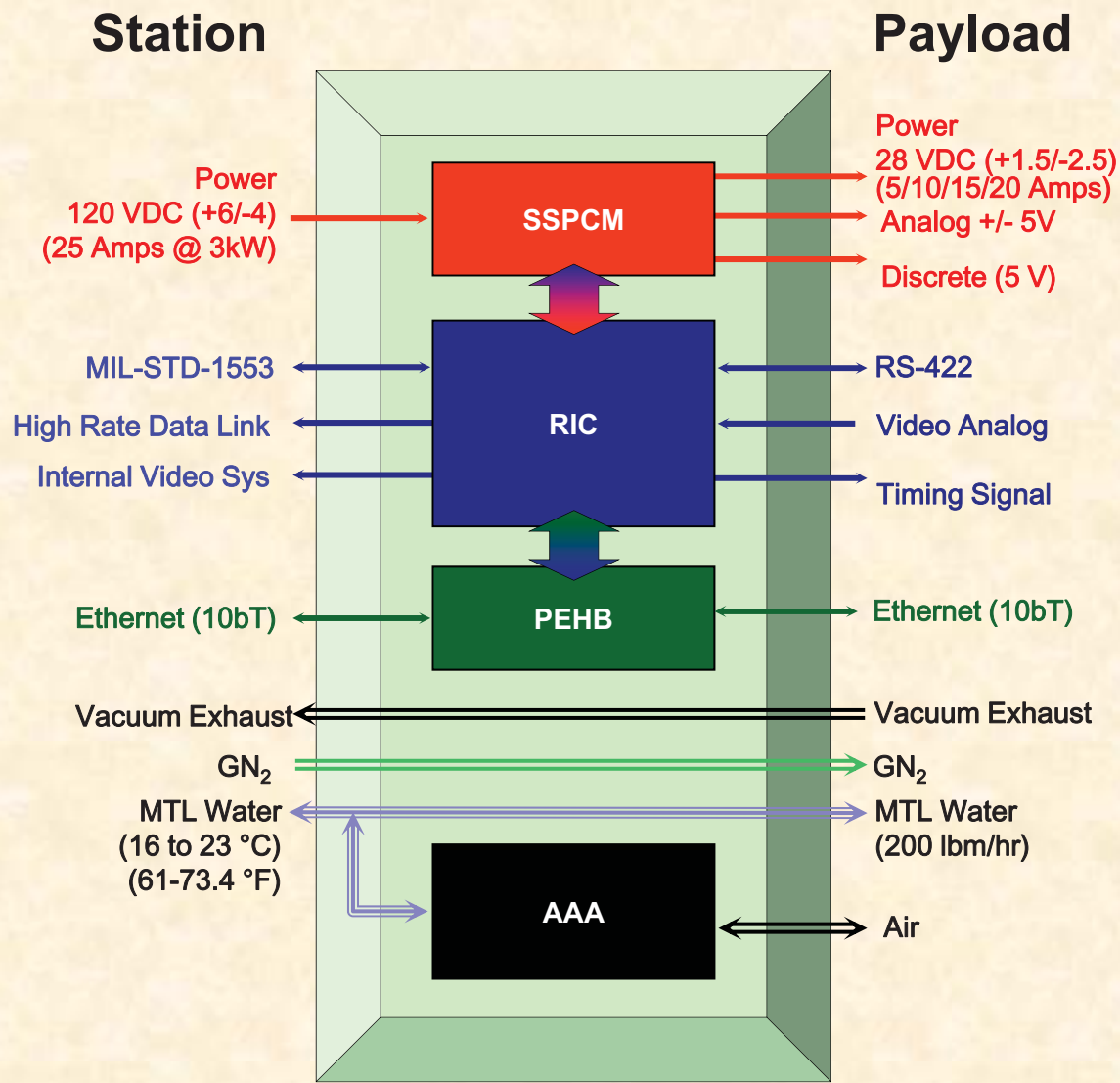
- Provides fire detection for the rack
- Payload Rear Breathers
  - ISS/EXPRESS-provided by smoke detector within rack
- Payload Front Breathers
  - Payload-provided parameter monitoring delivered through health & status data to PL MDM



# EXPRESS Functional Interfaces



Conducting Research on the ISS using the EXPRESS Rack





# EXPRESS Payload Resources



Conducting Research on the ISS using the EXPRESS Rack

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

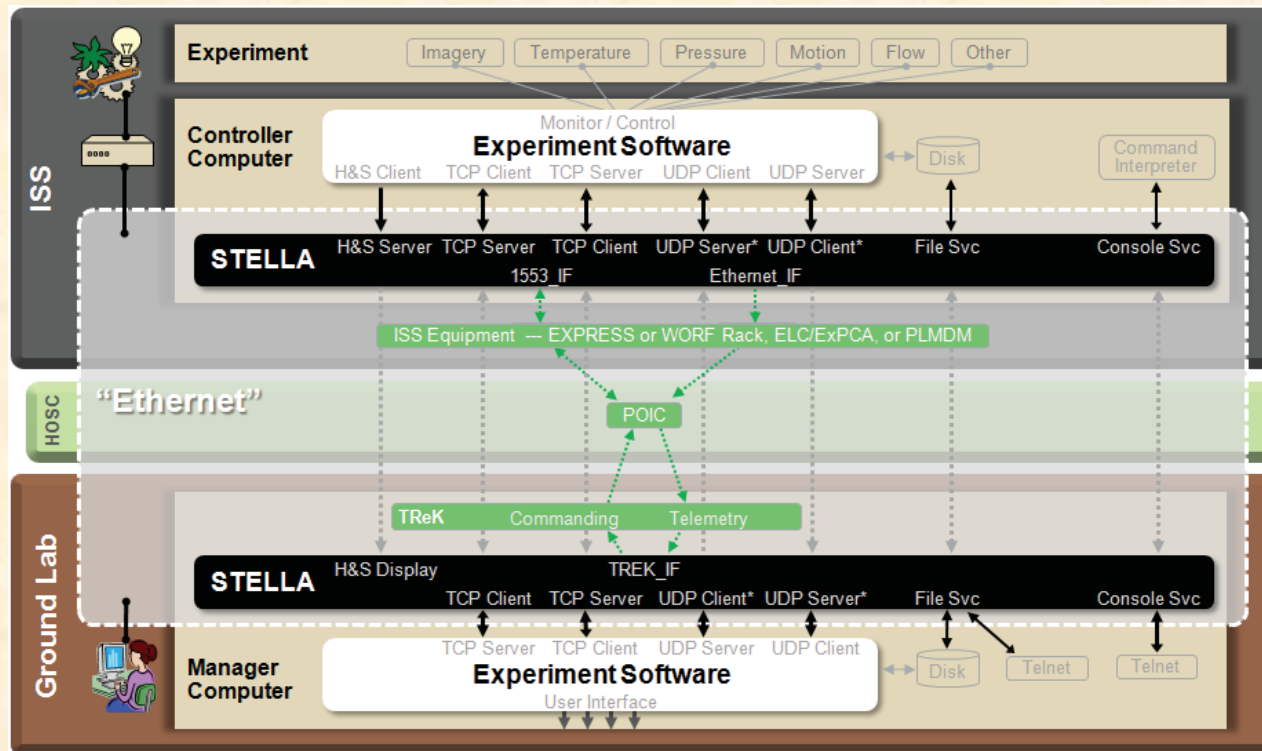


# Software Toolkit for Ethernet Lab-Like Architecture (STELLA)



Conducting Research on the ISS using the EXPRESS Rack

- Developed by Boeing, STELLA provides a generic software toolkit for Payload Developers to accommodate all of the unique software formatting required to communicate with the ISS.
- STELLA easily adapts Ethernet-based (TCP/UDP) software used in ground laboratories to software for conducting research on ISS; it enables a command and telemetry environment from ISS that is analogous to a terrestrial laboratory's control and data acquisition environment.
- STELLA functionality highlights:
  - Payload commanding and payload file upload
  - Remote console access to flight payload computer
  - Payload telemetry downlink and file downlink via the ISS Ethernet LAN
  - Payload health and status data routing to the Payload Operations Integration Center
- Boeing assists Payload Developers with STELLA software integration as a standard ISS integration service





# Payload Testing for EXPRESS Rack

Conducting Research on the ISS using the EXPRESS Rack

Payload



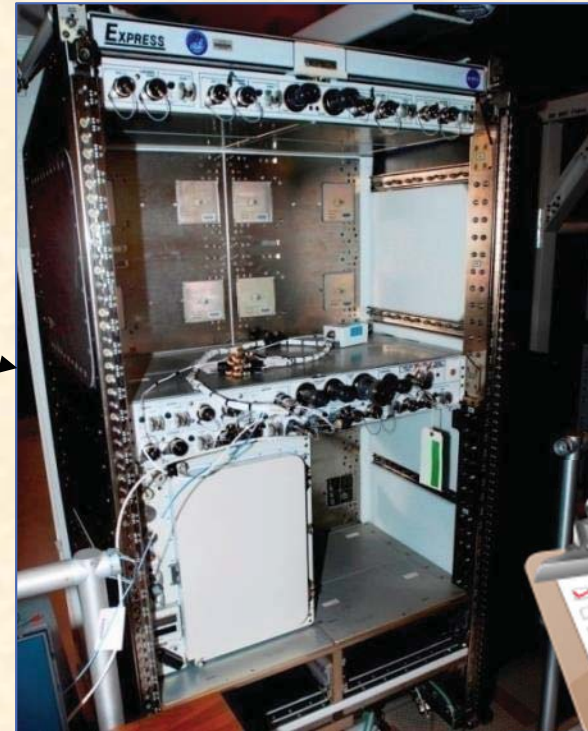
Rack simulator  
s/w provided for  
development

C&DH remote test  
possible using VPN

Virtual Private  
Network

Payload  
shipment to  
MSFC

EXPRESS Rack Functional Checkout Unit



Payload  
shipment  
to launch  
site or PD

Off-gas

Vibration

EMI/EMC

Acoustics

Additional Services  
Available

- Payload to rack interfaces verified efficiently for both Payload Developer and ISS
- End-to-end data flow from payload to rack to HOSC to PD ground station.
- Human Factors Team evaluates hardware locally
- Payload operations flight controller familiarization
- Validation of crew procedures



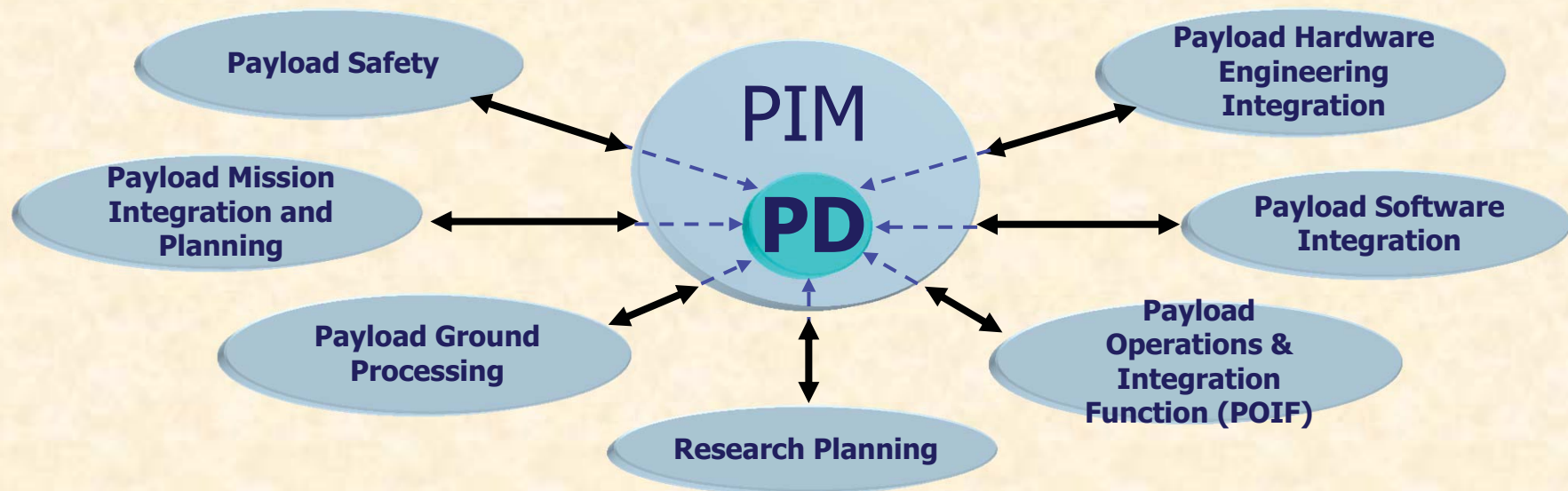
# Payload Integration Manager



Conducting Research on the ISS using the EXPRESS Rack

## ➤ NASA Payload Integration Manager (PIM)

- Functions as the Payload Developer's primary interface to the ISS Program
- Serves as payload advocate while protecting ISS Program Requirements



- Ensures payload requirements are accurately defined and documented
- Facilitates payload integration product development, delivery schedules, and communications with the ISS Program

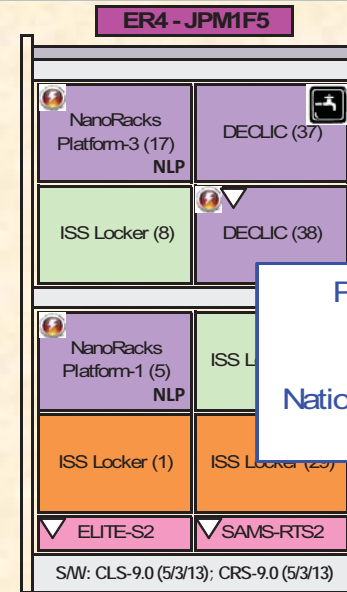
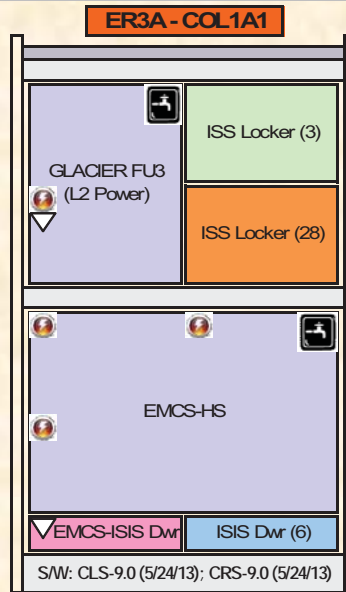
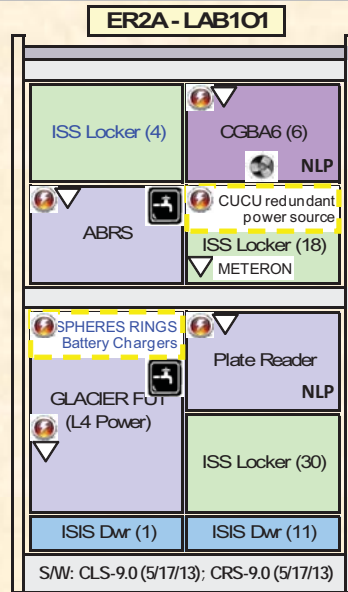
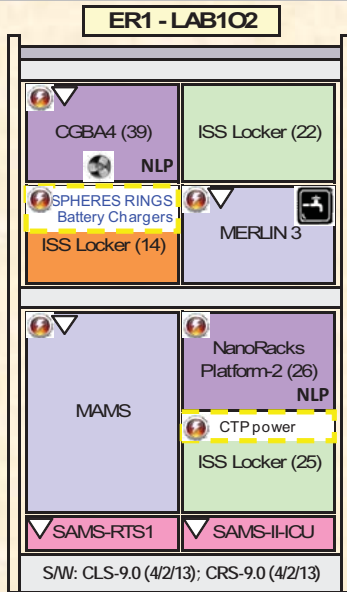




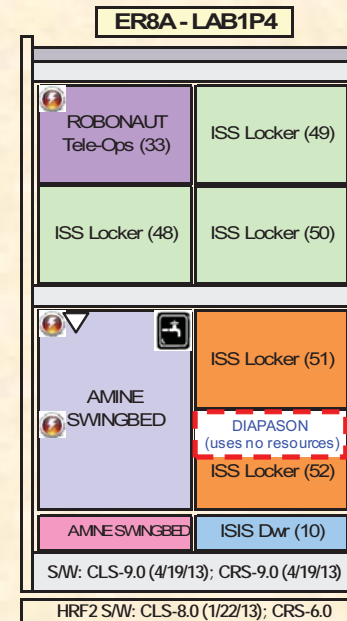
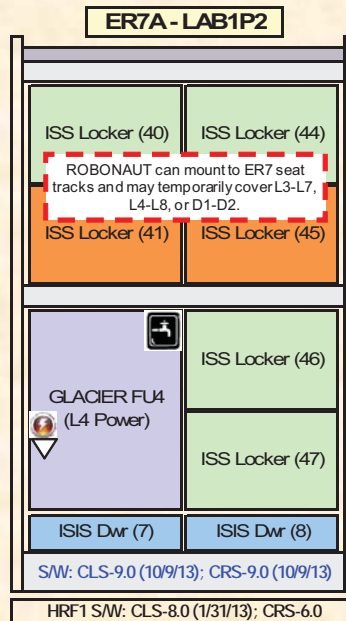
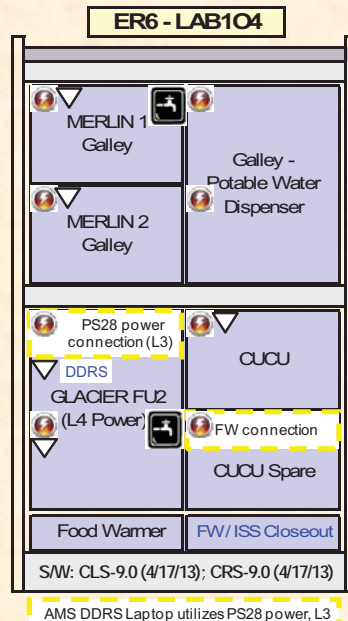
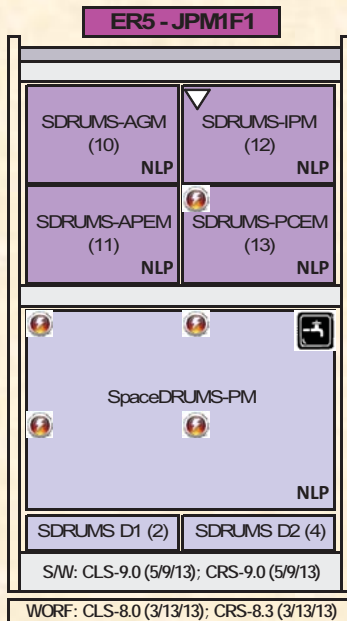
# EXPRESS Topology - 10/15/13



Conducting Research on the ISS using the EXPRESS Rack



Payload Locations 58  
Total Payloads 37 64%  
National Lab Payloads 14 24%  
Stowage Lockers 21

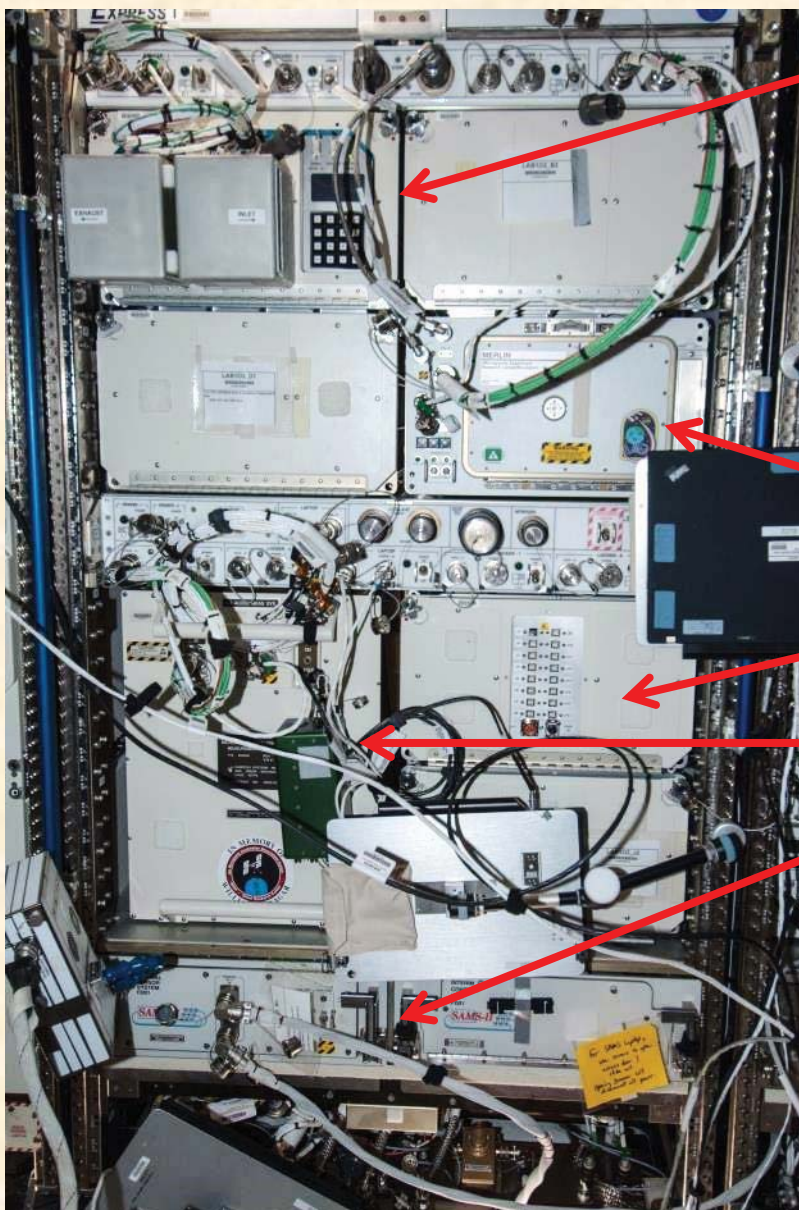




# EXPRESS Rack 1 (Inc 35)



Conducting Research on the ISS using the EXPRESS Rack



## Commercial Generic Bioprocessing Apparatus (CGBA) 4

- Provides programmable, accurate temperature control for applications ranging from cold storage to customizable incubation for experiments on cells, microbes, and plants.

- [http://www.nasa.gov/mission\\_pages/station/research/experiments/CGBA.html](http://www.nasa.gov/mission_pages/station/research/experiments/CGBA.html)

## Microgravity Experiment Research Locker/Incubator (MERLIN) 3

## NanoRacks Platform 2

## Microgravity Acceleration Measurement System (MAMS) & Space Acceleration Measurement System-II (SAMS-II)

- Studies the small forces, or vibrations and accelerations, on the ISS that result from the operation of hardware, crew activities, dockings and maneuvering.

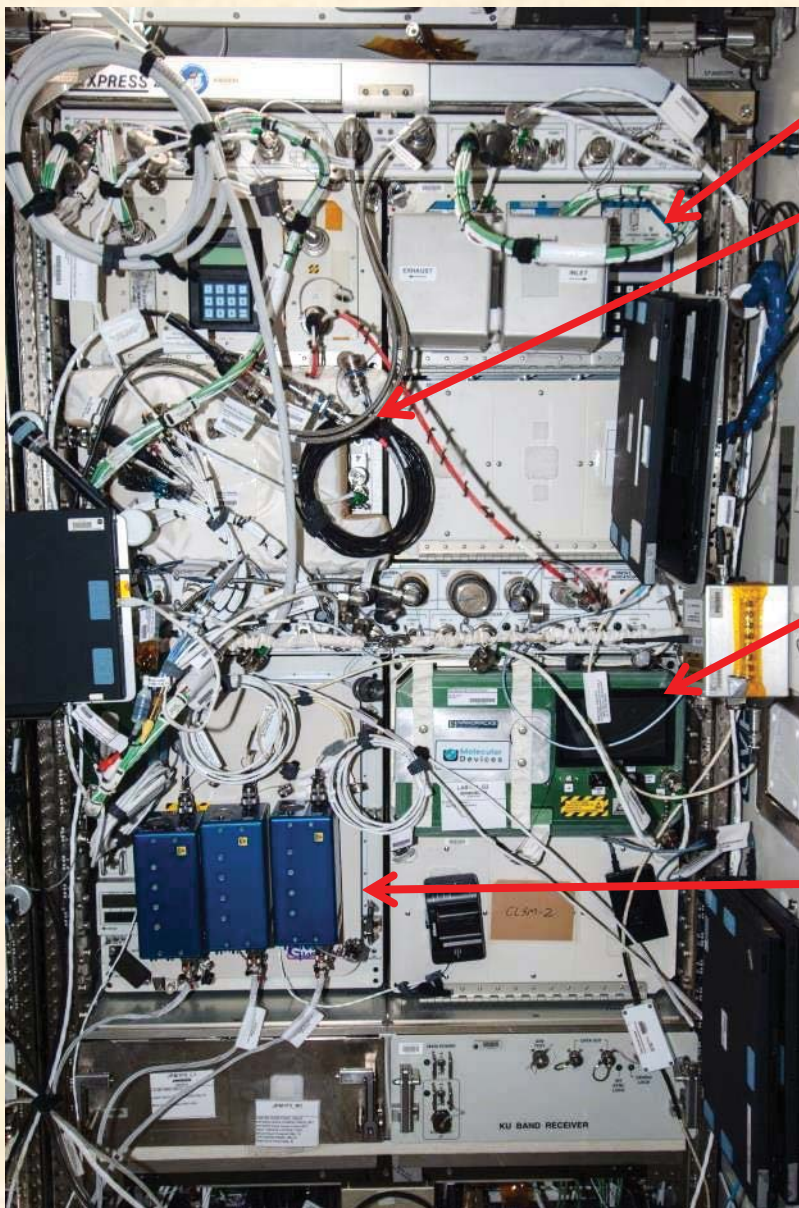
- [http://www.nasa.gov/mission\\_pages/station/research/experiments/914.html](http://www.nasa.gov/mission_pages/station/research/experiments/914.html)



# EXPRESS Rack 2 (Inc 35)



Conducting Research on the ISS using the EXPRESS Rack



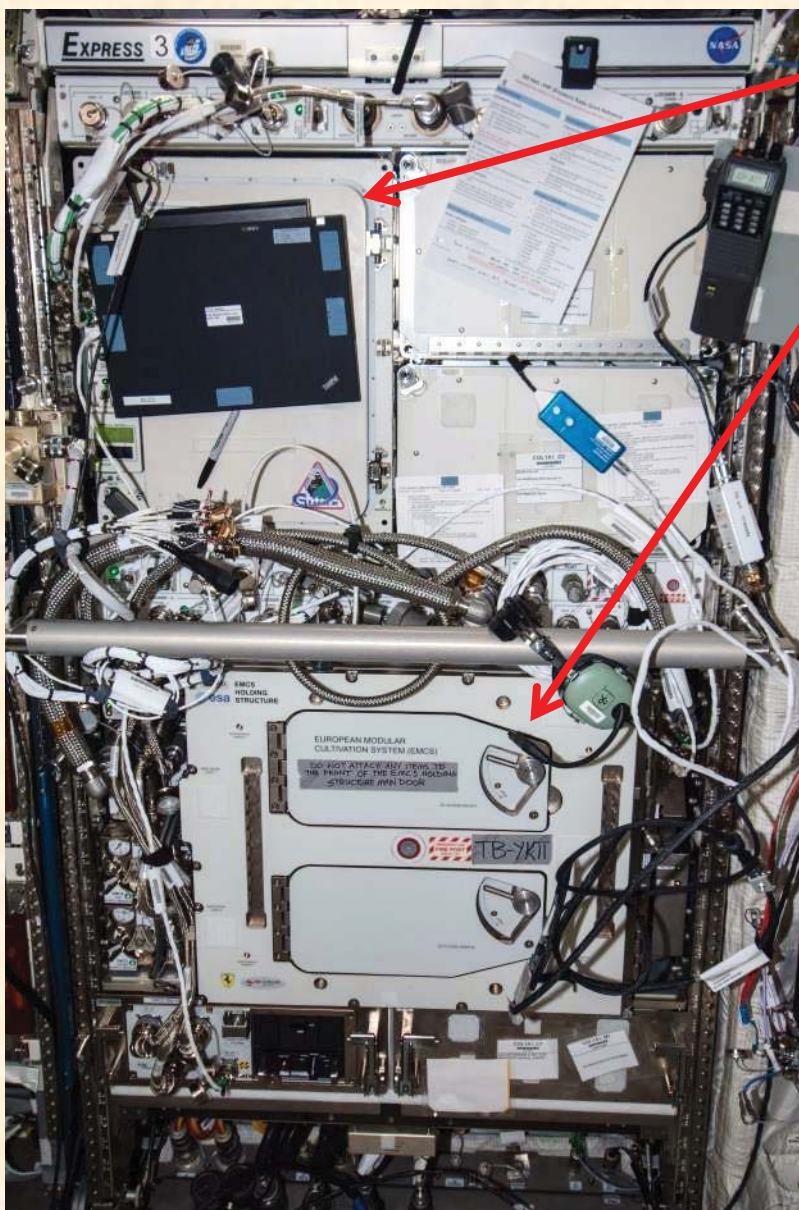
- **Commercial Generic Bioprocessing Apparatus (CGBA) 6**
- **Advanced Biological Research System (ABRS)**
  - Two growth chambers independently controlling temperature, illumination, and atmospheric composition to grow a variety of biological organisms.
  - [http://www.nasa.gov/mission\\_pages/station/research/experiments/MERLIN.html](http://www.nasa.gov/mission_pages/station/research/experiments/MERLIN.html)
- **NanoRacks Plate Reader**
  - Instrument designed to detect biological, chemical or physical events of samples in microtiter plates.
  - [http://www.nasa.gov/mission\\_pages/station/research/experiments/542.html](http://www.nasa.gov/mission_pages/station/research/experiments/542.html)
- **General Laboratory Active Cryogenic ISS Experiment Refrigerator (GLACIER) 1**
  - Ultra-cold freezers that will store samples at temperatures as low as -160 °C (-301 °F).
  - [http://www.nasa.gov/mission\\_pages/station/research/experiments/GLACIER.html](http://www.nasa.gov/mission_pages/station/research/experiments/GLACIER.html)



# EXPRESS Rack 3 (Inc 35)



Conducting Research on the ISS using the EXPRESS Rack



General Laboratory Active Cryogenic ISS Experiment Refrigerator (GLACIER) 1

European Modular Cultivation System (EMCS)

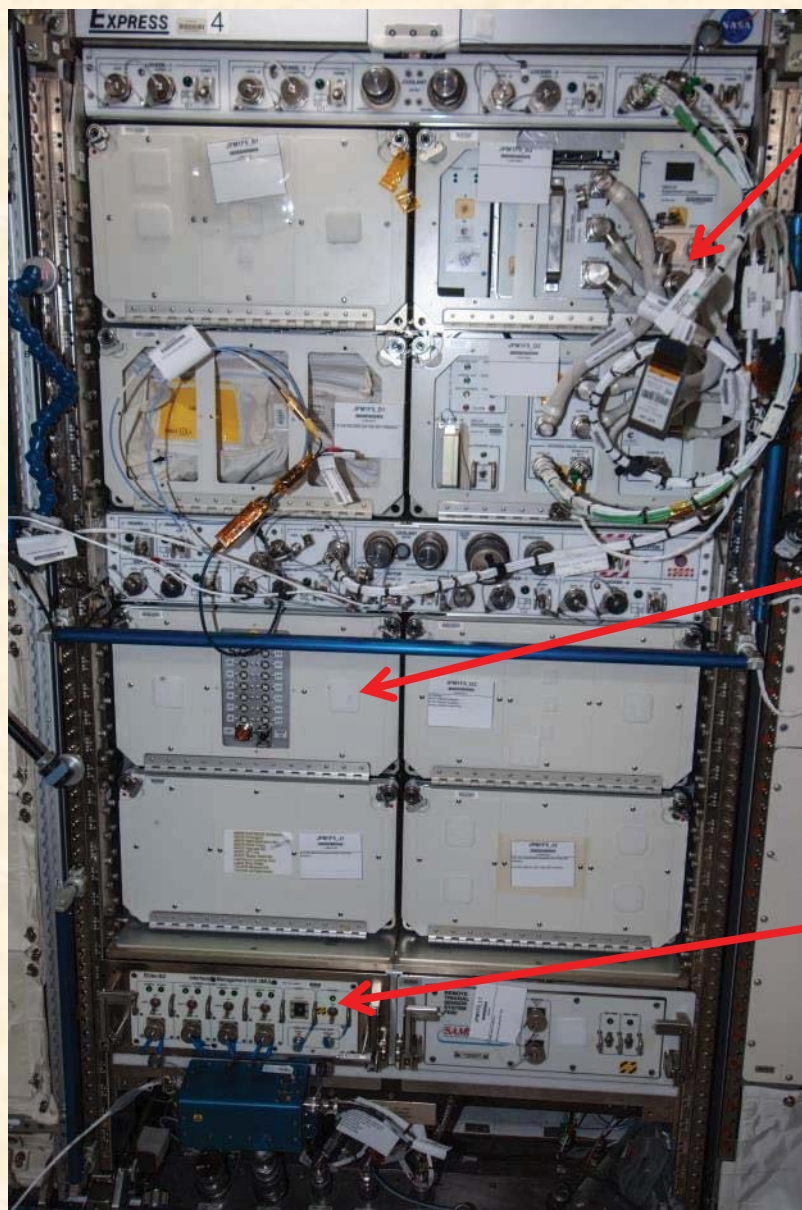
- Large incubator that provides control over the atmosphere, lighting and humidity of growth chambers to study plant growth.
- Contains two centrifuges whose speed can be set to exert a gravitational force ranging from nearly 0 to 2 g on four samples.
- Developed by the European Space Agency (ESA)
- [http://www.nasa.gov/mission\\_pages/station/research/experiments/542.html](http://www.nasa.gov/mission_pages/station/research/experiments/542.html)



# EXPRESS Rack 4 (Inc 35)



Conducting Research on the ISS using the EXPRESS Rack



## DEvice for the study of Critical LIquids and Crystallization (DECLIC)

- Multi-user facility utilized to study transparent media and their phase transitions in microgravity.
- Established the precise temperature (373.995 °C) at which water becomes supercritical.
- [http://www.nasa.gov/mission\\_pages/station/research/experiments/203.html](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](http://www.nasa.gov/mission_pages/station/research/experiments/829.html)

## ELaboratore Immagini TElevisive - Space 2 (ELITE-S2)

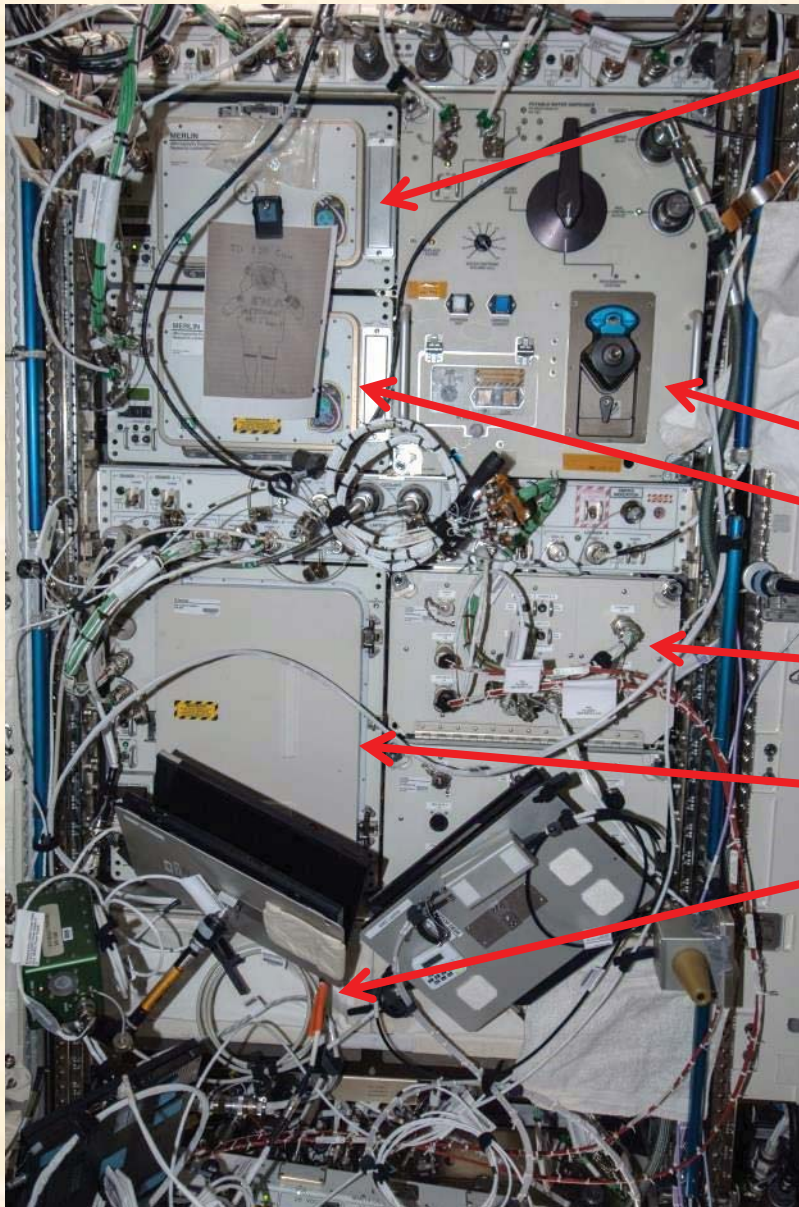
- Investigates the connection between brain, visualization and motion in the absence of gravity.
- [http://www.nasa.gov/mission\\_pages/station/research/experiments/78.html](http://www.nasa.gov/mission_pages/station/research/experiments/78.html)



# EXPRESS Rack 6, Galley (Inc 35)



Conducting Research on the ISS using the EXPRESS Rack



## Microgravity Experiment Research Locker/INcubator (MERLIN) 1

- Freezer/refrigerator or incubator that can be used for a variety of experiments.
- Temperature range for MERLIN is -20 °C (-4 °F) to + 48.5 °C (+119 °F).
- [http://www.nasa.gov/mission\\_pages/station/research/experiments/MERLIN.html](http://www.nasa.gov/mission_pages/station/research/experiments/MERLIN.html)

## Potable Water Dispenser

## Microgravity Experiment Research Locker/INcubator (MERLIN) 2

## COTS UHF Communication System (CUCU)

## GLACIER 2

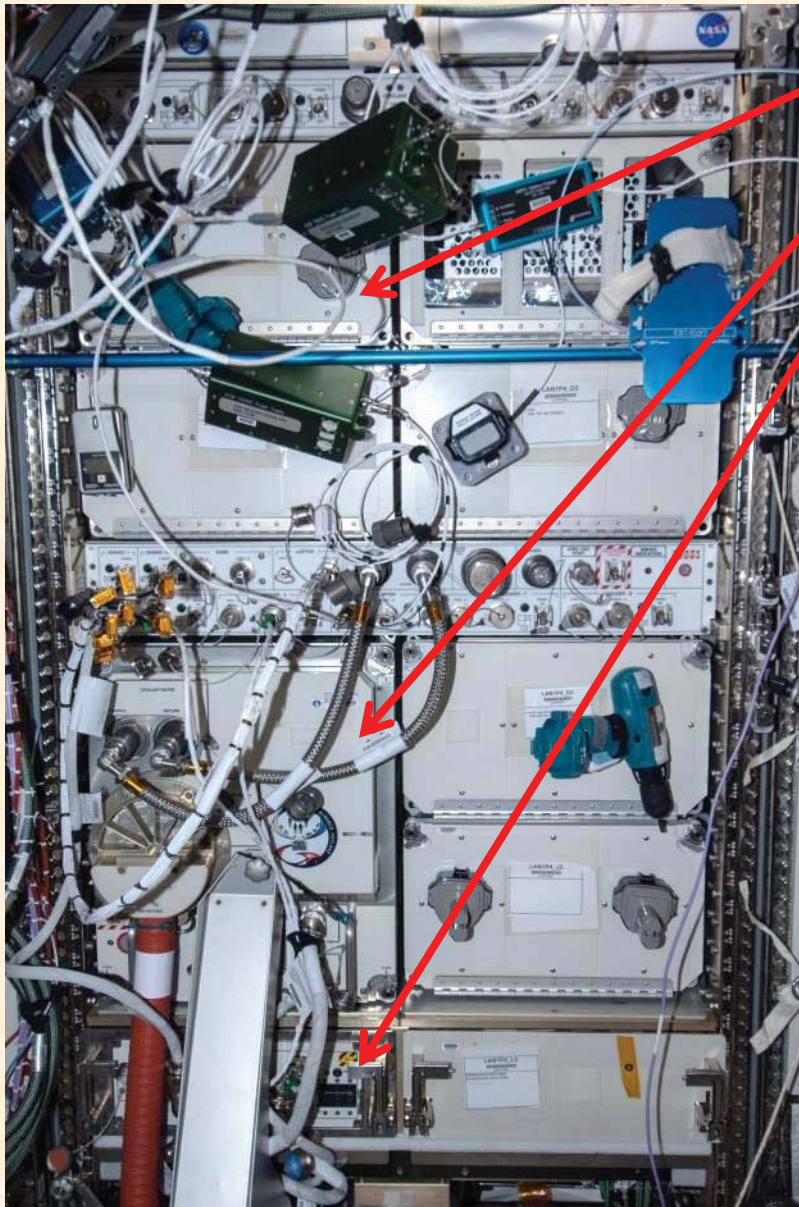
## Food Warmer



# EXPRESS Rack 8 (Inc 35)



Conducting Research on the ISS using the EXPRESS Rack



➤ Robonaut Tele-Ops

➤ Amine Swingbed

- Investigation determines if a vacuum-regenerated amine system can effectively remove carbon dioxide (CO<sub>2</sub>) from the ISS atmosphere using a smaller, more efficient, vacuum regeneration system.
- [http://www.nasa.gov/mission\\_pages/station/research/experiments/Amine\\_Swingbed.html](http://www.nasa.gov/mission_pages/station/research/experiments/Amine_Swingbed.html)



# Summary



Conducting Research on the ISS using the EXPRESS Rack

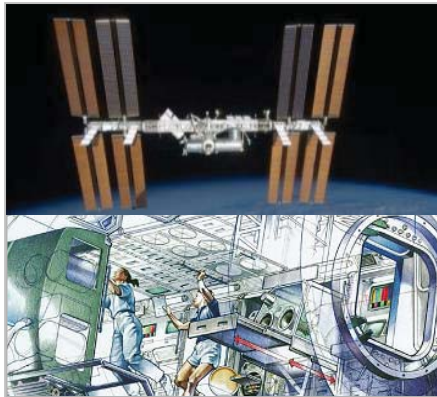
- **EXPRESS Racks provide capability for payload access to ISS resources.**
- **The successful on-orbit operations and versatility of the EXPRESS Rack has facilitated the operations of many scientific areas, with the promise of continued payload support for years to come.**
- **EXPRESS Racks are currently deployed in the US Lab, Columbus and JEM.**
- **Process improvements and enhancements continue to improve the accommodations and make the integration and operations process more efficient.**
- **Payload Integration Managers serve as the primary interface between the ISS Program and EXPRESS Payload Developers.**
- **EXPRESS Project coordinates across multiple functional areas and organizations to ensure integrated EXPRESS Rack and subrack products and hardware are complete, accurate, on time, safe, and certified for flight.**





# Back Up Material

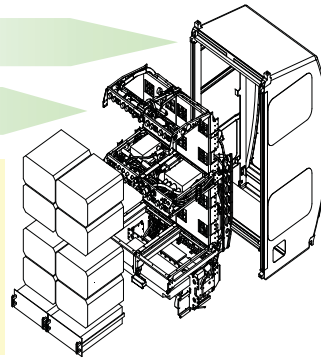
# EXPRESS – EXpedite the PROcessing of Experiments for Space Station – Research Accommodations



## EXPRESS 8/2 Configuration

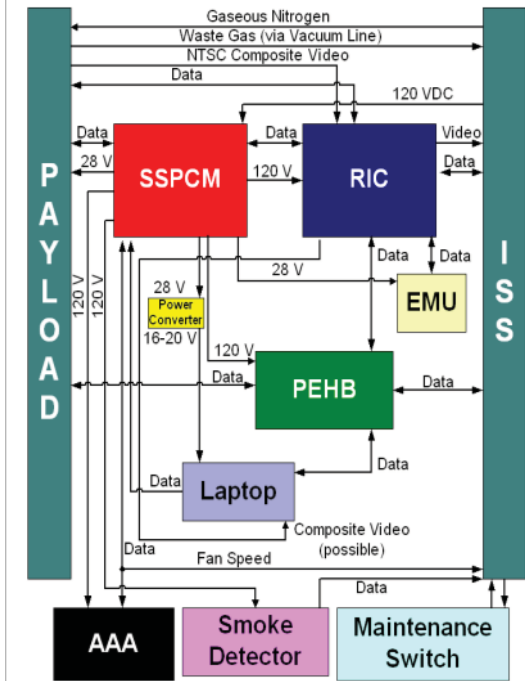
International Standard Payload Rack  
Secondary Structure & Subsystems

8/2 Payload Configuration  
(8 ISS Lockers, 2 ISIS Drawers)



Integrated Rack

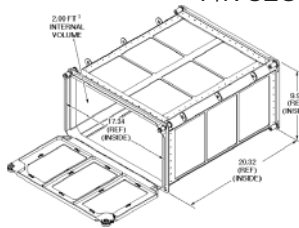
## EXPRESS 8/2 Functional Block Diagram



### ISS Locker P/N SEG46117022

#### Features

- 4 rear captive fastener attachments
- Friction hinge
- Dual door locks
- Installation tool guides on 4 corners
- Weight – 13 lbs empty
- Volume – 2 ft<sup>3</sup>

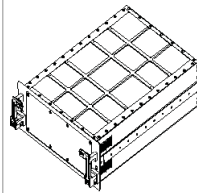


### International Subrack Interface Standard Drawer

Powered P/N 683-43650  
Stowage P/N 683-43656

#### Features

- 4 PU (Panel Unit)
- Blind Connectors
- Locking Handles
- Weight – 26 lbs empty
- Volume – 1.26 ft<sup>3</sup>



### EXPRESS Laptop Computer

- Dedicated laptop/rack
- Crew rack displays
- Crew rack commanding
- Crew payload commanding
- Unique operating system (NT)

Type	Total EXPRESS Rack Accommodations	EXPRESS Functional Interfaces	ISS Locker Position Accommodations**	4-PU Drawer Position Accommodations**	
<b>Structural</b>	8 Lockers & 2 4-PU ISIS Drawers	<p>Power 28 VDC (+1.5/-2.5) (5/10/15/20 Amps) Analog +/- 5V Discrete (5 V)</p> <p>MIL-STD-1553 HRDL IVS</p> <p>Ethernet (10bT)</p> <p>Vacuum Exhaust GN<sub>2</sub> MTL Water (16 to 23° C) (61-73.4° F)</p> <p>Air</p>	Mass vehicle dependent	64 lb total within cg constraints	
<b>Power</b>	2000 W 28 VDC power to payloads		120 VDC (+6/-4) (25 Amps @ 3kW)	5/10/15/20 Amps (@28 VDC)	5/10/15/20 Amps (@28 VDC)
<b>Thermal Control</b>	2000 W payload heat rejection air/water combined (1200 W air)			Nominal – 150 W (Ducted Air)	Nominal – 150 W (Ducted Air)
<b>Data</b>	10 – RS-422; 10 – Ethernet; 18 – Analog; 28 – Discrete (bi-dir)			500 W – 2 positions (Water)	500 W – 2 positions (Water)
<b>Video*</b>	1 – NTSC feed from each payload			1 – RS-422; 1 – Ethernet; 2 – Analog; 3 – Discrete	1 – RS-422; 1 – Ethernet; 1 – Analog; 2 – Discrete
<b>Vacuum Exhaust</b>	1 – Payload connection			1 – NTSC/170A feed - Shared	1 – NTSC/170A feed - Shared
<b>Nitrogen</b>	1 – Payload connection		1 – Shared	1 – Shared	
			1 – Shared (0 – 12 lbm/hr)	1 – Shared (0 – 12 lbm/hr)	

\* Digitized Payload Video may be included in ethernet telemetry

\*\* Grayed-out Accommodations are not supported with the Lean Payload Integration approach

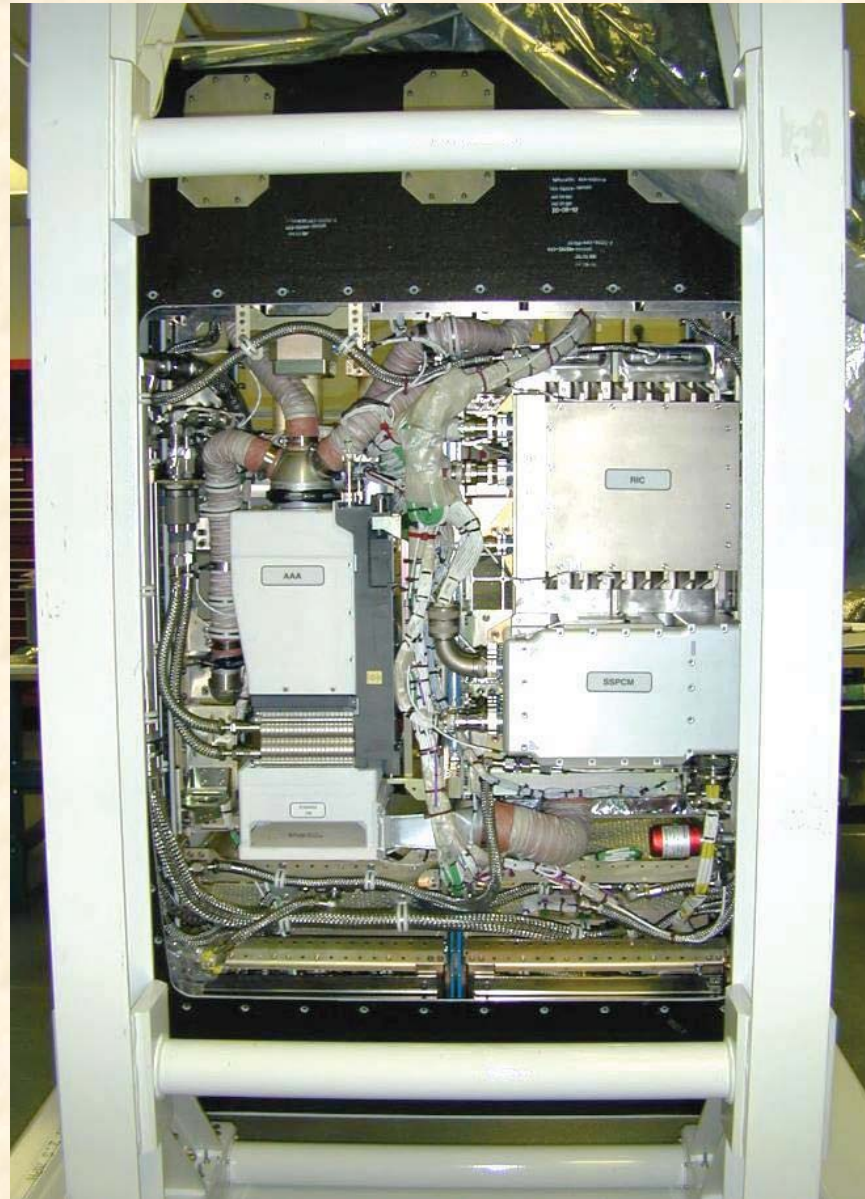


# EXPRESS Subsystems



Conducting Research on the ISS using the EXPRESS Rack

Rack Rear View



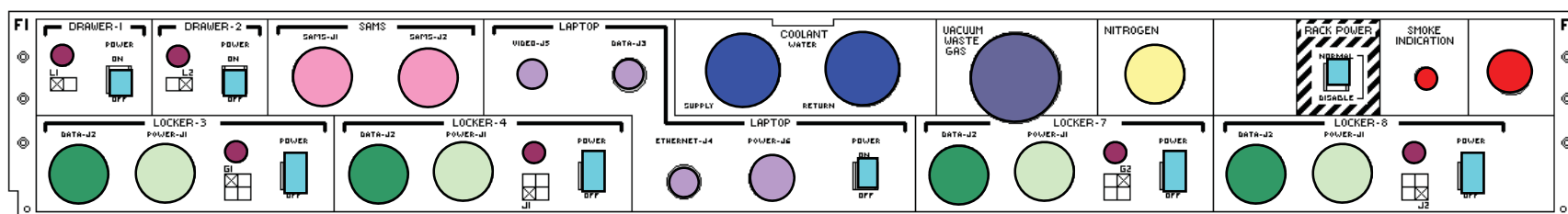
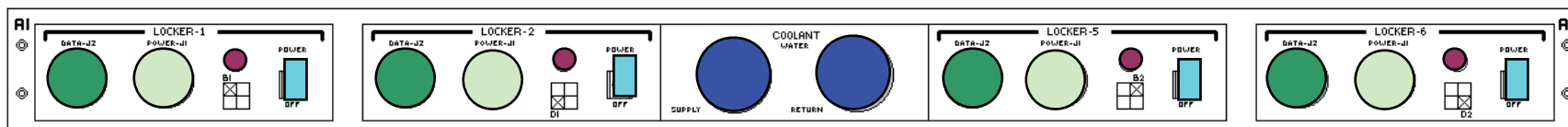


# EXPRESS Rack Connector Panels



Conducting Research on the ISS using the EXPRESS Rack

### Upper Connector Panel



### Lower Connector Panel

Data Ports

ELC Video/Data/Ethernet/Power

LEDs

Nitrogen

Power Switches

Power Ports

SAMS Data Ports

Smoke Indication LED & Fire Port (PFE Access)

Water Supply & Return

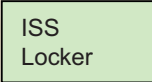
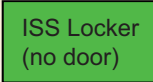

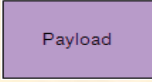
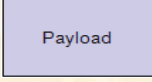




Vacuum Waste Gas



# EXPRESS Topology - Legend



Conducting Research on the ISS using the EXPRESS Rack

-  - **Stowage Locker**
-  - **Stowage Locker w/o door**
-  - **Location reserved for Lean Payloads**
-  - **Payload Insert (Payload inserted into ISS Locker or ISIS Drawer)**
-  - **Locker Replacement Payload**
-  - **ISIS Drawer**
-  - **Drawer Replacement Payload**
-  - **requires water (TCS)**
-  - **requires EXPRESS Rack provided power**
-  - **requires EXPRESS Rack provided data connection**
-  - **Front Breather payload**
-  - **deployed payload**
-  - **power resource utilized**
- NLP - National Lab Payload**

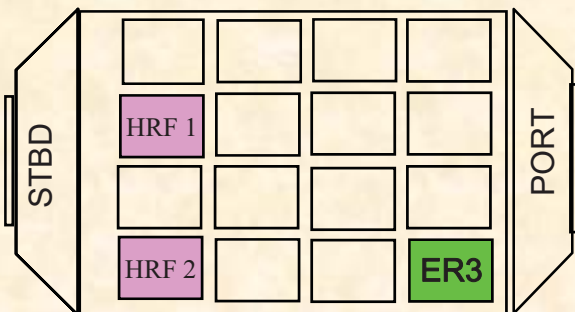


# ISS Topology at Assembly Complete

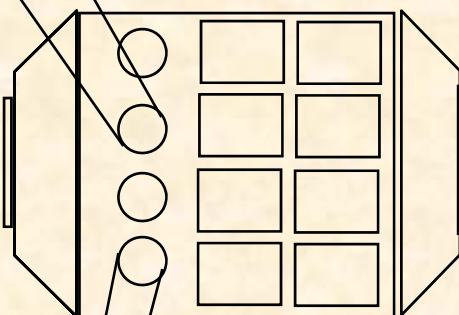


Conducting Research on the ISS using the EXPRESS Rack

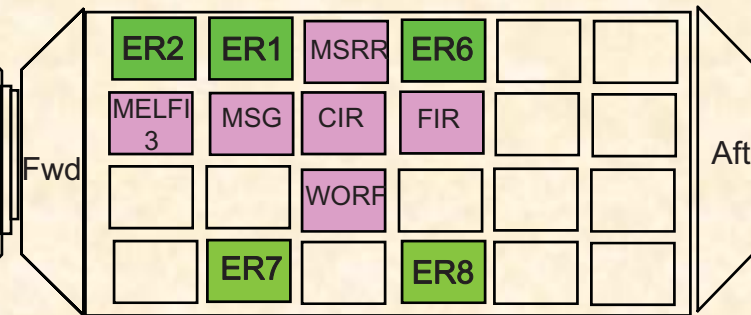
## Columbus Orbital Facility



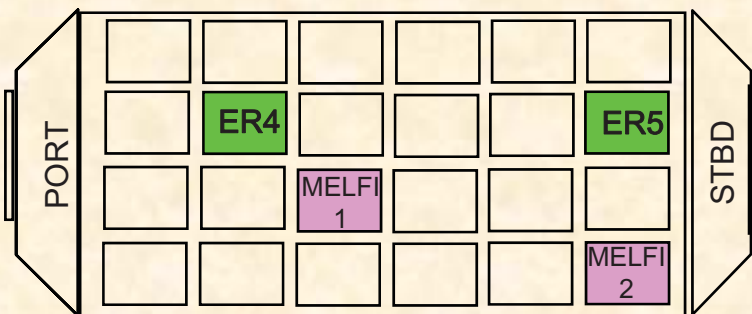
## Node 2





## US Lab



## Japanese Experiment Module



-  EXPRESS Racks
-  NASA Payload Racks

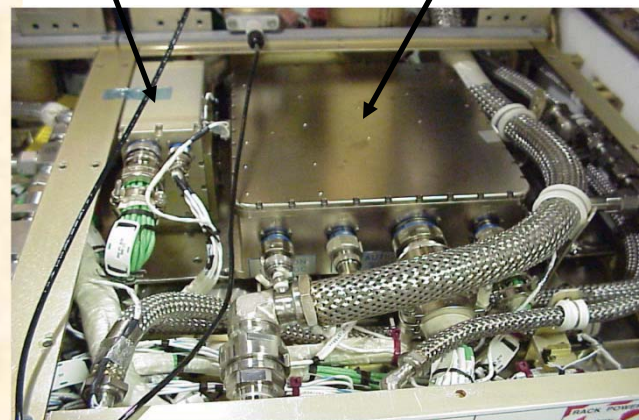
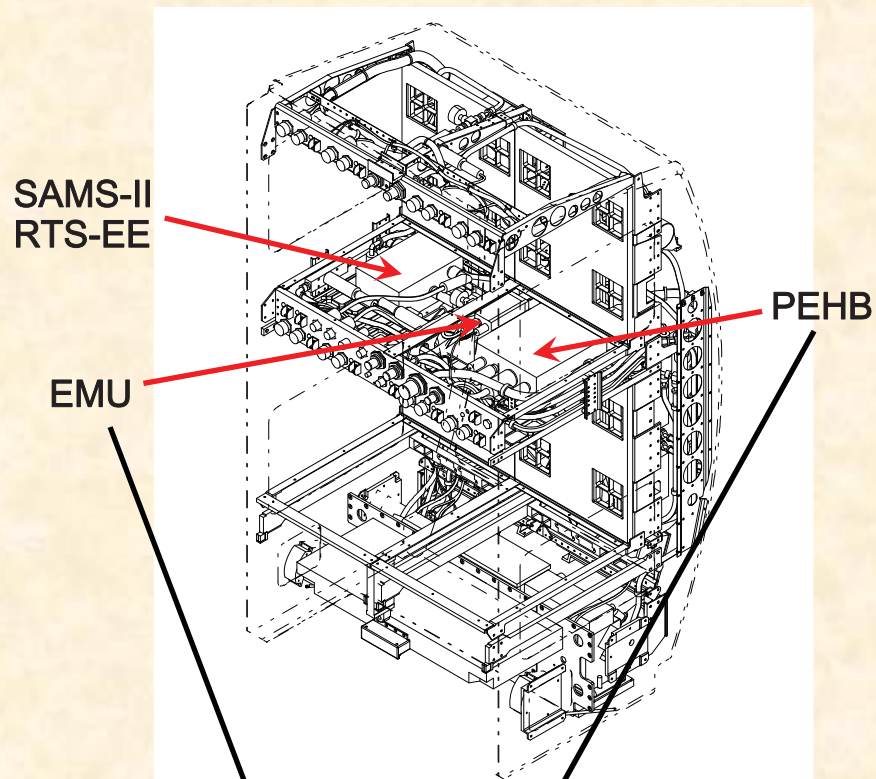


# EXPRESS Subsystems



Conducting Research on the ISS using the EXPRESS Rack

- **EMU: EXPRESS Memory Unit**
  - 320 MB solid state memory device that stores RIC boot-up and payload configuration data
- **PEHB: Payload Ethernet Hub Bridge**
  - Provides primary means of communication between EXPRESS rack, the payloads, and the ISS.
  - Provides 10 Mbps Ethernet data packet transfer between payloads, laptops, and the RIC and provides a bridge to the ISS LANs for telemetry downlink.
  - Command and data interface to EXPRESS laptop.
- **SAMS-II RTS-EE: Space Acceleration Measurement System Remote Triaxial System Electronics Enclosure (ARIS only)**





# EXPRESS Project



Conducting Research on the ISS using the EXPRESS Rack

- Manage engineering integration activities for the EXPRESS Racks.
- Review and submit the integrated EXPRESS Safety Data Package.
- Review and approve EXPRESS generic and payload-unique documentation and engineering integration products.
  - EXPRESS rack to payload hardware and software ICDs, IDD, IRD, PVP
  - ICD PIRNs, Exceptions, Verification
  - Stage Analysis/Guidelines & Constraints, On-Orbit Topology Config. Drawings
  - Review and sign CEFs for EXPRESS hardware manifests
- Facilitate identification and coordinate resolution of EXPRESS issues.
- Perform Mission/Stage Management & ensure accurate and complete accomplishment of CoFR activities for all launched and on-orbit EXPRESS hardware.
- Coordinate EXPRESS Project support for subrack payload development.
  - Review Payload Integration Agreements (PIAs)
    - Notify PSS manager of requested GSE and GFE (Connectors, QDs, Simulators, etc)
  - Facilitate EXPRESS Rack interface TIMs, as needed
  - Coordinate development and interface testing with Functional Checkout Unit
    - Support EXPRESS Integration Readiness Review (EIRR)