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

30th American Society for Gravitational and Space Research and October 2014

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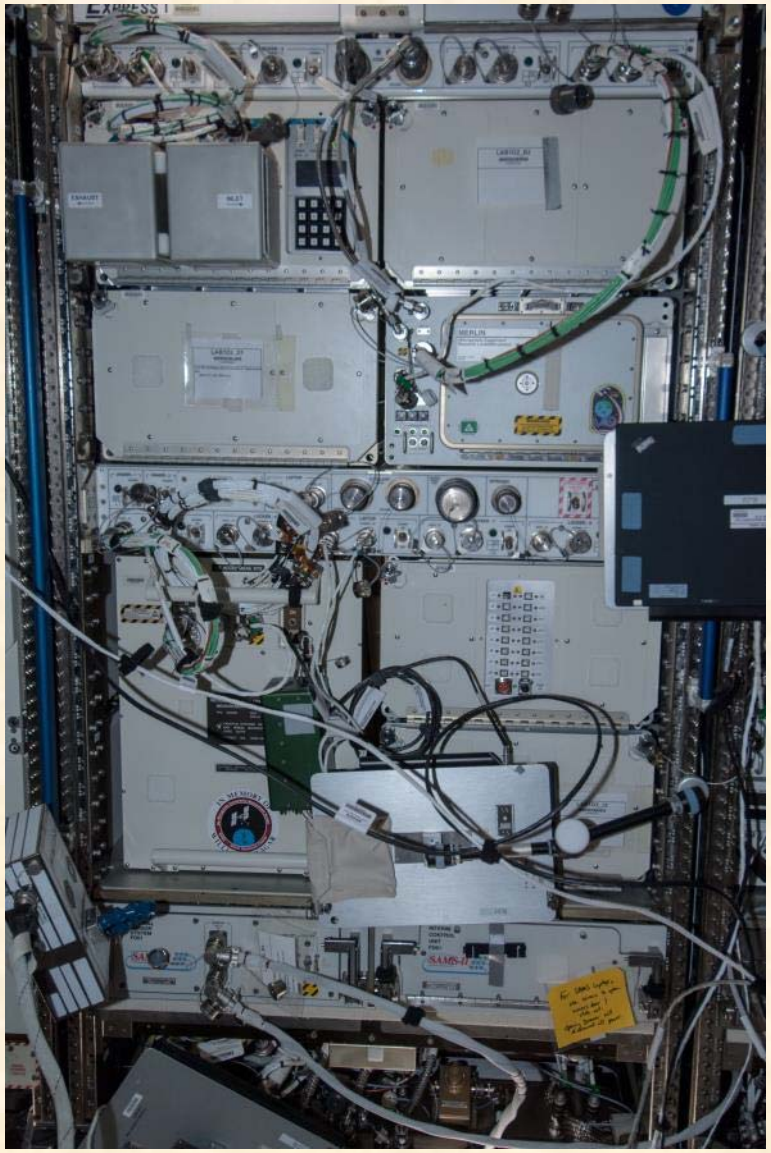
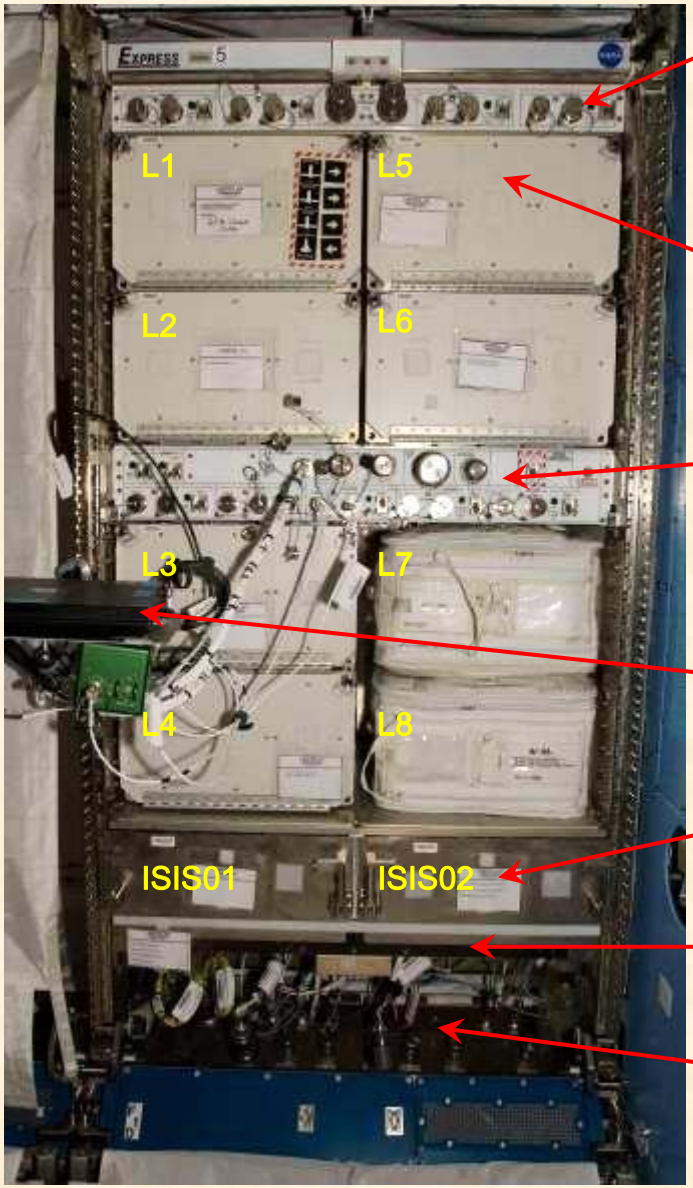
EXPRESS Rack

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



EXPRESS Rack 1, 7/9/13

EXPRESS Rack Front View



Upper Connector Panel

Lockers (8 locations)

Lower Connector Panel

EXPRESS Laptop Computer (ELC)

ISIS Drawers (2)

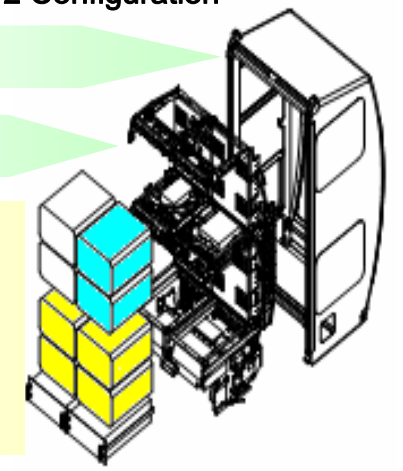
Utility Drawer

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 8/2 Configuration



EXPRESS Racks

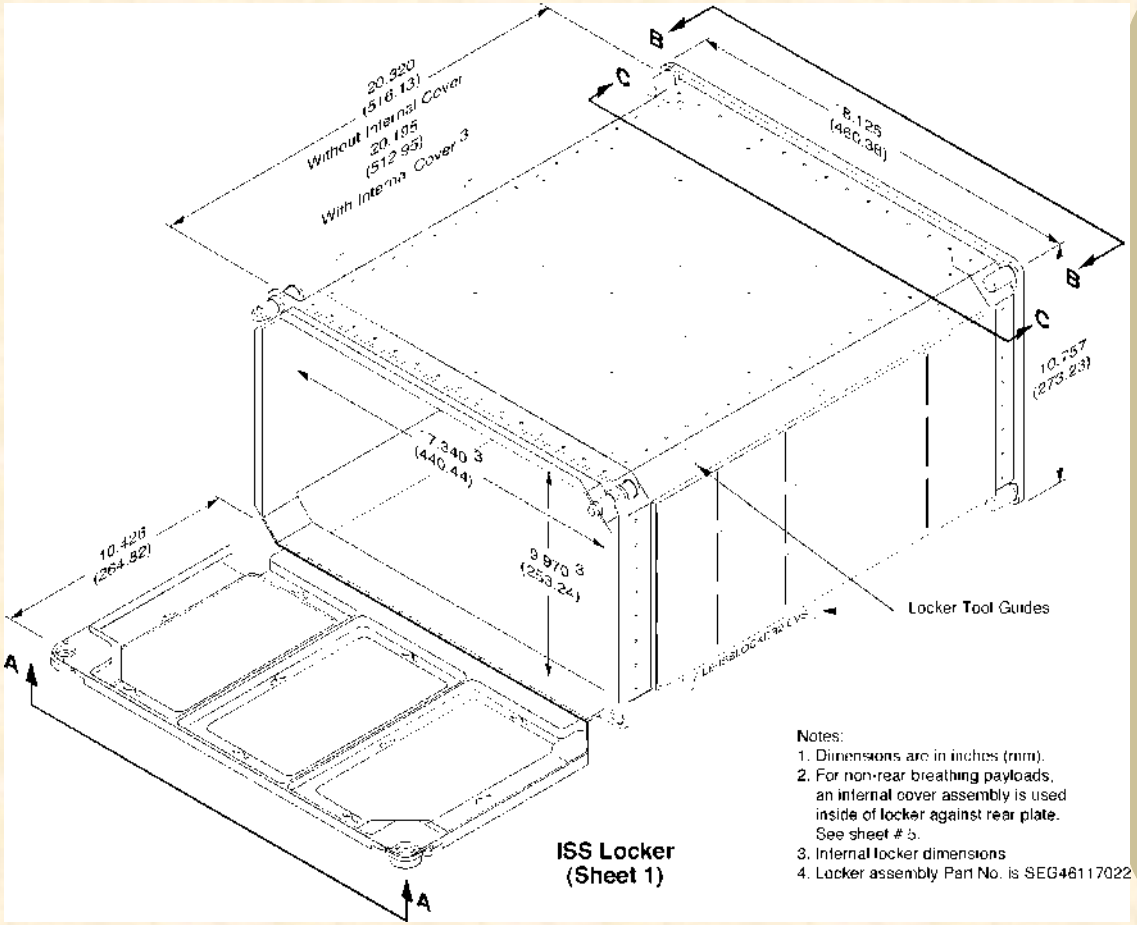
- 8 flight racks on-orbit (4 ARIS, 4 non-ARIS)
- First launched April 19, 2001
- Trainer Racks at JSC and MSFC to support crew and ground training
- Functional Checkout Unit (FCU) at MSFC to support payload testing

Rack	Location (Lab, Bay)	Launch (Flight, Date)	Aug. 2014 Operating Hrs	Total Operating Hours
EXPRESS Rack #1	US Lab, O2	6A, 4/19/01	744	99,172
EXPRESS Rack #2A	US Lab, O1	6A, 4/19/01	262	64,436
EXPRESS Rack #3A	Columbus, P2	UF2, 6/5/02	744	31,928
EXPRESS Rack #4	JEM, F5	7A.1, 8/10/01	744	93,654
EXPRESS Rack #5	JEM, F1	7A.1, 8/10/01	0	845
EXPRESS Rack #6	US Lab, O4	ULF2, 11/14/08	743	50,698
EXPRESS Rack #7A	US Lab, P2	19A, 4/5/10	744	7,043
EXPRESS Rack #8A	US Lab, P4	ULF5, 2/24/11	0	9,463

Total: 357,239

Operational Hours through 8/31/2014

EXPRESS ISS Locker Details



Features

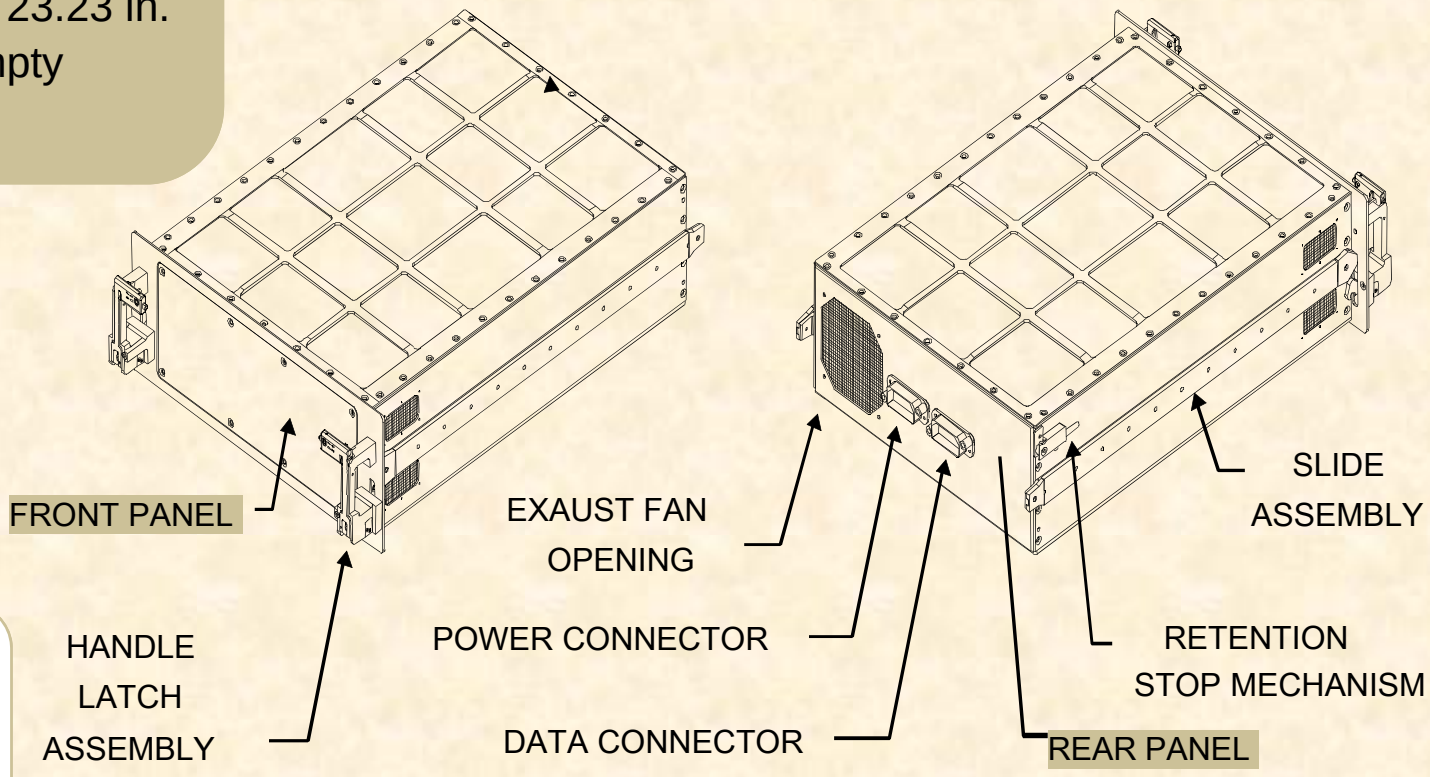
- 4 rear captive fastener attachments
- Installation tool guides on 4 corners
- Friction hinge
- Dual door locks
- 3 removable panels on door
- Rear internal closeout removed for active payloads
- Internal dimensions (ref)
  - Width 17.340 in.
  - Height 9.970 in.
  - Depth 20.320 in.
- Weight – 13 lbs.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

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

EXPRESS Powered ISIS 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

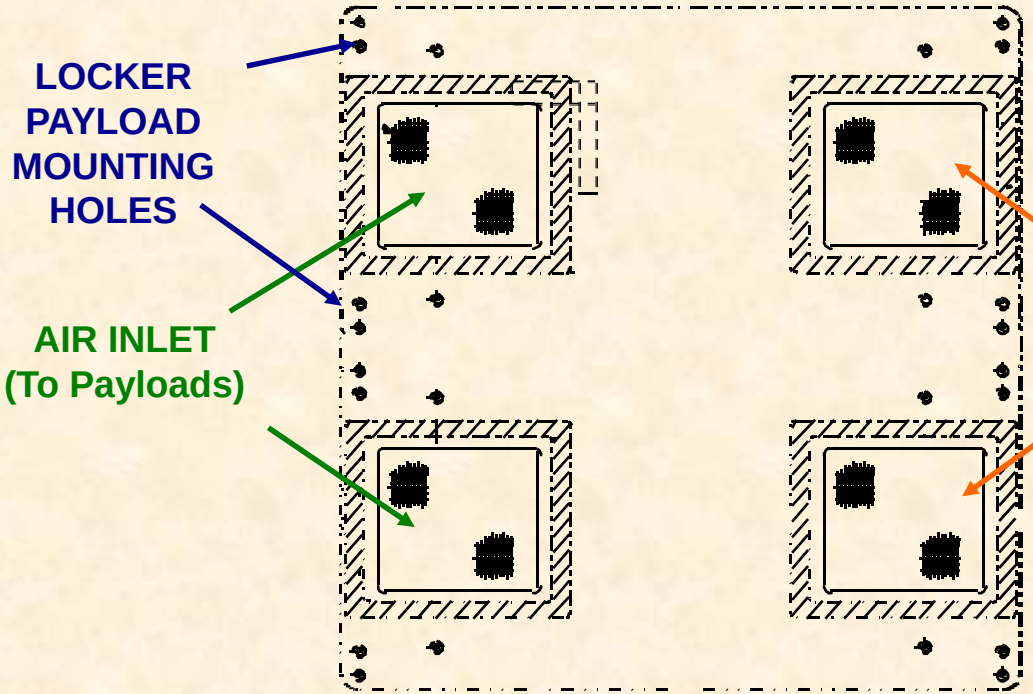


NASA provides a powered ISIS drawer for ground integration of powered payloads

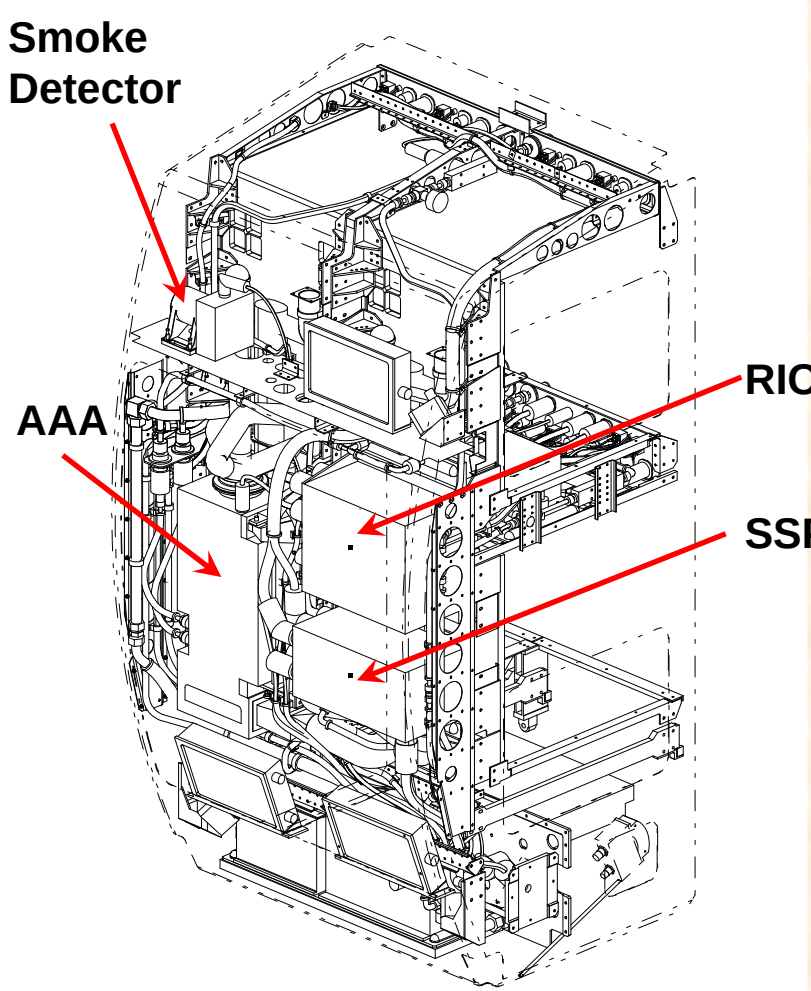
EXPRESS Subrack Payload Mounting

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

Front View



EXPRESS Subsystems

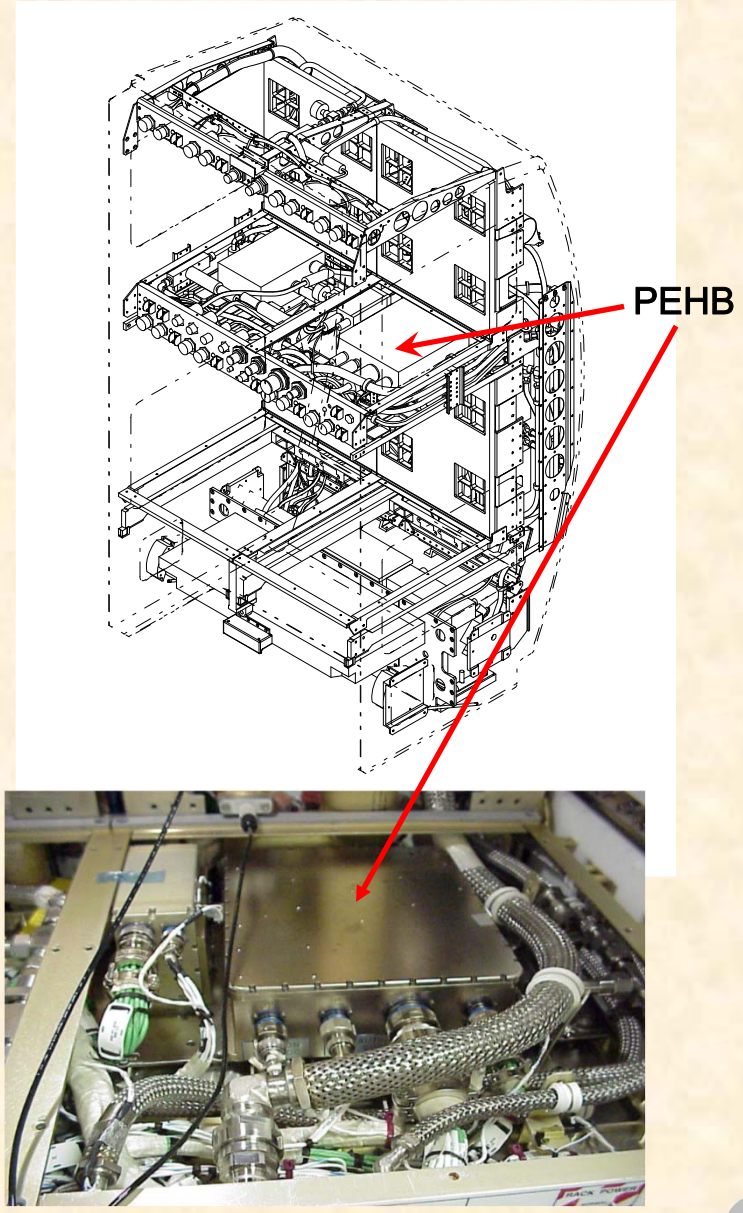


Rear View

- **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

- **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 2015-2016
  - 100 Mbps Ethernet



EXPRESS Subsystems

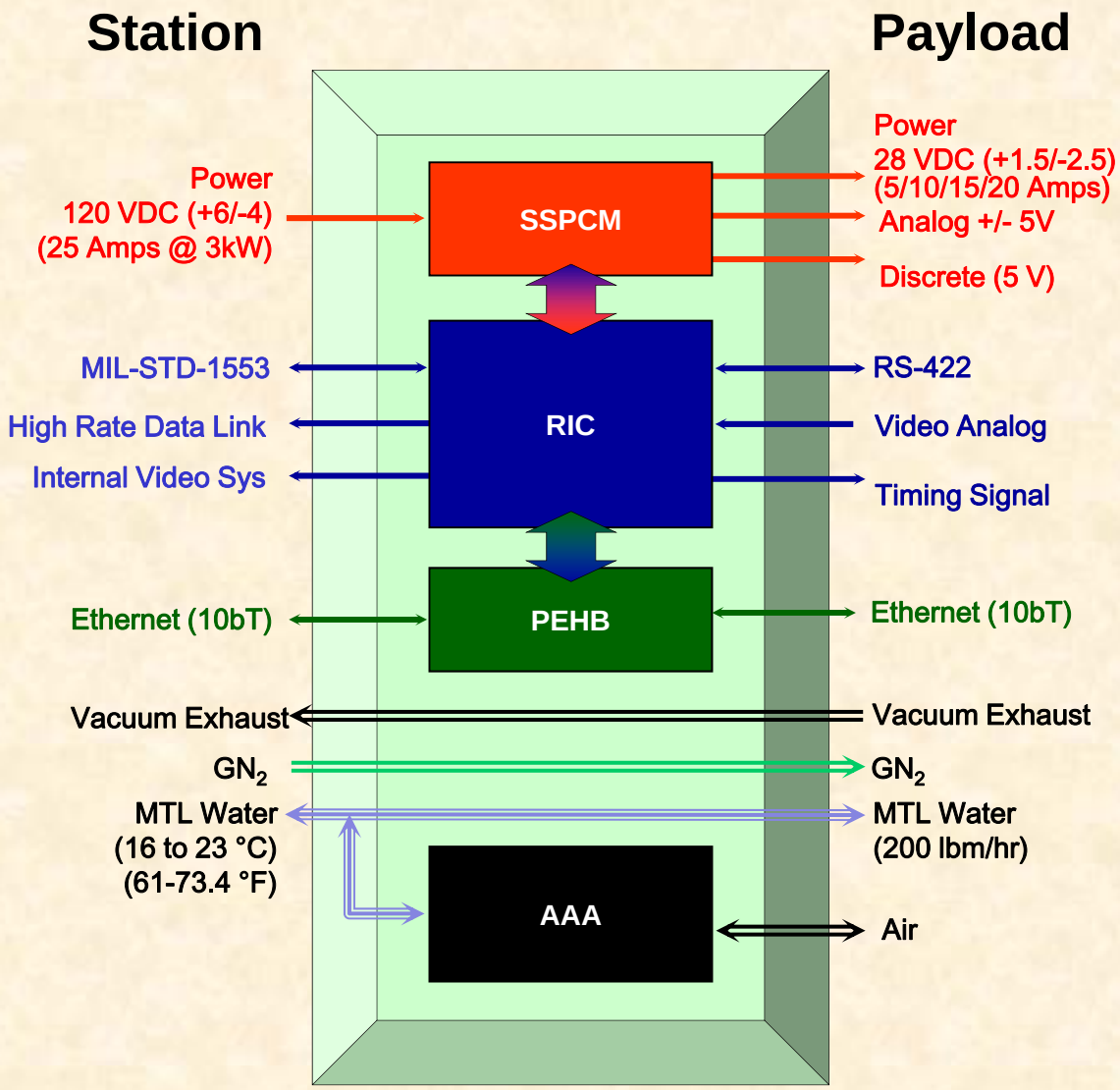
ELC: EXPRESS Laptop Computer

- 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 March 2014

EXPRESS Subsystems

- **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



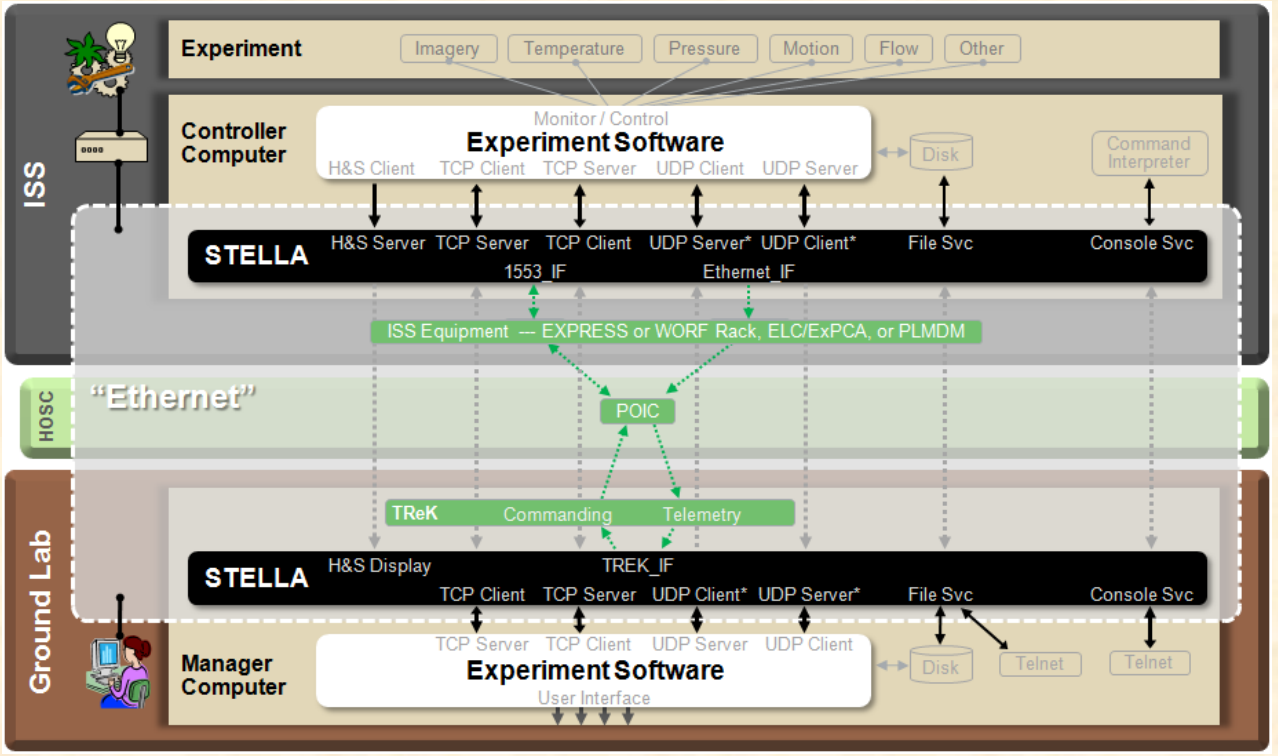
EXPRESS Payload Resources

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

Software Toolkit for Ethernet Lab-Like Architecture (STELLA)

- **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 uplink
  - 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

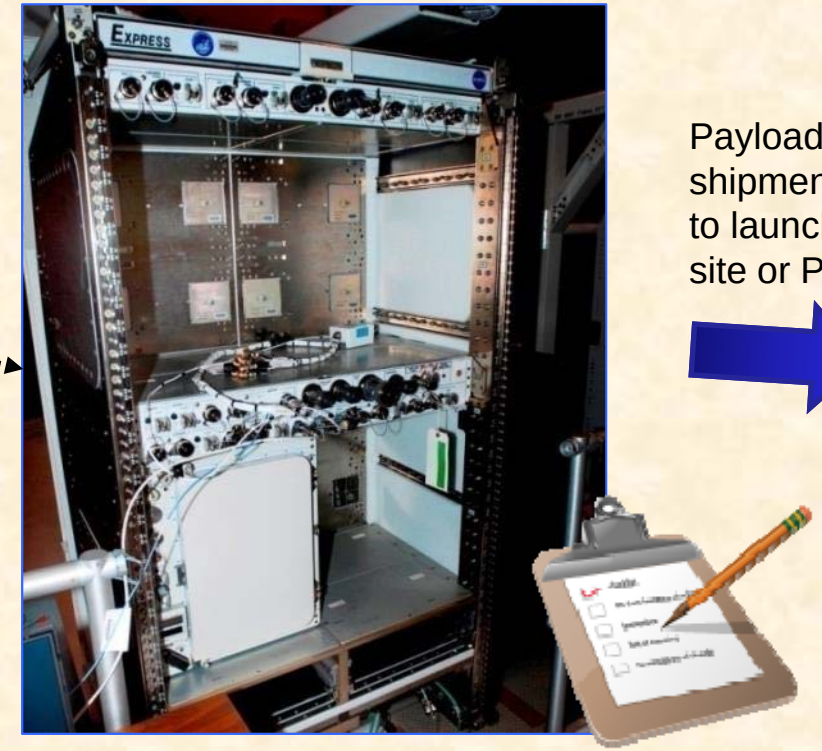
Payload

Rack simulator s/w provided for development

C&DH remote test possible using VPN

Virtual Private Network

EXPRESS Rack Functional Checkout Unit



Payload shipment to launch site or PD

Payload shipment to MSFC

Off-gas

Vibration

EMI/EMC

Acoustics

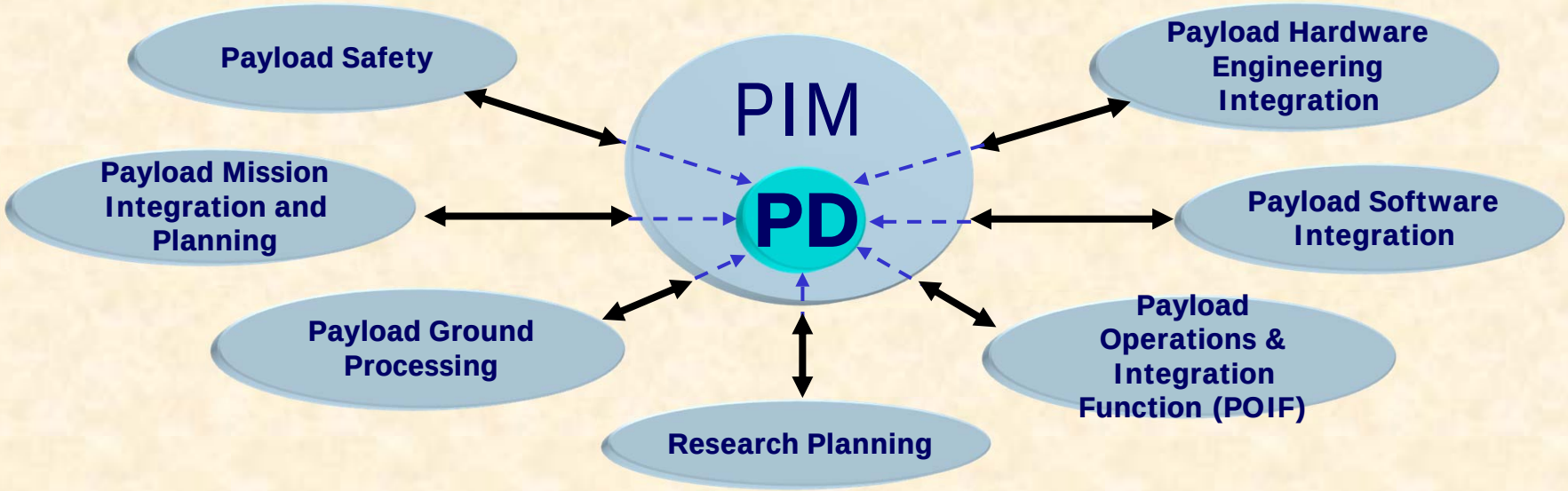
Additional Services Available

- 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

NASA Payload Integration Manager (PIM)

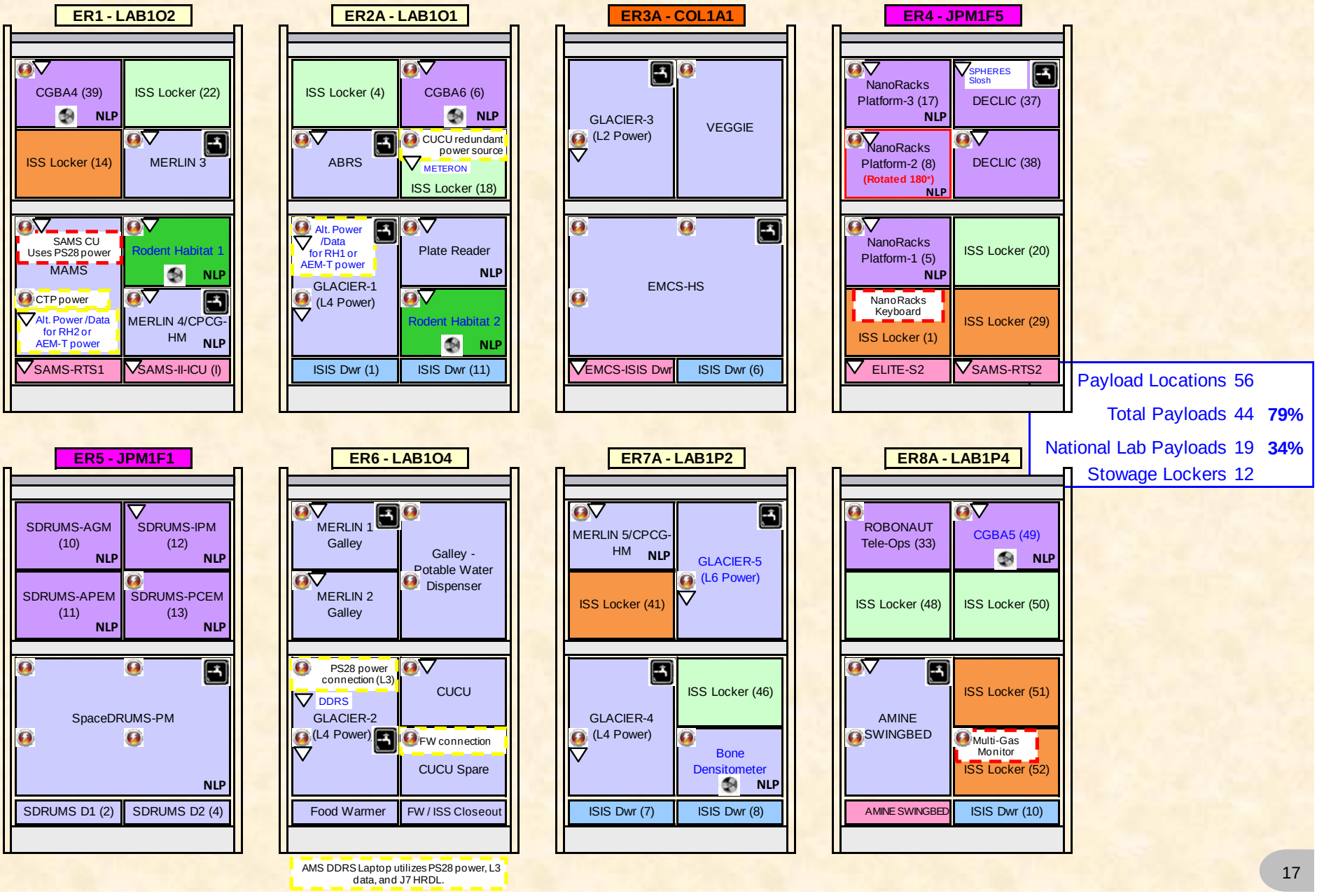
- Functions as the Payload Developer's primary interface to the ISS Program
- Serves as payload advocate while protecting ISS Program Requirements



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

EXPRESS Topology – 9/26/14

Conducting Research on the ISS using the EXPRESS Rack

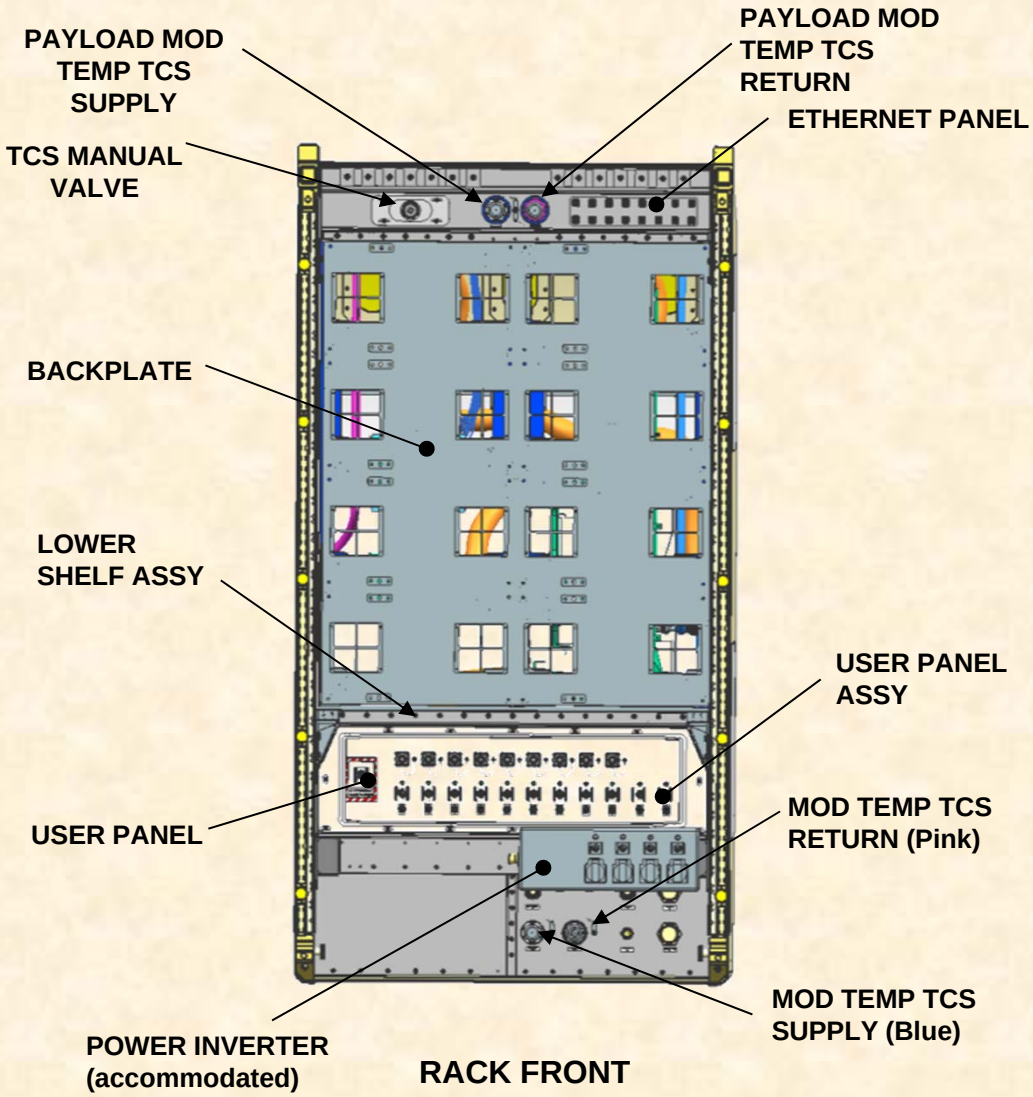


Payload Locations	56	
Total Payloads	44	**79%**
National Lab Payloads	19	**34%**
Stowage Lockers	12	

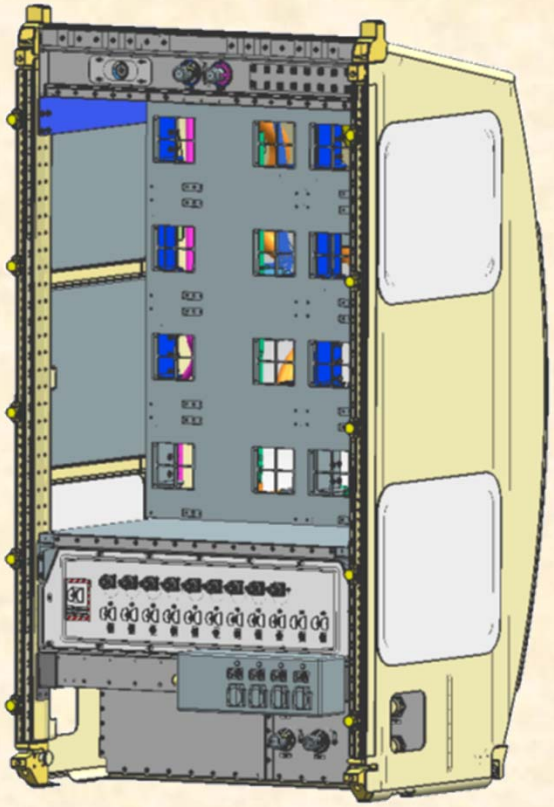
Basic Express Rack Concept

- NASA has identified the need to accommodate additional EXPRESS payloads on ISS
- NASA and Boeing are developing an additional 2 or 3 racks with limited functionality
  - Systems Requirements Review held 7/23/14
  - Concept waiting ISS Program approval
  - Anticipated on-orbit in 2018
- Basic Express Rack (BER) Architecture defined
  - Accommodations
    - 8 locker locations
    - Approximately 2000 W at 28Vdc available for payloads
    - Air cooling to payloads provided by Avionics Air Assembly (AAA)
    - Moderate Temperature Loop (MTL) interface provided with manually adjusted flow rate
    - ISS Smoke Detector (SD) provided
    - 16 port 100 baseT Ethernet Switch provided for C&DH interface to payloads
    - Payload MDM software modification to allow handling of payload health & status data and commands to payloads (replaces RIC)
    - 120Vdc outlet to accommodate the 120Vac inverter.
  - Racks designated ER9B, 10B and 11B

Basic Express Concept



RACK FRONT



RACK SIDE (ISO)

Proposed Basic Express Rack Payload Resources

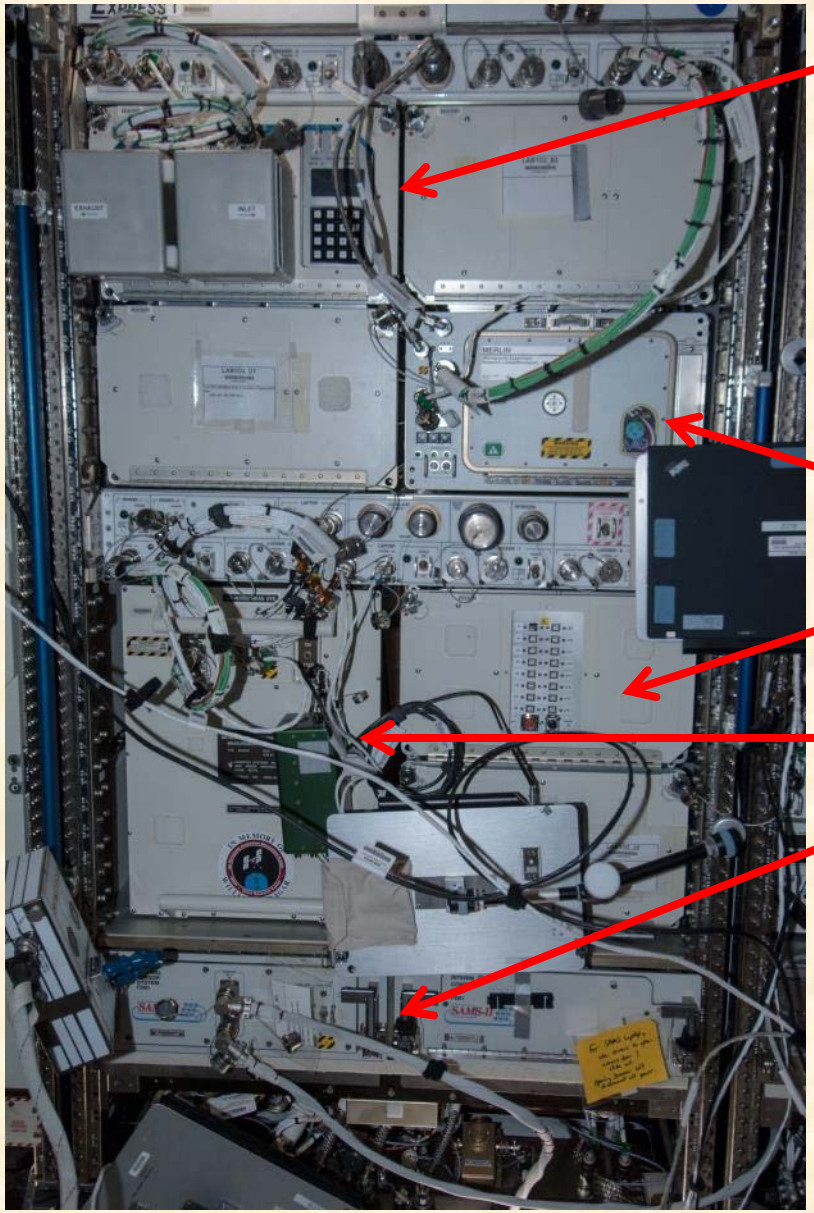
Resource	Amount per Payload Position	
	EXPRESS	Basic Express Rack
Structural Attachment	Attachment to Rack per IDD •Mass constraint launch vehicle dependent	Same
Power	5, 10, 15, or 20 Amp at 28 VDC	10 or 20 Amp at 28 VDC, manual only
Thermal Control Air	Nominal 150 W (1200 W rack maximum)	Same
Thermal Control Water	500 W Heat Rejection per position (2 positions per rack)	500 W Heat Rejection (1 position per rack)
Data	•1 - RS-422 •2 - +/- 5 Vdc Analog •1 - Ethernet •3 - 5 Vdc Discrete (bi-dir)	•1 - Ethernet
Video	NTSC/RS 170A feed from payload source (Shared)	None
Venting	1 payload interface per rack (Shared)	None
Nitrogen	1 payload interface per rack (Shared, 12 lbm/hr)	None
Aux Power	Automatic failover when set	None (TBD)

Summary

- **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.**
- **NASA is planning to expand the EXPRESS payload capacity by developing new Basic Express Racks expected to be on ISS in 2018.**

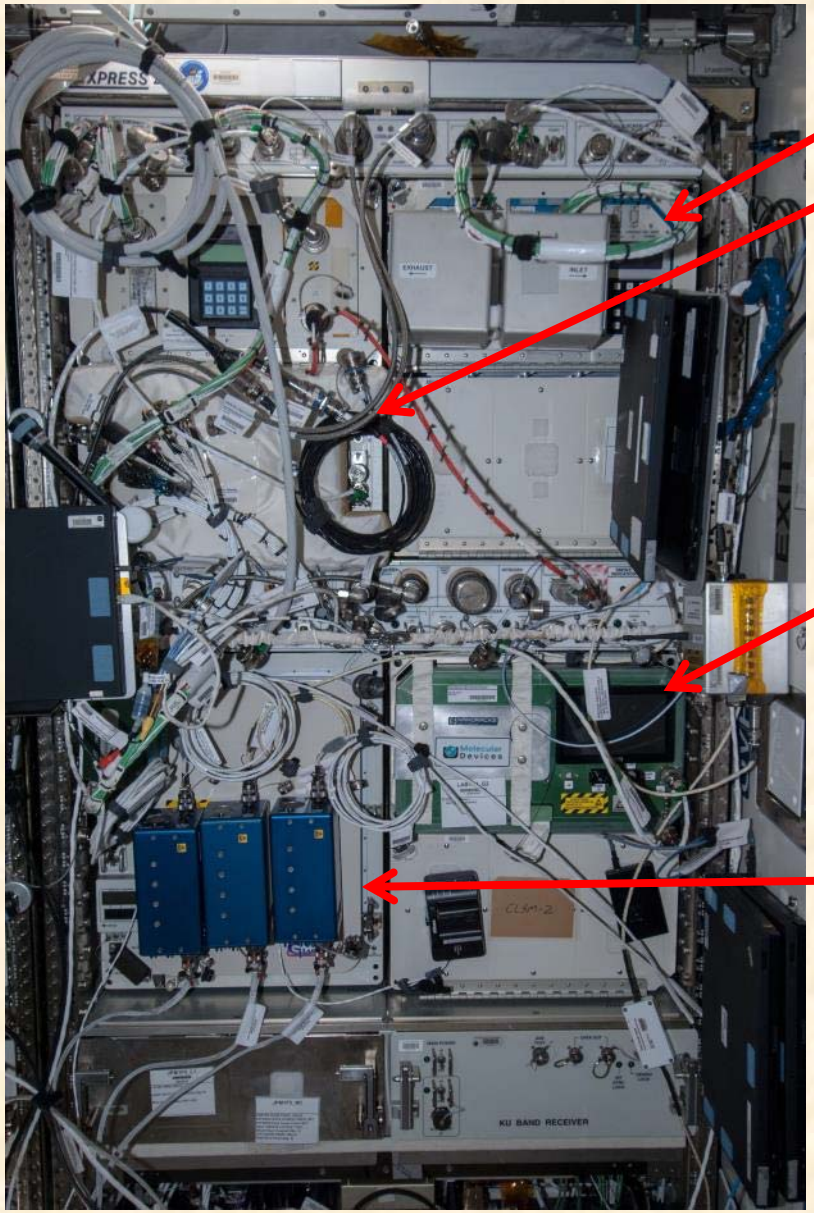
Back Up Material

EXPRESS Rack 1 INC 35



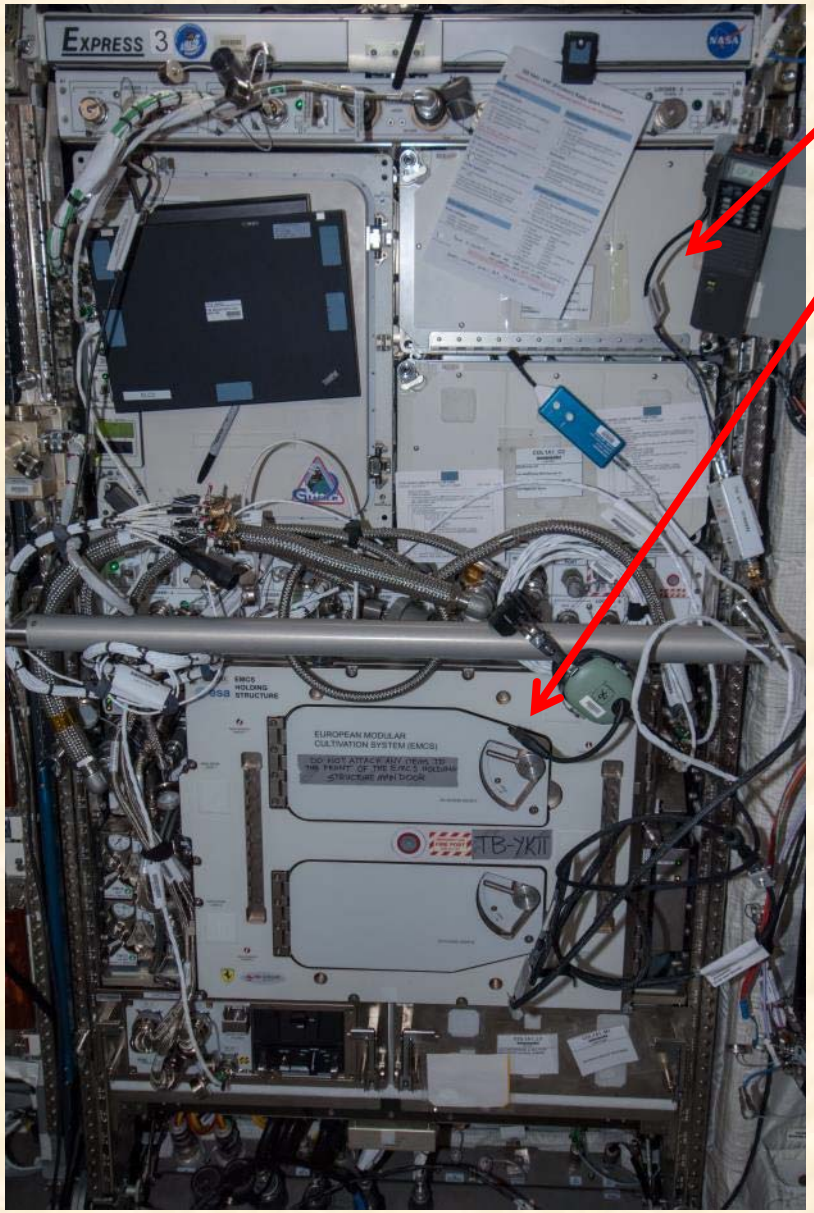
- **Commercial Generic Bioprocessing Apparatus (CGBA) 4**
  - **Provides programmable, accurate temperature control for applications ranging from cold stowage to customizable incubation for experiments on cells, microbes, and plants.**
  - **http://www.nasa.gov/mission_pages/station/research/experiments/CGBA.html**
- **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 International Space Station (ISS) that result from the operation of hardware, crew activities, dockings and maneuvering.**
  - **http://www.nasa.gov/mission_pages/station/research/experiments/914.html**

EXPRESS Rack 2 INC 35



- **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**
- **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**
- **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**

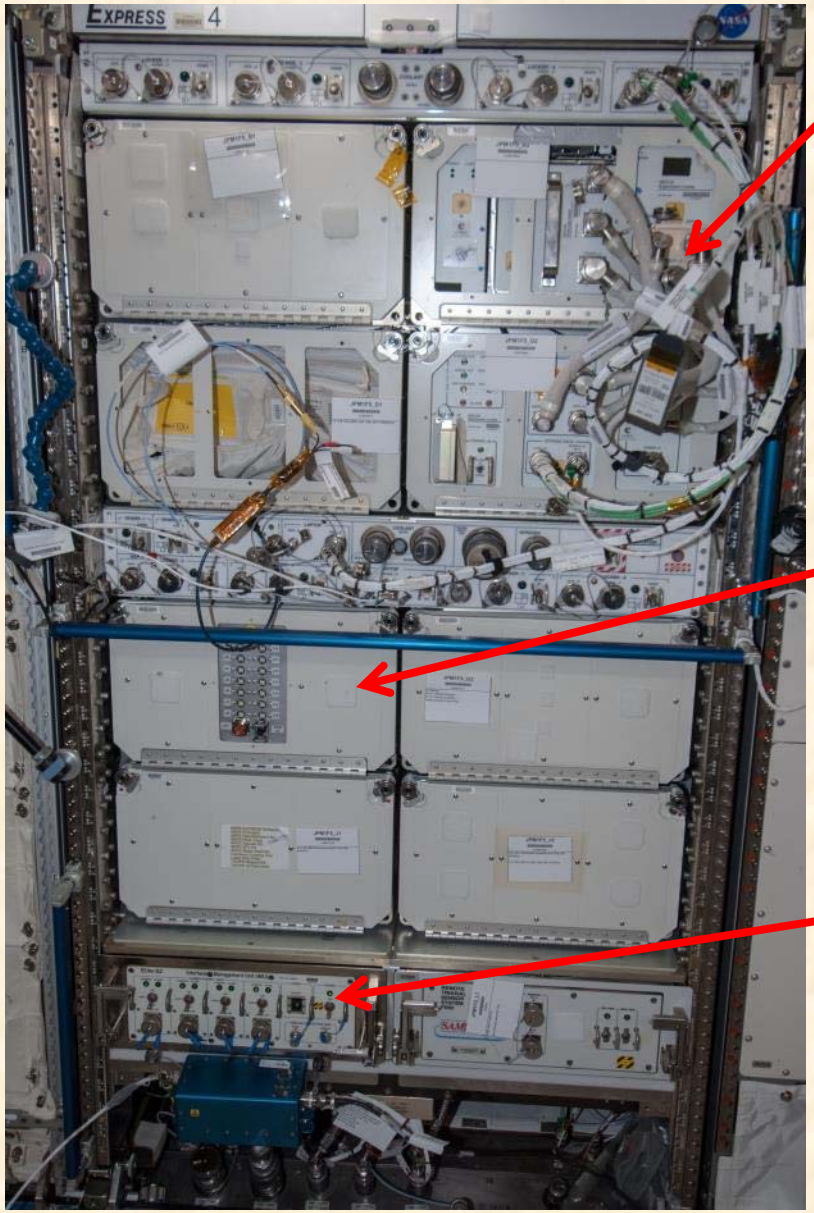
EXPRESS Rack 3 INC 35



- **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**

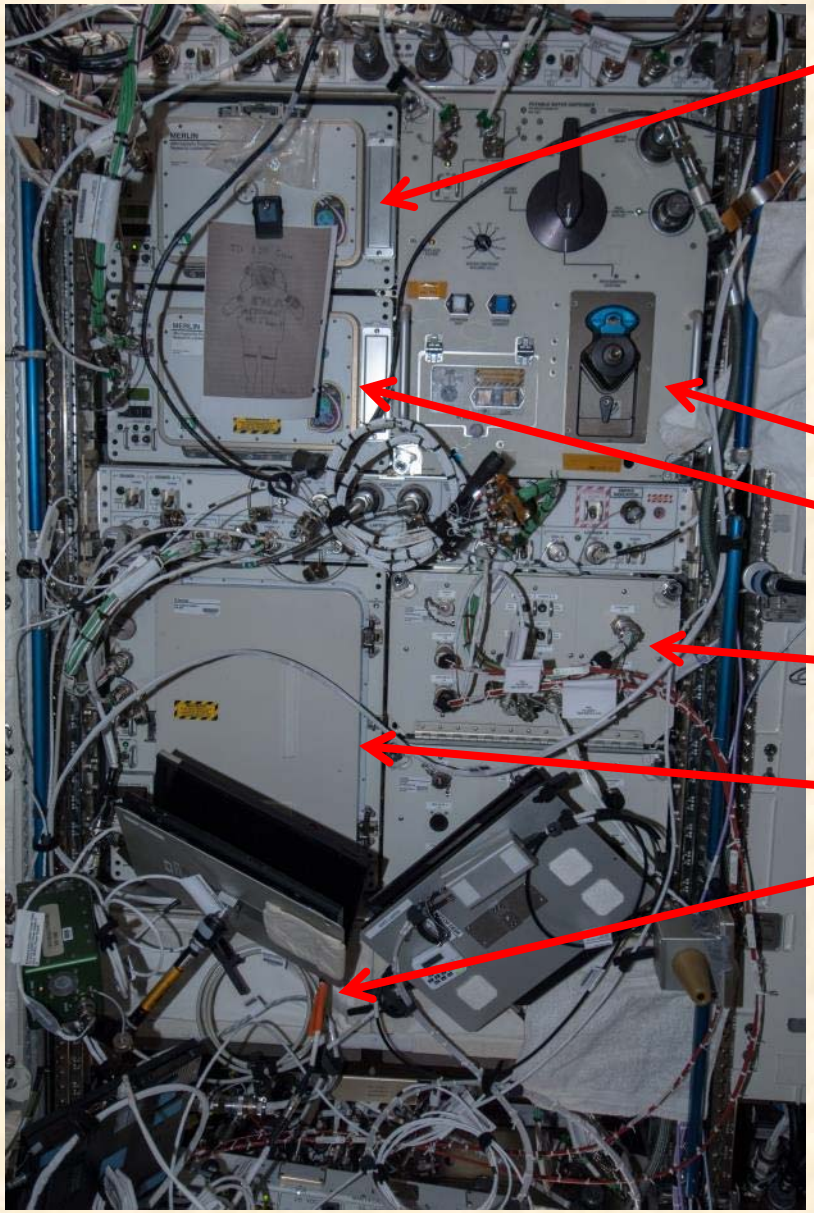
EXPRESS Rack 4 INC 35

Conducting Research on the ISS using the EXPRESS Rack



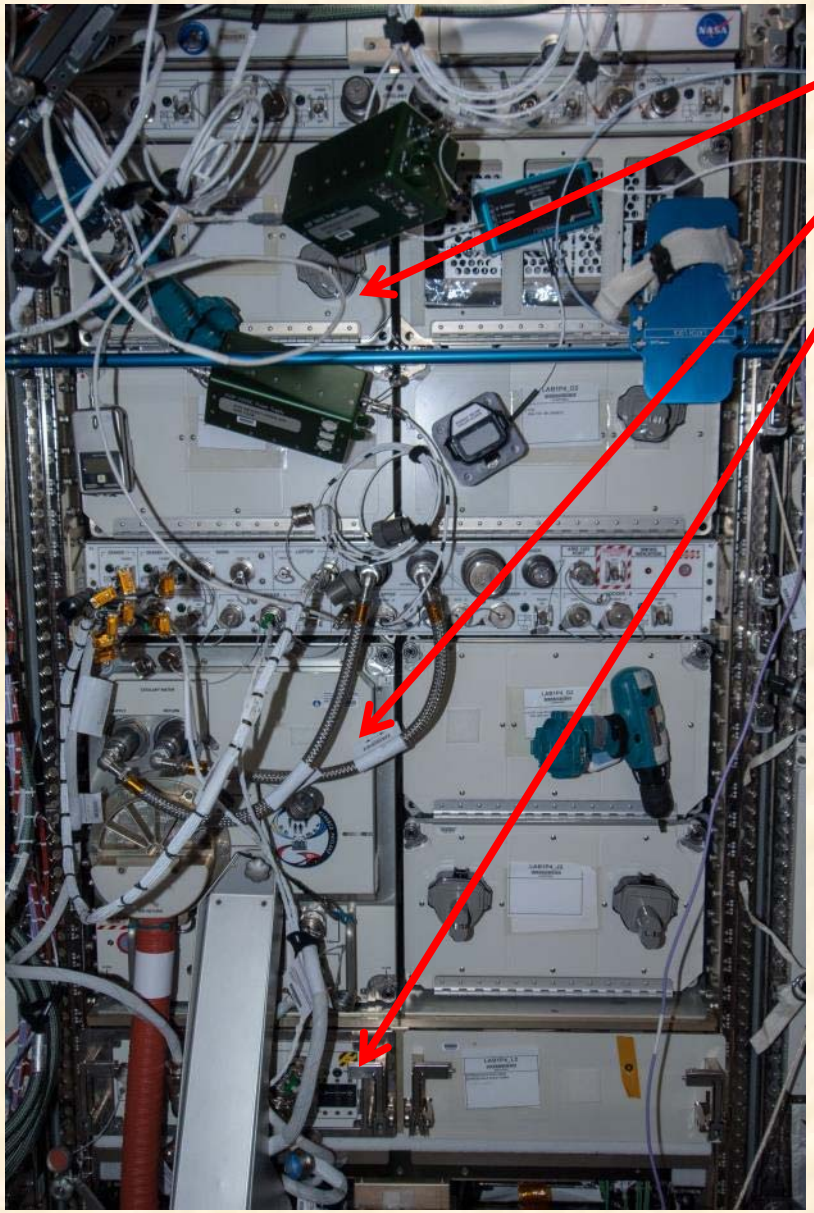
- **DEvice for the study of Critical LIquids and Crystallization (DECLIC)**
  - **Multi-user facility utilized to study transparent media and their phase transitions in microgravity.**
  - **Established the precise temperature (373.995 °C) at which water becomes supercritical.**
  - **http://www.nasa.gov/mission_pages/station/research/experiments/203.html**
- **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 Rack 6 (Galley)



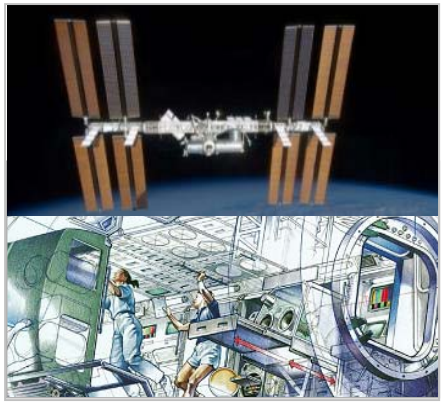
- **Microgravity Experiment Research Locker/INcubator (MERLIN) 1**
  - **Freezer/refrigerator or incubator that can be used for a variety of experiments.**
  - **Temperature range for MERLIN is -20 °C (-4 °F) to + 48.5 °C (+119 °F).**
  - **http://www.nasa.gov/mission_pages/station/research/experiments/MERLIN.html**
- **Potable Water Dispenser**
- **Microgravity Experiment Research Locker/INcubator (MERLIN) 2**
- **COTS UHF Communication System (CUCU)**
- **GLACIER 2**
- **Food Warmer**

EXPRESS Rack 8 INC 35



- **Robonaut Tele-Ops**
- **Amine Swingbed**
  - **Investigation determines if a vacuum-regenerated amine system can effectively remove carbon dioxide (CO_2) from the ISS atmosphere using a smaller more efficient vacuum regeneration system.**
  - **http://www.nasa.gov/mission_pages/station/research/experiments/Amine_Swingbed.html**

EXPRESS – EXpedite the PRocessing of Experiments for Space Station – Research Accommodations

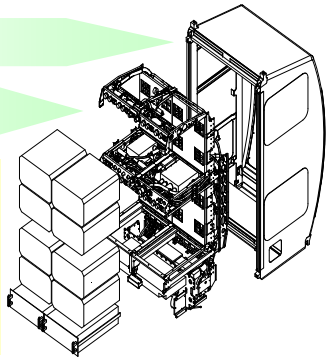


EXPRESS 8/2 Configuration

International Standard Payload Rack

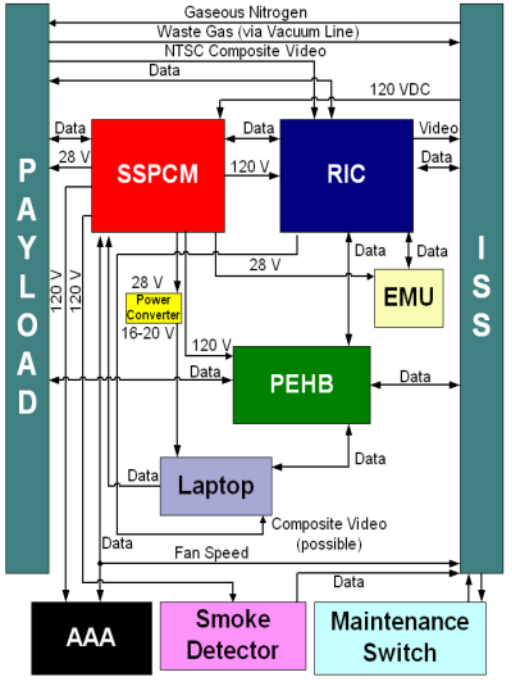
Secondary Structure & Subsystems

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



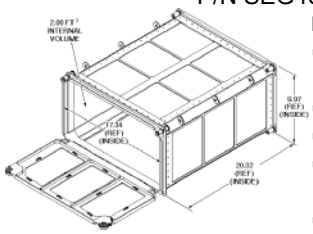
Integrated Rack

EXPRESS 8/2 Functional Block Diagram



ISS Locker

P/N SEG46117022



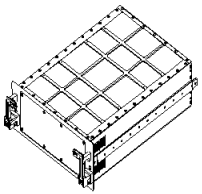
Features

- 4 rear captive fastener attachments
- Friction hinge
- Dual door locks
- Installation tool guides on 4 corners
- Weight – 13 lbs empty
- Volume – 2 ft³

International Subrack Interface Standard Drawer

Powered P/N 683-43650

Stowage P/N 683-43656



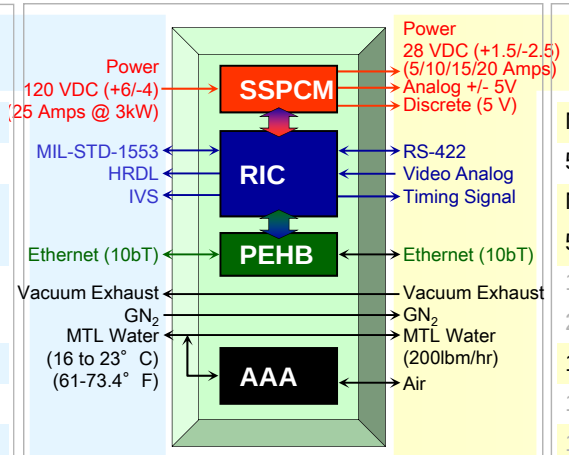
Features

- 4 PU (Panel Unit)
- Blind Connectors
- Locking Handles
- Weight – 26 lbs empty
- Volume – 1.26 ft³

EXPRESS Laptop Computer

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

Type	Total EXPRESS Rack Accommodations
Structural	8 Lockers & 2 4-PU ISIS Drawers
Power	2000 W 28 VDC power to payloads
Thermal Control	2000 W payload heat rejection air/water combined (1200 W air)
Data	10 – RS-422; 10 – Ethernet; 18 – Analog; 28 – Discrete (bi-dir)
Video*	1 – NTSC feed from each payload
Vacuum Exhaust	1 – Payload connection
Nitrogen	1 – Payload connection



EXPRESS Functional Interfaces

ISS Locker Position Accommodations**	4-PU Drawer Position Accommodations**
Mass vehicle dependent	64 lb total within cg constraints
5/10/15/20 Amps (@28 VDC)	5/10/15/20 Amps (@28 VDC)
Nominal – 150 W (Ducted Air)	Nominal – 150 W (Ducted Air)
500 W – 2 positions (Water)	500 W – 2 positions (Water)
1 – RS-422; 1 – Ethernet;	1 – RS-422; 1 – Ethernet;
2 – Analog; 3 – Discrete	1 – Analog; 2 – Discrete
1 – NTSC/170A feed - Shared	1 – NTSC/170A feed - Shared
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

Rack Rear View

EXPRESS Rack Connector Panels

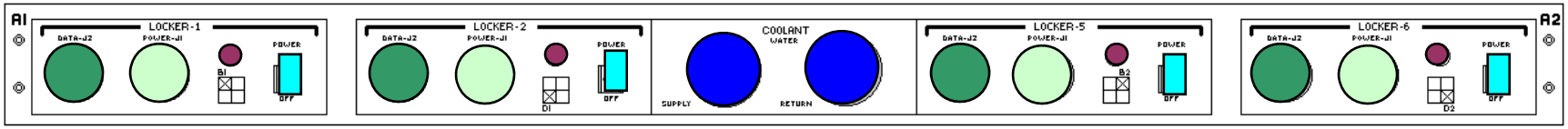
Power Ports

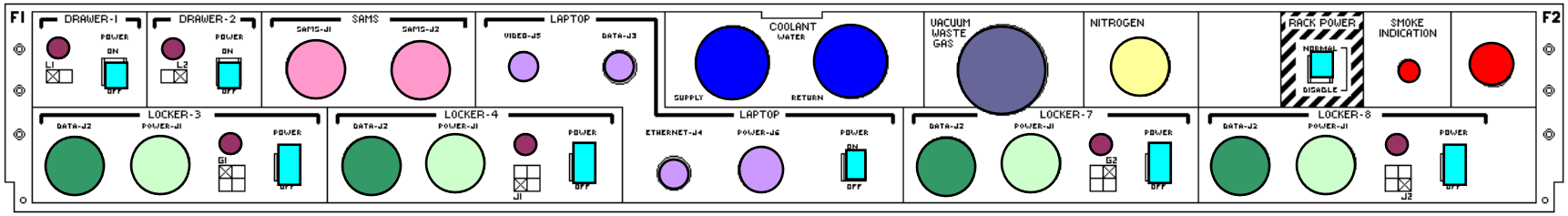
SAMS Data Ports

Data Ports

ELC Video/Data/Ethernet/Power

Upper Connector Panel





Power Switches

Vacuum Waste Gas

Nitrogen

Lower Connector Panel

Water Supply & Return

LEDs

Smoke Indication LED
& Fire Port (PFE Access)

EXPRESS Topology - Legend

ISS Locker - Stowage Locker

ISS Locker (no door) - Stowage Locker w/o door

ISS Locker - Location reserved for Lean Payloads

Payload - Payload Insert (Payload inserted into ISS Locker or ISIS Drawer)

Payload - Locker Replacement Payload

ISIS Dwr - ISIS Drawer

Payload - Drawer Replacement Payload

 - requires water (TCS)

 - requires EXPRESS Rack provided power

 - requires EXPRESS Rack provided data connection

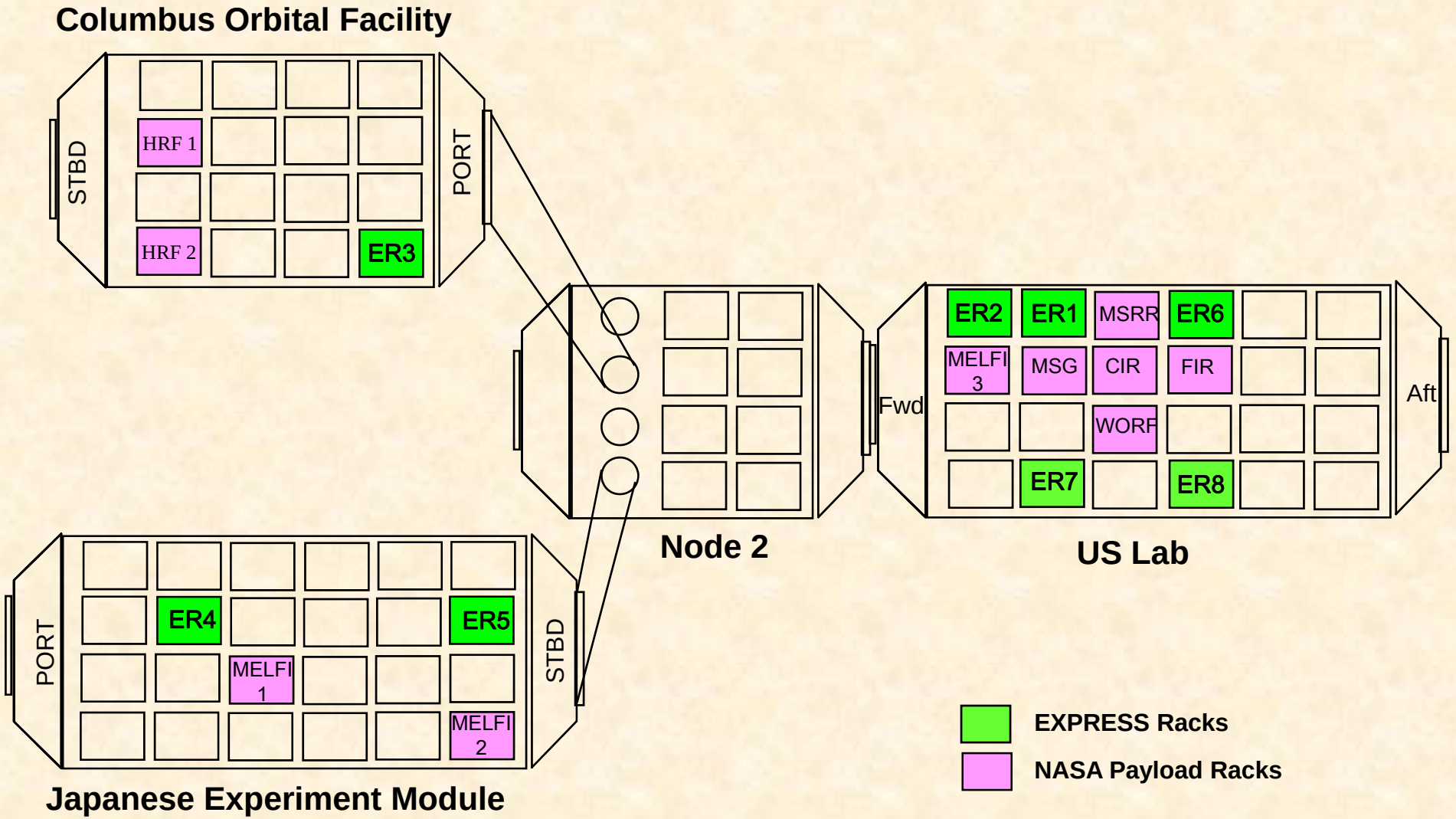
 - Front Breather payload

 - deployed payload

 - power resource utilized

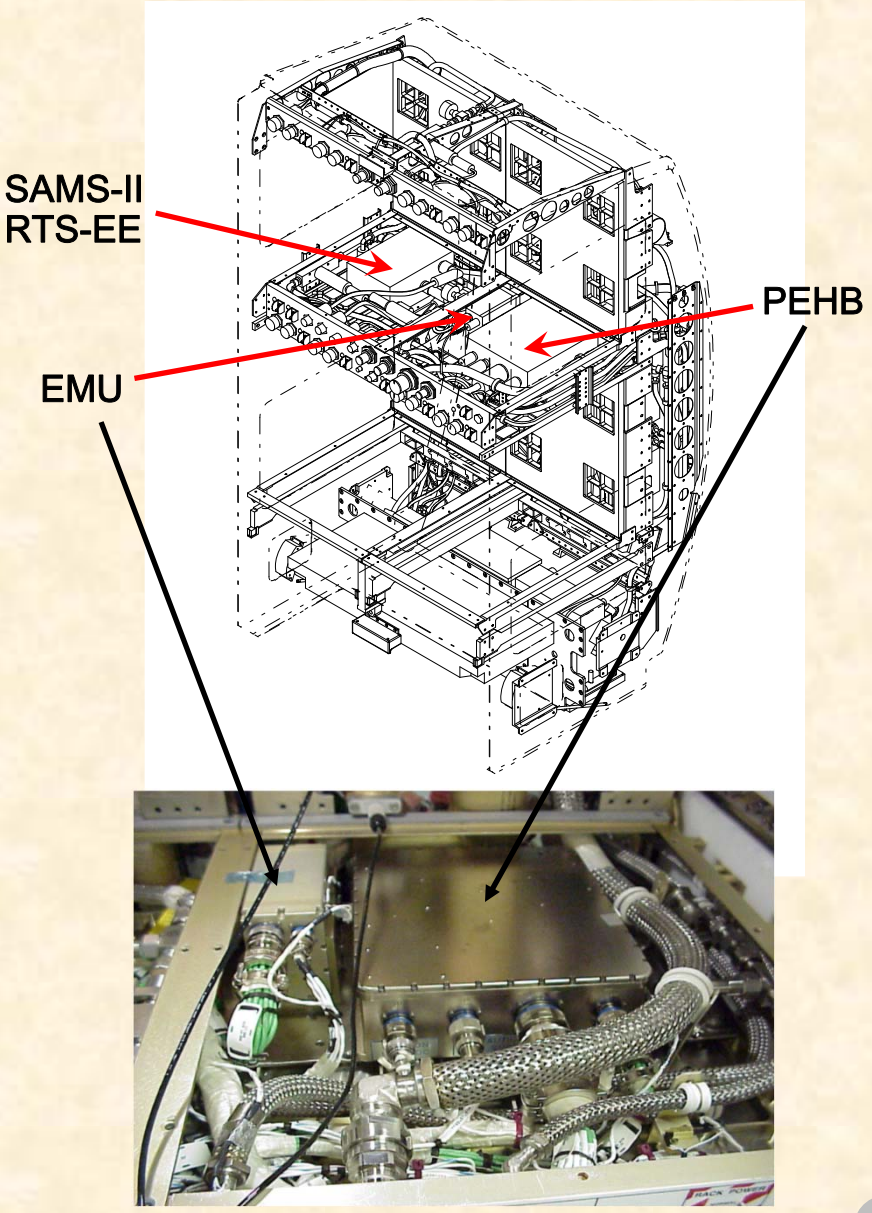
NLP - National Lab Payload

ISS Topology at Assembly Complete



EXPRESS Subsystems

- **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

- 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)