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

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➢ **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
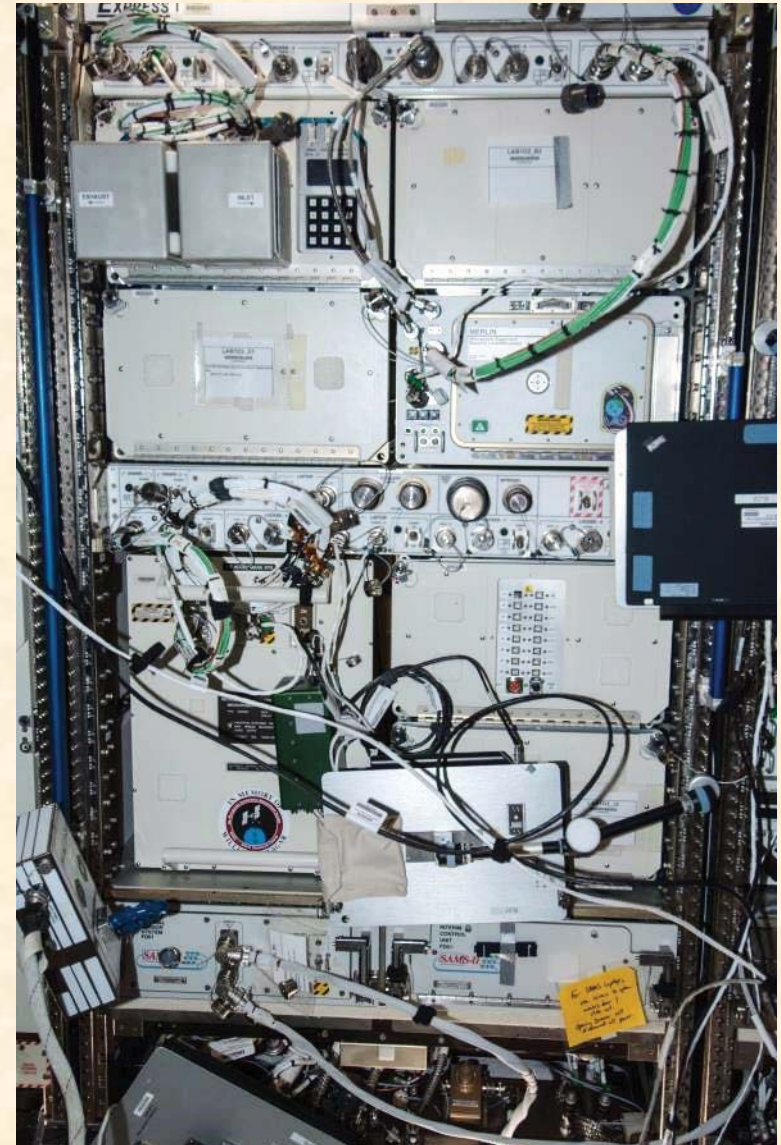
EXPRESS Rack 1, 7/9/13
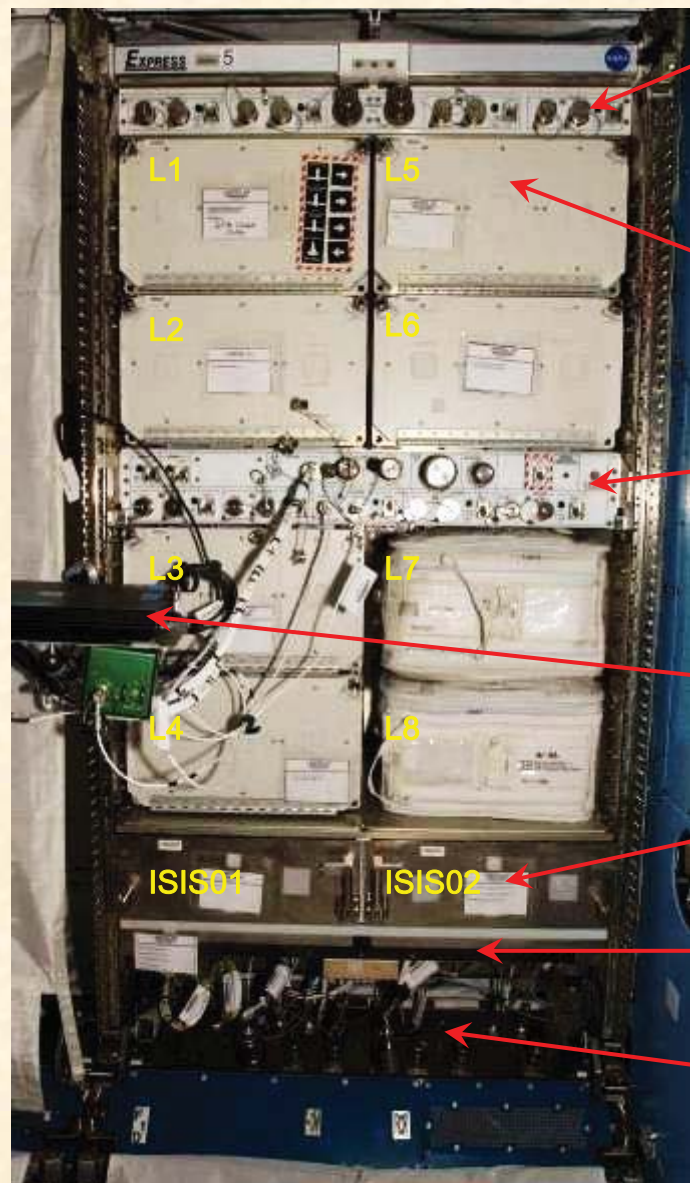
Upper Connector Panel

Lockers (8 locations)

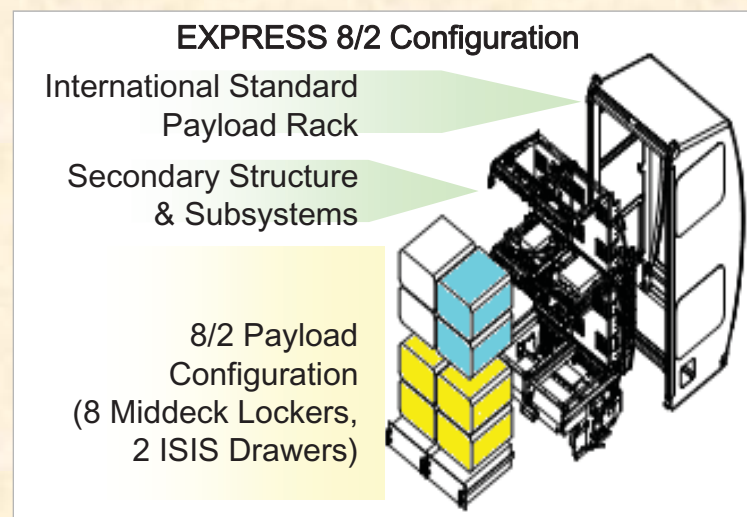Lower Connector Panel

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

International Standard Payload Rack

Secondary Structure & Subsystems

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

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
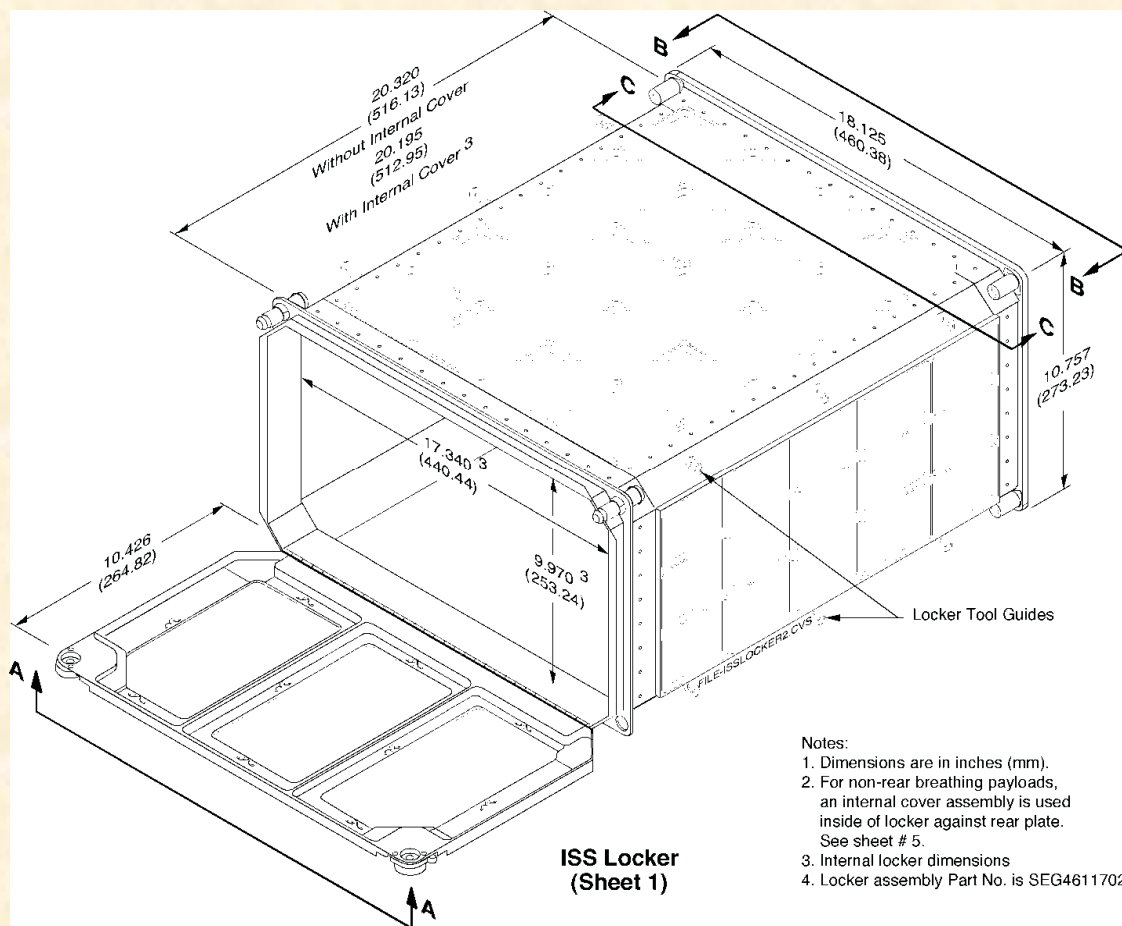
Rack	Location (Lab, Bay)	Launch (Flight, Date)	Sep. 2013 Operating Hrs	Total Operating Hours
EXPRESS Rack #1	US Lab, O2	6A, 4/19/01	720	91,133
EXPRESS Rack #2A	US Lab, O1	6A, 4/19/01	720	59,294
EXPRESS Rack #3A	Columbus, P2	UF2, 6/5/02	717	24,458
EXPRESS Rack #4	JEM, F5	7A.1, 8/10/01	720	86,015
EXPRESS 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

20.320
(516.13)
Without Internal Cover
20.195
(512.95)
With Internal Cover 3

18.125
(460.38)

10.757
(273.23)

17.340 3
(440.44)

10.426
(264.82)

9.970 3
(253.24)

Locker Tool Guides

FILE-ISSLOCKER2.CVS

Notes:
1. Dimensions are in inches (mm).
2. For non-rear breathing payloads, an internal cover assembly is used inside of locker against rear plate. See sheet # 5.
3. Internal locker dimensions
4. Locker assembly Part No. is SEG46117022

ISS Locker
(Sheet 1)

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

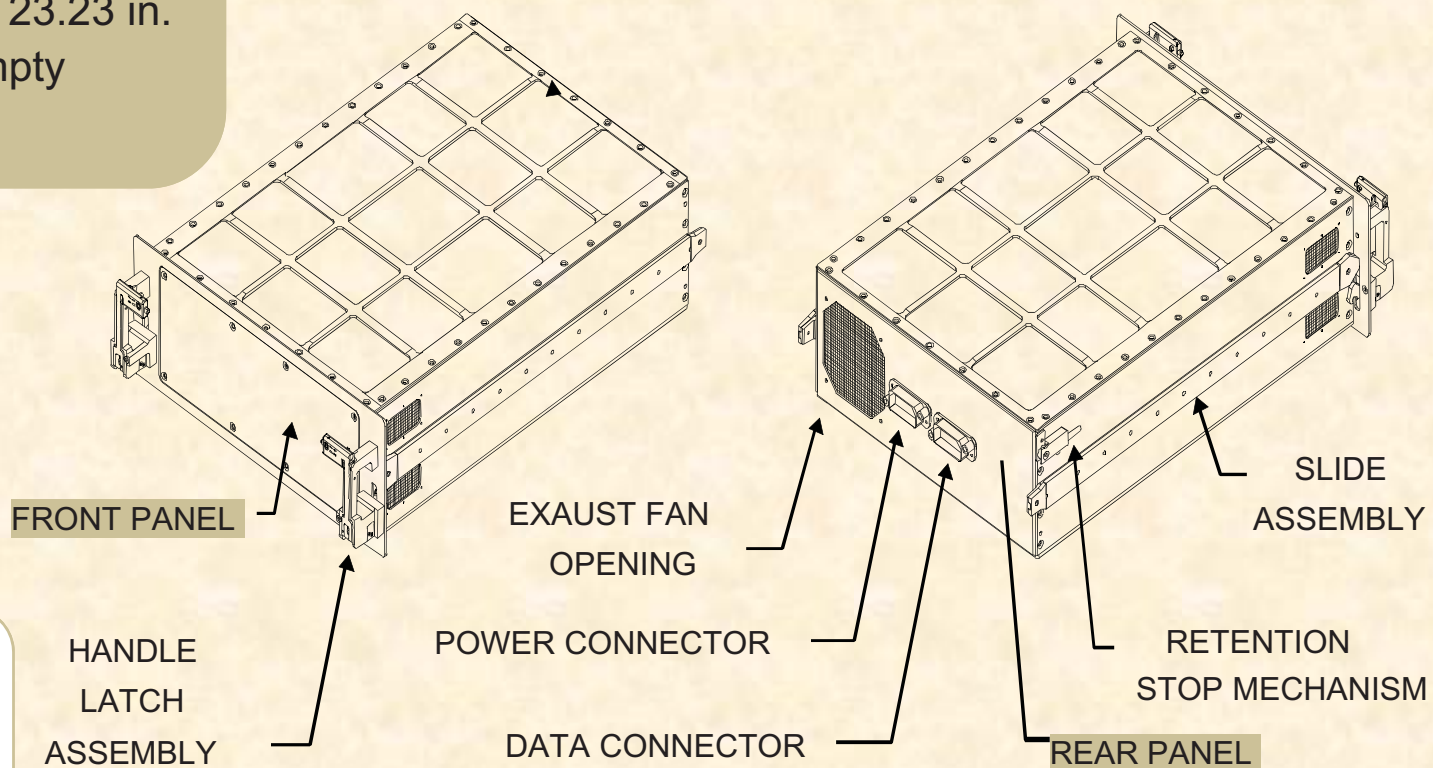Payloads can either be locker "inserts" or locker "replacements"

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

FRONT PANEL

HANDLE LATCH ASSEMBLY

EXAUST FAN OPENING

POWER CONNECTOR

DATA CONNECTOR

SLIDE ASSEMBLY

RETENTION STOP MECHANISM

REAR PANEL

EXPRESS Subrack Payload Mounting

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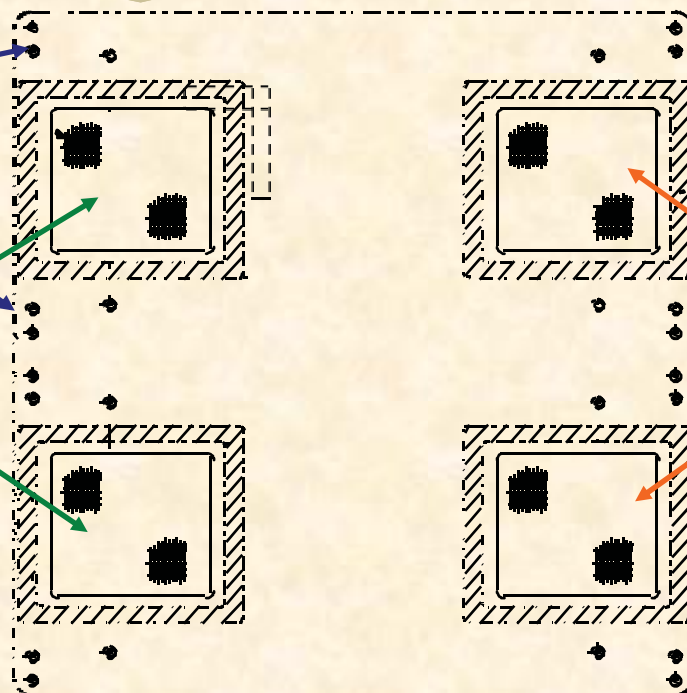- **Subsystem equipment located behind connector panels or mounting plates**

LOCKER PAYLOAD MOUNTING HOLES

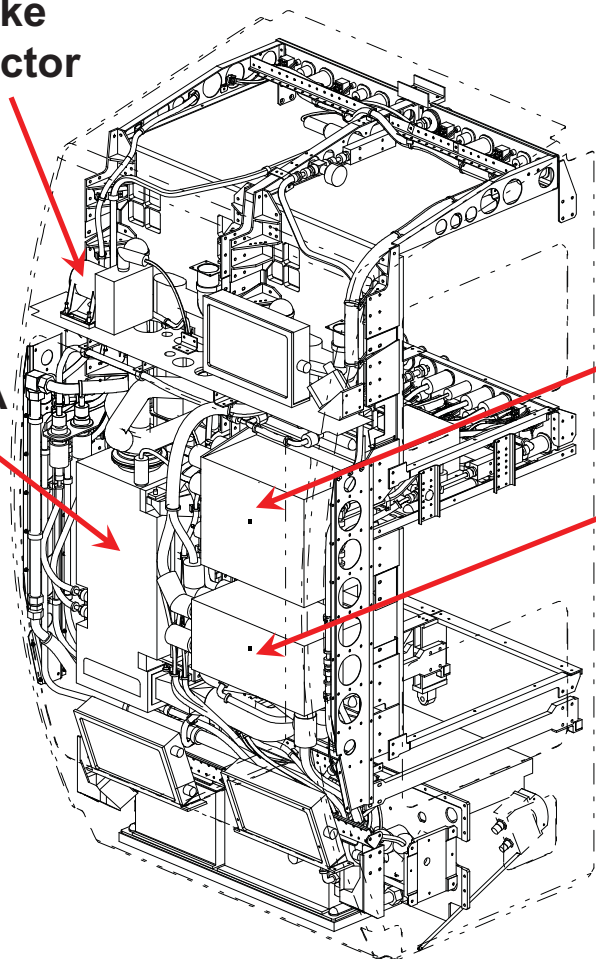**AIR INLET (To Payloads)**

AIR OUTLET (From Payloads)

Front View

EXPRESS Subsystems

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

➤ **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
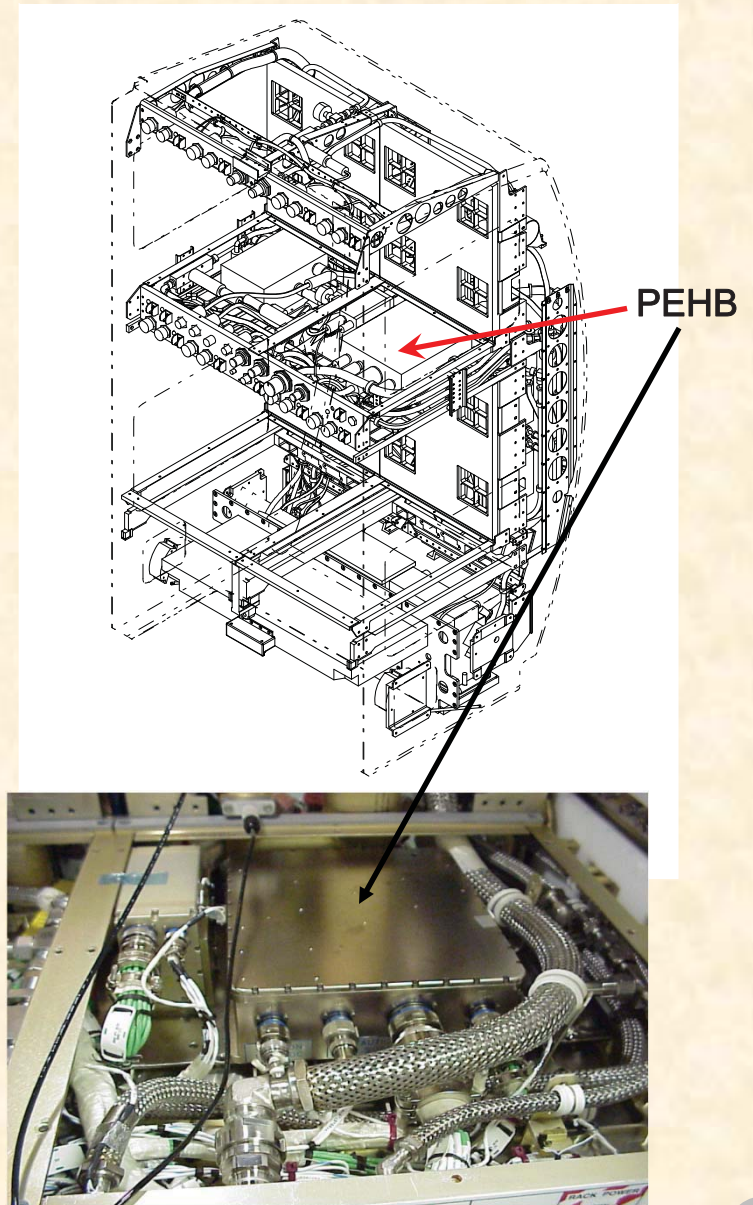
PEHB

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

➢ **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

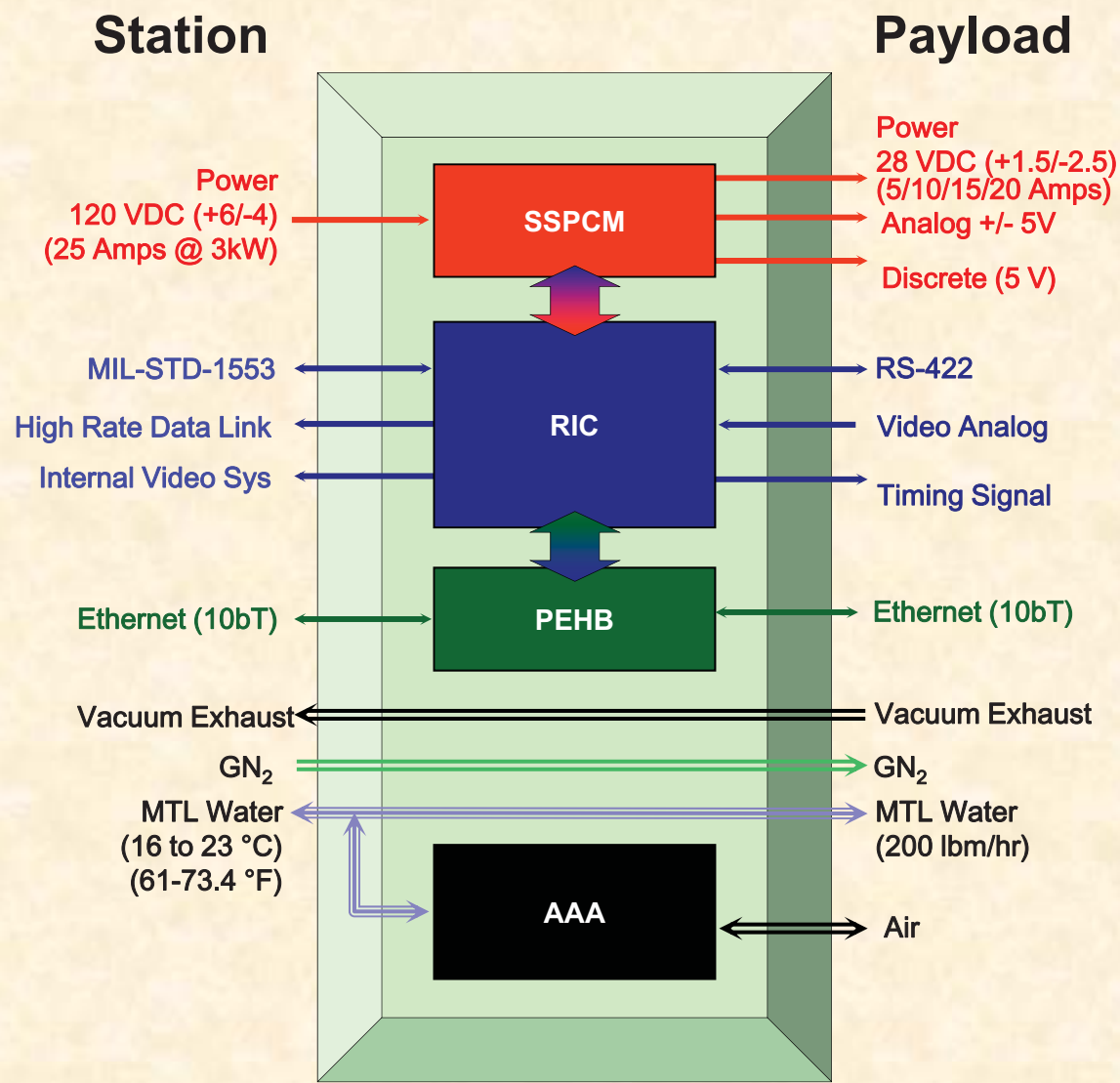➢ **Fire Detection System (FDS)**

- 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

Station

Payload

Power
120 VDC (+6/-4)
(25 Amps @ 3kW)

SSPCM

Power
28 VDC (+1.5/-2.5)
(5/10/15/20 Amps)
Analog +/- 5V

Discrete (5 V)

MIL-STD-1553

RIC

RS-422

High Rate Data Link

Video Analog

Internal Video Sys

Timing Signal

Ethernet (10bT)

PEHB

Ethernet (10bT)

Vacuum Exhaust

Vacuum Exhaust

GN_2

GN_2

MTL Water
(16 to 23 °C)
(61-73.4 °F)

MTL Water
(200 lbm/hr)

AAA

Air

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**
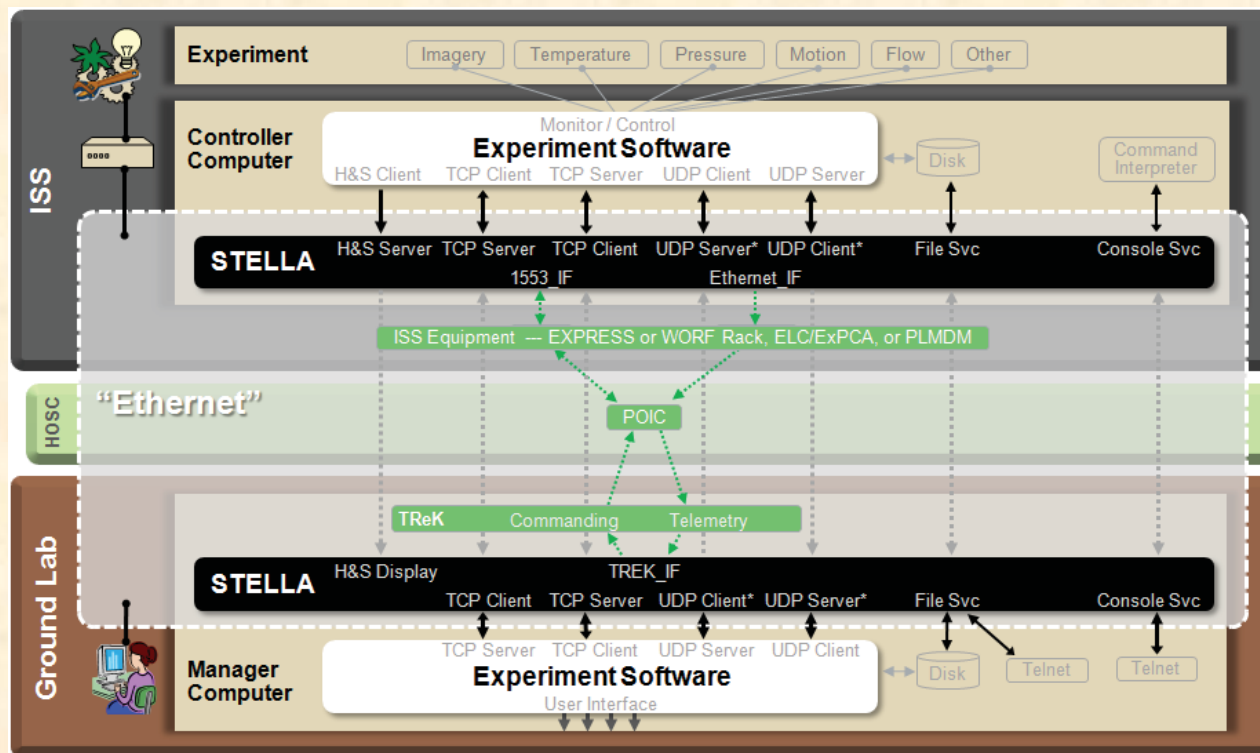
Payload Testing for EXPRESS Rack

Payload

Rack simulator s/w provided for development

C&DH remote test possible using VPN

EXPRESS Rack Functional Checkout Unit

Payload shipment to launch site or PD

Virtual Private Network

Payload shipment to MSFC

Off-gas

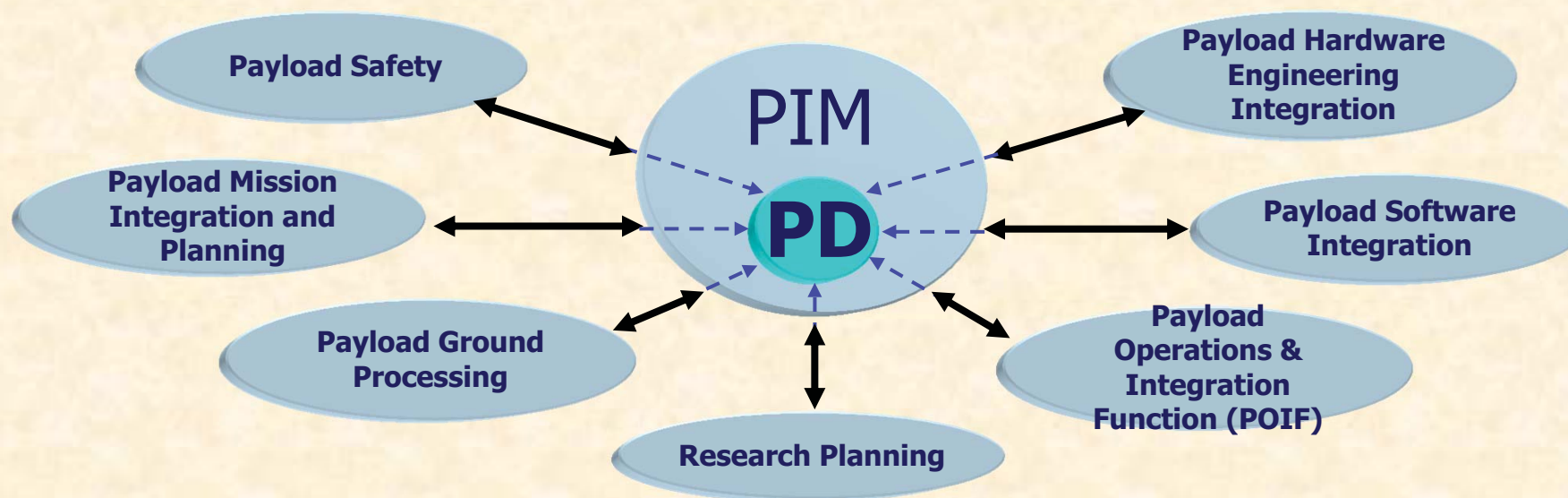Vibration

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

➤ **NASA Payload Integration Manager (PIM)**

▪ Functions as the Payload Developer's primary interface to the ISS Program

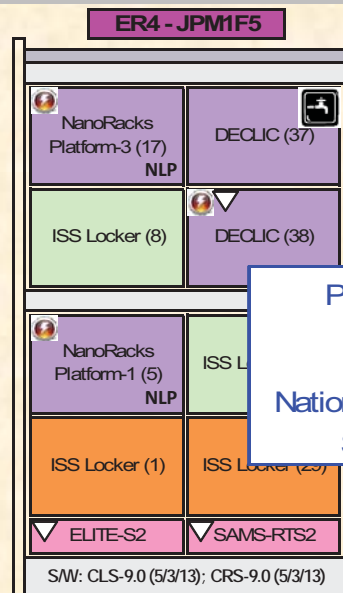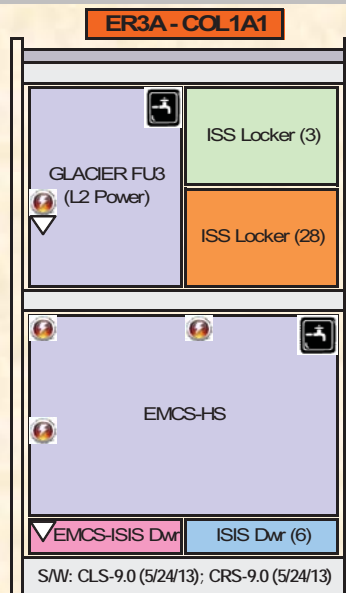▪ Serves as payload advocate while protecting ISS Program Requirements

PIM

PD

- Payload Safety
- Payload Hardware Engineering Integration
- Payload Mission Integration and Planning
- Payload Software Integration
- Payload Ground Processing
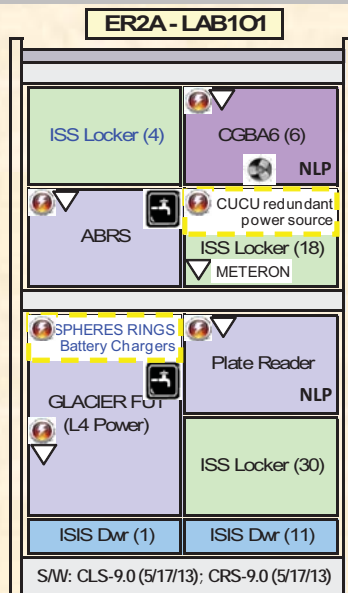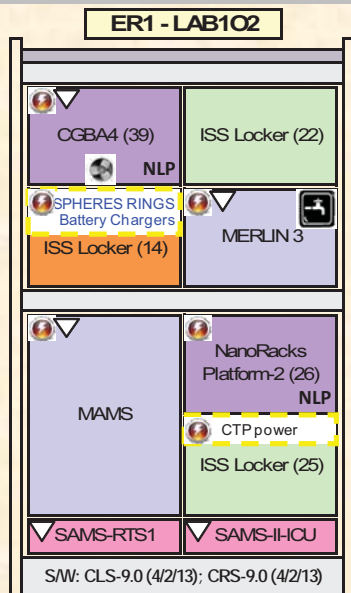- Payload Operations & Integration Function (POIF)
- Research Planning

▪ Ensures payload requirements are accurately defined and documented

▪ Facilitates payload integration product development, delivery schedules, and communications with the ISS Program
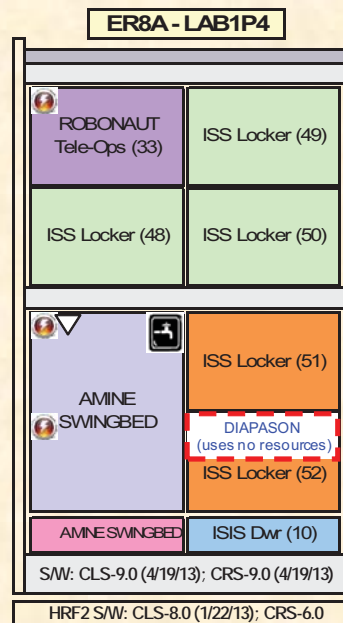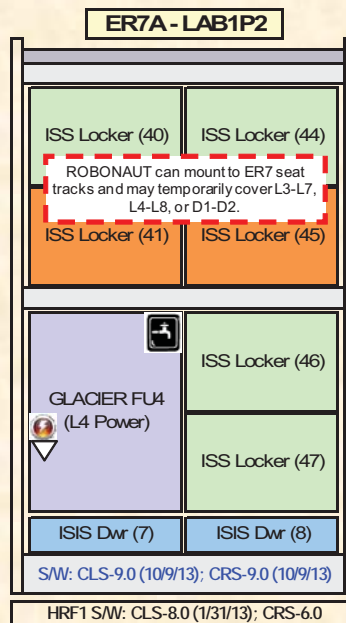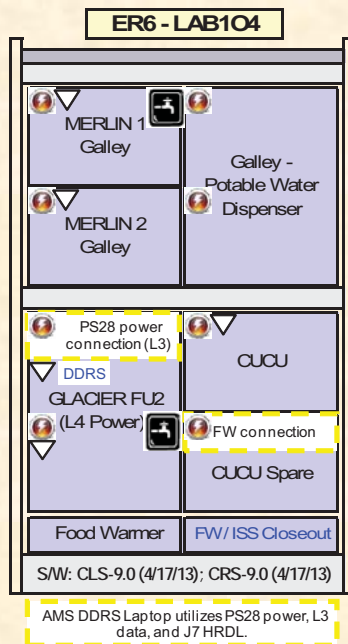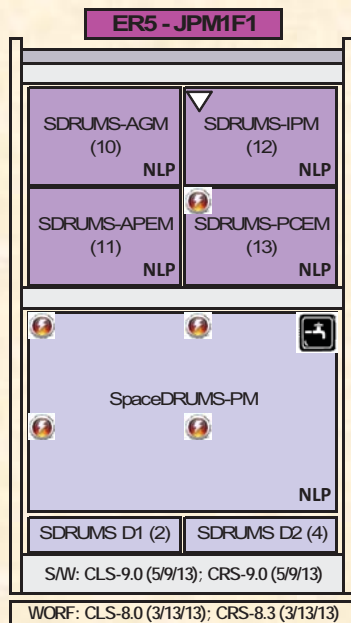
Conducting Research on the ISS using the EXPRESS Rack

ER1 - LAB1O2
- CGBA4 (39) | ISS Locker (22) | NLP
- SPHERES RINGS Battery Chargers | ISS Locker (14) | MERLIN 3
- MAMS | NanoRacks Platform-2 (26) NLP | CTP power | ISS Locker (25)
- SAMS-RTS1 | SAMS-II-ICU
- S/W: CLS-9.0 (4/2/13); CRS-9.0 (4/2/13)

ER2A - LAB1O1
- ISS Locker (4) | CGBA6 (6) NLP
- ABRS | CUCU redundant power source | ISS Locker (18) | METERON
- SPHERES RINGS Battery Chargers | GLACIER FU1 (L4 Power) | Plate Reader NLP | ISS Locker (30)
- ISIS Dwr (1) | ISIS Dwr (11)
- S/W: CLS-9.0 (5/17/13); CRS-9.0 (5/17/13)

ER3A - COL1A1
- GLACIER FU3 (L2 Power) | ISS Locker (3) | ISS Locker (28)
- EMCS-HS
- EMCS-ISIS Dwr | ISIS Dwr (6)
- S/W: CLS-9.0 (5/24/13); CRS-9.0 (5/24/13)

ER4 - JPM1F5
- NanoRacks Platform-3 (17) NLP | DECLIC (37)
- ISS Locker (8) | DECLIC (38)
- NanoRacks Platform-1 (5) NLP | ISS L...
- ISS Locker (1) | ISS Locker (29)
- ELITE-S2 | SAMS-RTS2
- S/W: CLS-9.0 (5/3/13); CRS-9.0 (5/3/13)

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

ER5 - JPM1F1
- SDRUMS-AGM (10) NLP | SDRUMS-IPM (12) NLP
- SDRUMS-APEM (11) NLP | SDRUMS-PCEM (13) NLP
- SpaceDRUMS-PM NLP
- SDRUMS D1 (2) | SDRUMS D2 (4)
- S/W: CLS-9.0 (5/9/13); CRS-9.0 (5/9/13)
- WORF: CLS-8.0 (3/13/13); CRS-8.3 (3/13/13)

ER6 - LAB1O4
- MERLIN 1 Galley | Galley - Potable Water Dispenser
- MERLIN 2 Galley
- PS28 power connection (L3) | DDRS | GLACIER FU2 (L4 Power) | CUCU | FW connection | CUCU Spare
- Food Warmer | FW / ISS Closeout
- S/W: CLS-9.0 (4/17/13); CRS-9.0 (4/17/13)
- AMS DDRS Laptop utilizes PS28 power, L3 data, and J7 HRDL.

ER7A - LAB1P2
- ISS Locker (40) | ISS Locker (44)
- ROBONAUT can mount to ER7 seat tracks and may temporarily cover L3-L7, L4-L8, or D1-D2.
- ISS Locker (41) | ISS Locker (45)
- GLACIER FU4 (L4 Power) | ISS Locker (46) | ISS Locker (47)
- ISIS Dwr (7) | ISIS Dwr (8)
- S/W: CLS-9.0 (10/9/13); CRS-9.0 (10/9/13)
- HRF1 S/W: CLS-8.0 (1/31/13); CRS-6.0

ER8A - LAB1P4
- ROBONAUT Tele-Ops (33) | ISS Locker (49)
- ISS Locker (48) | ISS Locker (50)
- AMINE SWINGBED | ISS Locker (51) | DIAPASON (uses no resources) | ISS Locker (52)
- AMINE SWINGBED | ISIS Dwr (10)
- S/W: CLS-9.0 (4/19/13); CRS-9.0 (4/19/13)
- HRF2 S/W: CLS-8.0 (1/22/13); CRS-6.0

➢ **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 ISS that result from the operation of hardware, crew activities, dockings and maneuvering.**

   ▪ http://www.nasa.gov/mission_pages/station/research/experiments/914.html
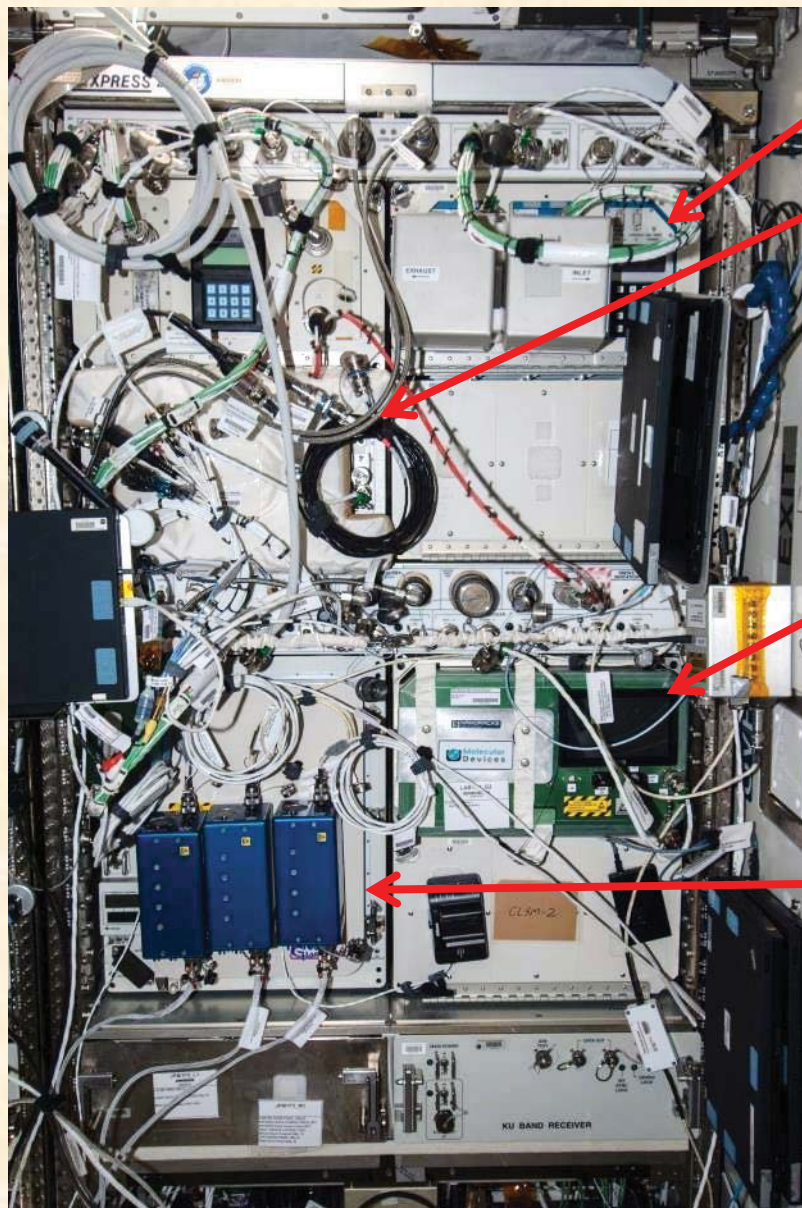
➢ **Commercial Generic Bioprocessing Apparatus (CGBA) 6**

➢ **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
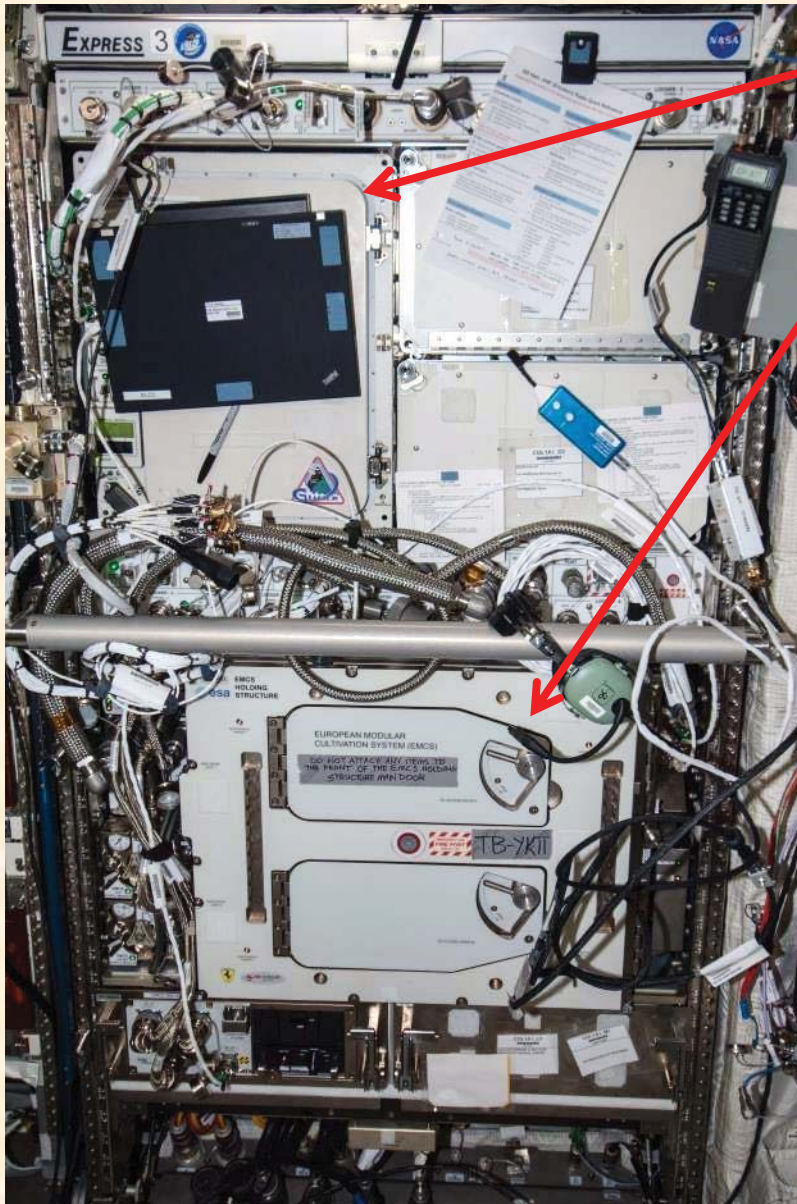
➢ **General Laboratory Active Cryogenic ISS Experiment Refrigerator (GLACIER) 1**

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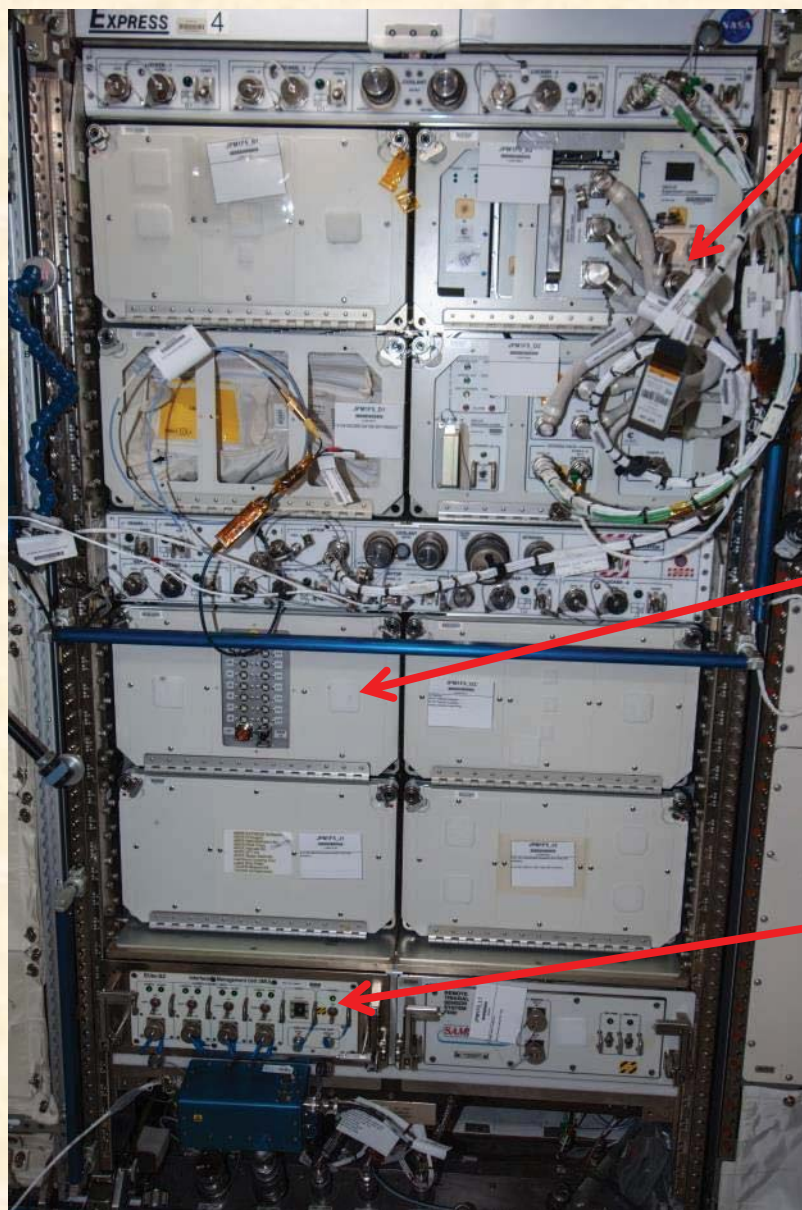
➢ **DEvice for the study of Critical LIquids and Crystallization (DECLIC)**

- **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
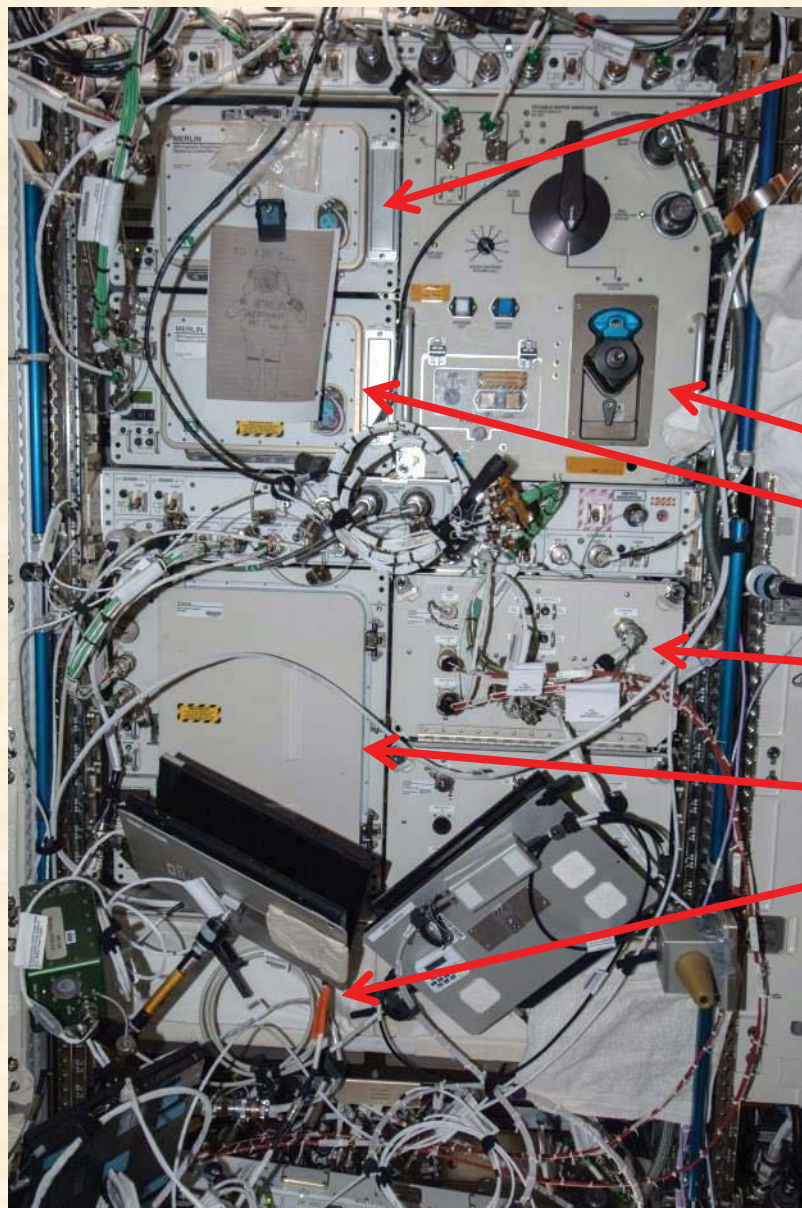
➢ **Microgravity Experiment Research Locker/INcubator (MERLIN) 1**

- ▪ **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**
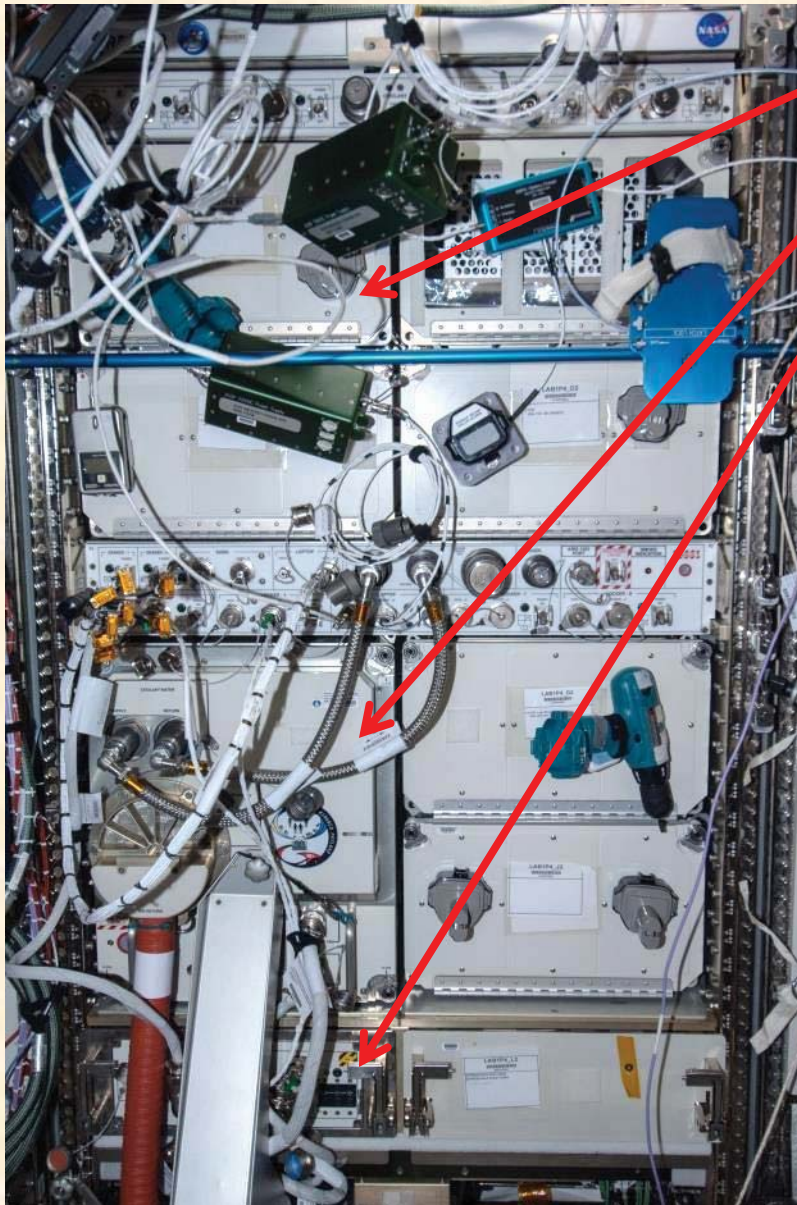
➢ **Robonaut Tele-Ops**

➢ **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**

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.**

Back Up Material

EXPRESS – EXpedite the PRocessing of Experiments for Space Station – Research Accommodations
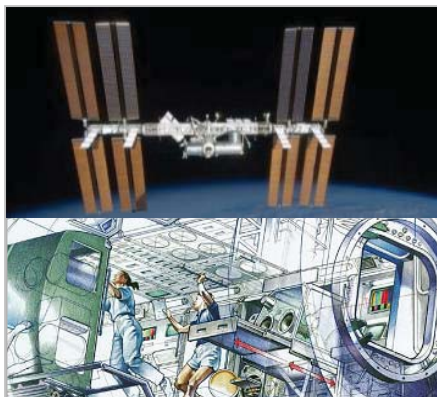
EXPRESS 8/2 Configuration

International Standard Payload Rack

Secondary Structure & Subsystems

8/2 Payload Configuration
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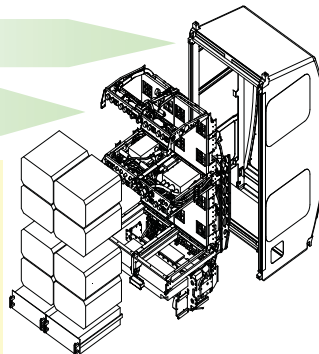
Integrated Rack

EXPRESS 8/2 Functional Block Diagram

Gaseous Nitrogen
Waste Gas (via Vacuum Line)
NTSC Composite Video
Data
120 VDC

PAYLOAD

SSPCM — RIC

EMU

Power Converter 16-20 V

PEHB

Laptop

Composite Video (possible)

Fan Speed

AAA — Smoke Detector — Maintenance Switch

ISS
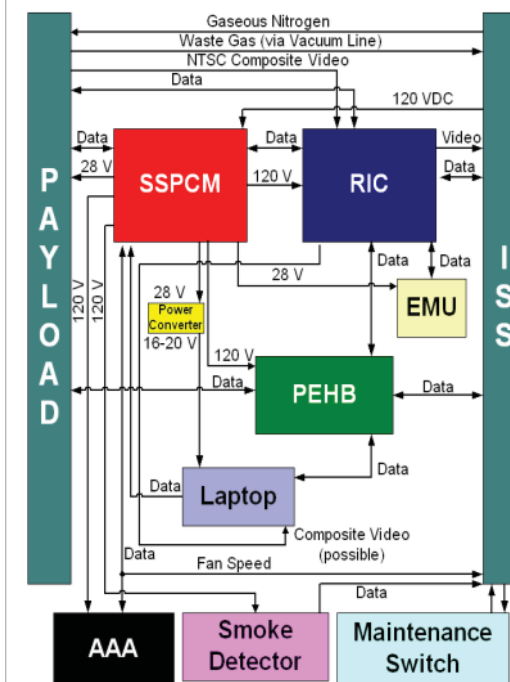
ISS Locker
P/N SEG46117022

Features
- 4 rear captive fastener attachments
- Friction hinge
- Dual door locks
- Installation tool guides on 4 corners
- Weight – 13 lbs empty
- Volume – 2 ft^3
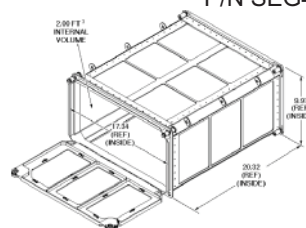
International Subrack Interface Standard Drawer
Powered P/N 683-43650
Stowage P/N 683-43656

Features
- 4 PU (Panel Unit)
- Blind Connectors
- Locking Handles
- Weight – 26 lbs empty
- Volume – 1.26 ft^3
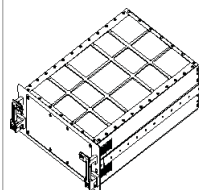
EXPRESS Laptop Computer

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

Type	Total EXPRESS Rack Accommodations	ISS Locker Position Accommodations**	4-PU Drawer Position Accommodations**
Structural	8 Lockers & 2 4-PU ISIS Drawers	Mass vehicle dependent	64 lb total within cg constraints
Power	2000 W 28 VDC power to payloads	5/10/15/20 Amps (@28 VDC)	5/10/15/20 Amps (@28 VDC)
Thermal Control	2000 W payload heat rejection	Nominal – 150 W (Ducted Air)	Nominal – 150 W (Ducted Air)
	air/water combined (1200 W air)	500 W – 2 positions (Water)	500 W – 2 positions (Water)
Data	10 – RS-422; 10 – Ethernet;	1 – RS-422; 1 – Ethernet;	1 – RS-422; 1 – Ethernet;
	18 – Analog; 28 – Discrete (bi-dir)	2 – Analog; 3 – Discrete	1 – Analog; 2 – Discrete
Video*	1 – NTSC feed from each payload	1 – NTSC/170A feed - Shared	1 – NTSC/170A feed - Shared
Vacuum Exhaust	1 – Payload connection	1 – Shared	1 – Shared
Nitrogen	1 – Payload connection	1 – Shared (0 – 12 lbm/hr)	1 – Shared (0 – 12 lbm/hr)

EXPRESS Functional Interfaces

Power
120 VDC (+6/-4)
(25 Amps @ 3kW)

Power
28 VDC (+1.5/-2.5)
(5/10/15/20 Amps)
Analog +/- 5V
Discrete (5 V)

SSPCM

MIL-STD-1553
HRDL
IVS

RIC

RS-422
Video Analog
Timing Signal

Ethernet (10bT)

PEHB

Ethernet (10bT)

Vacuum Exhaust
GN$_2$
MTL Water
(16 to 23° C)
(61-73.4° F)

AAA

Vacuum Exhaust
GN$_2$
MTL Water
(200lbm/hr)
Air

* Digitized Payload Video may be included in ethernet telemetry

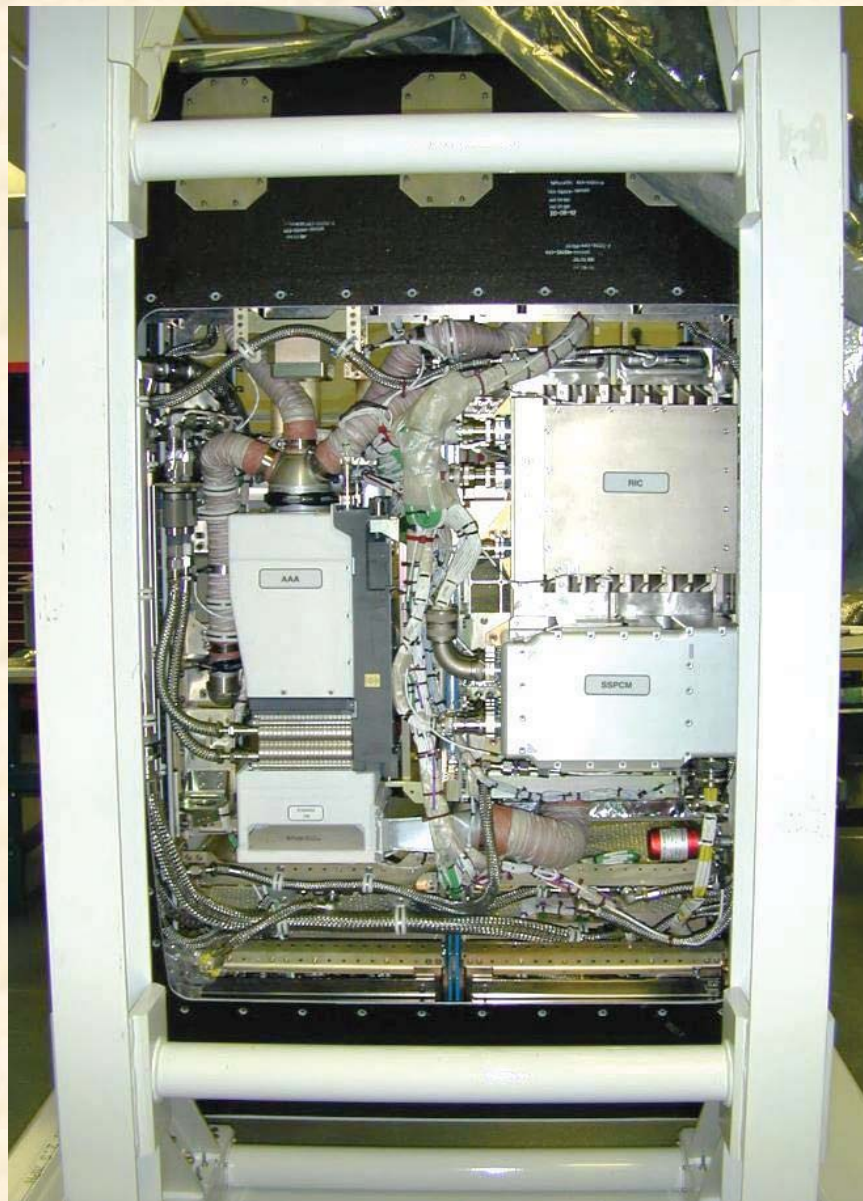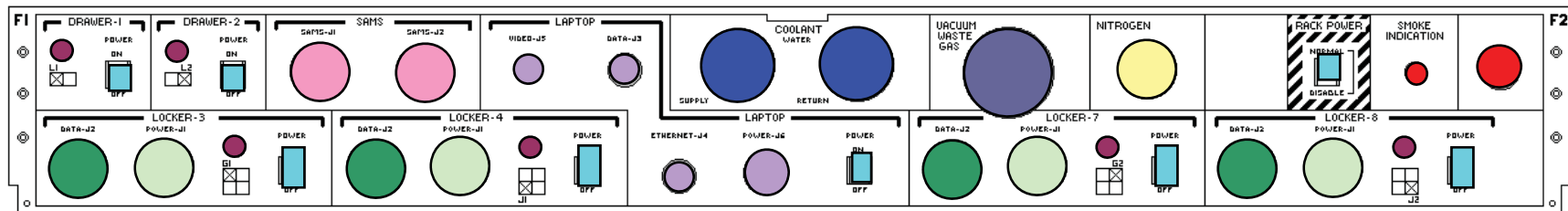** Grayed-out Accommodations are not supported with the Lean Payload Integration approach

Rack Rear View

EXPRESS Rack Connector Panels

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
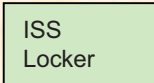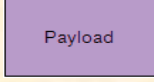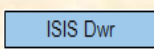
ISS Locker	- Stowage Locker
ISS Locker (no door)	- Stowage Locker w/o door
ISS Locker	- Location reserved for Lean Payloads
Payload	- Payload Insert (Payload inserted into ISS Locker or ISIS Drawer)
Payload	- Locker Replacement Payload
ISIS Dwr	- ISIS Drawer
Payload	- Drawer Replacement Payload

- 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

Columbus Orbital Facility
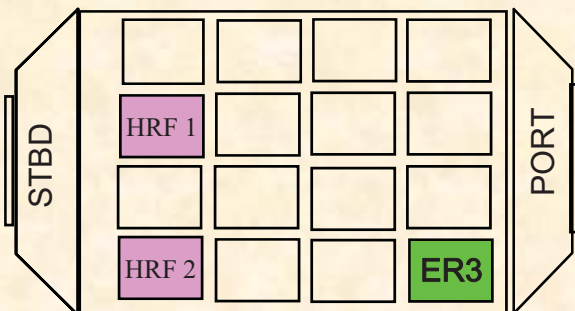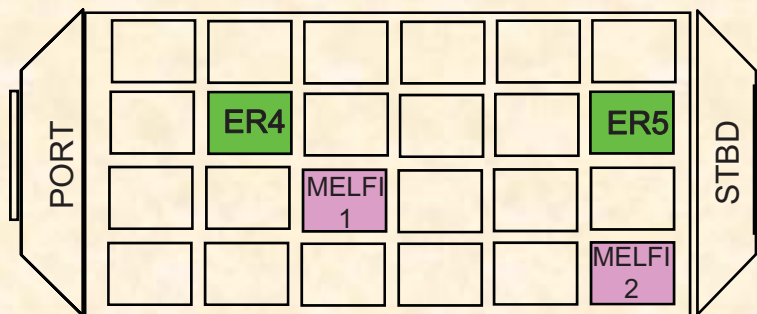
Node 2
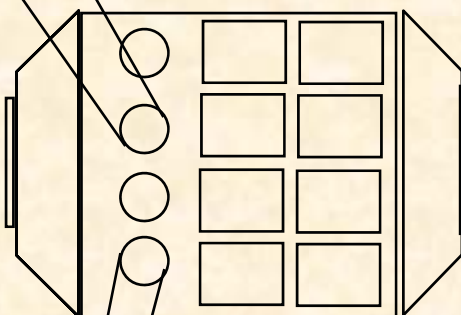
US Lab
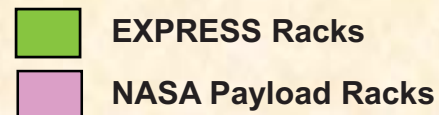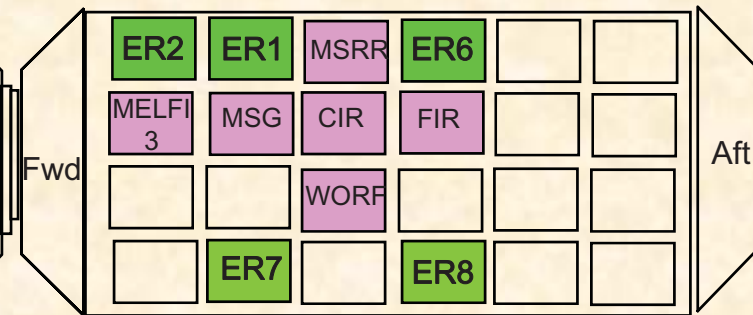
Japanese Experiment Module

EXPRESS Racks

NASA Payload Racks

- **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)**

SAMS-II RTS-EE

EMU

PEHB
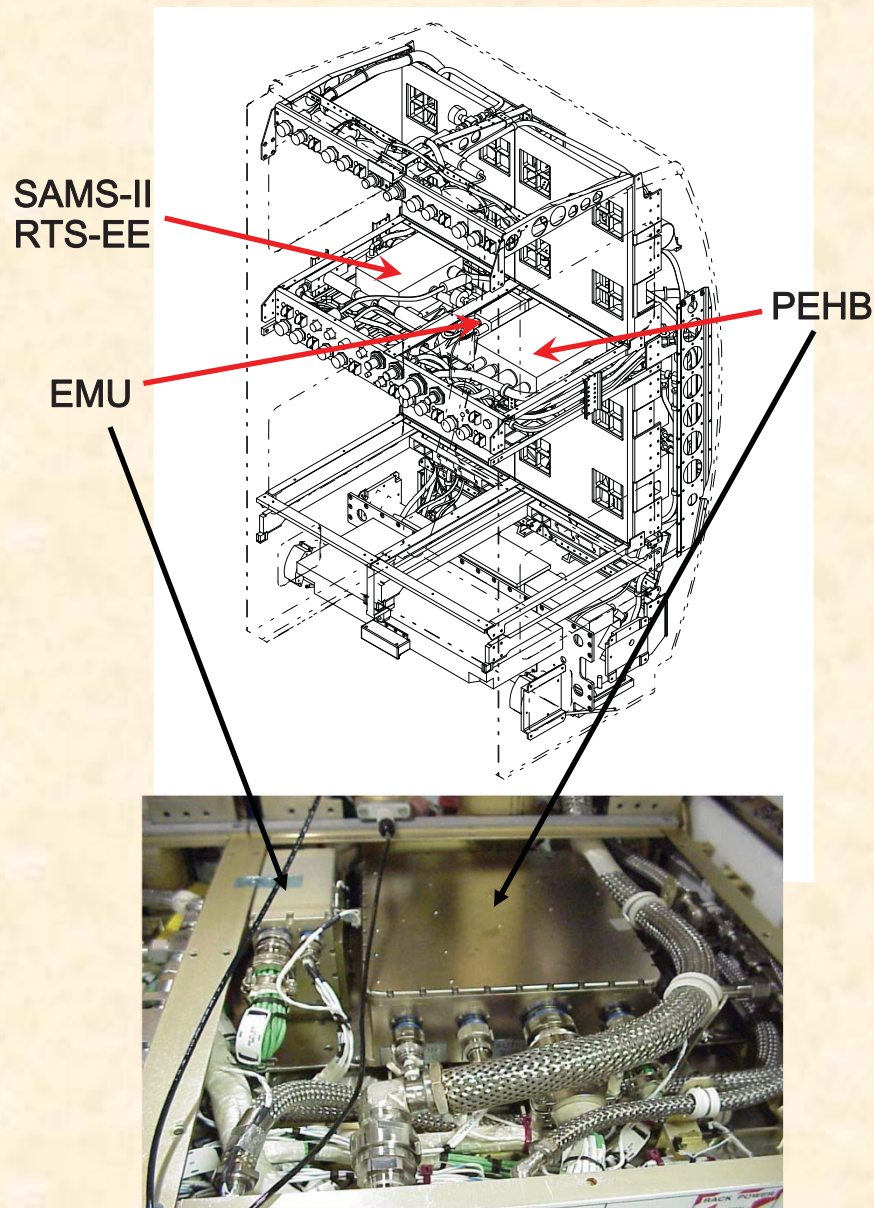
- Manage engineering integration activities for the EXPRESS Racks.

- 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)