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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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
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

- 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

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

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 ft³

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 ft³

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

- **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
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

Station

- Power
  - 120 VDC (+6/-4) (25 Amps @ 3kW)
- MIL-STD-1553
- High Rate Data Link
- Internal Video Sys
- Ethernet (10bT)
- Vacuum Exhaust
- GN₂
- MTL Water (16 to 23 °C) (61-73.4 °F)

Payload

- Power
  - 28 VDC (+1.5/-2.5) (5/10/15/20 Amps)
  - Analog +/- 5V
  - Discrete (5 V)
- RS-422
- Video Analog
- Timing Signal
- Ethernet (10bT)
- Vacuum Exhaust
- GN₂
- MTL Water (200 lbm/hr)
- Air
## EXPRESS Payload Resources

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

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

Additional Services Available
- Off-gas
- Vibration
- EMI/EMC
- Acoustics

Payload shipment to MSFC

C&DH remote test possible using VPN

Virtual Private Network

Payload shipment to launch site or PD
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
Conducting Research on the ISS using the EXPRESS Rack

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

Express Topology – 9/26/14

ER1 - LAB102
- CGBA4 (39)
- ISS Locker (22)
- ISS Locker (14)
- MERLIN 3
- SAMS CU
- SAMS-RTS1
- SAMS-IHCU (0)

ER2A - LAB101
- ISS Locker (4)
- CGBA6 (6)
- ABRs
- Alt. Power/Data for RH1 or AEM-T power
- GLACIER-1
- Rodent Habitat 2
- NLP

ER3A - COL1A1
- GLACIER-3
- VEGGIE
- Plate Reader
- ISS Dwr (1)
- ISS Dwr (11)
- ISMC-ISIS Dwr

ER4 - JPM1F5
- NanoRacks Platform-3 (17)
- NanoRacks Platform-2 (8)
- NanoRacks Platform-1 (5)
- ISS Locker (20)
- ISS Locker (1)
- ISS Locker (29)
- ISS Locker (1)

ER5 - JPM1F1
- SDRUMS-AGM (10)
- SDRUMS-IPM (12)
- SDRUMS-APEM (11)
- SDRUMS-PCEM (13)
- SpaceDRUMS-PM
- SDRUMS D1 (2)
- SDRUMS D2 (4)

ER6 - LAB104
- MERLIN 1
- Galley
- Potable Water Dispenser
- NLP

ER7A - LAB1P2
- MERLIN 5/CPCG-HM
- GLACIER-5
- ISMC
- ISMC-ISIS Dwr
- ISMC-ISIS Dwr

ER8A - LAB1P4
- ROBONAUT
- Tele-Ops (33)
- CGBA5 (49)

AMS DDRS Laptop utilizes PS28 power, L3 data, and J7 HRDL.
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

- Payload Mod Temp TCS Supply
- TCS Manual Valve
- Backplate
- Lower Shelf Assy
- User Panel
- Power Inverter (accommodated)
- Rack Front
- Payload Mod Temp TCS Return
- Ethernet Panel
- User Panel Assy
- Mod Temp TCS Return (Pink)
- Mod Temp TCS Supply (Blue)
- Rack Side (ISO)
### Proposed Basic Express Rack Payload Resources

<table>
<thead>
<tr>
<th>Resource</th>
<th>Amount per Payload Position</th>
<th>EXPRESS</th>
<th>Basic Express Rack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural Attachment</td>
<td>Attachment to Rack per IDD • Mass constraint launch vehicle dependent</td>
<td></td>
<td>Same</td>
</tr>
<tr>
<td>Power</td>
<td>5, 10, 15, or 20 Amp at 28 VDC • 10 or 20 Amp at 28 VDC, manual only</td>
<td>10 or 20 Amp at 28 VDC, manual only</td>
<td></td>
</tr>
<tr>
<td>Thermal Control</td>
<td>Nominal 150 W (1200 W rack maximum)</td>
<td>Same</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>1 payload interface per rack (Shared, 12 lbm/hr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aux Power</td>
<td>Automatic failover when set</td>
<td></td>
<td>None (TBD)</td>
</tr>
</tbody>
</table>
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.

- **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.
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.
- **NanoRacks Plate Reader**
  - Instrument designed to detect biological, chemical or physical events of samples in microtiter plates.
- **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).
Conducting Research on the ISS using the EXPRESS Rack

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)
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.

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.

ELaboratore Immagini TElevisive - Space 2 (ELITE-S2)
- Investigates the connection between brain, visualization and motion in the absence of gravity.
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).
- 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 (CO₂) from the ISS atmosphere using a smaller more efficient vacuum regeneration system.
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)

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)

ISS Locker Position Accommodations**
- Mass vehicle dependent
- 5/10/15/20 Amps (@28 VDC)
- Nominal – 150 W (Ducted Air)
- 500 W – 2 positions (Water)
- 1 – RS-422; 1 – Ethernet;
- 2 – Analog; 3 – Discrete
- Unique operating system (NT)

4-PU Drawer Position Accommodations**
- 64 lb total within cg constraints
- 5/10/15/20 Amps (@28 VDC)
- Nominal – 150 W (Ducted Air)
- 500 W – 2 positions (Water)
- 1 – RS-422; 1 – Ethernet;
- 1 – Analog; 2 – Discrete
- 1 – NTSC/170A feed - Shared
- 1 – Shared
- 1 – Shared (0 – 12 lbm/hr)

EXPRESS Functional Interfaces
- Power 28 VDC (+1.5/-2.5)
- 25 Amps @ 3kW
- Analog +/- 5V
- Discrete (5 V)
- Ethernet (10bT)
- Vacuum Exhaust
- LN₂
- MTL Water (200 lbs/m/hr)
- Air

EXPRESS 8/2 Functional Block Diagram

* Digitized Payload Video may be included in ethernet telemetry
** Grayed-out Accommodations are not supported with the Lean Payload Integration approach
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
- 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

Columbus Orbital Facility

Japanese Experiment Module

Node 2

US Lab

Express Racks

NASA Payload Racks
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)