Spacecraft Mass: 799,046 lb (362,441 kg)
Velocity: 17,500 mph (28,200 kph)
Altitude: 220 miles above Earth
Power: 80 kW continuous
Science Capability: Laboratories from four international space agencies – US, Europe, Japan, and Russia
International Space Station (ISS) External Research Facilities

- ELC2 (ULF6, 2011) AMS
- ELC3
- ELC4 (ULF5)
- ESP-3
- Columbus External Payload Facility (2 sites NASA, 4 sites total)
- Kibo External Facility (5 sites NASA, 10 sites total)
# External Research Accommodations
## Express Logistic Carrier

## ELC Single Adapter

<table>
<thead>
<tr>
<th>Resources</th>
<th>NASA payload sites per ELC</th>
</tr>
</thead>
</table>

### Mass capacity
- 227 kg (500 lb)

### Volume
- 1 m³

### Power
- 750 W, 113 – 126 VDC; 500 W at 28 VDC/adapter

### Thermal
- Active heating, passive cooling

### Low-rate data
- *1 Mbps (MIL-STD-1553)*

### Medium-rate data
- *6 Mbps (shared) - Return link (payload to ISS) only*

### Sites available per ELC
- 2 sites

### Total ELC sites available
- 8 sites

---

*Proposed C&DH Enhancement to each Research Payload site*

- **100 Mbps Two Way wireless LAN**

---

*Research Payload ExPA (see next chart)*
Express Logistics Carriers Overview

Payload Locations Circled

ELC-1
Port lower
2 Nadir payload sites

ELC-2
Starboard upper
2 Zenith payload sites
Express Logistics Carriers Overview

**Payload Locations Circled**

**ELC-3**
Port upper
2 Zenith payload sites

**ELC-4**
Starboard lower
2 Nadir payload sites
### Express Pallet Adapter (ExPA) Assembly

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>ExPA overall Mass</td>
<td>255 lb</td>
</tr>
<tr>
<td>ExPA overall dimension</td>
<td>46.05” x 47” x 13.06” (H)</td>
</tr>
<tr>
<td>ExPA payload carrying capability</td>
<td>34” x 46” x 49” (H) and 500 lb”</td>
</tr>
<tr>
<td>Payload electrical interface</td>
<td>Power(120VDC &amp; 28VDC): Four NATC connectors Data (1553, Ethernet): Six NATC connectors</td>
</tr>
<tr>
<td>Payload thermal interface</td>
<td>Active heating, passive cooling</td>
</tr>
<tr>
<td>Payload structural interface</td>
<td>2.756” X 2.756” Grid with 250-28 UNF Locking Inserts and 1.625” diameter Shear Boss Provisions</td>
</tr>
<tr>
<td>EVA compatibility</td>
<td>EVA handrail provisions</td>
</tr>
<tr>
<td>EVR compatibility</td>
<td>All EVR interfaces on ExPA</td>
</tr>
</tbody>
</table>
Japanese Experiment Module Exposed Facility (JEM EF) Overview

- ELM-PS
- JEM-RMS
- JEM-EF
- ICS-EF
- ELM-ES
- EF Payloads
- RAM
- Airlock

to ISS Node 2
Japanese Experiment Module - Kibo
JEM EF External Research Accommodations

Mass capacity
- 550 kg (1,150 lb) at standard site
- 2,250 kg (5,550 lb) at large site

Volume
- 1.5 m³

Power
- 3-6 kW, 113 – 126 VDC

Thermal
- 3-6 kW cooling

Low-rate data
- 1 Mbps (MIL-STD-1553, two way)

Medium-rate data
- 1EEE-802.3(10BASE-T, two way) *

High-rate data
- 43 Mbps (shared, one way downlink)

Sites available to NASA
- 5 sites

- Ethernet bus is tested to 100BASE-T capacity.
- Upgrade to 100BASE-T is being worked by JAXA
JEM EF EFU Location Overview

Pressurized Module

JEM-EF

1. FOV obstruction
   - 6 kW; Ethernet, 1553, Video

2. * 6 kW; Ethernet, 1553, Video

3. 3 kW; Ethernet, 1553, Video

4. 3 kW; Ethernet, 1553, Video

5. Currently unoccupied; reserved for ICS back-up

6. 3 kW; Ethernet, 1553, Video

7. Dedicated to ICS

8. 3 kW; Ethernet, 1553, Video

9. * 3 kW; Ethernet, 1553, Video

10. EPMP Berthing location

11. Good zenith viewing

12. Temporary Parking

Slight obstruction from camera mount; obstructed during EP berthing

* Capability for 2.5 MT payload

*  Capability for 2.5 MT payload

ISSP OZ 3/Chang
<table>
<thead>
<tr>
<th>Location</th>
<th>Viewing</th>
<th>Payload Size</th>
<th>Description / Notes</th>
<th>Power</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ram, Nadir, Zenith</td>
<td>500 kg</td>
<td>Ram field of View (FOV) obstruction by JEM module</td>
<td>6 kW</td>
<td>Ethernet, 1553, Video</td>
</tr>
<tr>
<td>3</td>
<td>Ram, Nadir, Zenith</td>
<td>500 kg</td>
<td>Clear view</td>
<td>3 kW</td>
<td>Ethernet, 1553, Video</td>
</tr>
<tr>
<td>5</td>
<td>Ram, Nadir, Zenith</td>
<td>500 kg</td>
<td>ICS System back-up site (negotiable?)</td>
<td>3 kW</td>
<td>1553, Video</td>
</tr>
<tr>
<td>7</td>
<td>Ram, Nadir, Zenith</td>
<td>500 kg</td>
<td>ICS-dedicated</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>Port, Zenith, Nadir</td>
<td>2.5 MT</td>
<td>Best volumetrically for large payloads (up to 2.5 MT), but not necessarily the best viewing</td>
<td>3 kW</td>
<td>Ethernet, 1553, Video</td>
</tr>
<tr>
<td>2</td>
<td>Wake, Nadir, Zenith</td>
<td>2.5 MT</td>
<td>Can hold large payloads, but has an FOV obstruction by JEM module</td>
<td>6 kW</td>
<td>Ethernet, 1553, Video</td>
</tr>
<tr>
<td>4</td>
<td>Wake, Nadir, Zenith</td>
<td>500 kg</td>
<td>Clear view</td>
<td>3 kW</td>
<td>1553, Video</td>
</tr>
<tr>
<td>6</td>
<td>Wake, Nadir, Zenith</td>
<td>500 kg</td>
<td>Clear view</td>
<td>3 kW</td>
<td>Ethernet, 1553, Video</td>
</tr>
<tr>
<td>8</td>
<td>Wake, Nadir, Zenith</td>
<td>500 kg</td>
<td>Obstruction during EP berthing, slight obstruction from camera mount</td>
<td>3 kW</td>
<td>1553, Video</td>
</tr>
<tr>
<td>10</td>
<td>Wake, Nadir, Zenith</td>
<td>500 kg</td>
<td>EPMP berthing site</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>Zenith only</td>
<td>500 kg</td>
<td>Good Zenith viewing</td>
<td>3 kW</td>
<td>Ethernet</td>
</tr>
<tr>
<td>12</td>
<td>Zenith only</td>
<td>500 kg</td>
<td>Temporary stowage location</td>
<td>3 kW</td>
<td>Ethernet</td>
</tr>
</tbody>
</table>
## Columbus EF Overview

![Diagram showing Columbus EF Overview](image)

### Key Specifications

<table>
<thead>
<tr>
<th>Location</th>
<th>Viewing</th>
<th>Payload Size</th>
<th>Power</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOZ</td>
<td>Zenith</td>
<td>226 kg + CEPA</td>
<td>1.25 kW at 120 VDC 2.5 kW max</td>
<td>Ethernet, 1553</td>
</tr>
<tr>
<td>SOX</td>
<td>Ram</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SDX</td>
<td>Ram</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SDN</td>
<td>Nadir</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: All 4 locations are allocated to Utilization.*
Dexterous End Effector

SSRMS attachment which the ground team or on-orbit crew can use robotically to install, remove and replace payloads and failed components
JEM RMS  Payload Support
ISS Cargo Vehicles

ATV (ESA)
Cargo Capacity 5,500 kg

Cygnus (Orbital Sciences Corp)
Cargo Capacity 2,000 kg

HTV (JAXA)
Cargo Capacity 5,500 kg

Progress (Roscosmos, The Russian Federal Space Agency)
Cargo Capacity 2,250 kg

Dragon (SpaceX)
Cargo Capacity 3,100 kg ascent
Payload Allowable Up-Mass & Volume Summary Table

<table>
<thead>
<tr>
<th>Attach Payload Location</th>
<th>Allowable Payload Weight (including Flight Support Equipment)</th>
<th>Accommodation Weight (including adapter plate)</th>
<th>Total Weight</th>
<th>Payload Volume (W x H x L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTV Exposed Pallet (JEM EF Payload)</td>
<td>979 Lb (445 Kg)</td>
<td>121 Lb (55 Kg)</td>
<td>1100 Lb (500 Kg)</td>
<td>31.5” x 39.4” x 72.8” (800mm x 1000mm x 1850 mm)</td>
</tr>
<tr>
<td>HTV Exposed Pallet (ExPA, CEPA Payload)</td>
<td>See ExPA &amp; CEPA payload specification for ELC &amp; CEF</td>
<td>See ExPA &amp; CEPA payload specification for ELC &amp; CEF</td>
<td>*See ExPA &amp; CEPA payload specification for ELC &amp; CEF</td>
<td>*See ExPA &amp; CEPA payload specification for ELC &amp; CEF</td>
</tr>
<tr>
<td>ELC (ExPA)</td>
<td>490 Lb (222 Kg)</td>
<td>250 Lb (114 Kg)</td>
<td>740 Lb (336 Kg)</td>
<td>34” x 49” X 46” (863mm x 1244mm x 1168 mm)</td>
</tr>
<tr>
<td>Columbus (CEPA)</td>
<td>388 Lb (176Kg)</td>
<td>250 Lb (114 Kg)</td>
<td>638 Lb (290 Kg)</td>
<td>34” x 49” X 46” (863mm x 1244mm x 1168 mm)</td>
</tr>
<tr>
<td>JEM-EF</td>
<td>979 Lb (445 Kg)</td>
<td>121 Lb (55 Kg)</td>
<td>1100 Lb (500 Kg)</td>
<td>31.5” x 39.4” x 72.8” (800mm x 1000mm x 1850 mm)</td>
</tr>
</tbody>
</table>

* Location constraint applies in HTV Exposed Pallet
## Upgrades In Work

<table>
<thead>
<tr>
<th>Project</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Enhanced Processor and Integrated Communications (EPIC) Project</strong></td>
<td>Phase A will upgrade the three Command and Control (C&amp;C) MDMs and the two Guidance, Navigation, &amp; Control (GN&amp;C) MDMs. Phase B will upgrade the two Payload MDMs, and add Ethernet support for the C&amp;C and Payload MDMs.</td>
</tr>
<tr>
<td><strong>Air to Ground High Rate Communications System (HRCS) Project</strong></td>
<td>Increase data rates internally and on the RF link 300 Mbps downlink, 7/25 Mbps uplink. Combine audio and video on orbit. Provide two way, high quality audio. Open the door to internet protocol communications. Open the forward link to multiple users. Allow for the capability of transmitting &amp; recording HDTV.</td>
</tr>
<tr>
<td><strong>On Orbit External Wireless High Rate</strong></td>
<td>100 Mbps 2-way Ethernet capability. 1 Mbps 1553 capability. Up to 4 antennas attached to EVA handrails on US Lab.</td>
</tr>
</tbody>
</table>
ISS as a Platform for Earth Science

All geographic locations between 51.6 North and South latitude can be observed NADIR pointing.

Provides coverage of 85% of the Earth’s surface and 95% of the world’s populated landmass every 1-3 days.
ISS coverage in 24 hrs for a 70°-swath optical payload. (Courtesy of ESA)

Processing lighting (changes with subsequent passes)
Well-suited for test bed concepts with hardware change out and upgrades
ISS Attitude Torque Equilibrium Attitude (TEA) & Wobble Oscillation Description

For Stage configurations (i.e.; no Orbiter or Orbiter sized vehicle docked on the ISS) in the foreseeable future, the predicted TEA ranges are:
Roll: -1.0 ~ +3.0 deg
Pitch: -7.0 ~ +2.0 deg
Yaw: -15 ~ +15 deg.

Momentum Manager Controller Peak to Peak Attitude Wobble Oscillation

<table>
<thead>
<tr>
<th>Performance Descriptions</th>
<th>Peak to Peak Attitude Oscillations Per Orbit</th>
<th>Peak Attitude Variation from Steady-State Orbit: Average Attitude</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Roll (X) (deg)</td>
<td>Pitch (Y) (deg)</td>
</tr>
<tr>
<td>Non-Micro-Gravity (Assembly Stages) Non-Propulsive (Momentum Manager) Attitude Control Performance Requirement</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Micro-Gravity (Assembly Complete) Non-Propulsive (Momentum Manager) Attitude Control Performance Requirement</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Typical Steady-State Performance of Minimum CMG momentum oscillation</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td>Typical Steady-State Performance of Minimum Attitude oscillation</td>
<td>1.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Typical Steady-State Performance of Minimum CMG momentum &amp; Attitude oscillation Blended</td>
<td>1.6</td>
<td>0.7</td>
</tr>
</tbody>
</table>
ISS Quiescent Mode Truss Vibratory Environment
For External Payload Pointing Instrument
Data measured on ISS S3 truss

- ISS quiescent mode = No thruster firings, dockings, EVA, or robotics operations
- Typical response, not worst case
- Maximum per octave band
  - SDMS S3B1N on-orbit accelerometer data.
  - Snapshot of 3 10-minute data takes
  - All data taken on March 16, 26, and 27, Stbd SARJ Rotating, exercise, 3 crew.

*ULF-4 analysis concluded peak ELC rotations on the order of 0.03 degrees (quiescent mode)*

Data provided by Boeing, June 2010
The International Space Station provides an exceptionally clean environment to external payloads and science assets.

External contamination control requirements limit contaminant deposition to 130Å/year on external payloads and ISS sensitive surfaces.
- Specified levels are lower than any previous space station (Mir, Skylab, Salyut) by several orders of magnitude.

Measurements of contaminant deposition on ISS returned hardware have demonstrated that requirements are met at ISS payload sites.

### ISS Contamination Environment Description

For Truss Attached Payload

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Side</th>
<th>Requirement (130Å/year)</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>MISSE 2</td>
<td>ram</td>
<td>520 Å (4 years)</td>
<td>50 Å</td>
</tr>
<tr>
<td></td>
<td>wake</td>
<td>520 Å (4 years)</td>
<td>500 Å</td>
</tr>
<tr>
<td>Node 1 nadir</td>
<td>nadir</td>
<td>390 Å (3 years)</td>
<td>50 Å</td>
</tr>
</tbody>
</table>

Data provided by Boeing, June 2010
ISS Payload Integration Process

ISS provides:
• Launch to ISS
• Installation on ISS at identified site
• On-orbit utilities and operations support, including crew or robotics time (if needed)
• Data handling and delivery
• End-of-life removal and disposal
Payload Operations Integration Center Interfaces

White Sands Complex, New Mexico

Mission Control Center Houston

Payload Ops Control Center Huntsville

International Partner Facilities

NASA Telescience Support Centers

Payload User Sites TReK

49 Telescience Resource Kit (TReK) Clients
References

• ISS Program Scientist Toolbox: http://iss-science.jsc.nasa.gov/index.cfm
For technical questions associated with International Space Station Payloads:

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NASA Johnson Space Center
Houston, TX 77058
Tel: 281-244-8514
Email: george.nelson-1@nasa.gov

Customer Service Helpline: The International Space Station Payloads Office has both a phone and an email customer service helpline that Payload Developers and others interested in doing research can contact to get assistance. The phone is staffed during regular business hours, or messages may be issued after hours, and a representative will return the call on the next business day. Phone: 281-244-6187, email: jsc-iss-payloads-helpline@mail.nasa.gov.”