NASA/TP–2007–214768

Overview of Attached Payload Accommodations and Environments on the International Space Station

International Space Station Payloads Office
NASA Johnson Space Center, Houston, Texas

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas 77058

September 2007

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CONTENTS

ACRONYMS

C&C	command and control
C&DH	command and data handling
C&T	communications and tracking
EF	Exposed Facility (i.e., JEM-EF)
EFU	exposed facility unit
ELC	Express Logistics Carrier
ELM	experiment logistics module
EMR	electromagnetic radiation
EPF	External Payload Facilities (i.e., Columbus-EPF)
ES	exposed section (i.e., JEM-ELM-ES)
EVA	extravehicular activity
EVR	extravehicular robotic
HRDL	high-rate data link
HTV	H-II transfer vehicle
ICC	integrated cargo carrier
ICD	interface control document
ISS	International Space Station
ITS	integrated truss segment
JAXA	Japanese Aerospace Exploration Agency
JEM	Japanese Experiment Module
LEO	low Earth orbit
LMC	lightweight MPESS carrier
LRDL	low-rate data link
MCAS	Mobile Remote Servicer Base System Common Attach System
MDM	multiplexer/demultiplexer
M/OD	meteoroid/orbital debris
MPESS	multipurpose equipment support structure
MSS	Mobile Servicing System
NIRA	non-isolated rack assessment
ORU	orbital replacement unit
OU	outboard upper
PAS	payload attachment system
PCS	Personal Computer System
PM	pressurized module
POA	Payload ORU Accommodation
POIC	Payload Operations Integration Center
SEU	single-event upset
SRMS	Shuttle Remote Manipulator System
SSRMS	Space Station Remote Manipulator System
UCCAS	unpressurized carrier common attach site
ULC	unpressurized logistics carrier
USOS	U.S. on-orbit segment

1 OVERVIEW

1.1 INTERNATIONAL SPACE STATION PAYLOAD ACCOMMODATIONS

External payload accommodations are provided at attach sites on the U.S-provided Express Logistics Carrier (ELC), the U.S. truss, the Japanese Experiment Module-Exposed Facility (JEM-EF) and the Columbus-EPF (External Payload Facilities).

The integrated truss segment (ITS) provides the backbone structure for the International Space Station (ISS). It attaches the solar and thermal control arrays to the rest of the complex, houses cable distribution trays extravehicular activity (EVA) support equipment such as hand-holds and lighting, and provides for extravehicular robotic (EVR) accommodations using the Mobile Servicing System (MSS). The element orientation is shown in figure 1.1-1.

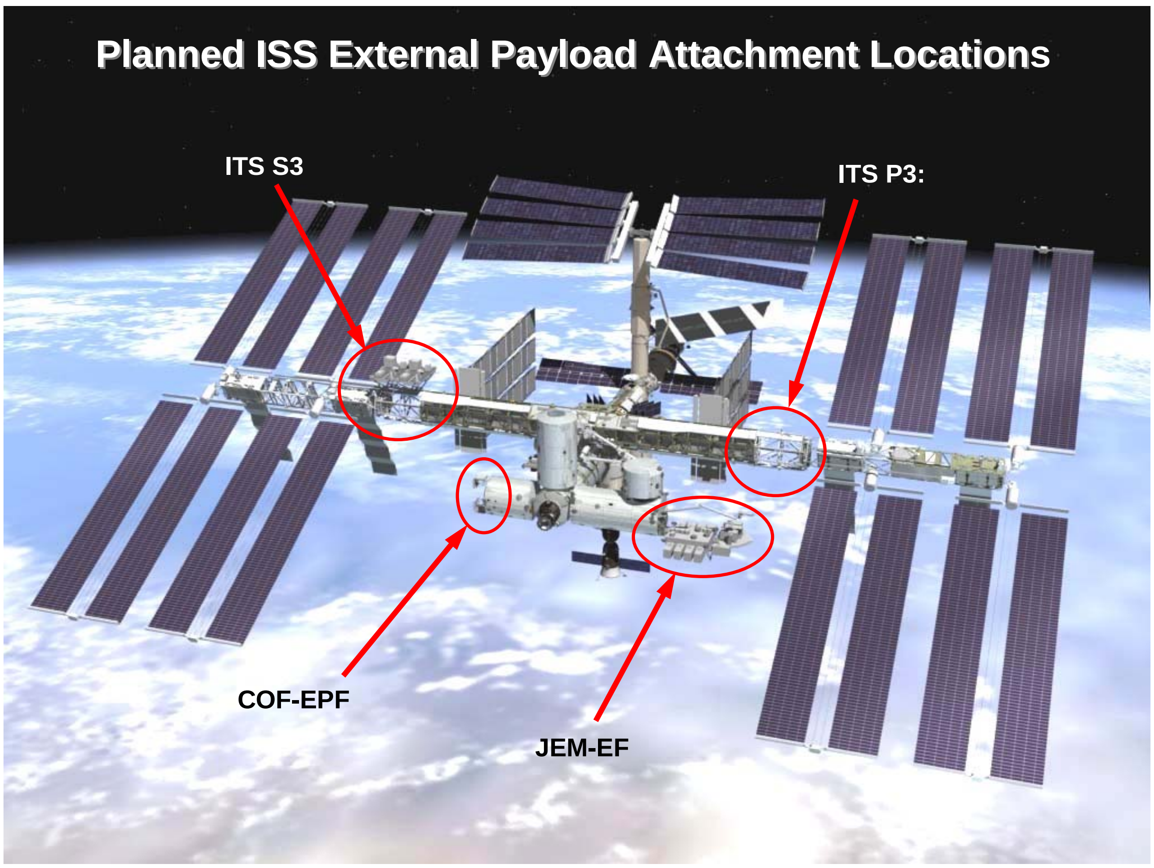


Figure 1.1-1: Element orientation.

The ITS also provides logistics and maintenance as well as payload attachment sites. The attachment sites accommodate logistics and maintenance and payloads carriers, both zenith and nadir. The JEM-EF, a back-porch-like attachment to the JEM pressurized module, accommodates up to eight payloads, which can be serviced by the crew via the JEM PM airlock and dedicated robotic arm. The Columbus-EPF is another back-porch-like platform that can accommodate two zenith- and two nadir-looking payloads.

1.2 DATA CONTROL AND HANDLING ARCHITECTURE[1]

The ISS command and data handling (C&DH) system consists of hardware and software that provide services for command, control, and data distribution for all ISS systems, subsystems, and payloads. The top level (system-level) C&DH architecture contains redundant command and control (C&C) multiplexer/demultiplexers (MDMs) and MIL-STD-1553B control buses. The payload service includes the payload MDM for low-rate data link (LRDL) (1553B local bus) data and command distribution, and a high-rate data link (HRDL) for payload-to-payload communication and data downlink service. LRDL (other than payload safety-related) data are downlinked via the HRDL to the ground. Safety-related data are routed via the C&C MDM to the S-band data services for downlink. The Personal Computer System (PCS) is used by the on-board crew for command and display interface. Payload commands can be uplinked from a ground site, issued from the PCS, or issued by a payload MDM automated procedure. The C&DH architecture diagram is shown in figures 1.2-1 and 1.2-2.

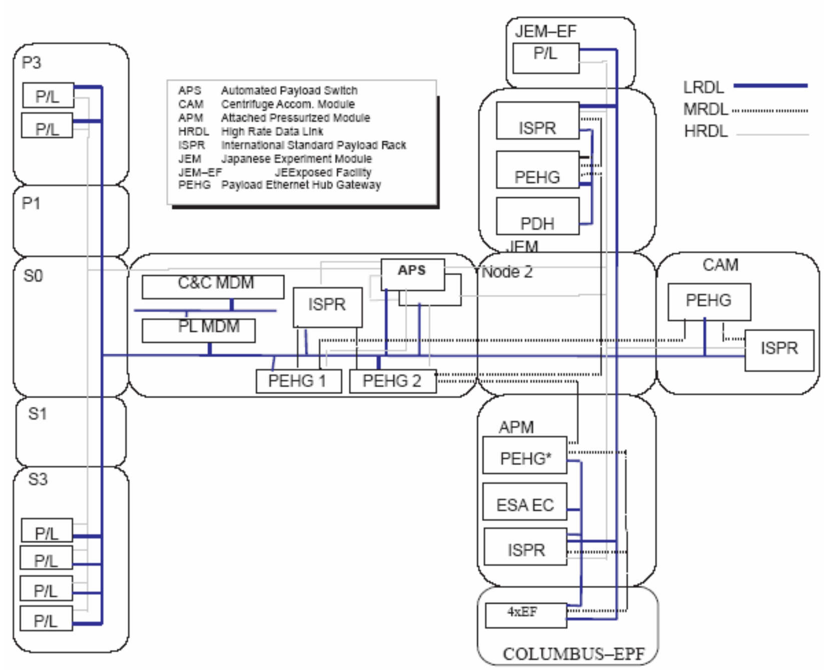
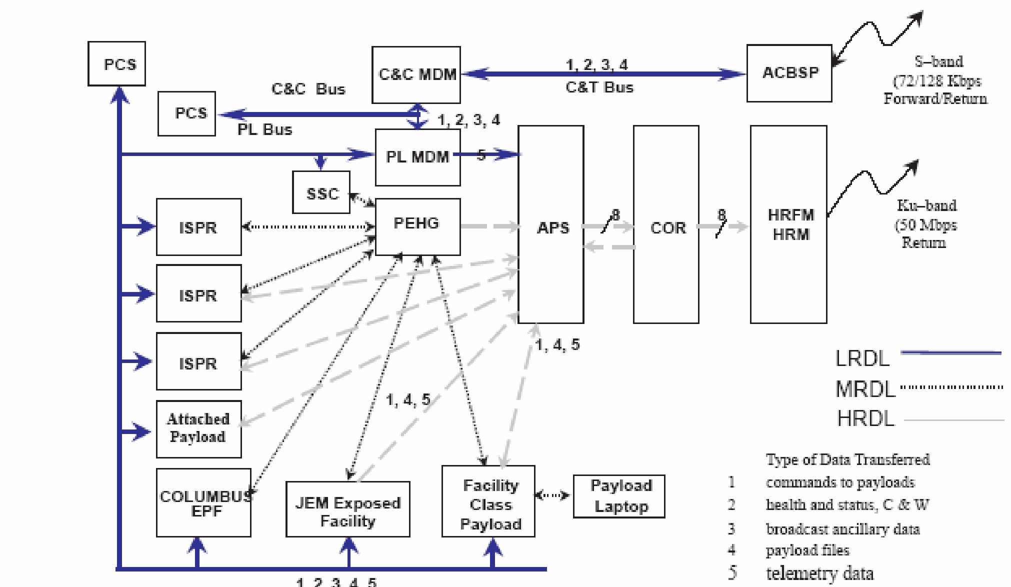


Figure 1.2-1: C&DH architecture.

[1]From SSP 57021, Attached Payload Accommodations Handbook, Rev A, Section 4.4.



Note:

- All LRDL and MRDL lines are bi–directional
- USOS data lines shown only

Figure 1.2-2: C&DH payload architecture functional data flow.

2 EXPRESS LOGISTICS CARRIER

The ELC is designed to carry a variety of orbital replacement units (ORUs or spares), first-time outfitting cargo, and external payloads (science experiments). The ELC, which is fully integrated with mounted cargo/payloads, will be delivered to the ISS and may be returned to Earth in the shuttle cargo bay. Transfer of the fully integrated ELC between the shuttle cargo bay and the ISS is accomplished using a series of robotic maneuvers using both the the Shuttle Remote Manipulator System (SRMS) and the Space Station Remote Manipulator System (SSRMS). Transfer of the fully integrated ELC may include an intermediate staging on the ISS MSS on the Mobile Remote Servicer Base System Common Attach System (MCAS) or Payload ORU Accommodation (POA). The U.S. EXPRESS logistics carriers will be located both port and starboard on the space station as indicated in the figures 2-1 through 2-4. The views from the different ELC locations can be Earth viewing or deep space viewing. Each view will also contain some percentage of space station structure or adjacent cargo or payload structure.

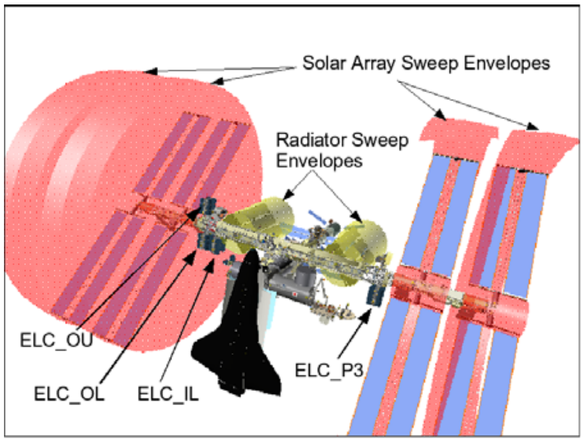


Figure 2-1: ISS and ELCs.

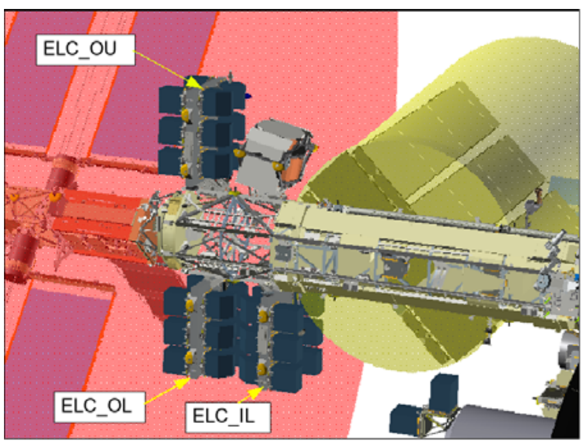


Figure 2-2: S3 ELCs.

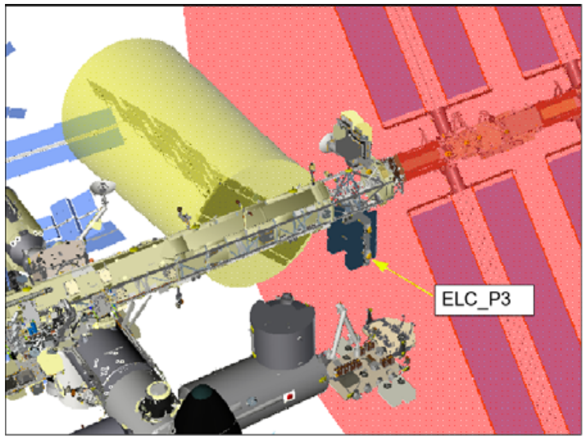


Figure 2-3: P3 ELC.

Isometric View Looking ISS Aft-Starboard-Nadir

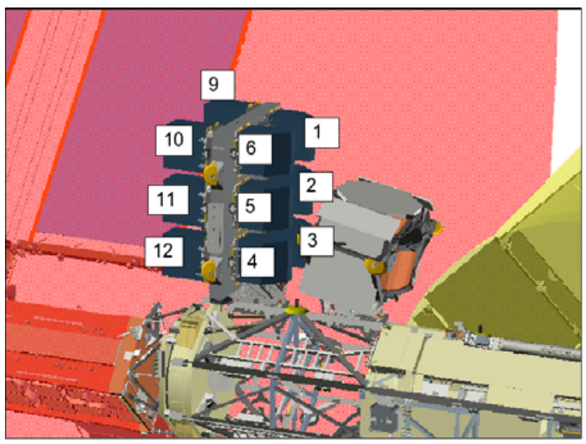


Figure 2-4: ELC Outboard upper (OU) payload designation.

2.1 POWER[2]

The ISS provides two 3-kW feeds at each S3/P3 attach site. Each site must use one of the feeds as main (primary) power for operational use, and the other as auxiliary (keep-alive) power. Attached payloads may use both power feeds simultaneously provided the power bus isolation requirements are met. Specific constraints on the use of main power and auxiliary power by attached payloads are defined in the payload-unique interface control document (ICD). Attached payloads delivered to the ISS by the shuttle should nominally expect to be unpowered during transfer to the ISS for up to 4.5 hours. Payloads that cannot withstand a lack of power for this duration must prearrange with the ISS for special accommodations or provide their own power source. During the assembly of ISS, electrical power generation hardware and software will be

[2]SSP57003, 3.2.2.2.2, pg 3-31.

installed to provide power to operate the ISS hardware as well as user payloads (fig. 2.1-1). Prior to Assembly Complete, payloads should be capable of withstanding several periods of approximately 8 hours of power disruptions. Planned power outages will be documented in SSP 50112, Operations Summary Document. However, unplanned payload power outages may also occur.

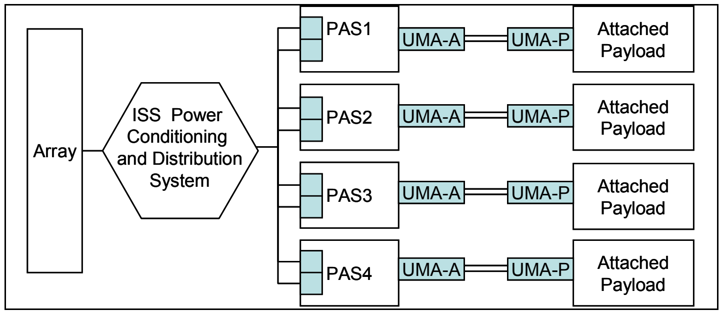


Figure 2.1-1: S3/P3 power distribution.

2.2 COMMUNICATION[3]

Each P3 and S3 attach site has access to both the LRDL and the HRDL (fig. 2.2-1). The LRDL is a MIL-STD-1553 bus that is used for data and command distribution. The HRDL is an optical fiber system that provides payload-to-payload communication and data downlink service. The LRDL (other than payload safety-related) data are downlinked via the HRDL to the ground. The PCS is used by the on-board crew for command and display interface. Payload commands can be uplinked from a ground site, issued from the PCS, or issued by a payload MDM automated procedure. The capabilities of the HRDL and LRDL are summarized in Table 2.2-1.

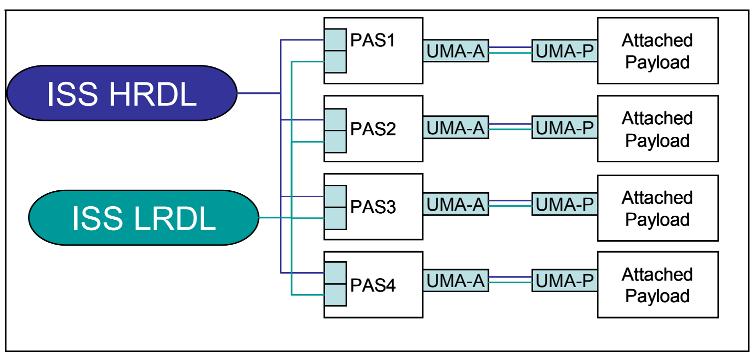


Figure 2.2-1: S3 C&DH diagram.

[3] SSP57003, 3.3.2, pg 3-43, SSP57021 Section 4.

Table 2.2-1: LRDL and HRDL Capabilities[4]

Type of Data Transferred	Payload to/from		by Data Link	
	Individual P/L Data Rate	Aggregate P/L Data Rate [5]	LRDL	HRDL
commands (to payloads)	10 commands per second [3]	8 commands per second [4]	X	
health and status	18720 bps	192 kbps (s–band) 256 kbps (Ku–band)	X	
C&W	160 bps			
payload ancillary data	3840 bps	N/A	X	
broadcast ancillary data	8960 bps			
payload files	≤ 40.96 kbps	≤ 40.96 kbps	X	
low rate telemetry data[1]	≤ 10240 bps		X	
		100 kbps		X
high rate telemetry data[2]	≤ 100 Mbps	≤ 20 Mbps		X

NOTE: Based on five (5) Payloads per LRDL

1 low rate data is sent via the HRDL to the ground

2 high rate data aggregate is total available after video

3 P/L MDM can support 10 commands per second (allows buffering of commands)

4 C&C MDM can support 8 commands per second (ground command through–put limit)

5 Aggregate payload refers to payloads on USOS C&DH System (internal and external P/Ls)

2.3 MICROGRAVITY[5]

The mechanical vibrations generated from all of the ISS systems are transmitted throughout the structure. These vibrations can affect experiments sensitive to acceleration. Both attached[6] and pressurized payloads are required to restrict their mechanical vibrations so as not to disturb these sensitive experiments while the ISS is in microgravity mode. Microgravity mode is an operation mode that precludes certain activities to minimize the vibration environment at some of the pressurized payload racks.[7] Figures 2.3-1 and 2.3-2 show the predicted microgravity environment at the S3 and P3 respectively. These figures depict the predicted environment while the ISS is not in Microgravity mode. Microgravity Mode is predicted to be lower.

[4]SSP 57021, Attached Payloads Accommodations Handbook, Revision A, Table 4.4.1-1, September 17, 2002.
[5]Hughes, William O. et.al, "Non-Isolated Rack Assessment (NIRA) 2003 of the International Space Station Microgravity Environment, NASA/GRC", Dec 2003.
[6]See SSP 57003,
[7]See SSP 41000, SSP 50036 for more information.

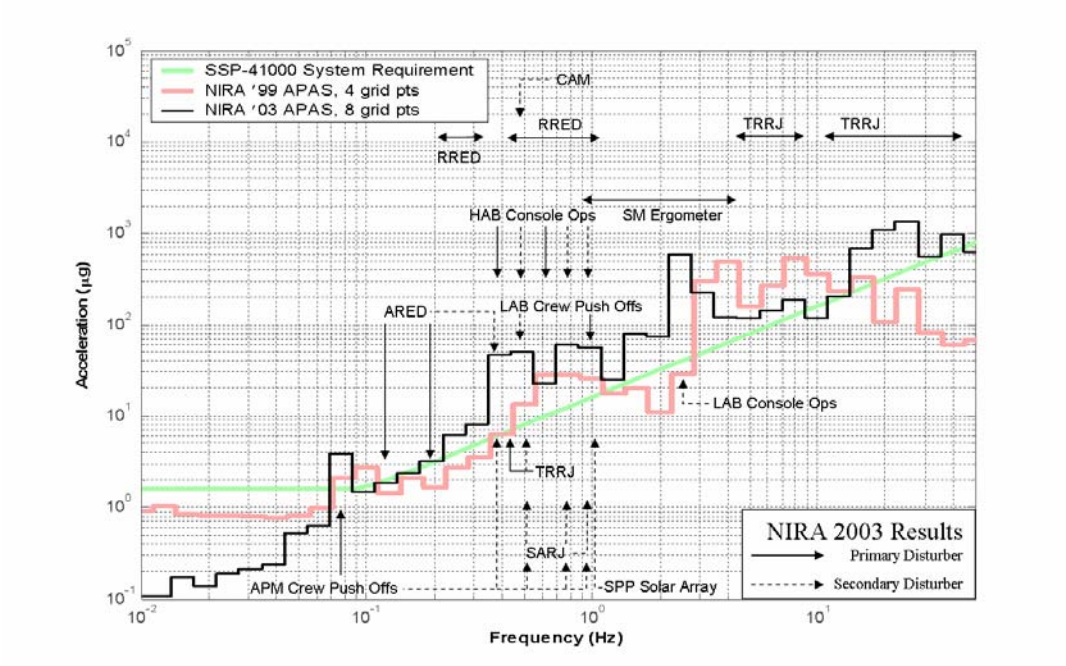


Figure 2.3-1: Predicted microgravity environment at S3 Payload Attach Site (PAS).

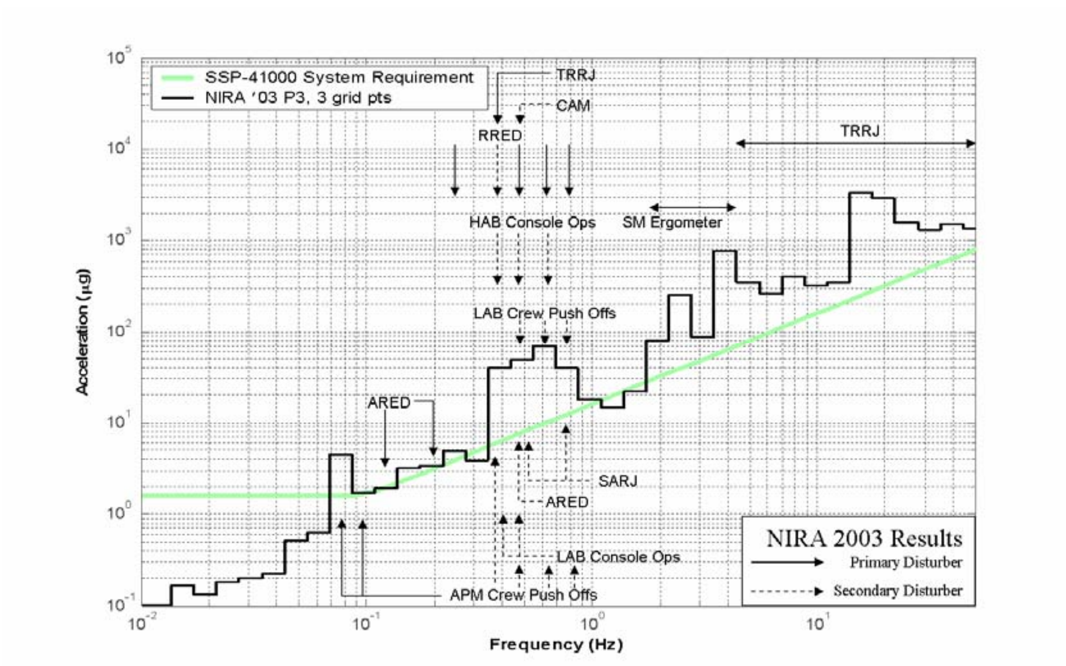


Figure 2.3-2: Microgravity environment at P3 unpressurized carrier common attach site (UCCAS).

2.4 VIEWS[8]

Attached payloads may require a view of the sky or of the Earth. Figures 2.4-1 through 2.4-9 depict modeled views from each of the P3 and S3 sites. The user may wish to request a particular site depending on the exact viewing requirement.

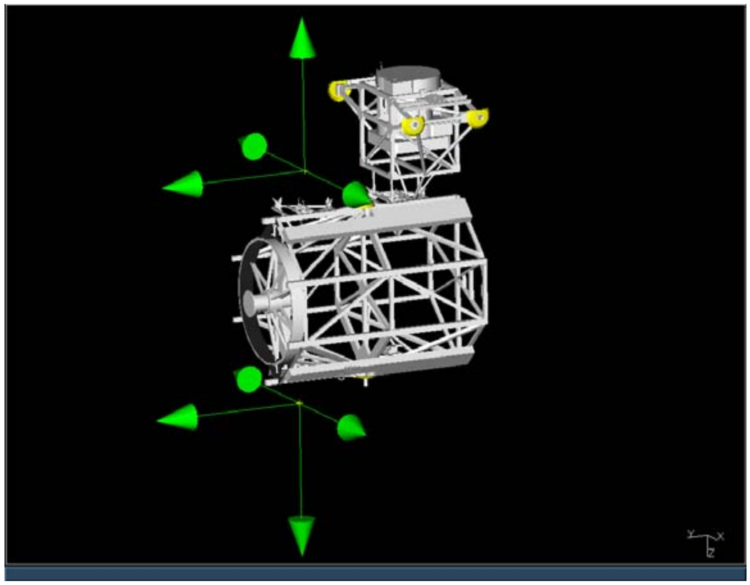


Figure 2.4-1: Payload attachment system (PAS) view coordinate system.

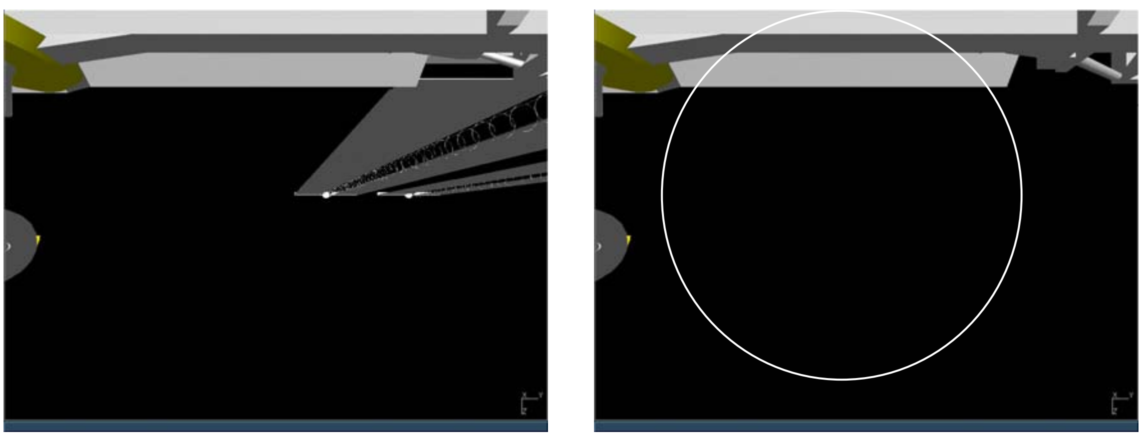


Figure 2.4-2: S3 lower truss, +X, orbital noon (left), and orbital sunrise (right).

[8] From Eppler, Dean, "ISS Attached Payload Fields of View", SSUAS Meeting Presentation, June 1999.

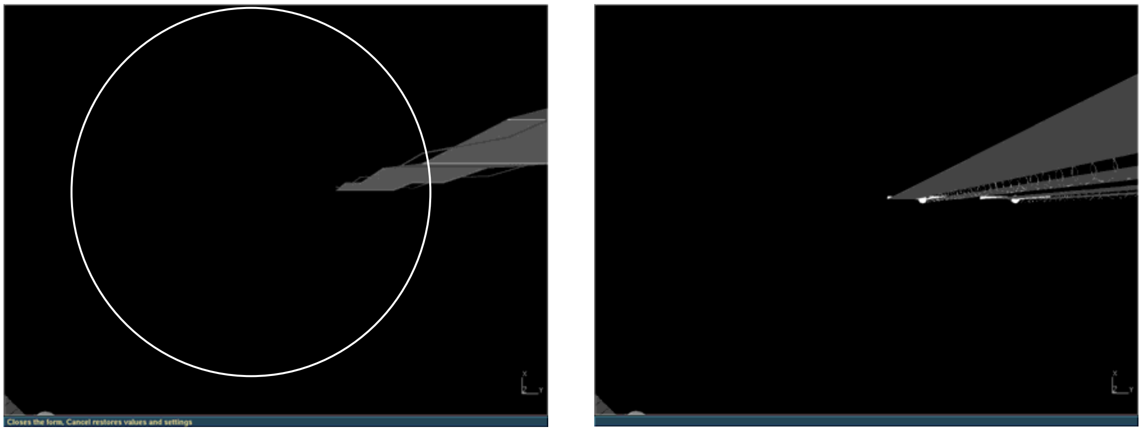


Figure 2.4-3: S3 lower truss, +Z , orbital noon (left), and orbital sunrise (right).

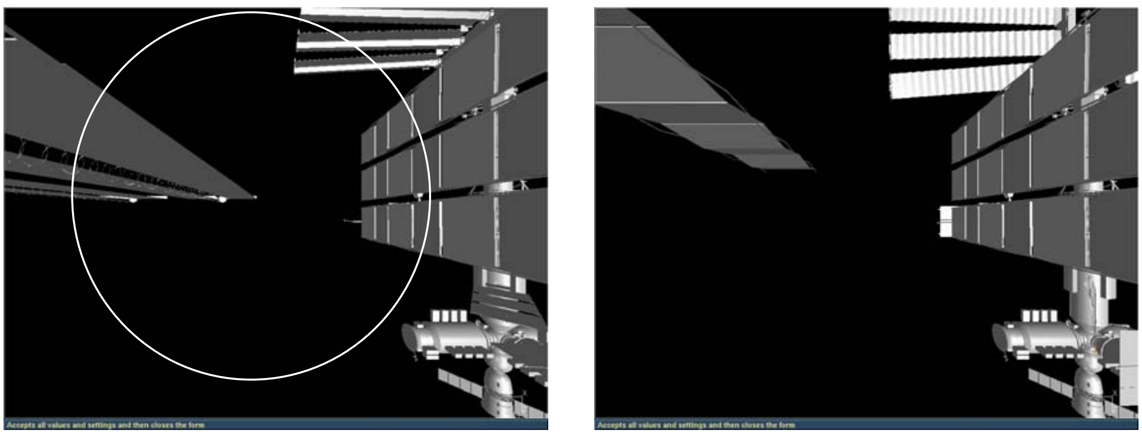


Figure 2.4-4: S3 lower truss, -X, orbital noon (left), and orbital sunrise (right).

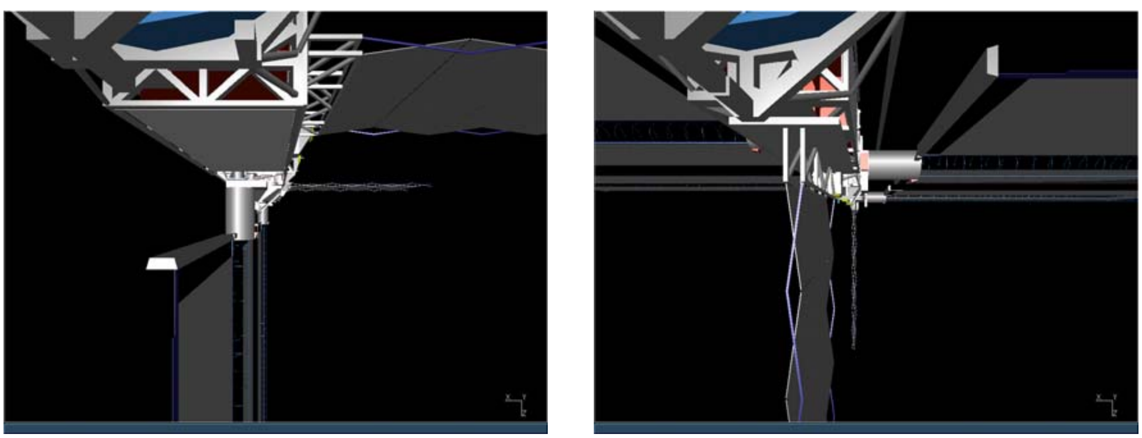


Figure 2.4-5: S3 lower truss, +Y, orbital sunrise (left), and orbital noon (right).

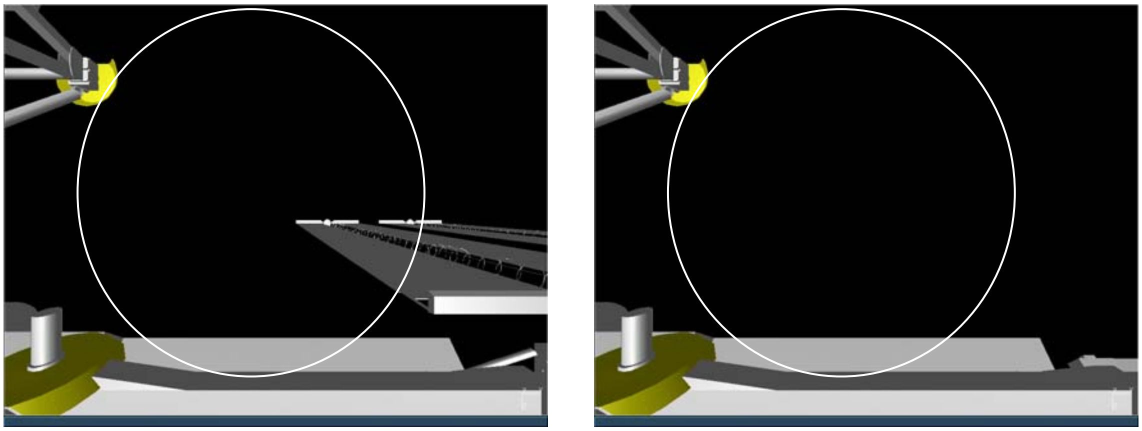


Figure 2.4-6: S3 upper truss, +X, orbital sunrise (left), and orbital noon (right).

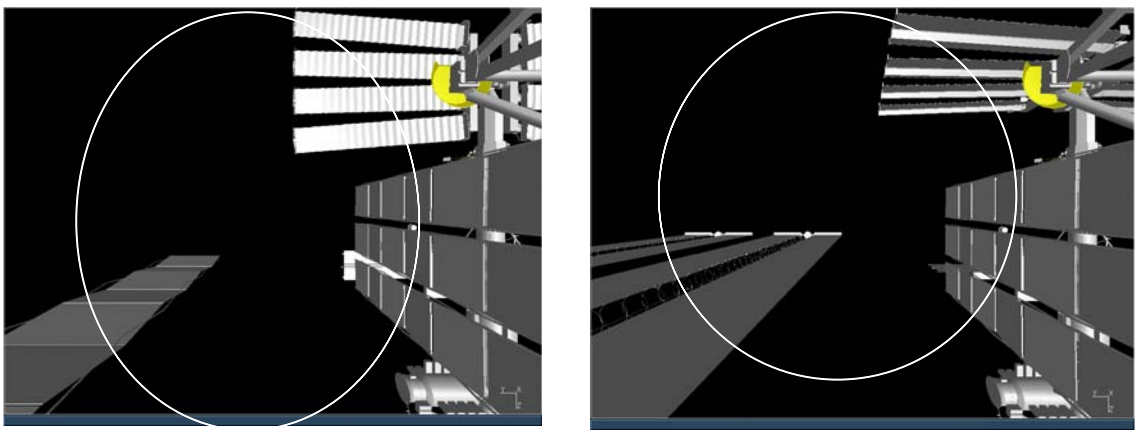


Figure 2.4-7: S3 upper truss, -X, orbital sunrise (left), and orbital noon (right).

Figure 2.4-8: S3 upper truss, -Z, orbital sunrise (left), and orbital noon (right).

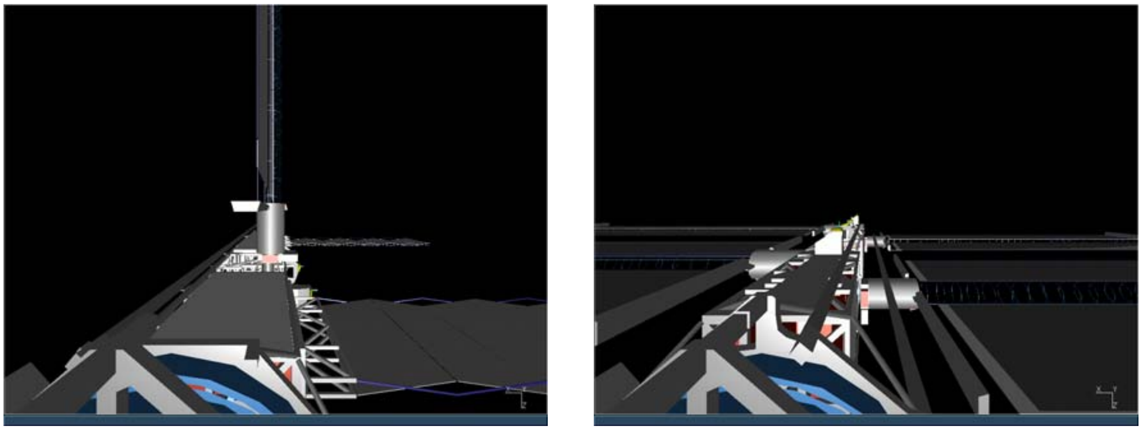


Figure 2.4-9: S3 upper truss, +Y, orbital sunrise (left), and orbital noon (right).

2.5 POINTING ACCURACY[9]

Limitations exist for the degree of pointing accuracy on any payload attachment site. The S3 site has a fixed alignment error of 0.2 to 0.5 degree/axis, 3σ. There is also a time-varying error (with a period of the order of an orbit) of ±0.08 degree for roll and pitch, and +0.23/-0.10 degree in yaw due to thermal bending of the truss. There is also a random error of 0.001-0.02 degree/axis, 3σ in position knowledge.

2.6 EXTERNAL CAMERAS[10]

Several remote cameras are located along the truss (fig. 2.6-1).

[9] Treder, Alfred, "Space Station GN&C Overview for Payloads", STAIF-2000.
[10] See http://mod.jsc.nasa.gov/do14/ISScamp.html

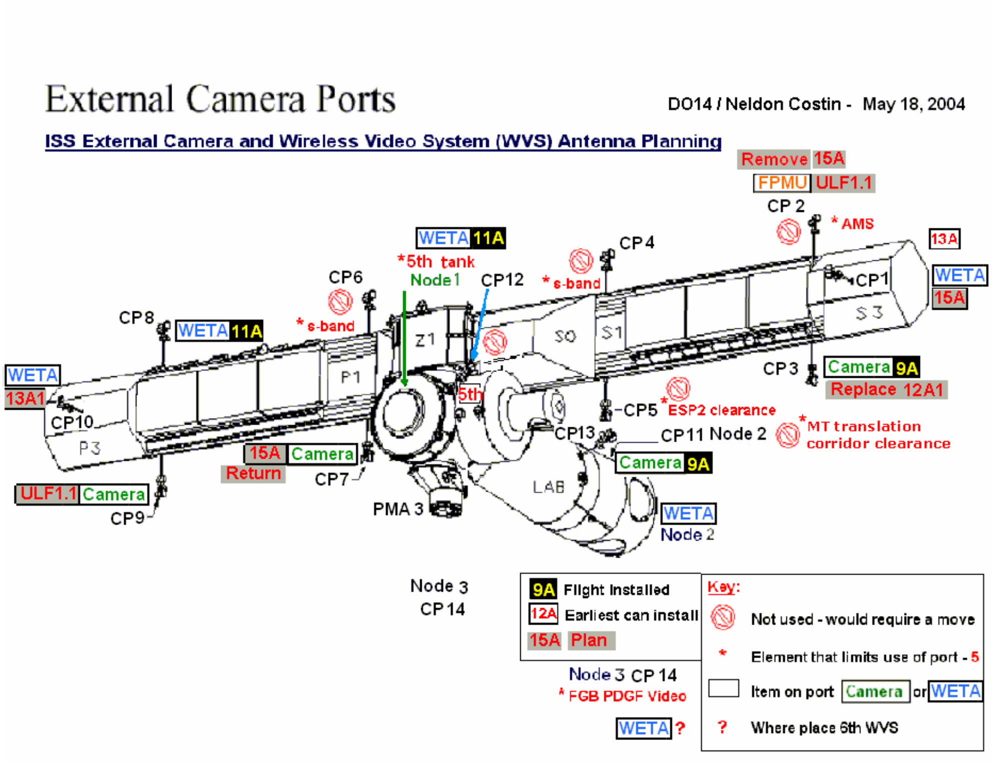


Figure 2.6-1: External camera port locations and views.

There are at least 14 external camera locations with cameras to operate between them. If a particular camera view is required but not available, a camera may be moved to a location that supports it.[11]

[11]ISS Familiarization Guide, TD9702A, July, 1998.

3 JAPANESE EXPERIMENT MODULE-EXPOSED FACILITY

The JEM-EF is an external platform for conducting scientific observations, Earth observations, and experiments in an environment exposed to space. The JEM-EF/payload interface on the JEM-EF side is the exposed facility unit (EFU). There are a total of 12 EFUs on the JEM-EF, nine of which are available for users. The other three EFUs are used for the JEM-experiment logistics module (ELM)-exposed section (ES) and for temporary storage. Figure 3-1 shows the JEM-EF flight unit under construction at the Japanese Aerospace Exploration Agency (JAXA) facility in Tsukuba, Japan, and figure 3-2 is a block diagram of the EFU locations. The JEM-EF provides payloads electrical power, data, and active thermal control.

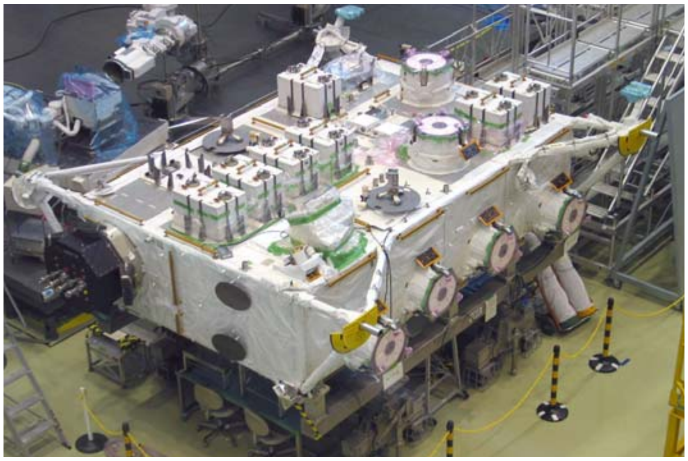


Figure 3-1: JEM-EF under construction at JAXA Facility in Tsukuba, Japan.

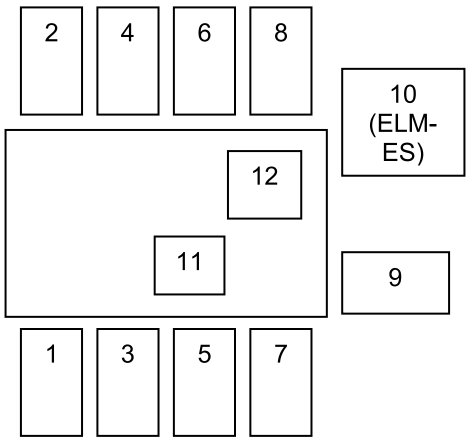


Figure 3-2: Location of JEM-EF EFUs.

3.1 POWER

Each EFU provides 3 kW of main power and 100 W of survival power on two separate buses.

3.2 COMMUNICATION

The JEM-EF provides eight high-data-rate channels, eight video data channels, and seven Ethernet channels.

3.3 MICROGRAVITY

The mechanical vibrations generated from all of the ISS systems are transmitted throughout the structure. These vibrations can affect experiments sensitive to acceleration. Both attached[12] and pressurized payloads are required to restrict their mechanical vibrations so as not to disturb these sensitive experiments while the ISS is in microgravity mode. Microgravity mode is an operation mode that precludes certain activities to minimize the vibration environment at some of the pressurized payload racks.[13] Figure 3.3-1 shows the predicted microgravity environment at the JEM-EF. This figure depicts the predicted environment while the ISS is not in microgravity mode. Microgravity mode is predicted to be lower.

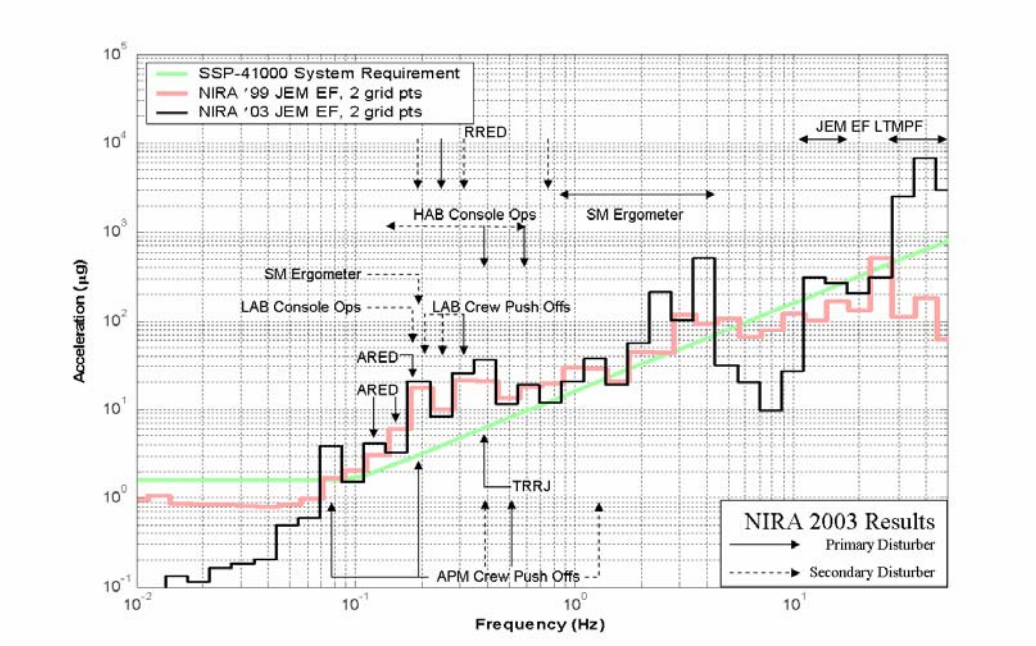


Figure 3.3-1: Microgravity environment in JEM-EF.[14]

[12]See SSP 57003,
[13] ee SSP 41000, SSP 50036 for more information.
[14]Hughes, William O. et.al, "Non-Isolated Rack Assessment (NIRA) 2003 of the International Space Station Microgravity Environment, NASA/GRC", Dec 2003.

3.4 JAPANESE EXPERIMENT MODULE-EXPOSED FACILITY VIEWS

Attached payloads may require a view of the sky or the Earth. Figures 3.5-1 through 3.4-6 depict modeled views from the JEM-EF. The user may wish to request a particular site depending on the exact viewing requirement.

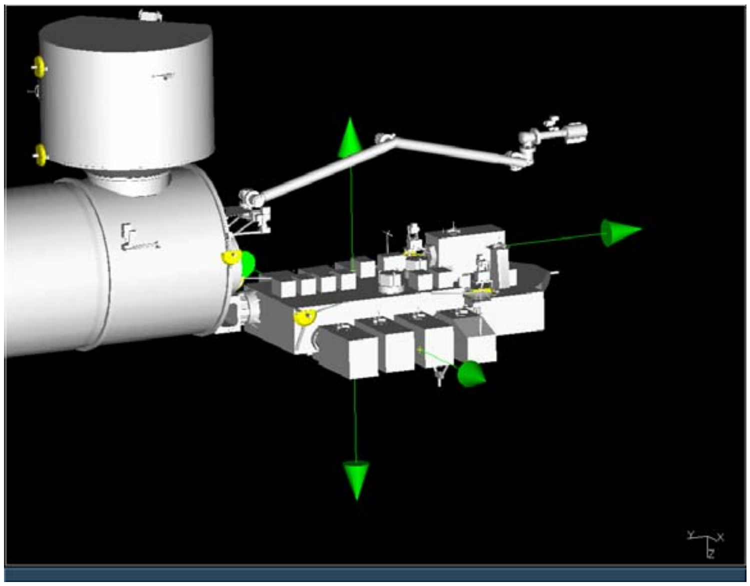


Figure 3.4-1: JEM-EF and coordinate system.

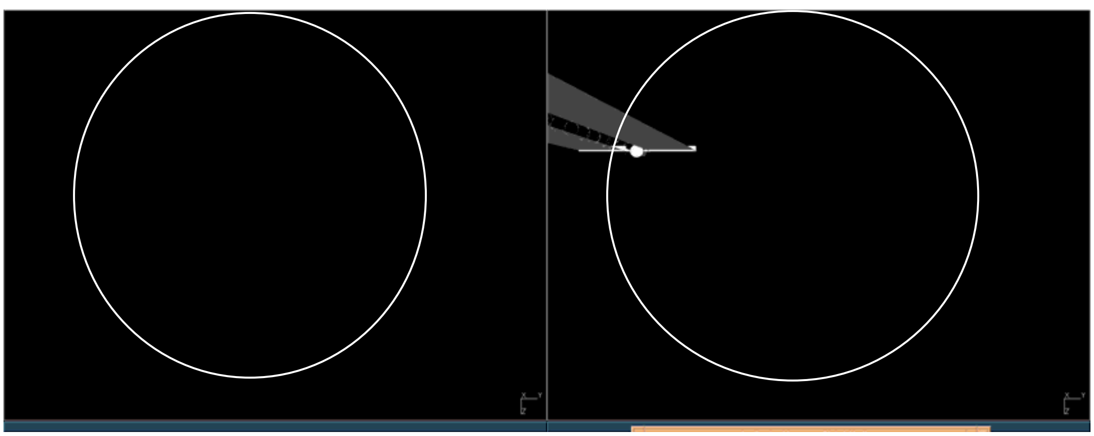


Figure 3.4-2: JEM-EF, +X, orbital sunrise (left), and orbital noon (right).

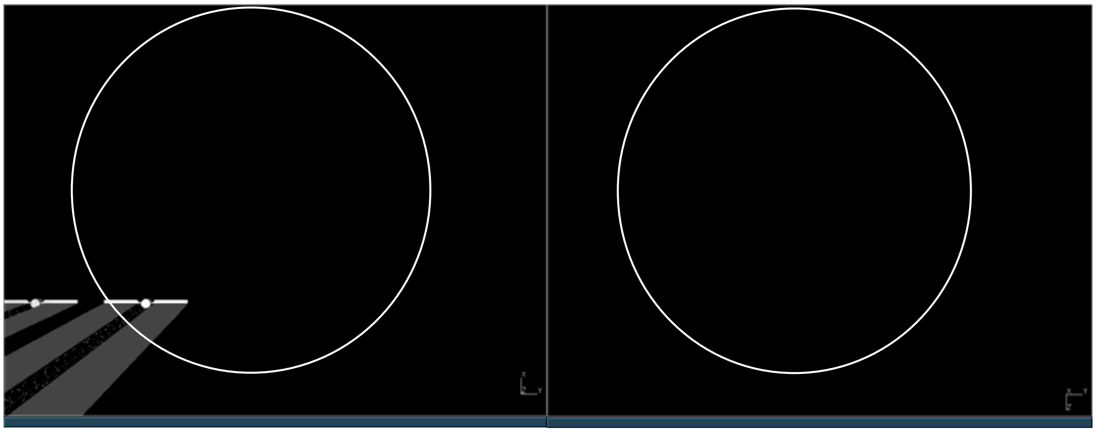


Figure 3.4-3: JEM-EF, +Z, orbital sunrise (left), and orbital noon (right).

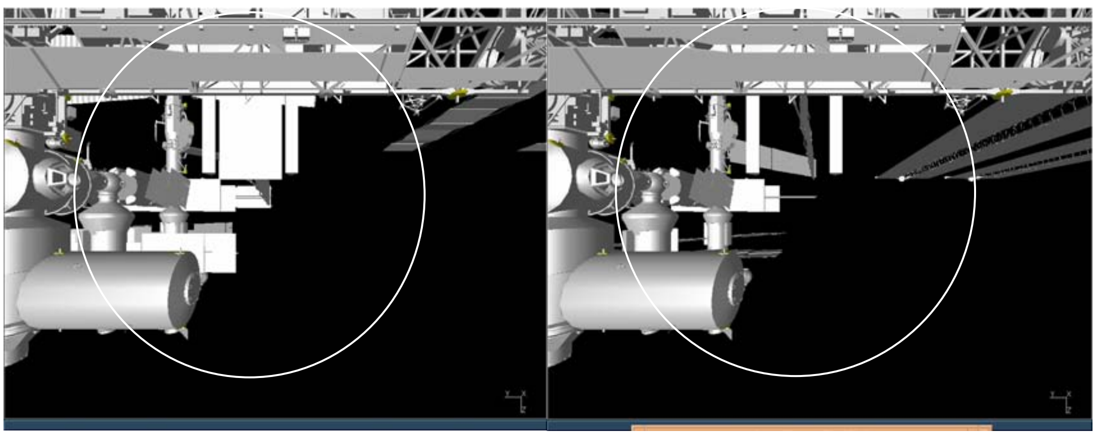


Figure 3.4-4: JEM-EF, -X, orbital sunrise (left), and orbital noon (right).

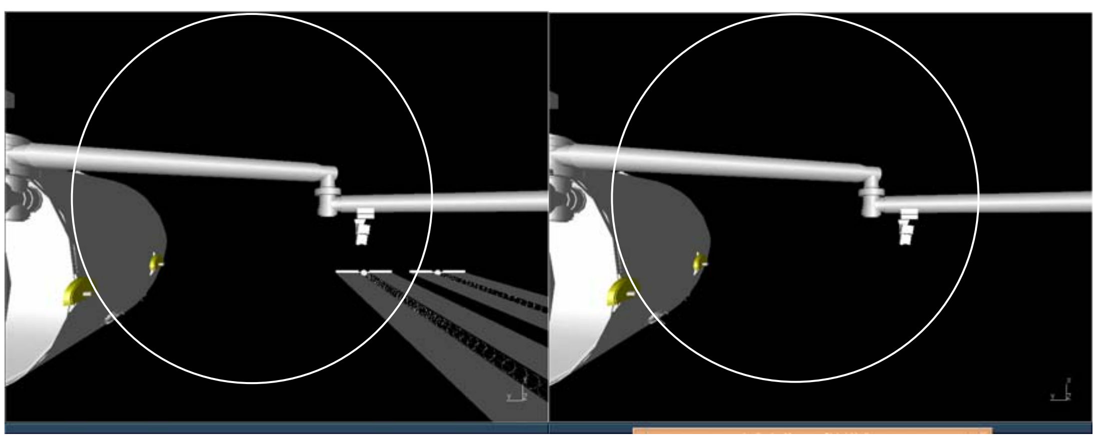


Figure 3.4-5: JEM-EF, -Z, orbital sunrise (left), and orbital noon (right).

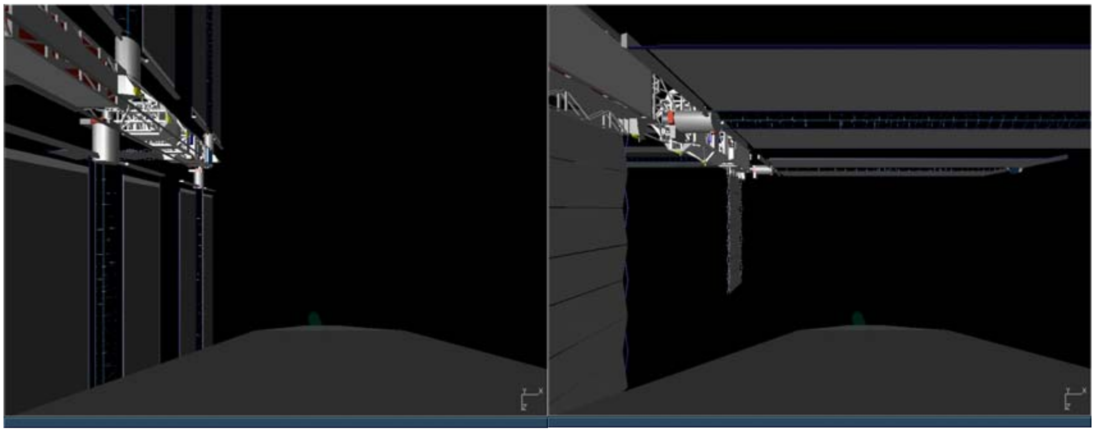


Figure 3.4-6: JEM-EF, -Y, orbital sunrise (left), and orbital noon (right).

3.5 JAPANESE EXPERIMENT MODULE AIRLOCK[15]

The JEM is unique within the U.S. on-orbit segment (USOS) in that it has a payload airlock. The airlock provides the capability to pass JEM-EF payloads between the pressurized cabin and space. The JEM airlock can accommodate a payload up to a volume of 6.4 m × 8.3 m × 1.605 m in volume and up to 300 kg in mass. It is nominally operated once a week with a maximum usage of two operations per day. The JEM-EF arm moves the payload between the JEM airlock and its place on the JEM-EF, and a slide table is available to move experiments or ORUs between the pressurized module (PM) and the EF.

[16]Additional information on the JEM airlock can be found at "International Space Station and Japanese Experiment Module "Kibo", http://iss.sfo.jaxa.jp/iss/kibo/develop_status_07_e.html.

4 COLUMBUS EXTERNAL PAYLOAD FACILITY[16]

The Columbus-EPF provides four attach sites: ONE nadir-facing, ONE zenith-facing, and two starboard-facing SITES. Each attach site is compatible with the EXPRESS Pallet adapter, or other custom-built adapter. Figure 4-1 illustrates the location of the EPF and some example payloads.

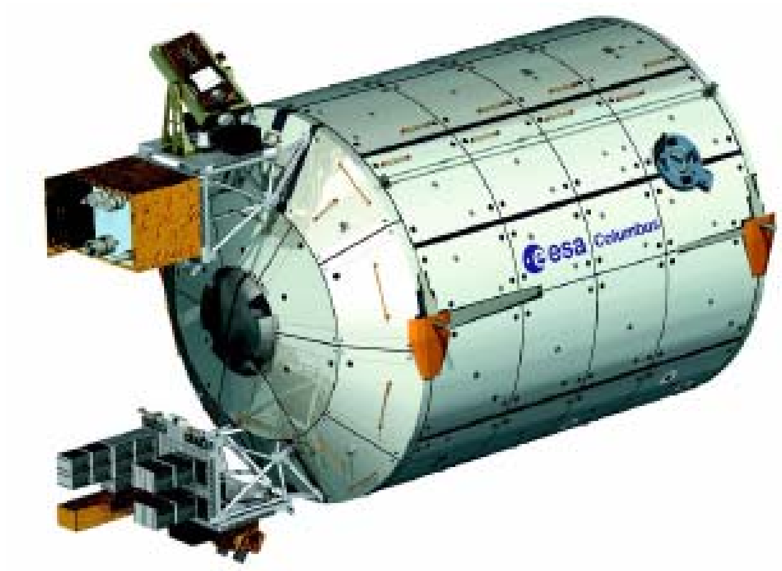


Figure 4-1: Columbus module with EPF.[17]

The interface is a removable adapter that attaches to the Columbus-EPF sites. Each payload may have a mass of up to 290 kg, including the adapter.

[16] Many of the details come from ISS European Users Guide, UIC-ESA-UM-0001, ESA, Issue 1, Rev.0.
[17] From ISS European Users Guide, UIC-ESA-UM-0001, ESA, Issue 1, Rev.0, Figure 3-1.

4.1 POWER

Each attach site is provided up to 1.25 kW by two 120-Vdc redundant power feeds. All four locations are provided a maximum of 2.5 kW.

4.2 COMMUNICATIONS[18]

Each attach site is provided a 1553-B low-rate data line for status data such as caution and warning, failure detection, etc. Each attach site is provided an Ethernet mediu- rate data line for transfer of commanding, ancillary data, and file transfer with rates up to 1.55 Mbps. The high-data-rate line interfaces to the video data processing unit and transmits up to 32.426 Mbps in increments of 32 kbps.

4.3 MICROGRAVITY

The mechanical vibrations generated from all of the ISS systems are transmitted throughout the structure. These vibrations can affect experiments sensitive to acceleration. Both attached[19] and pressurized payloads are required to restrict their mechanical vibrations so as not to disturb these sensitive experiments while the ISS is in microgravity mode. Microgravity mode is an operation mode that precludes certain activities to minimize the vibration environment at some of the pressurized payload racks.[20] Figure 4.3-1 shows the predicted microgravity environment at the Columbus-EPF. This figure depicts the predicted environment while the ISS is not in microgravity mode. Microgravity mode is predicted to be lower.

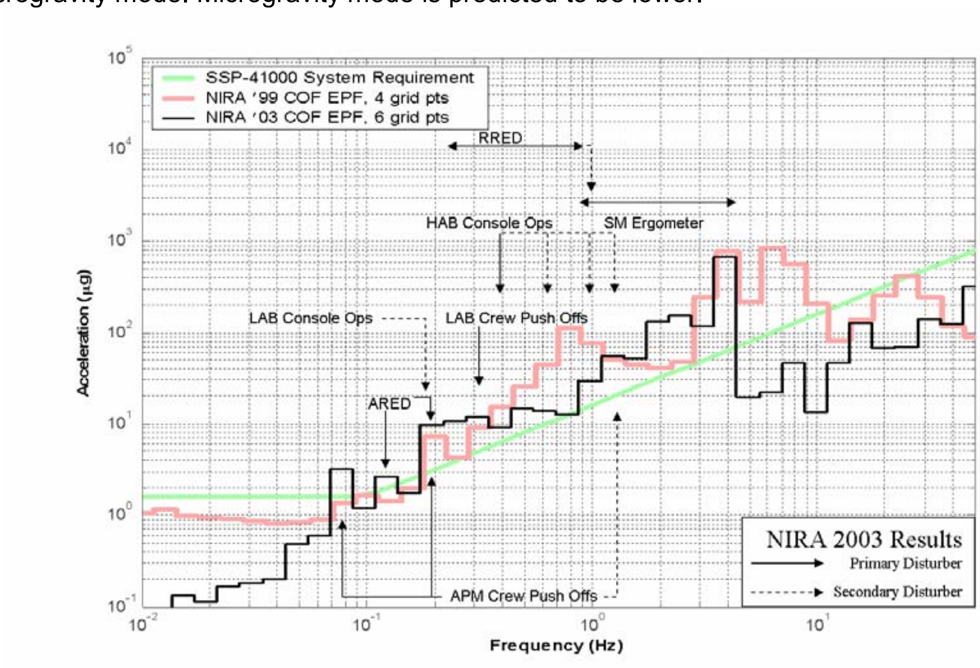


Figure 4.3-1: Microgravity environment in Columbus-EPF.

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[18]From ISS European Users Guide, UIC-ESA-UM-0001, ESA, Issue 1, Rev.0, Table 3-22, pg. 3-54.
[19]See SSP 57003,
[20]See SSP 41000, SSP 50036 for more information.

4.4 VIEWS

Attached payloads may require a view of the sky or of the Earth. Figures 4.4-1 through 4.4-6 depict modeled views from the Columbus-EPF. The user may wish to request a particular site depending on the exact viewing requirement.

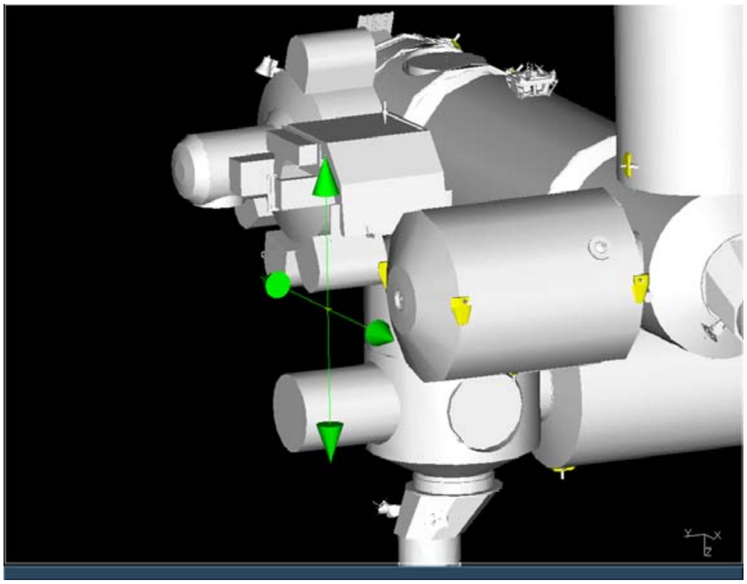

Figure 4.4-1: Columbus-EPF coordinate system.

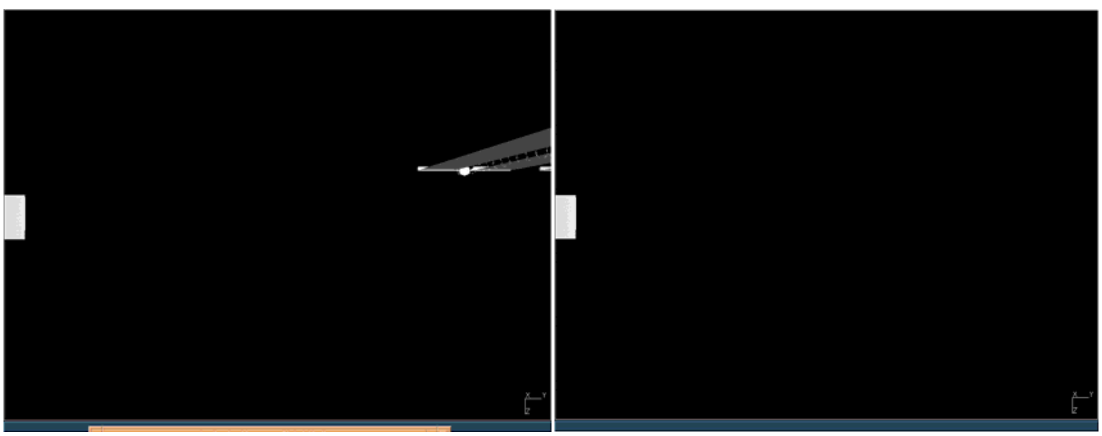

Figure 4.4-2: Columbus-EPF looking +X, orbital sunrise (left), and orbital noon (right).

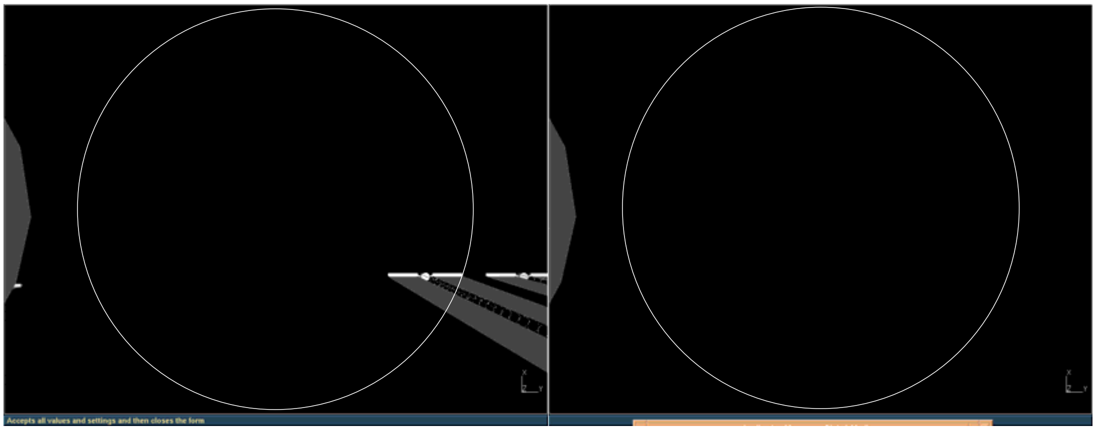

Figure 4.4-3: Columbus-EPF looking +Z, orbital sunrise (left), and orbital noon (right).

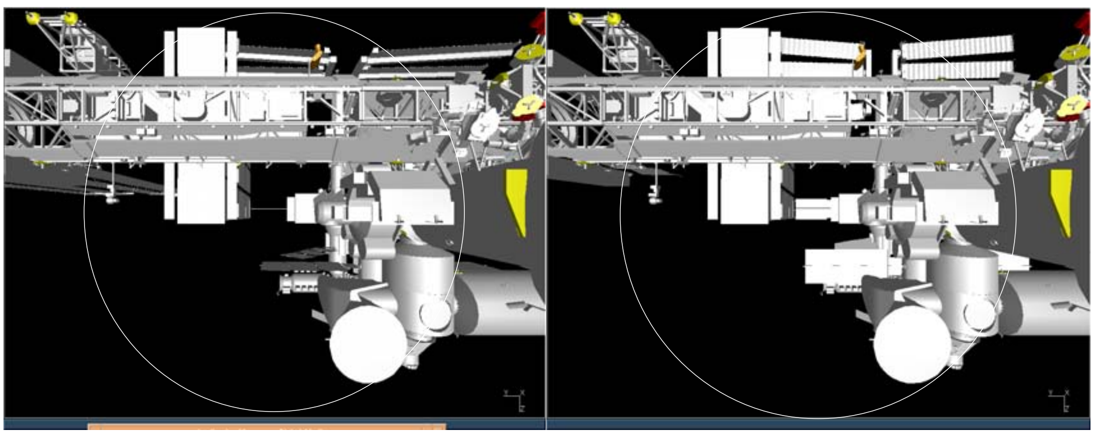

Figure 4.4-4: Columbus-EPF looking –X, orbital sunrise (left), and orbital noon (right).

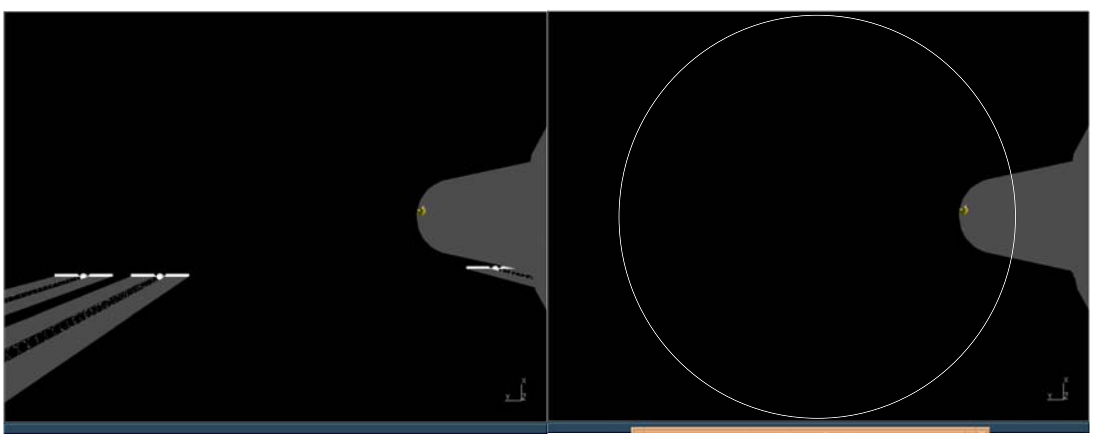

Figure 4.4-5: Columbus-EPF looking –Z, orbital sunrise (left), and orbital noon (right).

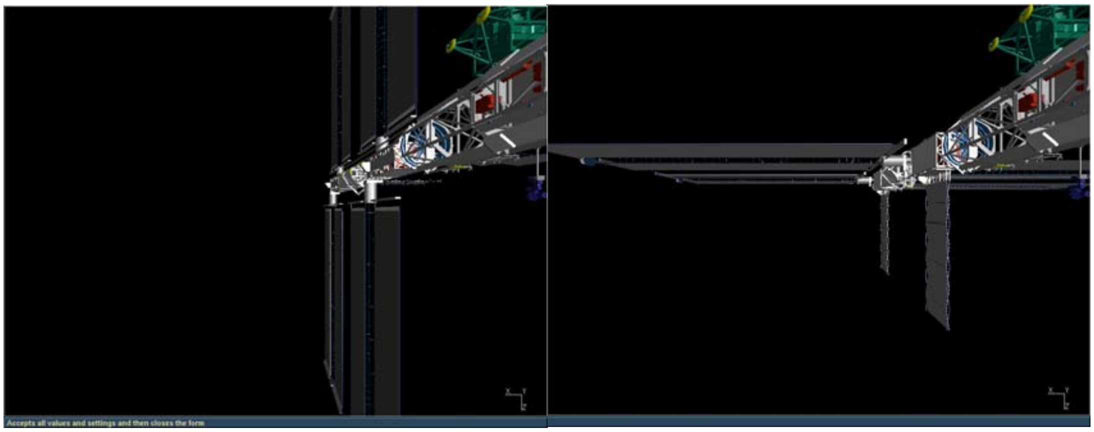

Figure 4.4-6: Columbus-EPF looking +Y, orbital sunrise (left), and orbital noon (right).

5 ATTACHED PAYLOAD TRANSPORTATION

Attached payloads may be transported to the ISS by the space shuttle, the Japanese H-II transfer vehicle (HTV), or some other ISS transportation vehicles. Attached payloads in the space shuttle are transported in the cargo bay, and attached payloads in the HTV are transported in its unpressurized carrier. Small attached payloads may be transported by any vehicle to the ISS pressurized section and then deployed by the JEM-EF robotic arm via the JEM airlock, or by EVA via one of the ISSs airlocks.

5.1 U.S. SPACE SHUTTLE

Attached payloads are delivered by the space shuttle in its cargo bay. Separate external payloads will be carried up on a “cross-bay” carrier (integrated cargo carrier (ICC), lightweight multipurpose equipment support structure (MPESS) carrier (LMC), an unpressurized logistics carrier (ULC)), or a “sidewall” carrier.

6 COMMAND AND CONTROL OF ATTACHED PAYLOADS

Payload operations are controlled by the flight crew, mission and payload controller, and automated processes. The C&DH system supports both manual and automated control for all nominal and planned contingency conditions. Payload commands may be issued from on-board automated command blocks or the PCS, or be uplinked from the ground. Procedures are automated (pre-programmed) where practical to relieve the crew workload and to preclude a need for crew activities to maintain or initiate payload functioning during normal communication outages.

The payload developer may receive data from an attached payload and issue payload commands while the payload is in operation on orbit. For payload developers who require near-real-time data from their attached payload, the on-board C&DH and the communications and tracking (C&T) system downlinks payload data to the Payload Operations Integration Center (POIC) first with ancillary data then forwarded to a payload developer’s facility. In addition, the C&DH extracts previously specified ancillary data necessary for the payload developer processing of payload data from the core operations data stream. The C&DH system forwards these data through the C&T system for nea- real-time downlink to the payload developer’s facility. The mode of data transmission is dependent upon the nature of the payload and the payload developer’s data requirements. Payload developers may receive data in near real time, at prescheduled times, and as playback anytime up to 1 year after the receipt of the payload or ancillary data.

7 EXTRAVEHICULAR ACTIVITY

For ISS, there are two types of EVAs: nominal and contingency. For attached payloads, only contingency EVA is available.

8 MEAN MAINTENANCE CREW HOURS PER YEAR

The attached payloads will be allowed a maximum allocation of Mean Maintenance Crew Hours Per Year of eight hours for contingency EVA only.

9 NATURAL ENVIRONMENT

The natural environment surrounding the ISS is of importance to the payload community for at least two reasons:

(1) It may affect the design and operation of attached payloads.
(2) it may be the object of investigation for experiments conducted using the payload equipment.

The objective of this description is to define the natural environment as it might affect the design and operation of payload equipment. The inclusive environments described here include:

A. Neutral atmosphere
B. Plasma
C. Charged particle radiation
D. Electromagnetic radiation (EMR)
E. Meteoroids
F. Space debris
G. Magnetic field
H. Thermal, pressure, and other physical constants
I. GravitationalfField

Note that the space debris and electromagnetic environments include elements produced by the activities of human beings: orbital debris and radio frequency radiation generated on the Earth (fig. 9-1). These latter two environments are included in this discussion because they are part of the ambient environment to which the ISS and its payloads are exposed. Detailed descriptions of direct interactions of orbiting elements with the Earth's atmosphere are contained in SSP 30425, Space Station Program Natural Environment Definition for Design.

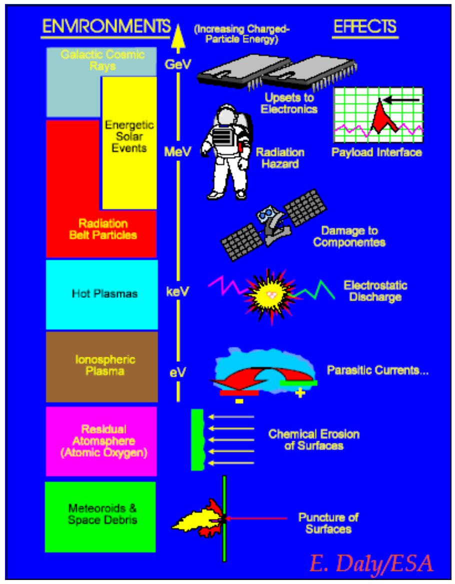

Figure 9-1: Radiation environment and associated effects.[21]

9.1 PLASMA ENVIRONMENT[22]

Plasma is a quasi-neutral gas of charged and neutral particles that exhibits collective behavior. The movements of the particles are controlled to a great extent by the Earth's magnetic field and the solar wind, but their collective behavior and movement generate electric and magnetic fields that, in turn, affect the particle motion and the motion of other charged particles far away. Plasmas are usually described by their density, the chemical composition of the ions, and the electron and ion temperatures.

9.2 SPACECRAFT-PLASMA INTERACTIONS

A spacecraft in low Earth orbit (LEO) accumulates electric charge from the plasma to establish electrical equilibrium with the plasma, a process called spacecraft charging. Spacecraft surfaces tend to accumulate a negative charge. Charging of passive surfaces is usually not a problem, however, for active surfaces—e.g., solar arrays and structure tied electrically to them—arcing and related significant effects can occur, depending upon the grounding scheme and the magnitude of the spacecraft-imposed voltages.

9.3 CHARGED PARTICLE RADIATION

Penetrating charged particles are produced from two sources: magnetospheric particles and cosmic rays. Magnetosphere particles, which are accelerated from the plasma by processes inside the magnetosphere, occur only within terrestrial space. Cosmic rays exist in interplanetary space and enter terrestrial space. The motion of both kinds of particles is controlled by the Earth's geomagnetic field. Charged particles present a significant challenge to the design and operation of most attached payloads. A high level of radiation will significantly affect materials, chemical processes, and living organisms. It will also affect electronics by causing soft upsets (referred to as single-event upsets (SEUs)) that degrade performance and sometimes produce permanent

[21] Barth J., "The Radiation Environment", NASA/GSFC Presentation.
[22] Exerpt from Space Station Program Natural Environment Definition for Design, SSP30425 Rev B.

damage. In addition, ionizing radiation will affect the propagation of light through optical materials by altering their optical properties.

Cosmic rays produced from galactic sources typically make up less of the total dose of radiation, in rads, than trapped protons. However, these cosmic rays produce significant effects. They are responsible for SEUs, latch up in microcircuits, and produce, along with trapped radiation-belt protons, the nuclei-induced radioactivity in most materials. Cosmic rays also induce noise by production of ionization in devices such as charged-coupled devices and by production of Cherenkov and fluorescence radiation in photomultiplier tubes.

For specific design issues, the actual anticipated radiation environment must be calculated. SSP 30512, Space Station Ionizing Radiation Design Environment, and SSP 30425 provide significantly more detail and information concerning available tools for calculating the expected environment. SSP 30425 describes the general shape of the Van Allen belts following the shape of the geomagnetic field. This means that the ISS penetrates most deeply into the belts in the region of the South Atlantic Anomaly. Because the flux is increasing with altitude in the region of 300 to 1000 km, the most intense radiation encountered in the anomaly, as shown in figure 9.3-1 as the brightly colored area over South America extending out into the southern Atlantic Ocean.

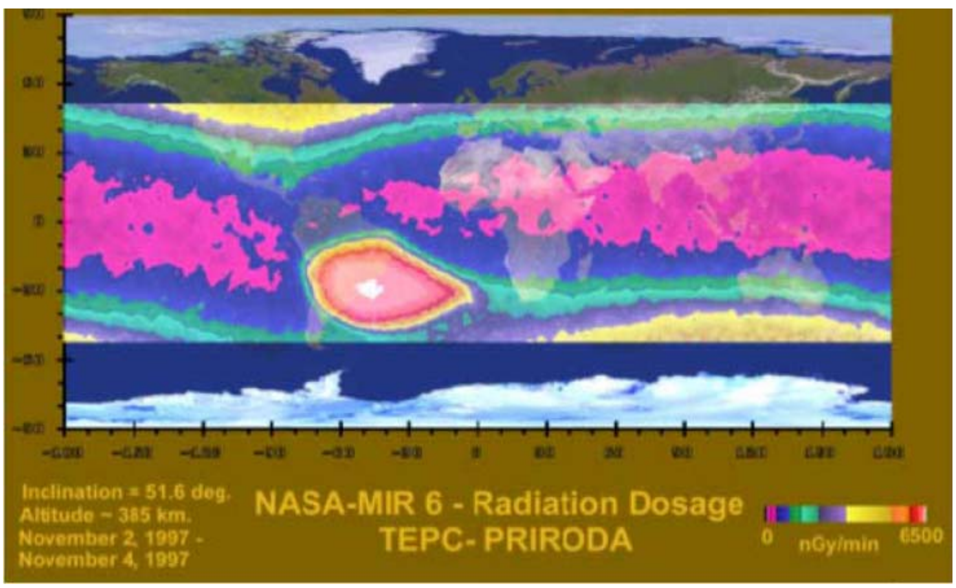

Figure 9.3-1: Representative data of radiation dosage in LEO similar to ISS.[23]

9.4 ELECTROMAGNETIC RADIATION

Electromagnetic noise sources of significance at the ISS extend from direct current to x ray. Only natural and remote human-madeEMR sources are considered here. The categories of noise producers are as follows:

[23]Johnson, Steve A, et al., "Minimizing Space Radiation Exposure During Extra-Vehicular Activity", COSPAR 2002.

A. Galactic
B. Solar
C. Near-Earth natural plasma
D. Human-made radio noise

The highest power densities expected to be irradiating the ISS are from the solar radiation in the ultraviolet and visible portions of the electromagnetic spectrum. The ultraviolet radiation can damage materials exposed to it. SSP 30425, paragraph 7.2, describes the degree of exposure of the payloads to the solar ultraviolet radiation environment. Other effects of EMR to be considered include radio noise and field strengths from the natural sources at the ISS. Field strengths produced from quasi-static field structures in the plasma have typical values around 25mV/m, but can be larger. These values generally occur at latitudes greater than 50°.

9.5 METEOROIDS/ORBITAL DEBRIS

The orbital environment contains a large number of naturally occurring and human-made objects that might impact the ISS and the payloads attached to it. Objects range in size from a mass of less than 0.62 cm to objects with a mass of much more than 1 m across. Most of the orbital debris is located at altitudes less than 2,000 km. SSP 30425, section 8.0, specifies the meteoroid/orbital debris (M/OD) environments to which the ITS S3 M/OD critical items are exposed.

9.6 MAGNETIC FIELD

The Earth's magnetic field, in addition to acting directly with the ISS to produce electric field gradients in the station and its components, traps charged particles and deflects low-energy cosmic rays. It is also basically a dipole field. The magnetic field at altitudes up to approximately 2000 km is determined by this near-Earth field, but above this altitude strong currents of charged particles within the magnetosphere cause deviations. The Earth's magnetic field is not constant and fluctuates with time (i.e., it may be cyclic). Various analytical computer models are in existence to calculate trapped radiation and the field strength expected to be encountered by the ISS for a specific time. The natural on-orbit electromagnetic field environment to which payloads will be exposed is defined in SSP 30425, section 7.0. The natural magnetic field created by the Earth to which payloads are exposed in LEO is defined in SSP 30425, section 9.0.

9.7 THERMAL, PRESSURE, AND PHYSICAL CONSTANTS

Detailed evaluations of external environments require the use of many thermal, ambient pressure, and other physical constants. To assist in the consistent use of physical constants for detailed analyses, SSP 30425 provides listings of constants that can be used in developing models of the environment.

9.8 GRAVITATIONAL FIELD

A model of the gravitational field that takes into account the Earth's nonuniform mass distributions is provided in SSP 30425, section 11.0.

9.9 CONTAMINATION[24]

The induced environment associated with the ISS will be strongly influenced by activities associated with its operation. For example, the level of induced environment will be increased during space shuttle docking and periodic reboost. It is prudent, therefore, to define two conditions of the inducted environment: quiescent periods and nonquiescent periods. Quiescent periods provide an induced environment that is consistent with designed measurement capability. For nonquiescent periods, it is assumed that the disturbed environment will be unacceptable for some

[24]Edited from Space Station External Contamination Control Requirements Document, SSP 30426, Rev D.

measurements; however, the environment shall not produce conditions that preclude returning to unrestricted measurements as soon as the disturbing activity is terminated. Disturbing activities leading to nonquiescent periods shall be of short duration, resulting in most of the operational time being quiescent. Nonquiescent periods shall be scheduled, and users shall be notified in sufficient time to take appropriate action.

All materials used in hardware that will be exposed to space vacuum must have low-outgassing characteristics as defined by a total mass loss of ≤ 1.0% and a volatile condensable material of ≤ 0.1%. Lower outgassing rates may be required for hardware that has large view factors to other hardware and for local regions such as window cavities.

The contribution to the molecular column density created by the presence of ISS contamination sources along any unobstructed line of sight is required to not exceed 1×10^{-4} molecular-cm^{-2} for individual released species. This includes contributions from outgassing, venting, leakage, and other ISS contamination sources but does not include ram-wake effects. Molecular column density requirements may be exceeded for line of sight through volumes in space of high molecular density near gas vents. Specifically, the molecular column density limit may be exceeded for all lines of sight parallel to and within 1 m from the vent axis. The vent axis will be oriented to preclude direct plume impingement on the JEM-EF and attached payload truss locations.

As the ISS moves through the Earth's rarefied environment, a ram-wake effect is created (i.e., density build-up preceding forward-facing surfaces and a density decrease on aft-facing surfaces). Build-up on surfaces that have some exposure to ram can be as high as 60 times the ambient density. Attached payloads that are sensitive to such a density should be carefully located relative to large surfaces to preclude interferences. A change in the composition of the surface local environment can be expected due to either reaction with the surface or to recombination occurring on or near these surfaces.

The release of particulates from the ISS is limited to one particle of 100 microns or larger per orbit per 1×10^{-5} steradian field of view as seen by a 1-m diameter aperture telescope. This includes contributions of particulates originating from external ISS surfaces, compartments vented to space, movable joints, vents (of solids, liquids, and gases), and other ISS particulate sources, but it excludes particulates in the natural environment and their effect on ISS hardware (i.e., their impact on ISS surfaces).

There are several areas on the ISS external surface (solar arrays, thermal radiators, observation windows, truss attached payloads, and the JEM-EF) where contamination fluxes are assessed. The flux of molecules emanating from the ISS are limited such that 300K, the mass deposition rate on the sampling surfaces, to 1×10^{-14} g-cm^{-2} sec^{-1} (daily average) and will not exceed 1×10^{-6} g cm^{-2} yr^{-1}.

10 References

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- Hughes, William O. et al, "Non-Isolated Rack Assessment (NIRA) 2003 of the International Space Station Microgravity Environment, NASA/GRC," Dec 2003.
- SSP 30425, Space Station Program Natural Environment Definition for Design, Rev B.
- SSP 30426, Space Station External Contamination Control Requirements, Rev D.
- SSP 30512, Space Station Ionizing Radiation Design Environment.
- SSP 41000, ISS System Specification.

- SSP 42131, Space Station Program Integrated Truss Segments P3 And S3 To Attached Payloads And Unpressurized Cargo Carriers (UCC) Standard Interface Control Document.
- SSP 50036, Microgravity Control Plan
- SSP 50112, Operations Summary Document
- SSP 57003, Attached Payload Integrated Requirements Document, Rev A.
- SSP 57021, Attached Payloads Accommodation Handbook, Rev A..

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13. ABSTRACT *(Maximum 200 words)*
External payload accommodations are provided at attachment sites on the: U.S-provided Express Logistics Carrier, U.S. truss, Japanese Experiment Module-Exposed Facility (JEM-EF), and Columbus-EPF (External Payload Facilities). The integrated truss segment attaches solar and thermal control arrays to the International Space Station (ISS), houses cable distribution trays and spacewalk support equipment, and provides for extravehicular robotic accommodations. The JEM-EF accommodates up to eight payloads, which can be serviced via the JEM PM airlock and dedicated robotic arm. The Columbus-EPF can accommodate two zenith- and two nadir-looking payloads. The ISS command and data handling (C&DH) system consists of hardware and software that provide services for command, control, and data distribution for all ISS systems, subsystems, and payloads. The system-level C&DH architecture contains redundant command and control (C&C) multiplexer/demultiplexers and MIL-STD-1553B control buses. The payload service includes the payload MDM for low-rate data link (LRDL) data and command distribution, and a high-rate data link (HRDL) for payload-to-payload communication and data downlink service. LRDL data are downlinked via the HRDL to the ground. Safety-related data are routed via the C&C MDM to S-band data services for downlink. The Personal Computer System is used by the crew for command and display interface.

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