# Z1 Integrated Truss Segment

Payload Bay

**Overview**

The Z1 is the base structure for the U.S. solar array. It includes two plasma contactors, two DC-to-DC converter units (DDCUs), four control moment gyro (CMG) assemblies, part of one string of the S-band communications system, one Ku-band communications system, primary and secondary power distribution, thermal control system hardware, mechanical interfaces, and EVA/extravehicular robotics (EVR) hardware.

**Command and Tracking Subsystem**

*S-Band Communications System*. The S-band communications system consists of two redundant strings, each of which comprises three on-orbit replaceable units (ORUs) and two antennas, the baseband signal processor (BSP), the Tracking and Data Relay Satellite System (TDRSS) transponder, and the antenna RF group, which includes a low-gain antenna and a high-gain directional antenna.

The radio frequency group (RFG) has two main functions. It amplifies and filters the radio signal and receives and radiates the signal, providing the interface with free space. It also controls antenna switching and pointing.

The RFG unit has two antennas. The high-gain antenna (HGA) can support the high-rate data link, but it requires TDRSS pointing updates that are generated by the guidance, navigation, and control (GN&C) pointing function (which will not be available until the GN&C multiplexer/demultiplexer [MDM] is activated on Mission 5A). The low-gain antenna (LGA) is fixed in position and needs no pointing data.

The RFG is launched on the Z1 starboard bulkhead. Since this is the DDCU heat pipe (HP) installation location, the RFG must be relocated temporarily during EVA1 to the stowage bracket.

The BSP is the heart of the S-band system. It provides data and voice processing for downlink and uplink. A voice line connects directly to the BSP to provide voice communications.

The TDRSS transponder, which will arrive on Mission 4A, receives downlink information from the BSP and modulates the RF carrier for transmission to the ground. The transponder receives the uplink information from the RF group, demodulates the signal, and routes it to the BSP for information separation and distribution.

The downlink output of the BSP is a constant-rate data stream of either 192 kbps or 12 kbps, as specified by a configuration command.

To support the uplink, the BSP inputs a digital bit stream from the standard TDRSS transponder at either 72 or 6 kbps depending on whether the BSP is configured for the high or low data rate. The data is processed by decryption, CCSDS header validation, and demultiplexing functions. If uplink audio channel data is present, it is expanded to 192 kbps per channel for interface to the AUAIU and is routed to the appropriate output port. The uplink core data channel packets are passed to the 1553 interface for transfer to the command and control processor.

*Ku-Band Communications System*. The Ku-band system is the primary return link for International Space Station (ISS) video and payload data transmitted in digital format to the ground. The space-to-ground antenna (SGANT) will be relocated and attached to the single-beam boom of the current Ku-band antenna on EVA1.

The Ku-band provides a 50-Mbps fixed-rate downlink with up to four video signals or up to 43-Mbps high-rate data with 7 Mbps overhead. A communication outage recorder records payload data in the zone of exclusion and during structural blockage outages. There are 12 logical channels (4 video and 8 payload) in the Ku-band downlink.
Like the S-band system, the Ku-band system does not inspect the data passing through it.

The ISS transmits at a constant rate of 50 Mbps. Of this, 43 Mbps is available to the user.

The video channels can be configured to downlink full-motion video or stop-action video, which consists of skipping video frames. Normally, the service is configured on the ground and commanded through the S-band uplink to the on-board C&DH, which routes commands via the 1553 local bus to the Ku-band.

The on-board Ku-band equipment includes a single string of four avionics units-the video baseband signal processor (VBSP), high-rate frame multiplexer (HRFM), high-rate modem (HRM), and the transmit/receive controller (TRC)-plus an erectable, steerable antenna. Video signals must be processed by the VBSP before they are routed to the HRFM for interleaving with high-rate data (HRD). HRD comes from the payload patch directly to the HRFM for processing and interleaving with the video signal. The HRFM builds the downlink transfer frames and routes the data stream to the HRM for modulation on an S-band interface (I/F) frequency for routing to the TRC for translation to the Ku-band frequency. The data stream is power amplified and routed to the steerable antenna for transmission through the TDRSS to the ground. An uplink carrier is received and processed by the TRC to maintain antenna autotracking only.

Video channels are directed to the VBSP for processing. The VBSP has four audio and four video input channels and four video plus audio output channels. Connectors are also provided for power and 1553 bus and I/F data out. The four video plus audio output channels are directed to the HRFM. The VBSP performs audio and video analog-to-digital (A/D) format conversions, packet formatting, built-in test (BIT), and ORU control functions. The VBSP converts incoming analog signals to digital, formats them for the selected mode of operation, and forwards them to the HRFM for interleaving with high-rate payload data.

**Electrical Power Subsystem**

The Z1 truss assembly has several power distribution components. These include two initialization diode assemblies (IDAs), two secondary power distribution assemblies (SPDAs), two plasma contactor units (PCUs), two DDCUs, and two patch panels.

The IDAs provide diode-protected power from the shuttle assembly power conversion unit (APCU) to P6 for module initialization on Mission 4A. They also provide a connection path from P6 to the lab DDCUs from Mission 5A until Mission 12A, when the P4 module will be delivered.

The SPDAs consist of remote power controller modules (RPCMs), power and data connections (central utility rail), and a cold plate. They control, protect, and isolate secondary distribution lines. The SPDAs accept secondary power from the DDCUs and distribute this power to RPDAs or downstream loads. The SPDA cold plates transfer heat from the RPCMs via radiant fins.

The central utility rail provides power connections from the DDCU power feed to the RPCMs and data connections via redundant 1553B data buses. Because the DDCUs will not be active during Mission 3A, SPDAs Z1-3B and Z1-4B will receive power directly from Russian-American conversion units (RACUs) 5 and 6, respectively.

RPCMs are electronic switches that control, protect, and isolate secondary distribution lines. There are six types of RPCMs, which differ in their rated output current, number of switches per module, and trip functions.

The PCU emits electrons through a self-generated plasma and is self-regulating. The PCUs control the voltage between the space plasma and the ISS structure. PCUs mounted on the Z1 truss maintain the structure potential of the ISS within 40 volts of the plasma potential. A central element of each PCU is the hollow cathode assembly (HCA), which emits up to 10 amps of electron current to the ambient plasma. The PCU actively emits when the ISS is in sunlight. Without the PCUs, the ISS could reach structure potentials of approximately -150 volts.

Two DDCUs, which are launched attached to cargo handling interface adapters (CHIAs), will be delivered on Mission 3A. The DDCUs will be removed from the CHIAs and attached to the starboard side of Z1 during EVA1. The units convert power from primary (115 to 173 volts DC) to secondary (123 to 126 volts DC). They will not be activated until Mission 4A, when P6 power comes on line.

Two patch panels on the port side of Z1 allow the Z1 input power source to be changed. On the outside of the panels are a fixed output and three interchangeable input connectors. To change the panel configuration, an umbilical is simply demated and mated to a different connector on the patch panel. The launch configuration of the patch panels provides Russian segment (RS) power to Z1 components for keep-alive purposes. The panels will be reconfigured during Mission 4A to prepare for the transition to U.S. power via P6.

**Extravehicular Activity Subsystems**

The Z1 truss segment is equipped with several spacewalk aids: Two EVA tool stowage devices (ETSDs), 22 worksite interface (WIF) sockets, 1 flight-releasable grapple fixture (FRGF), 11 trusses, 2 tray launch restraints, numerous standard handholds and handrails, and several custom handles.

**Motion Control Subsystem**

The motion control subsystem (MCS) hardware launched as part of the Z1 element includes the CMGs and the CMG assemblies. This hardware will not be activated until Mission 5A, when the GN&C MDM will be activated with the U.S. Lab.

The CMG assembly consists of four CMGs and a micrometeorite/orbital debris shield. The four CMGs, which will control the attitude of the ISS, have a spherical momentum storage capability of 14,000 ft-lb/sec, the scalar sum of the individual CMG wheel moments. The momentum stored in the CMG system at any given time equals the vector sum of the individual CMG momentum vectors.

To maintain the ISS in the desired attitude, the CMG system must cancel, or absorb, the momentum generated by the disturbance torques acting on the station. If the average disturbance torque is nonzero, the resulting CMG output torque is also nonzero, and momentum builds up in the CMG system. When the CMG system saturates, it is unable to generate the torque required to cancel the disturbance torque, which results in the loss of attitude control.

The CMG system saturates when momentum vectors have become parallel and only momentum vectors change. When this happens, control torques perpendicular to this parallel line are possible, and controllability about the parallel line is lost.

Russian segment thrusters are used to desaturate the CMGs.

An ISS CMG consists of a large flat wheel that rotates at a constant speed (6,600 rpm) and develops an angular momentum of 3,500 ft-lb/sec about its spin axis. This rotating wheel is mounted in a two-degree-of-freedom gimbal system that can point the spin axis (momentum vector) of the wheel in any direction.

At least two CMGs are needed to provide attitude control. The CMG generates an output reaction torque that is applied to the ISS by inertially changing the direction of its wheel momentum. The CMG's output torque has two components, one proportional to the rate of change of the CMG gimbals and a second proportional to the inertial body rate of the ISS as sensed at the CMG base. Because the momentum along the direction of the spin axis is fixed, the output torque is constrained to lie in the plane of the wheel. That is why one CMG cannot provide the three-axis torque needed to control the attitude of the ISS.

Each CMG has a thermostatically controlled survival heater to keep it within thermal limits before the CMGs are activated on Mission 5A. The heaters are rated at 120 watts and have an operating temperature range of -42 to -35°F.

**Structures and Mechanisms**

Mechanical interfaces are provided between Z1 and the P6 long spacer on the Z1 zenith face, between Z1 and Node 1 on the Z1 nadir face, between Z1 and PMA-2 on the Z1 forward face, and across a cable tray from the Z1 forward face to the U.S. Lab.

A manual berthing mechanism (MBM) on the forward face of Z1 allows temporary stowage of PMA-2. The device is similar to the one used on the Spacelab pallet to stow PMA-3 on this flight (but without the perimeter bolts).

A hinged cable tray on the forward face of Z1 provides a direct interface for power, data, and coolant lines to the U.S. Lab. Mission 3A EVA crew members will deploy the tray to expose the MBM and will release 32 bolts on the 4 coolant lines.

The Z1 truss structure is designed to maximize component packaging and support load paths during launch and on orbit. A solid plate beneath the CMG face provides additional protection from micrometeorites and orbital debris for the CMGs and other Z1 components. The structural framework beam and shell elements are aluminum 2219-T851. The trunnion and keel pin beam elements are INCO 718, and the Ku-band antenna boom beam elements are steel.

**Thermal Control Subsystem**

The Z1 truss assembly includes the following elements of the early external active thermal control system (EEATCS): 4 accumulators, ammonia, and 12 quick disconnects and associated plumbing. The accumulators charge the EEATCS with ammonia on orbit, accommodate thermal expansion in the fluid, and maintain the system's operating pressure. The quick disconnects facilitate the connection of ammonia transfer lines between P6 and Z1 and between Z1 and the U.S. Lab.