International Space Station Overview

This chapter provides an overview of the technical characteristics of the ISS elements as a prelude to the detailed utilisation accommodation and resource information given in the following chapters.

Background

A new Intergovernmental Agreement (IGA) was concluded on 29 January 1998 between the governments of the five International Partners – Europe (11 participating States), Canada, Japan, Russia and USA. This new IGA enlarges the earlier 1988-partnership agreement by including Russia in the largest international cooperative civil space programme ever undertaken.

It is the responsibility of the US National Aeronautics and Space Administration (NASA) to lead the ISS programme development and implementation, and in conjunction with the Russian Space Agency (RSA) provide the major foundation blocks for the Station (Table 1). The European Space Agency (ESA) and the National Space Development Agency of Japan (NASDA) provide additional elements that significantly enhance those blocks, and the Canadian Space Agency (CSA) provides an essential mobile robotics servicing capability.

The provision of these elements gives each ISS Partner certain rights for Station utilisation as well as participation in its management and operations. For example, each Partner has the right to provide suitably qualified flight crew. Each Partner may also access the Station using its own transportation system. Nevertheless, each Partner has to develop and maintain the elements that it provides, as well as participate in the equitable sharing of the Station's common operating costs.

<table>
<tr><th colspan="6">Table 1. Major ISS Elements to be Provided by the International Partners</th></tr>
<tr><th colspan="3">United States</th><th colspan="3">Russia</th></tr>
<tr><td colspan="3">¥ Space Station infrastructure elements
¥ Laboratory modules and equipment for attached payloads
¥ Flight elements to supply ISS
¥ Ground infrastructure elements</td><td colspan="3">¥ Space Station infrastructure elements
¥ Research modules and equipment for attached payloads
¥ Flight elements to supply and reboost ISS
¥ Ground infrastructure elements</td></tr>
<tr><th colspan="2">Canada</th><th colspan="2">Europe</th><th colspan="2">Japan</th></tr>
<tr><td colspan="2">¥ Mobile servicing system
¥ Special Purpose Dexterous Manipulator</td><td colspan="2">¥ Columbus Laboratory
¥ Automated Transfer Vehicle
¥ Outfitting Elements</td><td colspan="2">¥ Japanese Experiment Module
¥ Japanese Exposure Facility
¥ Flight elements to supply ISS
¥ Ground infrastructure elements</td></tr>
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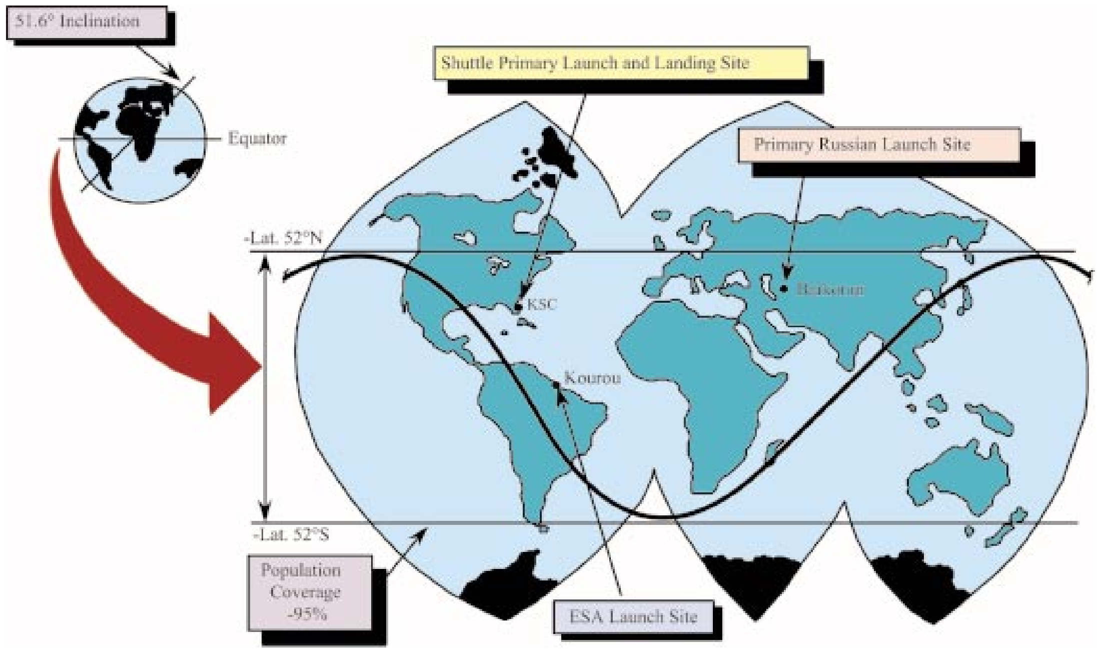


Fig. 1. The ISS orbit provides coverage of most of the world's inhabited regions.

ESA has acquired through its contributions the following utilisation shares:

- 51% usage of the user accommodation of the Columbus Laboratory, incl. attachment points
- 8.3% usage of the on-orbit utilisation resources (eg electrical power, crew time), as well as the right to purchase launch & return, and Tracking & Data Relay Satellite (TDRS) system communications services.

ESA has acquired further crew flight opportunities commensurate with its utilisation resources allocation.

Table 2. ISS Characteristics at Completion

Truss length Total module length Mass	108 m 74 m about 420 t
Maximum power output	110 kW
Pressurised volume Atmospheric pressure	1200 m^3 1013 mbar
Orbital altitude Orbital inclination Orbital velocity Attitude	370-460 km 51.6.. 29 000 km/h local horizontal/vertical
Minimum crew	6
Data rate uplink Date rate downlink Ku-band coverage S-band coverage	72 kbit/s 150 Mbit/s 68% 50%
Expected lifetime	>10 years

ISS: General Description

The Space Station will be a permanently inhabited outpost in low Earth orbit and composed of flight elements, provided by all five Partners, and associated ground elements to support on-orbit operations and utilisation.

A summary of the ISS key characteristics at the end of the 5-year build-up period is provided in Table 2. ISS assembly began in November 1998 with the launch of the US-procured/Russian-built 'Zarya' Control Module.

On the second assembly flight, in December 1998, the US-built 'Unity' resource node was attached to Zarya. This will be followed by the third assembly flight with the Russian-built Service Module. A 3-person Permanent International Human Presence Capability will then begin in early 2000. At that time, the ISS will already be flying at an average altitude of 407 km in its 51.6° inclination orbit (Fig. 1).

European users will have some early payload utilisation opportunities before the launch of the Columbus Laboratory, once the US Laboratory module is on-orbit and operational for users, as well as on the Integrated Truss Assembly following the check-out of the Mobile Remote Servicer Base System (MBS) and the arrival of the first Express Pallets for external payloads in 2002.

The 6-person Permanent International Human Presence Capability will be established in late 2002. The Columbus Laboratory will be coupled to the ISS early in 2003 and Station assembly will be completed (Fig. 2) with the launch of the US Habitation module.

A summary of the major ISS elements, their first year on-orbit according to Assembly Sequence Revision D, and their potential availability for utilisation are presented in Tables 3 and 4.

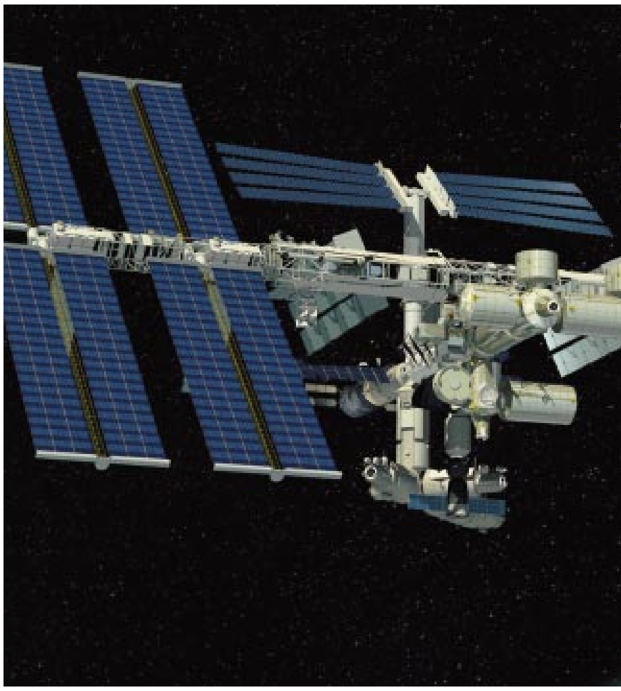


Fig. 2. ISS configuration when assembly is completed in 2004.

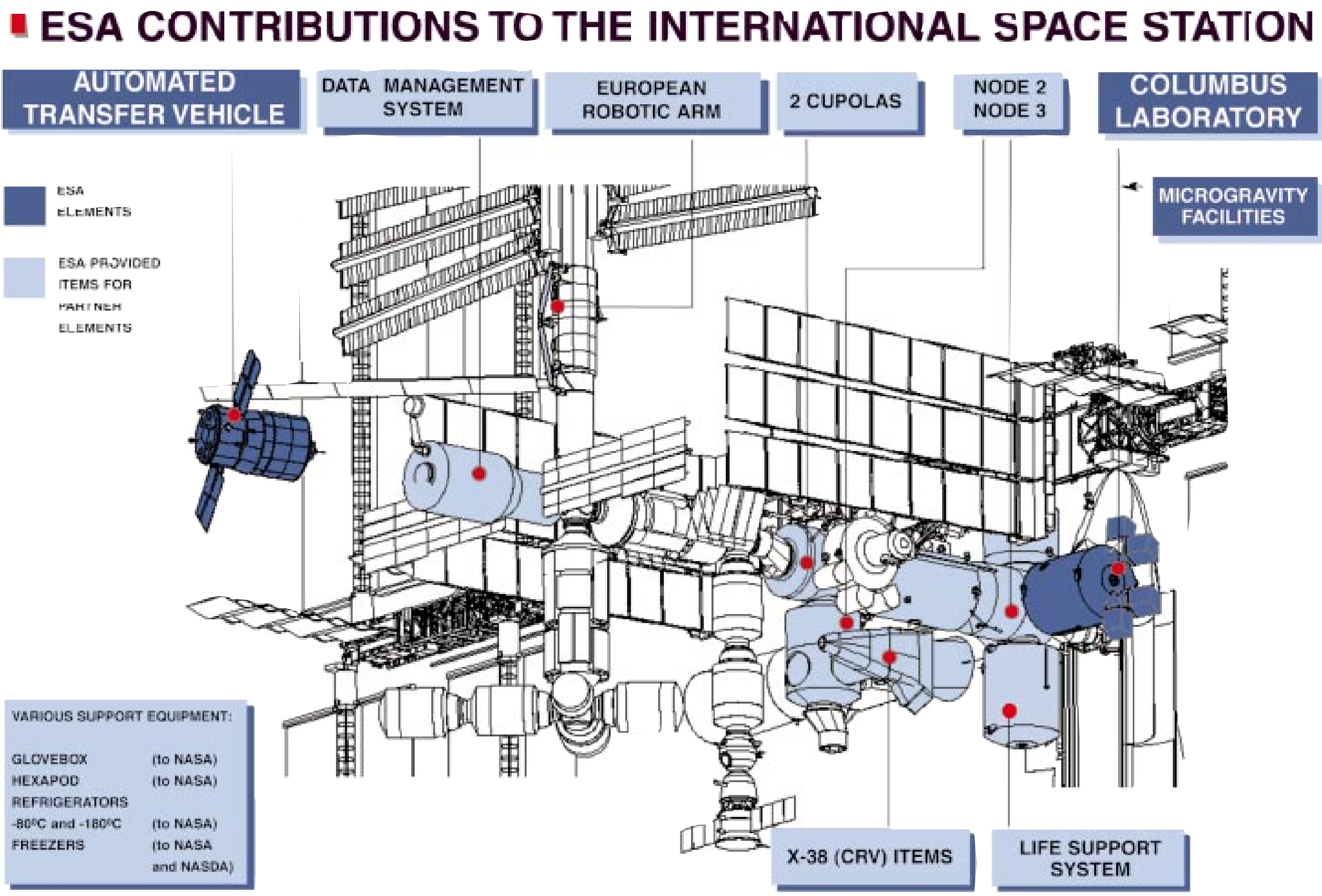
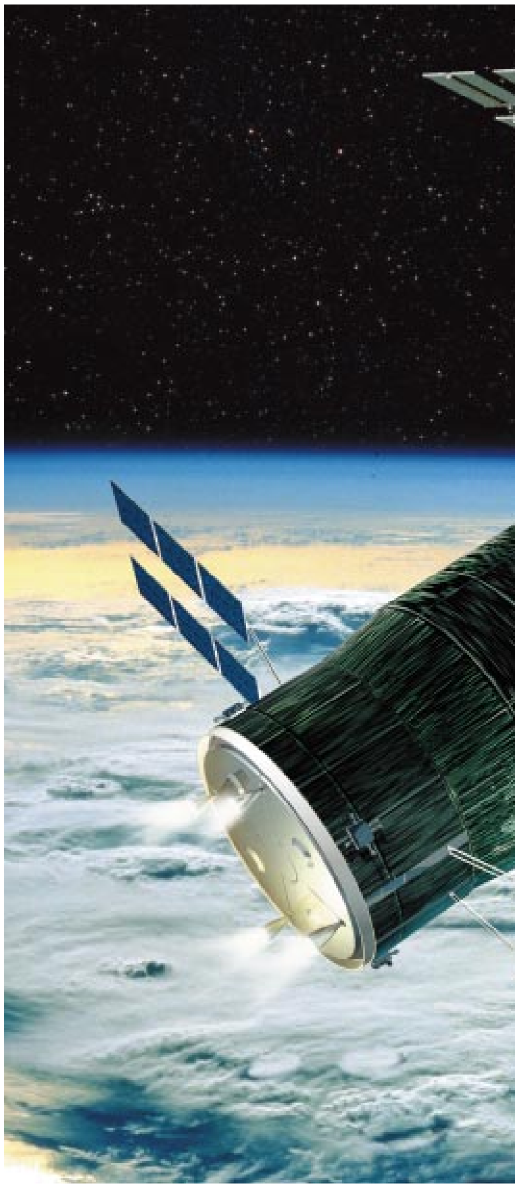


Table 3. Principal ISS Pressurised Elements				
Pressurised Element	On-orbit (year)	Outer Dimensions (length x diameter)	Number of ISPRs	Comments
Zarya Control Module (FGB)	1998	12.6x4.1 m		Provides initial propulsion and power
Unity Node-1	1998	5.5x4.6 m		Connector node for pressurised modules
Service Module	1999	13.1x29.6 m (including solar panels)		Early crew living and working quarters. Limited possibilities for payloads
3-person Permanent International Human Presence Capability	2000			Soyuz crew return vehicle docked to ISS
US Laboratory module	2000	8.2x4.4 m	13	
Node-2	2001	6.4x4.6 m		
Japanese Experiment Module (JEM)	2002	11.2x4.4 m	10	Including Exposed Facility
Cupola	2002			360… viewing window
Russian Research Module-1	2002	Design details not available	Design details not available	
Node-3	2002	6.4x4.6 m		
Russian Research Module-2	2002	Design details not available	Design details not available	
6-person Permanent International Human Presence Capability	late 2002			
Columbus Laboratory	2003	6.1x4.4 m	10	Launched with 5 outfitted ISPRs
Centrifuge Accommodation Module (CAM)	2003		4	Contains a 2.5 m-dia centrifuge for g levels 0.01-2 g
US Habitation module	2004	8.2x4.4 m		

Table 4. Principal ISS Unpressurised Elements				
Unpressurised Element	On-orbit (year)	Outer Size	Payload Adapters	Comments
Space Station Remote Manipulator System (SSRMS)	2000	17 m length		Initially a measuring worm capability (until MT available) to support ISS assembly & Orbiter cargo bay loading & unloading
Mobile Transporter (MT)	2000			Provides structural, power, data and video links between ISS and MBS
Mobile Remote Servicer Base System (MBS)	2000			Serves as stable base for SSRMS
Integrated Truss Assembly (ITA)	2002	108 m length	24	Utilisation start after MBS commissioning
JEM-Exposed Facility	2002	5x5.2 m widthxlength	10	
Special Purpose Dexterous Manipulator (SPDM)	2002	two 3.5 m-long arms		Extends SSRMS capability for intricate manipulations
Columbus-External Payload Facility (EPF)	2003		4	

Fig. 3. ESA's Automated Transfer Vehicle (ATV) will transport mixed cargo items to/from the ISS. (ESA/D. Ducros)



The major elements of the Station include:

- modules and nodes housing essential systems, providing a habitable environment and serving as pressurised payload laboratories;
- the 108 m-long Truss is a major structural framework mounted on Unity (Node-1). It provides the ISS 'backbone' and interconnection between the pressurised modules, external payloads and systems equipment. It also hosts umbilicals, radiators, communications antennas, batteries, Mobile Transporter rails and mechanical systems such as joints and mechanisms. Truss segments are located on the starboard and port sides, and labelled accordingly. For example, the P6 section is on the outermost port side;
- the Mobile Servicing Center and Mobile Transporter make up the Mobile Remote Servicer Base System that will be used to remove payloads from the Shuttle cargo bay and transport them to designated locations on the outpost. The 17 m-long remote manipulator arm can carry payloads of up to 128 t, while the Special Purpose Dexterous Manipulator (SPDM), with two arms each 3.5 m long, can perform more delicate tasks such as connecting utilities or exchanging small hardware items.

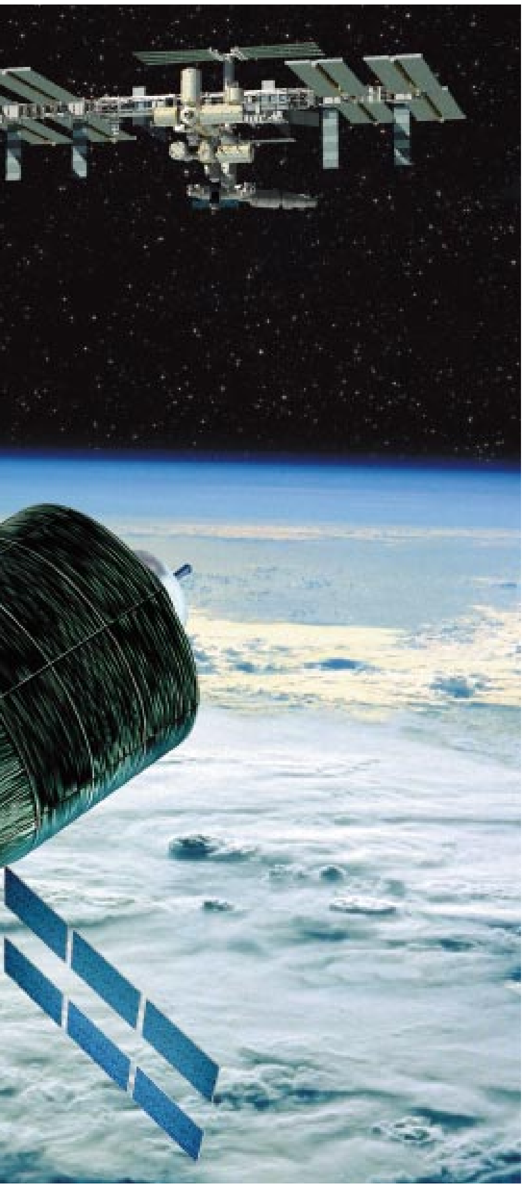
Payload Transportation and Logistics Carriers

A mixed fleet of launch vehicles is potentially available for the transportation of payloads. It includes:

- US Space Shuttle;
- Russian Proton;
- European Ariane-5;
- Japanese H-IIA.

The US Space Shuttle is the prime vehicle for transporting system elements, logistics, crew and payloads (including the Columbus Laboratory) to the Station. For the assembly of the Station from 1998 to 2004, some 34 Shuttle flights are projected, including several user-oriented flights. The Shuttle-to-Station cargo options also include:

- the Italian-built Mini Pressurised Logistics Module (MPLM) for transporting pressurised cargo to/from the Station, accommodating 16 racks comprising five powered for



refrigerators, freezers or active payloads and 11 racks for passive payloads;
- Unpressurized Logistics Carrier (ULC) for transporting external systems and payloads to/from the Station.

The Russian Proton is the prime vehicle for transporting the Russian pressurised and unpressurised elements to the Station. The Soyuz rocket will be used for delivering the Soyuz crew vehicle and the Progress cargo spacecraft.

The European Ariane-5 is the vehicle for launching the Automated Transfer Vehicle (ATV; Fig. 3) that will be used for transporting mixed cargo items to/from the Station.

The Japanese H-IIA is the prime vehicle for launching the H-II Transfer Vehicle (HTV) that will be used for transporting mixed cargo items to the Station.

Distributed Station Systems

Command & Data Handling (C&DH) System

As the 'brain' of the ISS, the C&DH system (Fig. 4) monitors all aspects of the Station's operations. Furthermore, it distributes payload and systems data to the crew, and to personnel on Earth via the Tracking and Data Relay Satellite (TDRS) system.

C&DH hardware includes data processors, control and monitoring processors, crew interface computers, data acquisition and distribution networks, and interfaces to systems and payloads. The C&DH data distribution architecture relies heavily on network technology, and is composed of three major components: local area networks (LANs) based upon IEEE 802.3; local data buses based upon MIL-STD-1553B; and high-rate data (HRD) links.

Even during the early stages of assembly, system and payload networks will be provided throughout the evolving Station to link all system and payload data units. The networks will be extended as the Station matures, with system and payload networks being routed through the Nodes, US Laboratory, JEM, Columbus Laboratory and the Russian Research Modules.

The MIL-STD 1553 data bus provides a low-rate data transfer capability; the IEEE 802.3 data bus provides a medium-rate data transfer capability. The HRD link provides payloads with return data rates higher than can be met by the LANs.

Laptops are available for the crew to: interface with the data system; monitor and control systems; display video, and

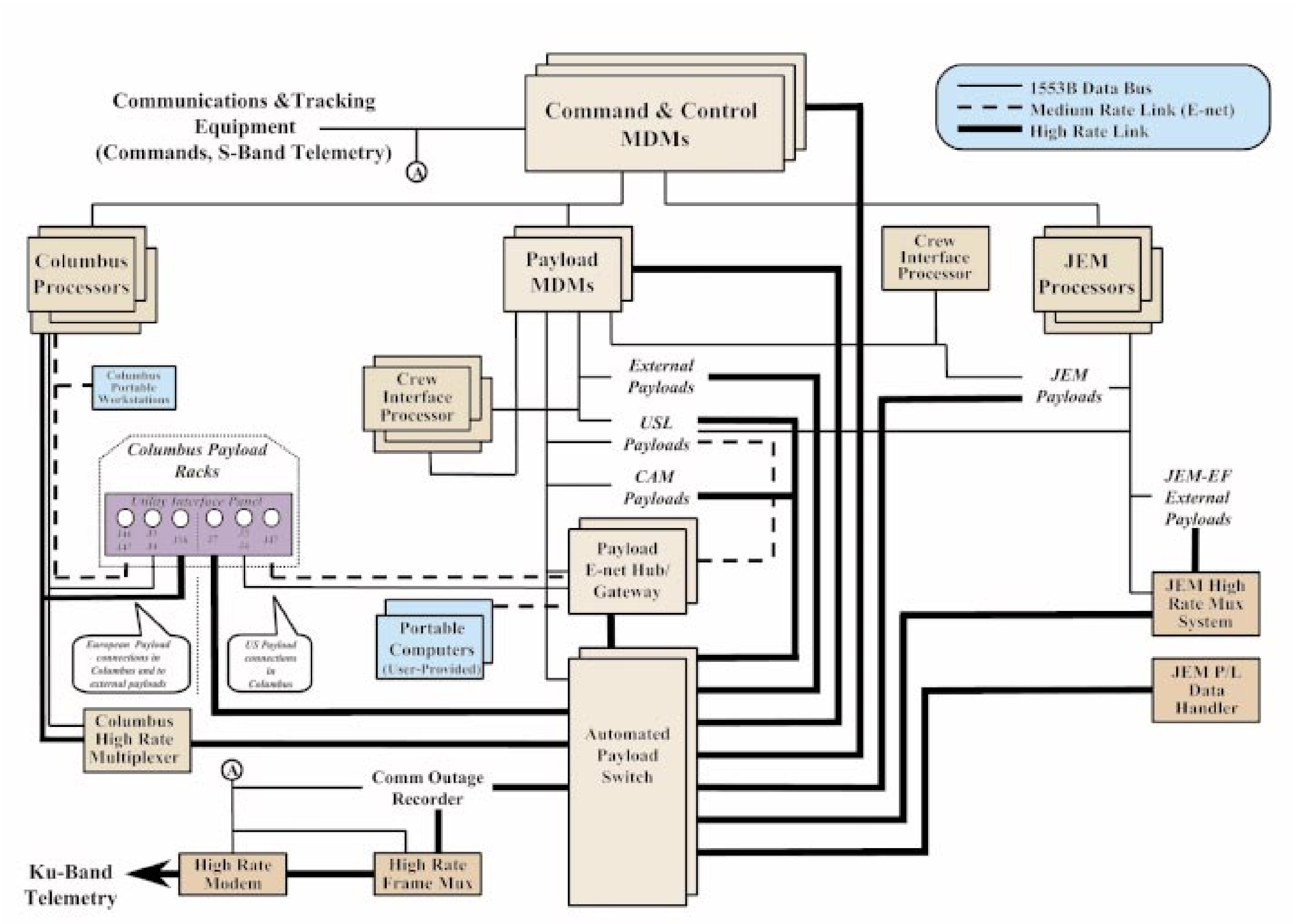


Fig. 4. Overview of the ISS Command & Data Handling System. MDM: Multiplexer/ Demultiplexer. C&T: Communications & Tracking. USL: US Laboratory.

payload and system data; and communicate with the ground. The crew Man Machine Interfaces for all the Station laptops are similar and the data displayed on them can also be displayed on monitors on Earth.

A stable frequency and time reference is provided by the C&DH time distribution system.

The interface between the Columbus processors and the Columbus payloads is achieved over the Utility Interface Panel; this is detailed in later chapters.

Payload users may develop and provide their own application software for integration into the element payload computers. However, the interfaces for the bulk of such applications consist primarily of standard services. These standard services provide payload and core systems with access to data communications, data acquisition and commanding and timing information. Payloads are required to use standard services for commands, and for all communications with the LANs and buses.

Communications and Tracking System (C&TS)

The C&TS provides audio, data and video communications with the ground and other spacecraft. Payload commands and audio may be transmitted from the ground to the Station. The downward ('return') usable data transmission capability is via the Ku-band system. The upward ('forward') transmission capability is via an S-band system from the ground for Station systems and payload operations.

The European end-to-end communications infrastructure is shown in Fig. 5.

NASA's TDRS system is the primary Station data and communications link with the ground. Data and commands are transmitted to/from the Station via TDRS to White Sands in New Mexico. The data are then distributed through a combination of satellite and terrestrial links.

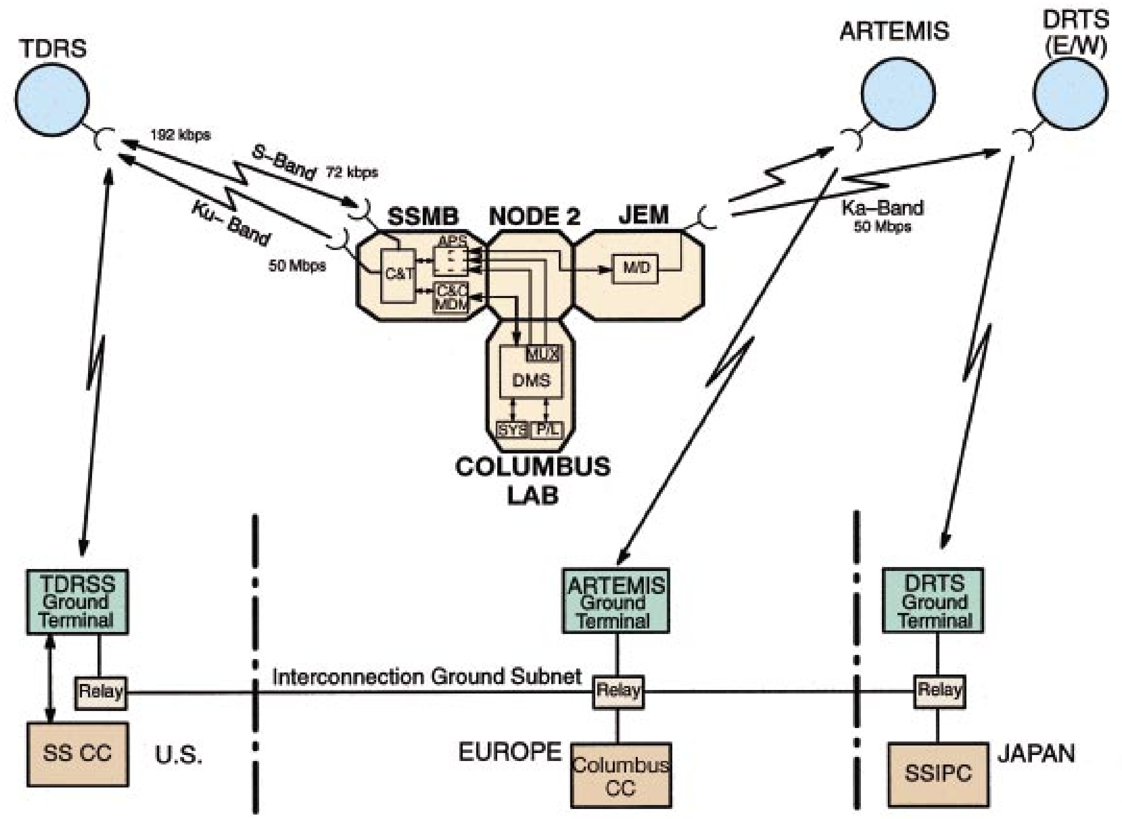


Fig. 5. The European communications infrastructure for ISS. APS: Automated Payload Switch. C&C MDM: Command & Control Multiplexer/ Demultiplexer. C&T: Communications & Tracking. DRTS: Data Relay & Test Satellite. SSCC: Space Station Control Center. SSIPC: Space Station Integration & Promotion Centre. SSMB: Space Station Manned Base.

The TDRS system and Station are in communication for most of each orbit except for a brief period known as the Zone of Exclusion (ZOE) when there is no TDRS-to-ground coverage, or during particular Station attitudes when there is no line-of-sight link between the Station and TDRS. The coverage period can range up to 60 min in any one 90 min orbit. During this time, users are able to transmit or receive data. There is also a very short period of disruption (of the order of 2 min each orbit) when communications are being handed over from one TDRS to the other.

As an additional link, communications via the Japanese (DRTS) and European (Artemis) data relay systems are under consideration (Fig. 5).

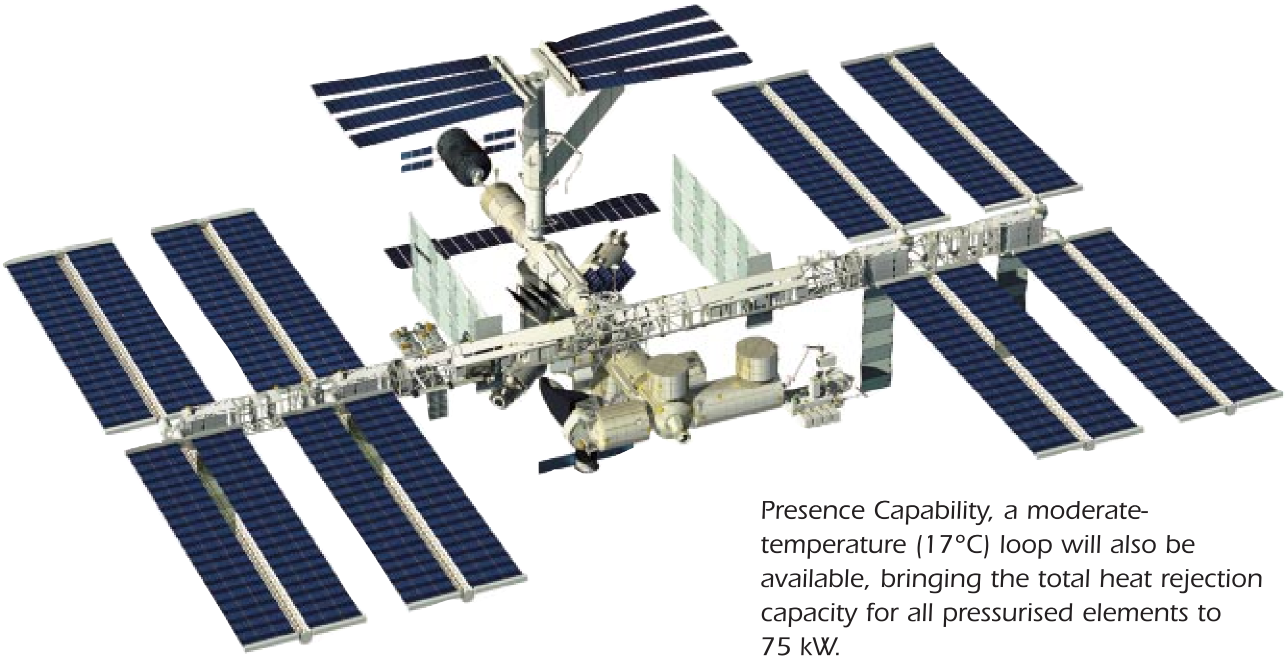
Video cameras are located throughout the pressurised elements and on the Truss. The Video Switching Unit (VSU) allows images from any Station-supplied camera to be displayed on any monitor.

The pulse frequency-modulated onboard video signals, distributed by fibre optic analog video lines, are compatible with the NTSC standard.

The JEM and Columbus Laboratory have video and audio systems that are compatible with the US network. Video and audio signals are digitised, assembled into data transfer frames (packets), and multiplexed with other data for Ku-band downlink transmission. Video, audio and data signals have time synchronisation for proper time stamping and voice/data correlation. However, the Russian elements use the SECAM video standard and there is no video connectivity with the other Partner video systems.

Electrical Power System (EPS)

Two parallel sets of solar array wings generate the primary Station power. Nickel-hydrogen batteries store the dc power generated by the solar arrays for use when the station is in the Earth's shadow. 18.75 kW of orbital average



power is generated initially, increasing to 110 kW with the full Station capability. The EPS provides 120 Vdc power to the user interface. The Russian segment also generates additional electrical power, for the Russian elements.

Thermal Control System (TCS)
The TCS maintains the Station's structure, systems, equipment and payloads within their allowable temperature ranges. Heat rejection is achieved through two large radiators attached to the Truss.

A passive thermal control system is provided through insulation coatings and heaters, and is responsible for maintaining Station structures and external equipment within allowable temperature ranges.

An active thermal control system is provided through mechanically-pumped fluid in closed loop circuits and is responsible for heat collection, heat transportation and heat rejection within the pressurised elements. Water is used in the active system within the pressurised elements; anhydrous-ammonia is used in the active system in the external areas. Both fluids remain in a liquid state.

Initially, two low-temperature (4°C) loops provide a total of 14 kW heat rejection. At 6-person Permanent International Human Presence Capability, a moderate-temperature (17°C) loop will also be available, bringing the total heat rejection capacity for all pressurised elements to 75 kW.

No active thermal control system is provided for attached payloads mounted on the Truss.

Guidance, Navigation and Control (GN&C)
The GN&C system maintains the Station attitude and orbit control that is optimised for the proper microgravity environment in support of payload requirements. In addition, GN&C controls include debris avoidance, reboost and rendezvous operations. The GN&C system can provide the Station's exact orbital speed, attitude and altitude as telemetry to payloads.

Flight Crew Systems
Flight crew systems include restraints and mobility aids, portable emergency provisions, housekeeping and trash management, Crew Health Care System (CHeCS), lighting, personal hygiene equipment, wardroom and crew privacy. They provide the crew with a safe environment and the basic necessities for life.

The most complex of these, CHeCS, comprises the Health Maintenance System (HMS), the Countermeasure System (CMS) and the Environmental Health System (EHS). The HMS monitors crew health, responds to crew illness or injury, provides preventative health care, and stabilisation and emergency transport between vehicles. The CMS evaluates crew fitness, provides countermeasures for musculoskeletal and cardiovascular deconditioning, and monitors the crew during countermeasures. The EHS monitors the Station's internal environment and includes instruments for microbiological, toxicological, radiation and acoustics measurements. CHeCS interfaces with the C&DH system to provide onboard data display and data transmission to the ground.

Environmental Control & Life Support System (ECLSS)

The ECLSS provides a comfortable shirtsleeve environment throughout the Station's pressurised elements. Temperature, humidity, air composition and atmospheric pressure are maintained, as well as nitrogen and potable water supplies, and fire detection/suppression equipment. The ECLSS maintains an atmospheric pressure of 978-1026 mbar (14.2-14.9 psia) with an oxygen concentration of not more than 24.1%.

Information Services

The Station programme coordinates and sustains diverse information services required for Station operations. These include command & control services, payload support services and automated information security services.

Command & control services provide for the interactive control and monitoring of payloads, elements and systems, as well as for the acquisition, transmission processing, storage and exchange of data among Partner system and payload operators and users. Within the European scenario, these services include information exchange between the ISS and the:

- Mission Control Center-Houston (MCC-H), responsible for integrated Station operations;
- Payload Operations Integration Center (POIC), responsible for consolidating the planning and execution of all element payload operations;

- Columbus Control Centre, responsible for integrating the planning and execution of all Columbus Laboratory payload and system flight operations;
- User Support and Operations Centre (USOC) or Facility Responsible Centre (FRC), responsible for monitoring and controlling one or more payload facilities.

Payload support services increase the productivity of payload user operations. Telescience, for example, allows payload users to access remote equipment and databases interactively in pursuit of their experimental objectives. One such aspect is the capability for users, at their home institutions or User Home Base (UHB), to control and monitor payloads in space. The Station delivers data to the payload user in the form in which it was acquired from the payload onboard. The handling and provision of ancillary data necessary for the meaningful processing of payload data is another support service. Examples of ancillary data include orbital position, attitude references and standard time references, as well as physical characteristics such as an element's temperature, oxygen partial pressure, or external environmental parameters.

Automated information security services control access to the information network and ensure the quality and integrity of the data traversing it on an end-to-end basis. The Station does not provide data encryption services for payload user data. However, payload users may encrypt their data if they wish.

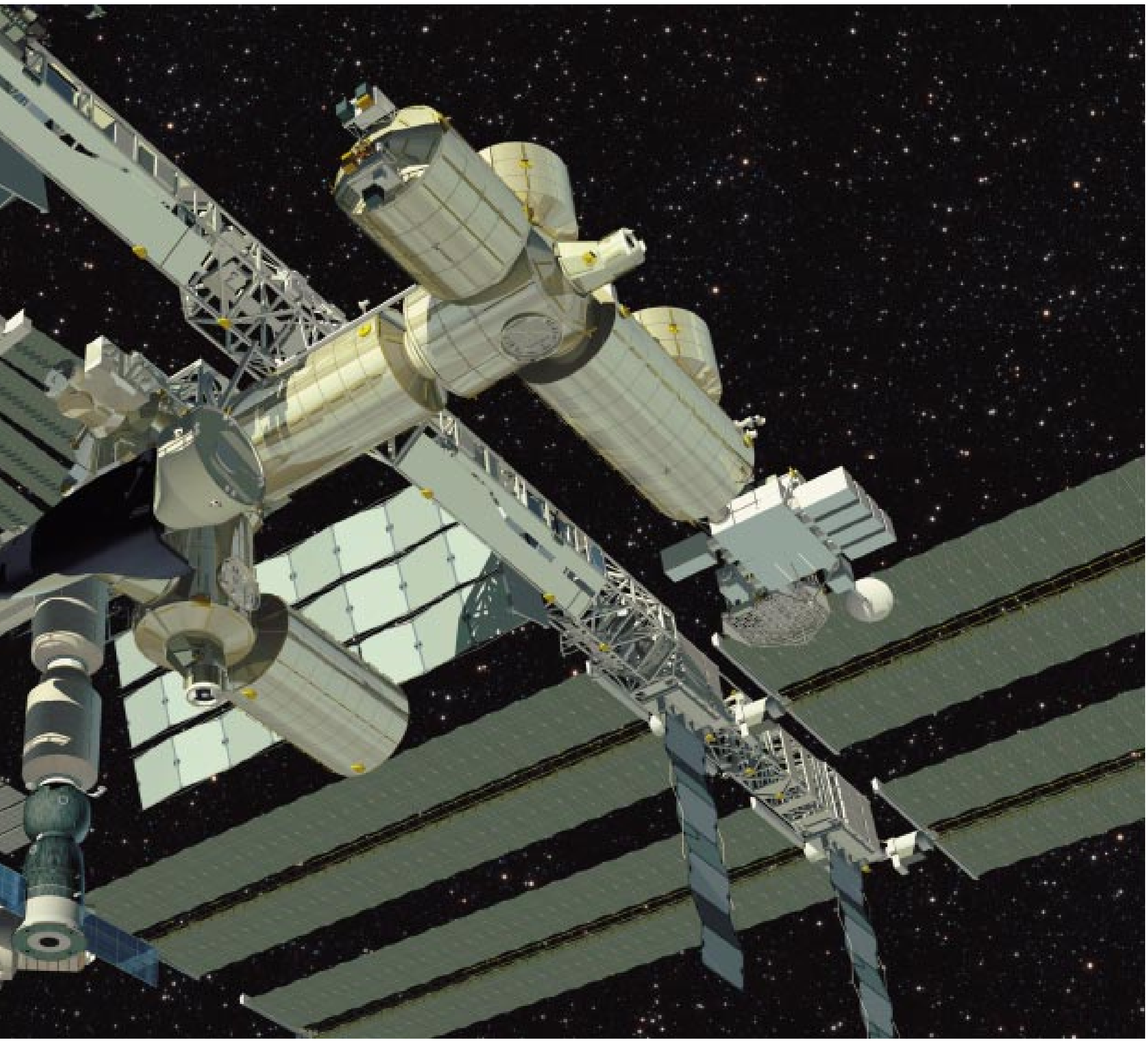
Environment Considerations

The natural environment exists unperturbed by the presence of the Space Station, while the induced environment exists as a result of the Station's presence. Payload users should be aware of the potential effects that these environments can have on payloads.

Natural Environment

The neutral atmosphere is significant for Station operations for two reasons. Firstly, it produces torques and drag that degrade the Station's altitude. Secondly, it affects the flux of trapped radiation encountered by the Station.

Plasma is important to Station operations because it controls the extent of spacecraft charging, affects the propagation of electromagnetic waves such as radio frequency signals, and probably contributes to surface erosion. Another important effect is the production of electric fields in the structure as the Station moves across the geomagnetic field.



Charged particle radiation can have sufficient energy to penetrate several centimetres of metal and, after penetration, still produce significant levels of ionised radiation. A high level of radiation can significantly affect materials, chemical processes and living organisms, and especially the crew. It can also affect electronics by causing soft upsets and degrading the performance or producing permanent damage. In addition, it can affect the propagation of light through optical materials by altering their optical properties.

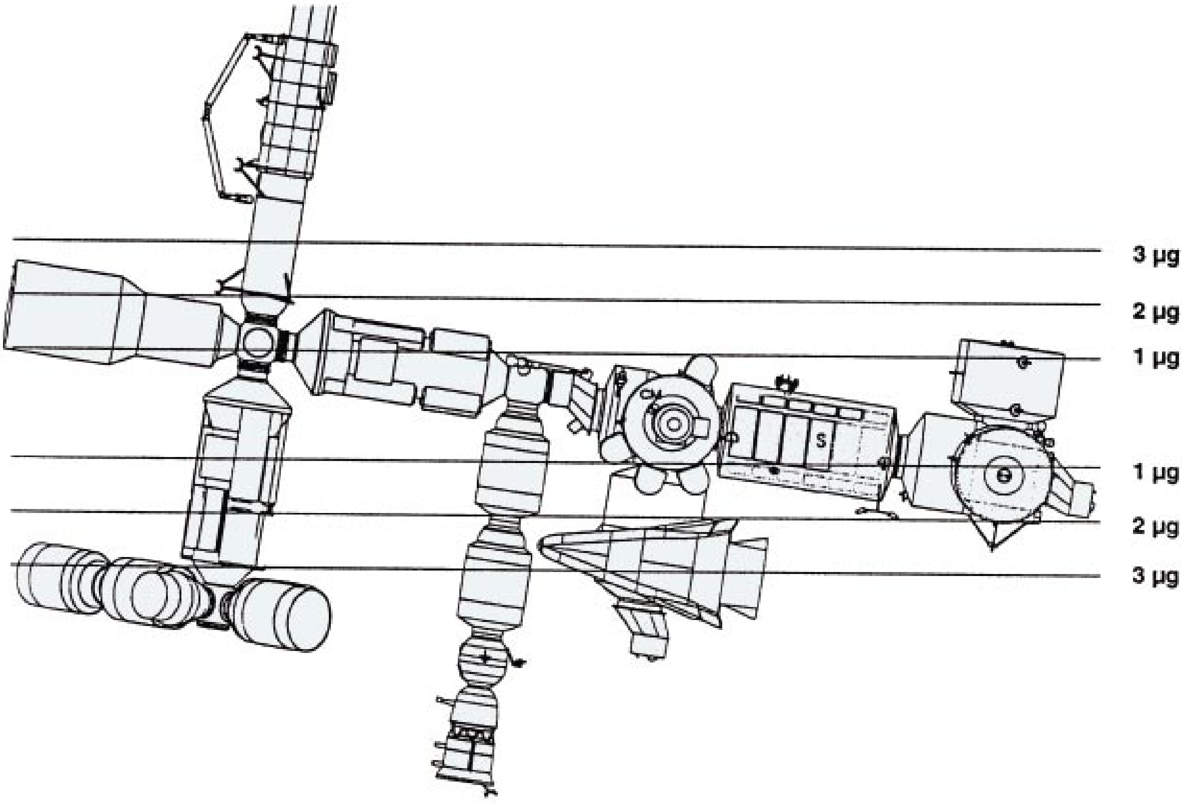
The Station's systems and payloads are immersed in electromagnetic radiation. Such radiation originates from the Earth, from plasmas surrounding the Earth, Sun and stars; and from the nearby ionosphere, and is disrupted by the passage of the Station itself. Intense radiation can affect the Station's systems or payloads.

Micrometeoroids and space debris can damage the Station and its attached payloads. Critical Station elements are protected by a combination of shielding and shadowing.

Induced Environment

The Station provides an environment suitable for the performance of microgravity experiments (Fig. 6). Acceleration levels of 1.8×10^{-6}g or less, at frequencies <0.1 Hz, are maintained for at least 50% of the pressurised user accommodation locations for continuous periods of up to 30 days beginning at 3-person Permanent International Human Presence Capability and continuing thereafter. These conditions are provided for at least 180 days per year. For frequencies of 0.1-100 Hz, the acceleration levels are less than the product of 18×10^{-5}g*frequency, while for frequencies exceeding 100 Hz, acceleration levels of 1.8×10^{-3}g are predicted. The Station's use of control moment gyroscopes for attitude control

Figure 6. The predicted quasi-steady acceleration environment side view. (NASA)



during normal operations minimises vibration disturbances. However, the greatest disturbances (~10^{-3}g) occur during Shuttle docking and Station reboost.

Microgravity quiescent and non-quiescent periods are scheduled in advance. Quiescent periods are maintained for up to 30 days, to provide optimal microgravity conditions. Non-quiescent periods, such as during Station reboost, may be unacceptable for the operation of some payloads. The predicted quasi-steady acceleration environment is shown in Fig. 6.

The Station's external environment will be affected by its presence, operation and motion with induced effects from:

- Plasma wake, the variation of plasma density from the ram to the wake side;
- Neutral wake, the variation of neutral density;
- Plasma waves induced by the Station's motion;
- Vehicle glow on the ram or forward side;
- Change of local plasma density and production of electrical noise caused by spacecraft charging;
- Enhancement of neutral density and the change of neutral composition by outgassing, offgassing and the plumes from thrusters;
- Emission of conducted and radiated electromagnetic power by systems on the Station;
- Deliberate perturbation of the environment by active experiments and devices such as:
  - Transmitters/wave injectors
  - Particle beam emitters
  - Plasma emitters
  - Chemical releases
  - Laser beams
- Visible light generated by the Station and reflections from it;
- Induced currents and voltage potential differences that are generated by the motion of the Station through Earth's magnetic field, which can draw current through the surrounding plasma.