7 INTERNATIONAL SPACE STATION – ISS

This section is aimed at providing users with basic utilisation information regarding the International Space Station (ISS). It begins with an introduction to the ISS.

7.1 Introduction to the ISS

7.1.1 What Is the ISS?

After the Space Shuttle entered service in 1981, NASA regarded a permanently manned space station as the next logical step in human spaceflight. The objectives of the space station would be:

- To act as a manned Earth-orbiting laboratory for carrying out long-term scientific research in the unique environment of space;
- To accelerate innovations in technology and engineering with resulting applications on Earth;
- To study the effects on humans of working and living in space for long periods of time, thus acting as a stepping-stone to future human exploration of the Moon, Mars and beyond;
- To promote partnerships between industries and research institutes;
- To promote the image of science and engineering, influencing the educational paths chosen by future generations;
- To sustain and reinforce the highly technological aerospace industry;
- To satisfy the age-old human nature of exploration.

As a consequence, NASA established the Space Station Task Force in May 1982 to study user requirements and to propose a conceptual design of a Space Station. Also in 1982, NASA decided to turn this project into an international cooperative programme, and invited Canada, Europe (represented by the European Space Agency, ESA) and Japan to take part.
The Space Station project was finally approved by US President Ronald Reagan in January 1984 (Figure 7-1), and in 1985, Canada, ESA and Japan all signed a Memorandum of Understanding (MOU) with NASA, covering the preliminary design of a Space Station. In June 1988, the new Space Station configuration (named “Freedom” by President Reagan), made up of the various international elements and modules, was presented (Figure 7-2). In September of that year, a Space Station Inter Governmental Agreement (IGA) was signed by NASA, Canada and ESA, and successively by Japan in March 1989.

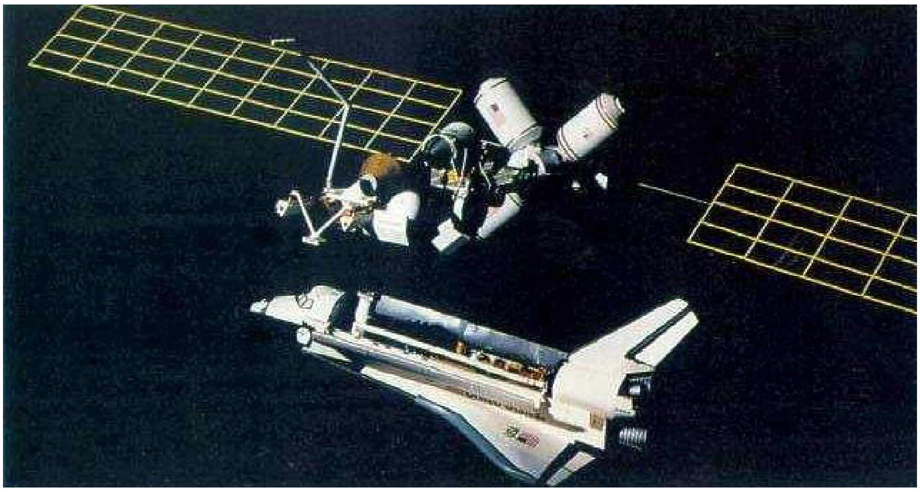

Figure 7-1: Space Station concept – January 1984 **(Image: NASA)**

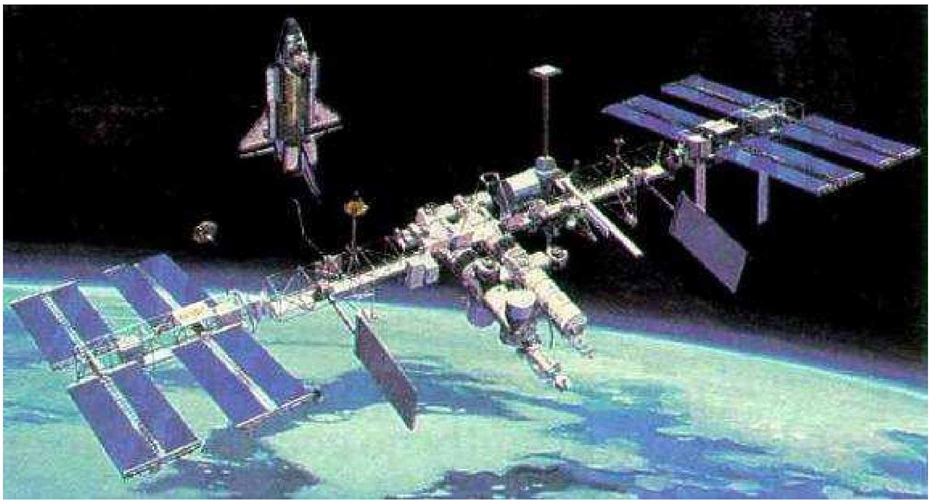

Figure 7-2: Space Station "Freedom" concept – 1988 **(Image: NASA)**

Between 1988 and 1993 the Space Station underwent several redesigns (see 1991 design concept Figure 7-3), mainly due to budget cuts, and on more than one occasion, the entire programme came close to being cancelled by the higher political echelons of the United States. In 1993 the Russian Federation was also invited to join the endeavour and an interim agreement was signed, giving birth to the International Space Station (ISS). In late 1997, the Italian Space Agency (ASI) and NASA signed a bilateral Memorandum of Understanding (based on the original one signed in 1991) for additional Multi-Purpose Logistics Module (MPLM) flight units with enhanced operational capabilities. Also in 1997, NASA and the Brazilian Space Agency (AEB) signed an Implementing Arrangement for Brazil's contribution of Space Station hardware and payload facilities in exchange for utilisation rights from NASA's allocation.

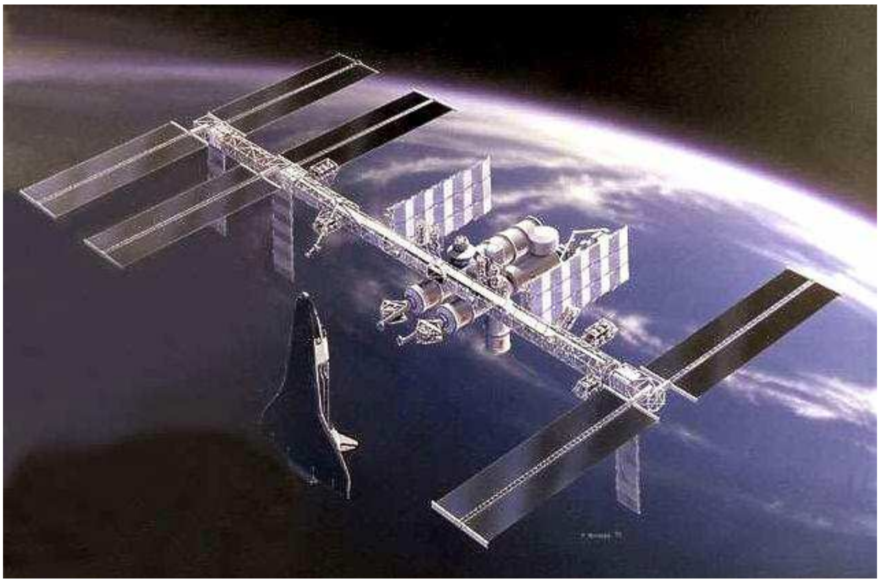

Figure 7-3: Space Station "Fred" Concept – 1991 **(Image: NASA)**

As a result of significant Russian participation and programme design changes that were undertaken after 1988, new agreements between the various partners and NASA were necessary. In January 1998, senior government officials from the U.S., Russia, Japan, Canada and participating countries of the European Space Agency (Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland and the

United Kingdom), met in Washington to sign an Intergovernmental Agreement on Space Station Cooperation. This agreement established the framework for cooperation among the partners on the design, development, operation and utilisation of the International Space Station. Also on that date, three separate bilateral memoranda of understanding were signed by the NASA Administrator and his counterparts: the Russian Space Agency General Director, the ESA Director General and the Canadian Space Agency President. The memorandum of understanding between NASA and the government of Japan was signed almost a month later on 24 February 1998. On the 20th of November of the same year, the first element of the ISS, the Russian Control Module "Zarya", was launched, initiating the assembly of the largest international project ever undertaken.

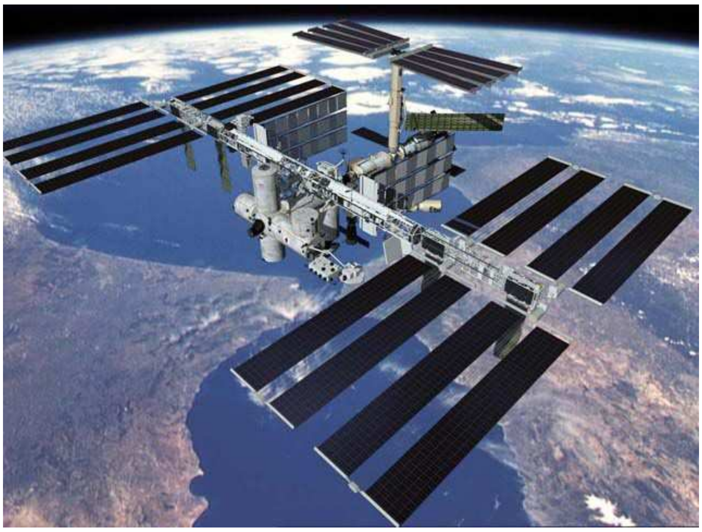

Figure 7-4: International Space Station Configuration at 1998 IGA signing. (Image: NASA)

7.1.2 What Does the ISS Offer?

The International Space Station offers:

- The capability to perform an experiment or observation programme over an extended period of time in weightless conditions or/and exposed to the space environment. Typically, experiments can be performed over a period of an Increment (~ 6 months), during which microgravity levels of 10^{-6}g are possible for a minimum uninterrupted period of 30 days;
- The possibility of frequent and regular access to and return from the Station of payloads and experimental hardware;
- Access to a significant level of on-board resources (e.g. crew time, power, etc.);
- The permanent presence of crew during experiment execution, to carry out established procedures or for troubleshooting;
- An extensive range of facilities (including external sites) that allow for research in a wide spectrum of utilisation fields.

7.1.3 Why Use the ISS?

The ISS offers a range of facilities in a unique environment, and therefore how it is used depends mainly on the specific needs of an individual user. Some of these uses are summarised as follows:

- The simplest use of the Station by a user would be to use the image of the Station in some way, e.g. advertising. This utilisation may not even require anything to be specifically built or flown on the Station;
- The next simplest use would be to provide a user with access to data that has been collected on the Station by on-board experiments or instruments, either in real-time or on a suitable storage medium. An example here would be Earth observation data. As in the "image" situation, nothing physical may need to be built or flown on the Station;
- The next use requires volume and mass. An example would be a simple inert box not requiring access to resources, but only exposure either inside or outside the on-orbit modules. The item would need to be transported to and returned from the Station;
- A further use of the ISS is the participation by a user in an existing multi-user facility, through the provision of samples requiring some kind of processing. An example here would be the processing of a sample in the glovebox of the European Biolab facility;
- A higher level of complexity in terms of use would be the provision of an instrument by a user that needs access to resources in order to achieve experimental results. An example would be the Solution Crystallisation Diagnostics Facility;
- The highest level of complexity in terms of utilisation is when users provide an experiment that occupies a complete rack (the largest item available to users to accommodate experiments within the pressurised volume of the Station), or utilises one or more of the external experiment accommodation sites. An example would be the (internal) European Drawer Rack facility.

7.1.4 Principal Parameters and Characteristics of the ISS

The ISS has a nearly circular orbit inclined at 51.63° to the equator with an average altitude that has, since assembly began, ranged between 330 and 400 km. The ISS moves along its orbit at a velocity of approximately 27000 km/hr, orbiting the Earth every 91 minutes. The characteristics of the ISS are such that it flies over 85 % of the globe, populated by 95 % of the Earth's population. At assembly complete, the ISS will have a total mass of approximately 450 tonnes, made up of elements that together will result in a structure with dimensions of 108-by-79-by-43 metres, providing an overall pressurised volume of 1300 m^3. The maximum power output available at assembly complete will be 108 kW, with an average of 30 kW (minimum 25 kW, maximum 35 kW) available to payload operations and support to payload operations. The principal parameters of the ISS at assembly complete are reported in Table 7-1 (see also Figure 7-5), together with the values as of May 2005.

Table 7-1: Principal ISS parameters at Assembly Complete and as of May 2005

PARAMETER	ASSEMBLY COMPLETE (~ 2010)	MAY 2005
Length	79 m (~ 86 m with either ATV or Progress docked)	52 m (including Progress re-supply vehicle)
Width	108 m (along truss)	73 m (along solar arrays)
Height	43 m	27.5 m
Mass	455 000 kg	183 283 kg
Pressurised volume	1300 m^3	425 m^3
Total Power output	Max. 108 kW (non-Russian segment = 78 kW; Russian segment = 30 kW)	Max. 26.6 kW
Power available to for payload operations (non-Russian segment)	Min 25 kW; Max 35 kW	Max 6.8 kW
Pressurised Laboratory Modules	6 (2 US, 2 Russian, 1 European, 1 Japanese)	1 (US Lab “Destiny”)
ISPR Racks	35 (11 in US Lab, 10 in Columbus, 8 in Kibo, 4 in CAM, 2 TBD)	7 Note: 8 after LF1, 9 after ULF1.1
Multi-user External Payload Sites	18 (4 on S3 Truss, 4 on Columbus module, 10 on Kibo External Facility)	0
Crew	6	2
Orbit inclination	51.64°	51.64°
Mean Altitude	350 – 450 km	352 km
Orbital period	92 minutes	91.59 minutes
Orbital velocity	~ 7.69 km/s	~ 7.69 km/s
Eccentricity of orbit	~ 0	0.0004842
Attitude	XVV (LVLH)	XPH (XPOP)
Average Research Crew Time/Week (Hours)	~ 100 (crew of 6)	5.8/10.3 (US/Russian)
Command Uplink Rate (S-Band)	High Data Rate (HDR): 72 kbps Low Data Rate (LDR): 6 kbps	High Data Rate (HDR): 72 kbps Low Data Rate (LDR): 6 kbps
Command Downlink Rate (S-Band)	High Data Rate (HDR): 192 kbps Low Data Rate (LDR): 12 kbps	High Data Rate (HDR): 192 kbps Low Data Rate (LDR): 12 kbps
Data/Video Downlink Rate (Ku-Band)	150 Mbps total (US Segment only). ~ 100 Mbps available for utilisation	43 Mbps total (US Segment); 42 Mbps for utilisation
S-band& Ku-band coverage	30 – 70 %	36 – 45 % (Ku-Band); 54 – 62 % (S-Band)

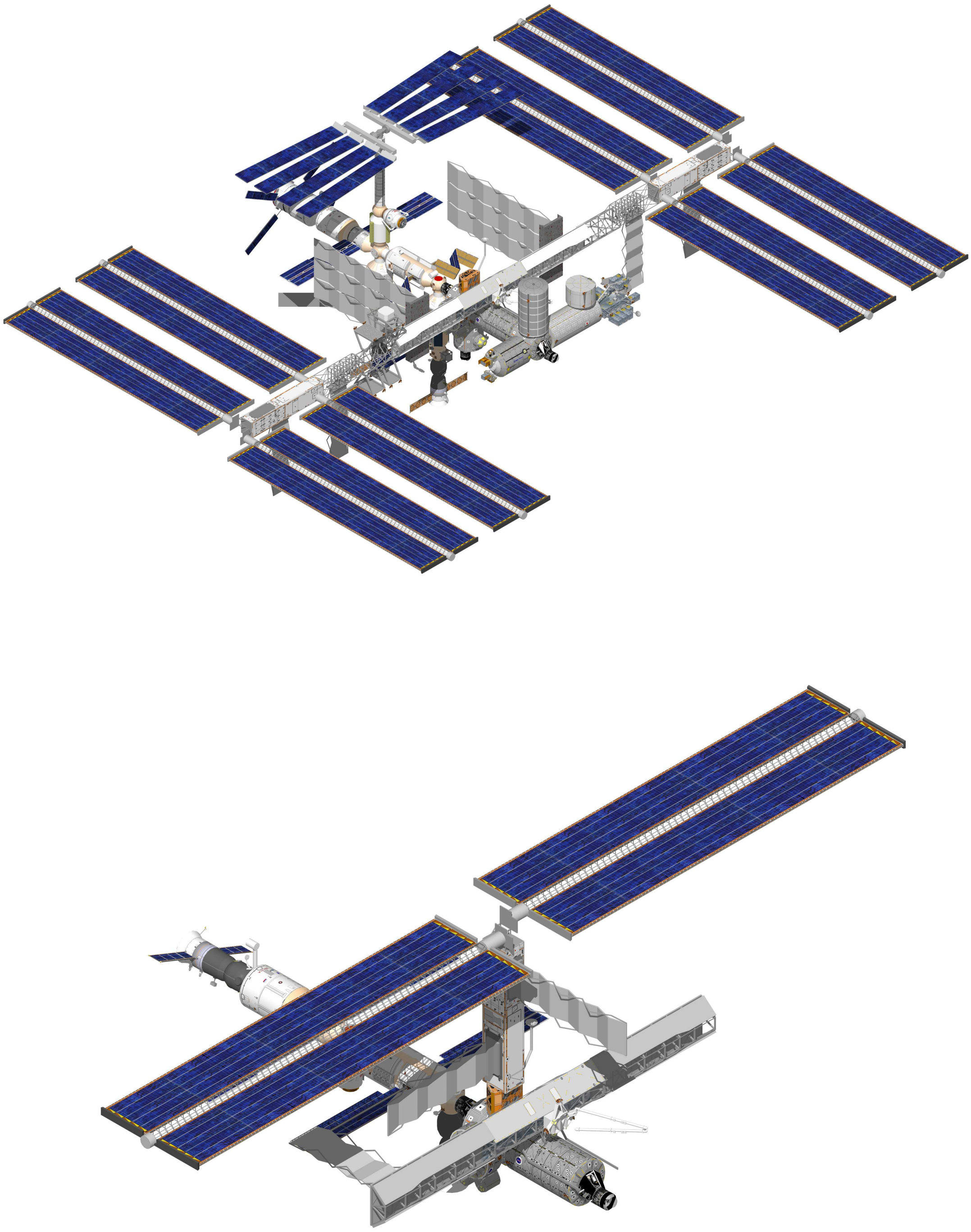

Figure 7-5: ISS at Assembly Complete and at May 2005

7.1.5 Major Elements and Launch Dates

In January 2005, the Heads of Space Agencies from the USA, Russia, Japan, Europe and Canada met in Montreal, Canada to review and further advance ISS cooperation. During this meeting the Heads endorsed the Multilateral Coordination Board approved ISS configuration (Figure 7-6), which had already been presented at a previous Heads of Agencies meeting held in July 2004 at ESA/ESTEC, The Netherlands.
The following tables provide a summary of the principal elements of the ISS, and are grouped into three main types: Pressurised Laboratory Modules, Elements dedicated to exposed payloads, Structural and Logistics Elements/Modules. The numbers in the first column ('Ref. Number') of each table refer to the labels in Figure 7-6. All launch dates prior to May 2005 refer to elements already in orbit; the remaining launch dates are to be considered "To Be Reviewed (TBR)". For further details on the ESA developed Columbus module, users should refer to the dedicated fact sheet in chapter **9**.

Table 7-2: ISS Pressurised Laboratory Modules

REF. NUMBER (Figure 7-6)	MODULE NAME	DESCRIPTION	OWNER-SHIP	LAUNCH DATE
1	Columbus (see paragraph 7.6)	European pressurised laboratory module for multidisciplinary research. 10 Utilisation ISPR locations available.	ESA	03/2007
2	US Lab "Destiny"	American pressurised laboratory module for multidisciplinary research. 13 Utilisation ISPR locations available.	NASA	02/2001
3	JEM PM "Kibo"	Japanese pressurised laboratory module for multidisciplinary research. 10 Utilisation ISPR locations available.	JAXA	09/2007
4	CAM – Centrifuge Accommodation Module	American pressurised laboratory module dedicated to gravitational biology research. 4 Utilisation ISPR locations and a 2.5 m diameter centrifuge available.	NASA	07/2009
5	RM – Research Module	Russian pressurised laboratory module for multidisciplinary research	Roscosmos	2010
6	MLM – Multipurpose Laboratory Module	Russian pressurised laboratory module for multidisciplinary research	Roscosmos	11/2007

Table 7-3: Elements dedicated to exposed payloads

REF. NUMBER (Figure 7-6)	ELEMENT NAME	DESCRIPTION	OWNER-SHIP	LAUNCH DATE
7	Express Pallets	External accommodation platforms for exposed payloads. Each pallet is capable of accommodating up to 6 smaller payloads.	NASA	*Pallet 2*: 08/2007 *Pallet 1*: 03/2008 *Pallet 3*: 03/2009
8	AMS – Alpha Magnetic Spectrometer	An international particle physics research payload occupying a full starboard truss external facility site. Operational life time: ~ 3 years	International	03/2008
9	JEM-EF Japanese Exposed Facility	Japanese external platform capable of accommodating up to 10 exposed payloads.	JAXA	05/2008
10	JEM-RMS Japanese Remote Manipulator System	Japanese robotic arm used for handling the payloads and logistics of the JEM-EF.	JAXA	05/2008
11	Columbus External Payload Facility – CEPF (see paragraph 7.6.3)	European exposed platforms located on the starboard end cone of the Columbus module. Accommodates up to 4 exposed payloads	ESA	03/2007

Table 7-4: Structural and Logistic elements/modules

REF. NUMBER (Figure 7-6)	ELEMENT NAME	DESCRIPTION	OWNER-SHIP	LAUNCH DATE
12	ESP – External Stowage Platform	Externally attached platforms providing temporary accommodation for orbital replacement units and spares	NASA	*ESP 1*: 03/2001 *ESP 2*: 07/2005 *ESP 3*: 01/2010 *ESP 4*: 03/2010
13	ULC – Unpressurised Logistics Carrier	General purpose unpressurised carrier for transporting cargo to and from ISS in Shuttle payload bay. Temporarily attached to ISS truss during change-out of orbital replacement units.	NASA	*First flight*: 01/2010
14	Functional Cargo Block “Zarya”	Russian control module and first element of ISS in orbit. Provided initial propulsion and power to ISS.	Roscosmos	11/1998
15	Node 1 “Unity”	Connecting node providing docking ports for other modules. Also provides temporary stowage capabilities.	NASA	12/1998
16	Service Module “Zvezda”	Structural and functional core of Russian segment, providing early ISS living quarters, life support, electrical power distribution, data processing, flight control, communication and propulsion systems.	Roscosmos	07/2000
17	Node 2	ESA developed element that controls and distributes resources from truss and Destiny to other connected elements (Columbus, Kibo, CAM, MPLM, HII Transfer Vehicle).	NASA	12/2006
18	Node 3	ESA developed element that controls and distributes resources from Node 1 to connected elements (Cupola, PMA 3). Also houses environmental control and life support systems.	NASA	10/2008
19	Docking Compartment 1 “PIRS”	Docked to Zvezda, serves as docking port for transport and cargo vehicles to ISS and as an airlock for spacewalks by 2 crewmembers using Russian Orlan spacesuits.	Roscosmos	09/2001

20	Cupola	ESA developed pressurised observation and work area for ISS crew giving visibility to support the control of the SSRMS and EVA activities, and general external viewing of the Earth, celestial objects and visiting vehicles.	NASA	03/2009
21	Mobile Servicing System – MSS	Mobile robotic system located on central truss used for assembly and maintenance tasks including moving equipment and supplies, supporting astronauts, servicing instruments and payloads. Made up of three parts: Canadarm2 (SSRMS), Mobile Base System (MBS) and Special Purpose Dextrous Manipulator (SPDM)	CSA	*Canadarm2:* 04/2001 *MBS:* 06/2002 *SPDM:* 03/2008
22	Integrated Truss Structure - ITS	Lattice framework structural elements that make up the "backbone" of the ISS. The solar arrays, radiators, and the MSS are all located on the ITS.	NASA	*First element (Z1 ITA)*: 10/2000 *Last Element (S6)*: 09/2006
23	Science Power Module (SPM)	Solar array structure for provision of extra power to the Russian segment of the ISS	Roscosmos	10/2009
24	Photovoltaic Arrays	Solar array structures for provision of power to the ISS.	NASA	*First Arrays (P6)*: 12/2000 *Final Arrays (S6)*: 09/2006
25	Multi-Purpose Logistics Module – MPLM	Italian built pressurised modules that serve as "moving vans", carrying laboratory racks filled with equipment, experiments and supplies to and from the ISS on board the Space Shuttle.	NASA	*First Flight:* 03/2001
26	JEM Experiment Logistics Modules (ELM)	Japanese logistics modules serving as on-orbit storage areas that house materials for experiments, maintenance tools and supplies. Made up of two parts: the Pressurised Section (PS) attached to Kibo, and the Exposed Section (ES) accommodated on the JEM-EF.	JAXA	*ELM-PS:* 08/2007 *ELM-ES:* 05/2008
27	Pressurised Mating Adaptors (PMA) 1, 2 and 3	PMA 1 attaches Unity to Zarya; PMA 2 & PMA 3 act as docking ports for the Space Shuttle to the US segment of the ISS.	NASA	*PMA 1:* 12/1998 *PMA 2:* 12/1998 *PMA 3:* 10/2000

28	Thermal Control Panels	Act as radiators in the overall ISS thermal control system.	NASA	*First panel (P6):* 12/2000 *Last panel (S6):* 09/2006
29	Airlock “Quest”	Airlock for spacewalks using either US EMUs (Extravehicular Mobility Units) or Russian Orlan spacesuits.	NASA	07/2001
30	European Robotic Arm (ERA)	Large re-locatable symmetrical robotic arm with 7 degrees of freedom attached on various points of the Russian Multipurpose Laboratory Module.	ESA	11/2007

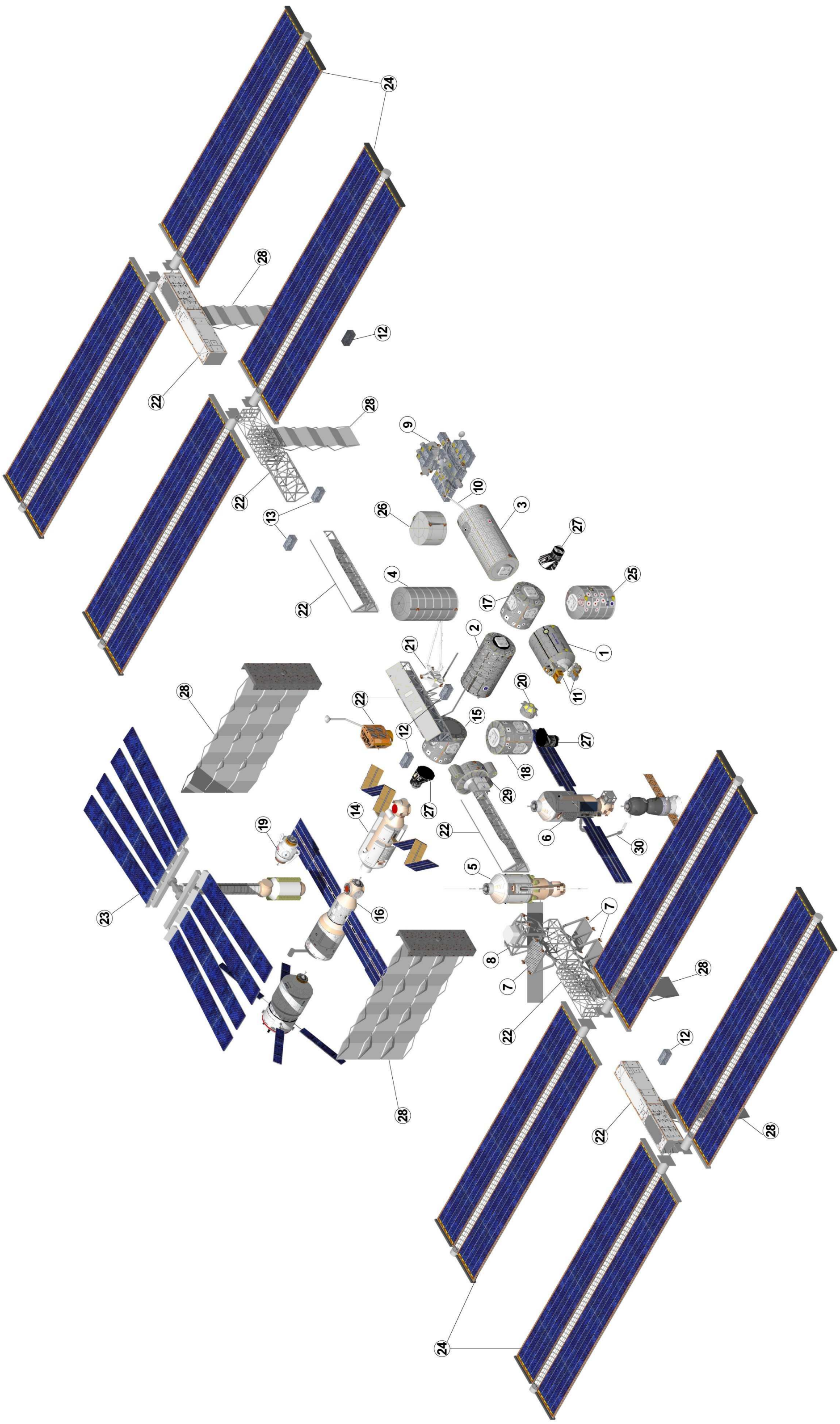

Figure 7-6: Exploded view of ISS Assembly Complete Configuration

7.1.6 Launch and Transfer Vehicles

During the assembly and utilisation phases of the International Space Station programme, various types of launch and transfer vehicles will be used to deliver crew, assembly elements, experimental equipment, water, food, propellant, etc. to orbit. The following tables provide a brief description of these vehicles. Where indicated, users are requested to refer to the fact sheets in chapter **9** for more details:

Table 7-5: ISS Programme Launch Vehicles

VEHICLE NAME	DESCRIPTION	OWNER-SHIP	LAUNCH DATE
Ariane 5 ES ATV	Ariane 5 is Europe's main expendable launcher used for placing communications, Earth observation and scientific research satellites into geostationary transfer orbits, medium and low Earth orbits and sun-synchronous orbits. The ES ATV version has been designed to place ESA's Automated Transfer Vehicle (ATV) into low Earth orbit, from where the ATV will use its own propulsion to reach and dock with the ISS (see Table 7-6). Launches take place from Kourou, French Guiana.	ESA	*First ISS Flight:* 05/2006
Space Shuttle	The re-usable American Space Shuttle is the main launch and transportation vehicle for carrying crew, assembly elements and cargo to and from the ISS. It is due to retire at assembly complete (~ 2010)	NASA	*First ISS flight*: 12/1998
Proton	Russian expendable launcher used to launch larger Russian elements and modules during the assembly phase of the ISS	Roscosmos	*First ISS Flight:* 11/1998
Soyuz	Russian expendable launcher used to launch the manned Soyuz and unmanned Progress transfer vehicles to the ISS	Roscosmos	*First ISS Flight*: 08/2000
H-II A	Japanese expendable launcher which will be used to launch the H-II Transfer Vehicle (HTV) to the ISS (see Table 7-6).	JAXA	*First ISS Flight*: 07/2008

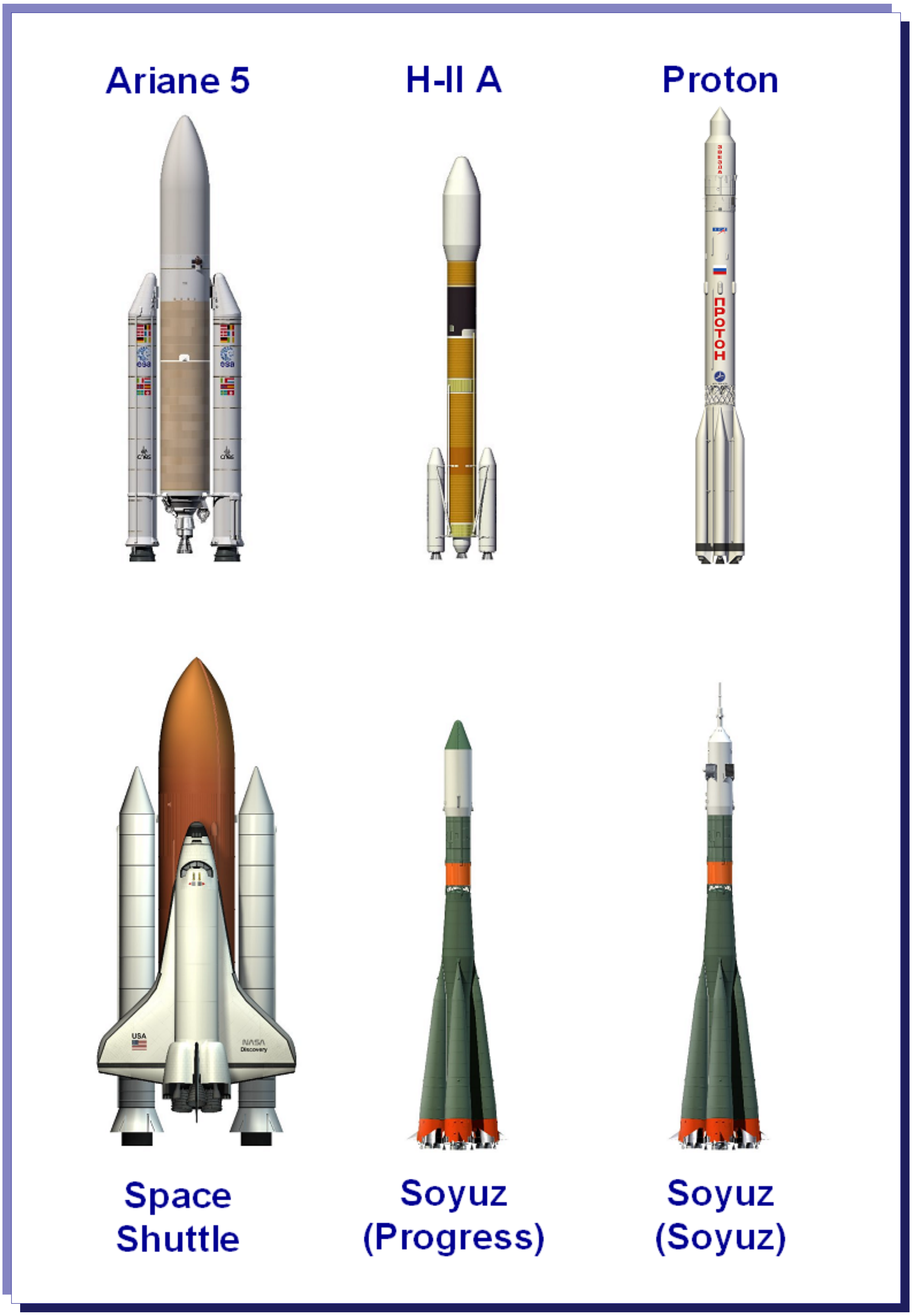

Figure 7-7: ISS Programme Launch Vehicles (Image: ESA Ducros)

Table 7-6: ISS Programme Transfer Vehicles

VEHICLE NAME	DESCRIPTION	OWNER-SHIP	LAUNCH DATE
Automated Transfer Vehicle – ATV	European unmanned transfer vehicle that is placed in orbit by the European Ariane 5 launcher. It provides the ISS with pressurised cargo, water, air, Nitrogen, Oxygen and attitude control propellant. It is loaded with unwanted equipment and waste before undocking, and burns up upon re-entry into Earth's atmosphere. ATV is also used to re-boost the ISS to a higher altitude to compensate for atmospheric drag. See also section 7.1.6.1 and the dedicated fact sheet in chapter 9.	ESA	*First ISS Flight:* 05/2006
H-II Transfer Vehicle (HTV)	Japanese unmanned transfer vehicle launched to the ISS with the H-II A launcher. Designed to deliver up to 6 tonnes of pressurised and unpressurised cargo to the ISS. Like ESA's ATV, it will be loaded with unwanted equipment and waste before undocking, and will burn up upon re-entry into Earth's atmosphere.	JAXA	*First ISS flight:* 07/2008
Progress M1	Russian unmanned re-supply vehicle based on Soyuz design (see below) used to bring supplies and fuel to the ISS. Also has the ability to raise the Station's altitude and control its orientation. Before undocking it is filled up with trash, unneeded equipment, and waste water. It burns up during re-entry into Earth's atmosphere after undocking from ISS.	Roscosmos	*First ISS Flight:* 08/2000
Soyuz TMA	Russian manned vehicle that serves as the International Space Station's crew return vehicle, acting as a lifeboat in the unlikely event of an emergency that would require the crew to abandon the ISS. A new Soyuz capsule is delivered to the station approximately every six months.	Roscosmos	*First ISS Flight:* 10/2000

7.1.6.1 Automated Transfer Vehicle (ATV)

ESA's Automated Transfer Vehicle (ATV) is an unmanned pressurised module, which provides a contribution to the logistic servicing of the ISS through:

- Re-boost and support to attitude control for the ISS;
- Delivery of items (dry pressurised cargo, water, gases and propellant);
- Disposal of ISS wastes, solid and liquid.

The ATV consists of two main elements: the Integrated Cargo Carrier (ICC) and the Spacecraft (S/C).

The ICC includes the Russian Docking System (RDS), the Equipped Pressurised Module (EPM), or simply Pressurised Module (PM), and the Equipped External Bay (EEB). Internally, the ICC is a two-bay module capable of accommodating up to eight racks (see section 7.6.1.1). The racks provide for the accommodation of the pressurised dry cargo.

The S/C provides the mechanical interfaces to the Ariane-5 launcher and consists of a self-contained module which accommodates equipment mainly dedicated to the ATV thermal control, power supply, C&DH, propulsion, Guidance, Navigation and Control (GNC) and communications, and to the ISS re-boost.

The S/C includes the following sub-elements:
- Equipped Propulsion Bay (EPB);
- Equipped Avionic Bay (EAB);
- Separation and Distancing Module (SDM).

The following cargo can be transported by the ATV:
- Pressurised dry cargo and solid wastes accommodated in the ICC Secondary Structure (racks);
- Water, gas, refuelling propellant and fluid wastes contained in tanks accommodated in the ICC EEB;
- ISS re-boost propellant contained in tanks accommodated in the S/C EPB.

The ATV provides for the accommodation of up to 16.844 m^3 of pressurised dry cargo:
- Up to 12.376 m^3 of pressurised dry cargo can be arranged in the volume available inside the racks (1.547 m^3 for each rack);
- Up to 4.469 m^3 of pressurised dry cargo can be placed outside of the racks, in the cabin habitable volume, attached to the Rack Adapter Plates (1.117 m^3 for each rack).

In principle, up to 23.6 m^3 of pressurised dry cargo volume can be transported in the event that some racks are removed to accommodate exceptionally large dry cargo items, fixed to the rack mechanical interfaces.

The accommodation of the cargo is performed in different ways depending on the cargo size (small vs.large). The accommodation of the small cargo items employs either soft Cargo Transfer Bags or hard ISIS drawers and Middeck Lockers for cargo packaging (see 7.6.2).
The large cargo items can be attached directly to the rack walls or to the Adapter Plates, depending on their envelope dimensions, without prior packaging. Brackets and adapters are used for the accommodation of these cargo items, if necessary.

The ATV is capable of carrying up to 7500 kg of net cargo mass (this does not include the mass of the racks and of the fluid storage tanks). The net cargo mass includes:
- The mass of the packaged small (dry) cargo items to be physically transferred from the ATV to the ISS, or vice-versa, including the mass of the soft/hard containers (if any);
- The mass of the structures (shelves, liners, etc.) needed to integrate the soft/hard containers into the racks;
- The mass of the provisions needed to fix the large (dry) cargo items directly to the rack structure (adapters, brackets, fixation hardware);
- The mass of the fluids to be delivered to the ISS;
- The mass of the ISS re-boost propellant contained in the tanks located in the S/C EPB.

The 7500 kg net cargo carrying capability is broken down as follows:
- From 1500 kg up to 5500 kg of pressurised dry cargo;
- Up to 840 kg of water;
- Up to 100 kg of gas – two gases maximum per flight, selected among air, oxygen and nitrogen, with the following limitations:
  - Mass of the first gas less than 66.666 kg;
  - Mass of the second gas less than 33.333 kg.
  - If only one gas is carried, the mass of this gas is up to 100 kg.
- Up to 860 kg of refuelling propellant, including up to 300 kg of fuel and up to 560 kg of oxidiser;
- Up to 4080 kg of ISS re-boost propellant.

During the re-entry phase, the ATV is capable of accommodating:
- From 1500 up to 5500 kg of pressurised dry cargo, including solid wastes;
- Up to 840 kg of liquid wastes, contained in the water tanks.

For more technical data, users can refer to the ATV fact sheet in chapter 9. Detailed cargo accommodation information can be found in ATV-HB-AI-0001 Issue 05 “ATV Cargo Accommodation Handbook”, March 2004.

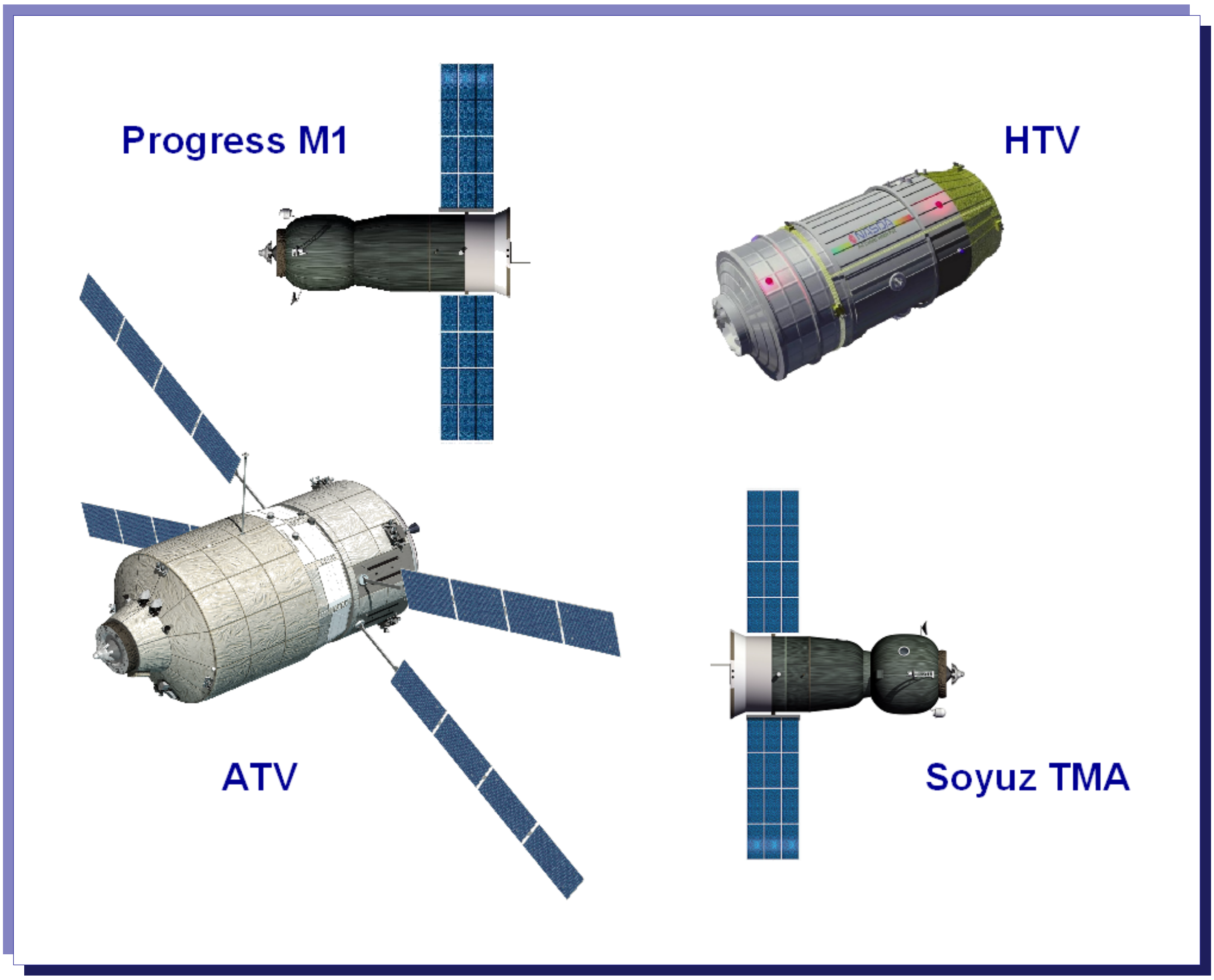

Figure 7-8: ISS Transfer Vehicles (Image: ESA Ducros)

7.2 Operational Environment

7.2.1 Altitude

The altitude of the ISS is determined primarily by safety and logistics considerations. It must be high enough to avoid re-entry altitude (the Minimum Recoverable Altitude – MRA – is considered to be about 278 km) and low enough to optimise the transportation flights to and from the ISS. The ISS altitude profile is managed to achieve the optimal balance among the following:

- Orbit lifetime;
- Propellant;
- Launch vehicle performance;
- Visiting vehicle support;
- Microgravity environment;
- Crew radiation exposure.

The variation in altitude of the ISS between November 1998 (launch of the first element) and May 2005 is shown in Figure 7-9. The altitude range of the ISS over this period was between 330 km and 410 km.
The "saw-tooth" appearance of the altitude profile represents the decrease in altitude (between 100 and 200 metres per day) caused by atmospheric drag, and the subsequent periodic re-boosts to counteract this decrease and which increase the altitude temporarily. The rate of descent is not constant and this variation is caused by changes in the density of the outer atmosphere, which is a consequence of solar activity. The re-boosts can take place at intervals anywhere between 10 and 80 days, and are currently executed by the Shuttle, Progress and Soyuz spacecraft. In the future, ESA's Automated Transfer Vehicle (ATV) will also be used to carry out re-boosts.

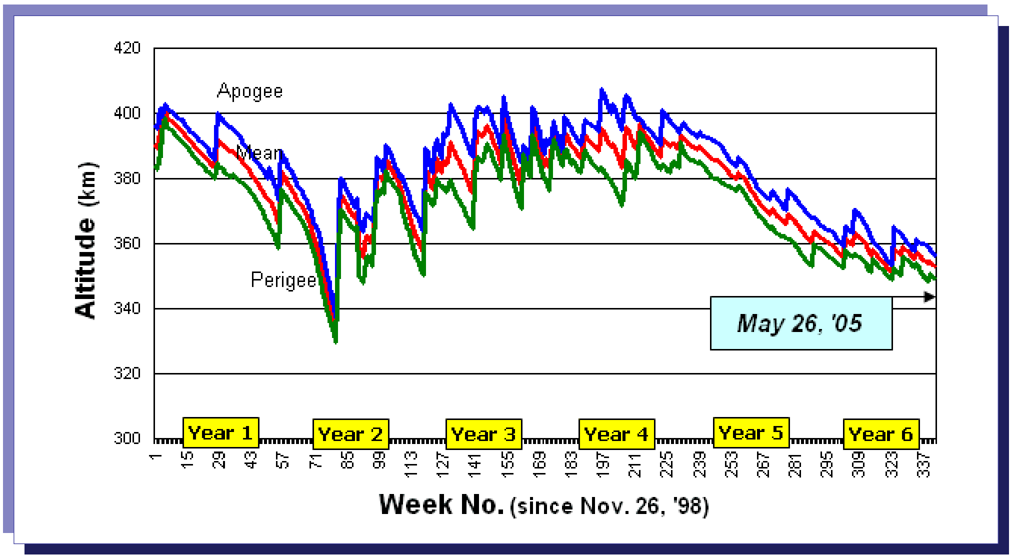

Figure 7-9: ISS altitude history November 1998 - May 2005 (Image: NASA)

7.2.2 Inclination

The ISS orbit around the Earth is inclined at an angle of 51.6 degrees to the equator, which means that it reaches almost 52 degrees latitude north and south of the Equator (Figure 7-10). The projection of the orbit onto the Earth's surface (i.e. the ground track) extends over an area containing 95 % of the world's population, completing one orbit approximately every 92 minutes. The ground track traced each orbit (an example of which can be seen in Figure 7-10) varies due to the rotation of the Earth and the variation in altitude of the ISS.

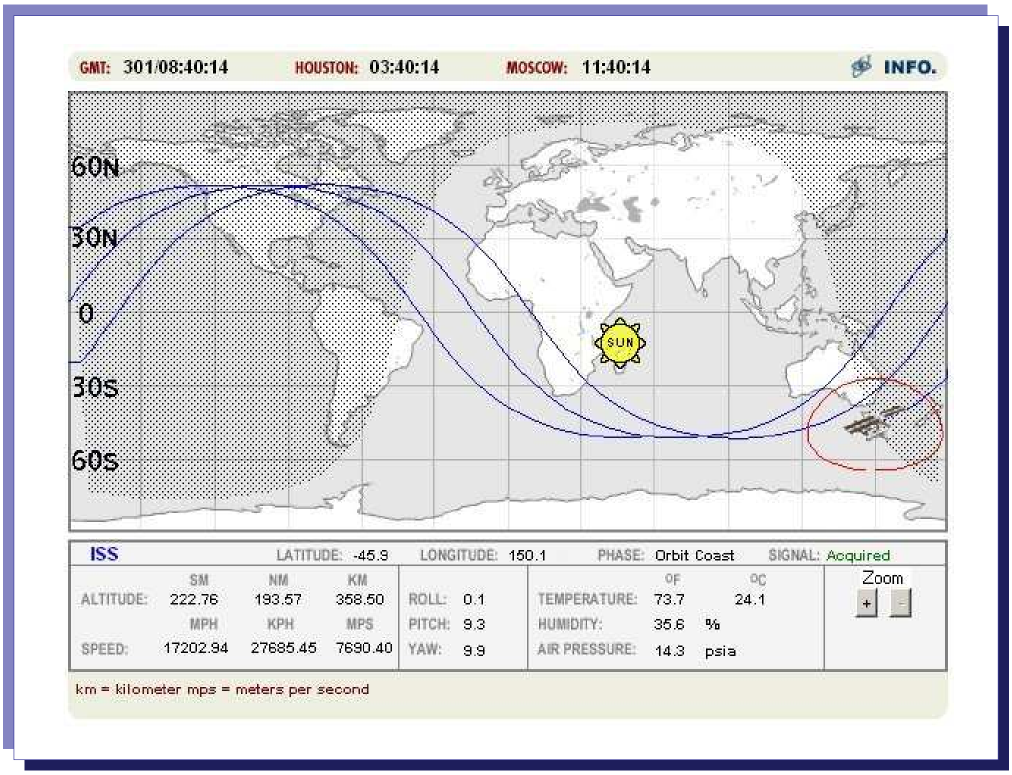

Figure 7-10: Example of ISS ground tracks (shaded area refers to night time areas) **(Image: NASA)**

7.2.3 Attitude

The ISS incorporates different flight attitudes in order to maximise power and minimise negative thermal effects. The ISS will fly three major attitudes until the main solar arrays are in position:

- X-axis in the Velocity Vector (XVV);
- X-axis Perpendicular Out of Plane (XPOP);
- Y-axis in the Velocity Vector (YVV).

Once the solar arrays are in position only the XVV attitude will be flown.

Before explaining the 3 above attitudes it is important to define the coordinate systems used in the definition of these attitudes.

7.2.3.1 Coordinate Systems

7.2.3.1.1 ISS Body Coordinate System

The ISS body axes are a set of Right-Handed Cartesian, Body-Fixed axes that remain fixed to the Space Station and therefore rotate with ISS rotation (Figure 7-11). The origin of the body axes is located at the ISS centre of mass. The x-axis is parallel to the longitudinal axis of the US Lab “Destiny” and is positive in the direction moving away from the Russian segment. The y-axis is parallel to the Integrated Truss Segment (ITS) S0 and is positive in the starboard direction. Completing the right-handed coordinate system is the z-axis, which is positive in the nadir direction, i.e. Earth pointing.

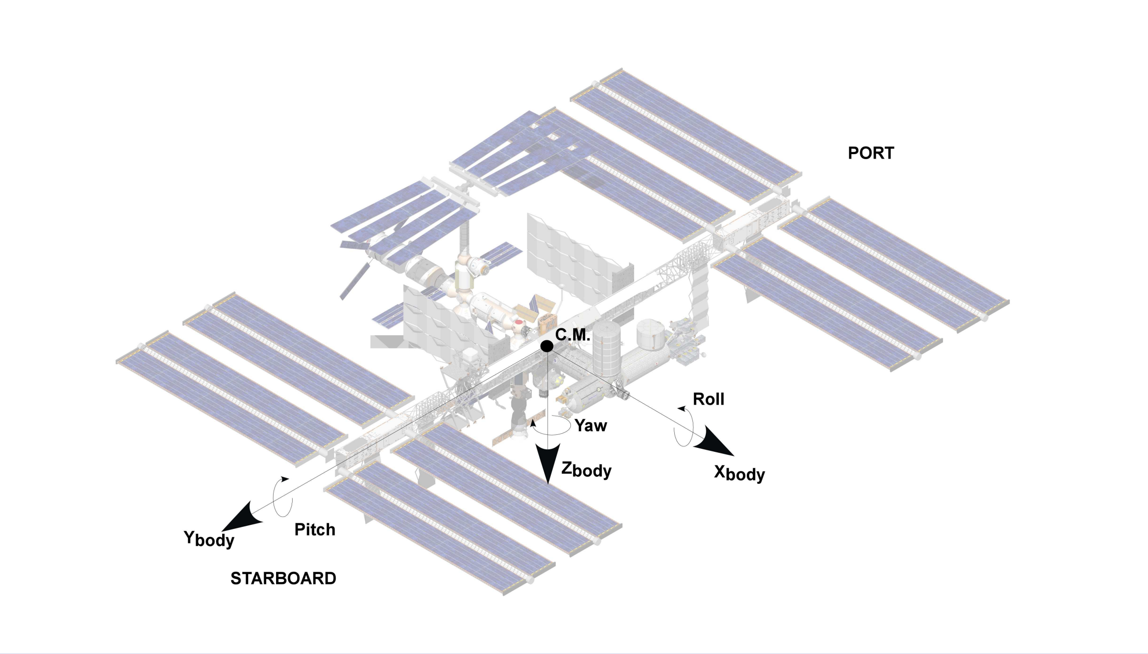

Figure 7-11: ISS Body Coordinate System

7.2.3.1.2 Local Vertical/Local Horizontal (LVLH) Coordinate System

The local-vertical/local-horizontal (LVLH) coordinate system is referenced to the Station's near-circular orbit (Figure 7-12). The LVLH origin is at the Station's centre of mass. The x-axis points along the orbital velocity vector (the ram direction, with wake being opposite), the z-axis points radially toward the Earth's centre (or toward the nadir direction), and the y-axis completes the right-hand coordinate system, i.e. perpendicular to the orbit plane.

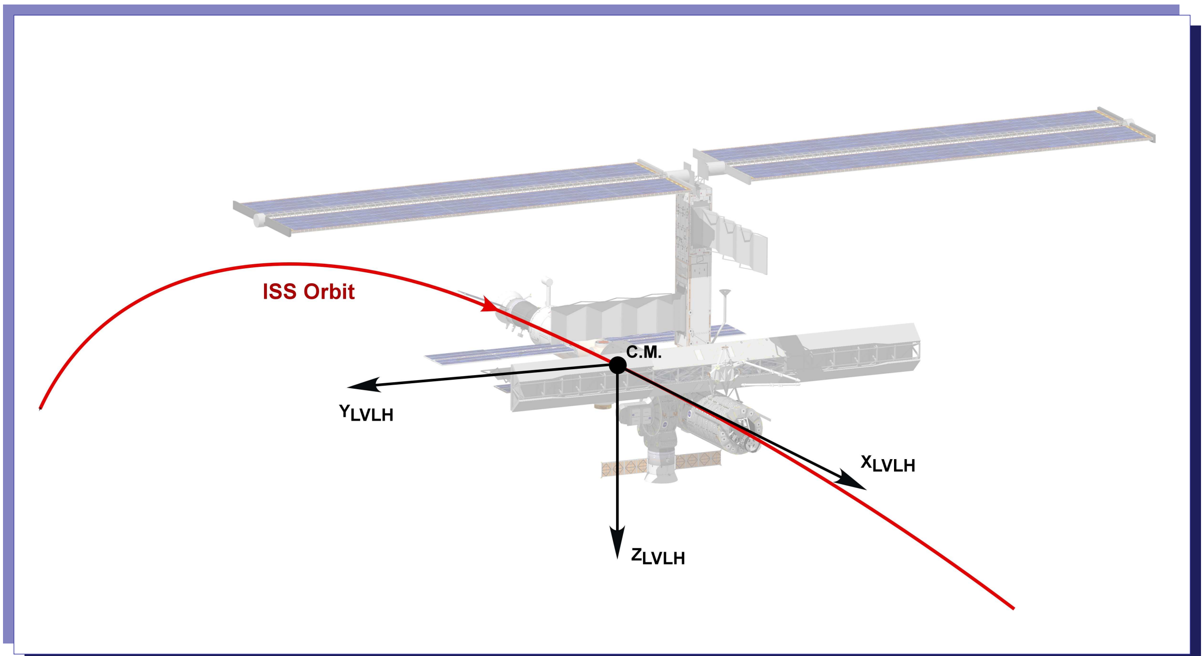

Figure 7-12: LVLH reference system

7.2.3.1.3 X-Perpendicular Out of Plane (XPOP) Coordinate System

The X-Perpendicular Out of Plane (XPOP) coordinate system (Figure 7-13) is also referenced to the Station's near circular orbit, with the origin at the ISS centre of mass. The x-axis is always perpendicular to the plane of the orbit, with the z-axis pointing in the nadir direction (Earth pointing) at the orbital noon. The y-axis completes the right-hand rule of the coordinate system.

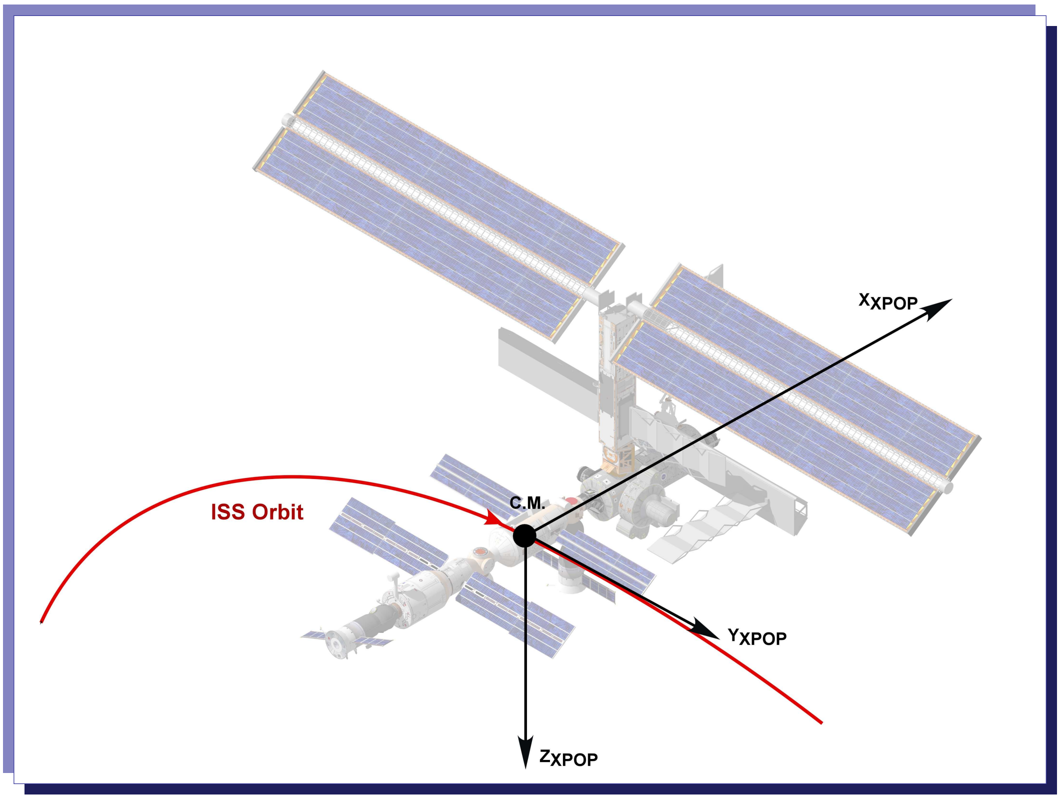

Figure 7-13: XPOP Reference Coordinate System

7.2.3.2 X-axis in the Velocity Vector (XVV) Attitude

The overall ISS design is optimised to fly in the XVV attitude for the following reasons:

- It provides the best microgravity conditions;
- It supports attitude re-boosts;
- It supports service vehicle docking;
- It minimises aerodynamic drag.

XVV (Figure 7-14) is an "airplane like" attitude maintained relative to the Local Vertical Local Horizontal (LVLH) with the ISS body x-axis towards the velocity vector, and the z-axis positive towards the nadir direction. In order to specify the attitude of the ISS with respect to the LVLH, a system based on Eulerian angles of roll, pitch and yaw is used. To optimise the thermal control, power generation and communication links, etc. the normal XVV attitude is ±15° roll (around x), ±15° yaw (around z) and +10 to -20° pitch (around y) with respect to LVLH.

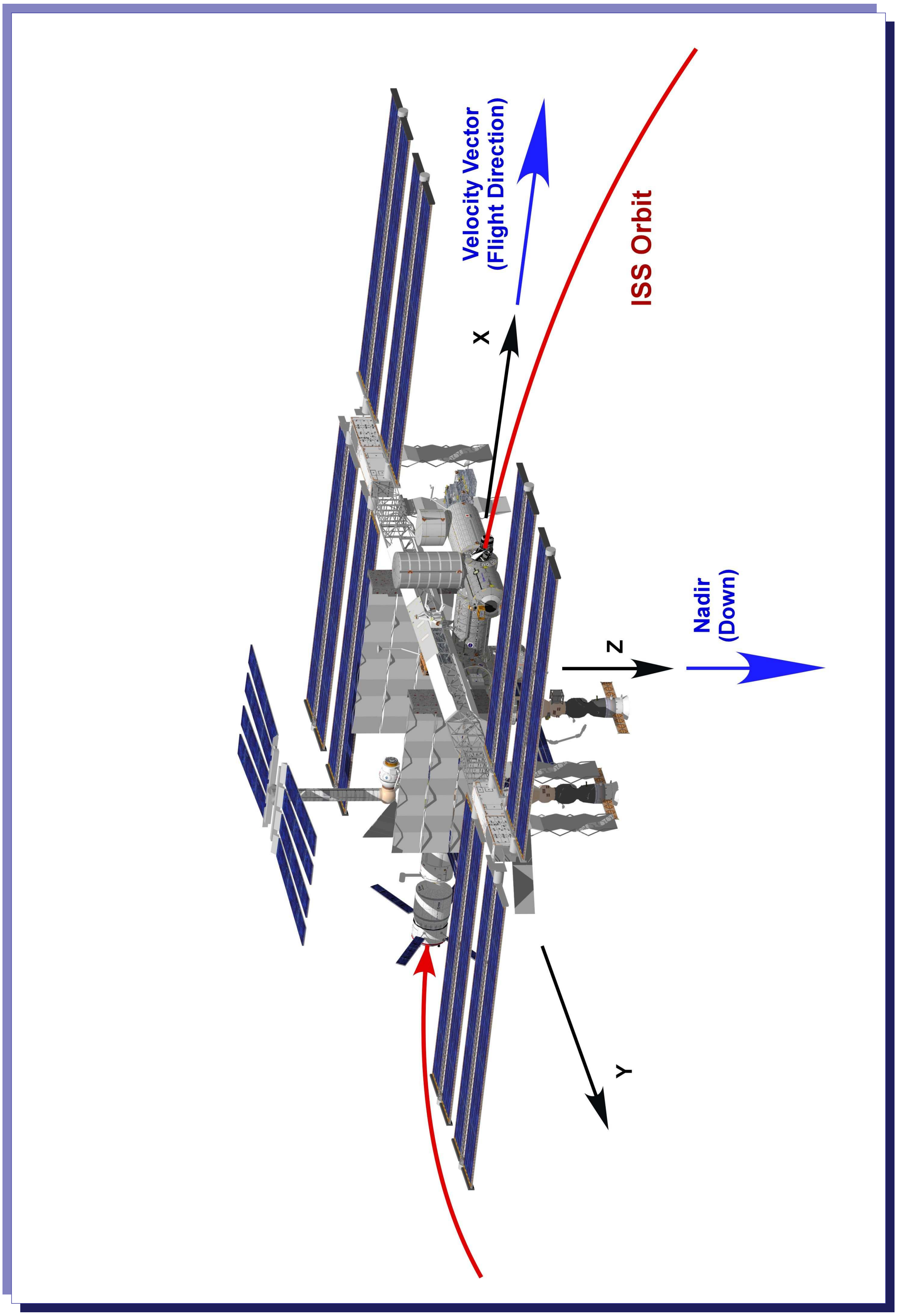

Figure 7-14: XVV attitude

7.2.3.3 XPOP Attitude

For the XPOP attitude, the ISS body coordinates are parallel to the XPOP coordinate system described in section 7.2.3.1.3, i.e. x-axis is always perpendicular to the plane of the orbit, with the z-axis pointing in the nadir direction (Earth pointing) at the orbital noon. In the XPOP attitude the x-axis will always be positive in the direction opposite to the sun side of the orbital plane. This attitude was developed for the assembly stage in which only a single axis of solar array sun tracking is available, hence maximising power production.

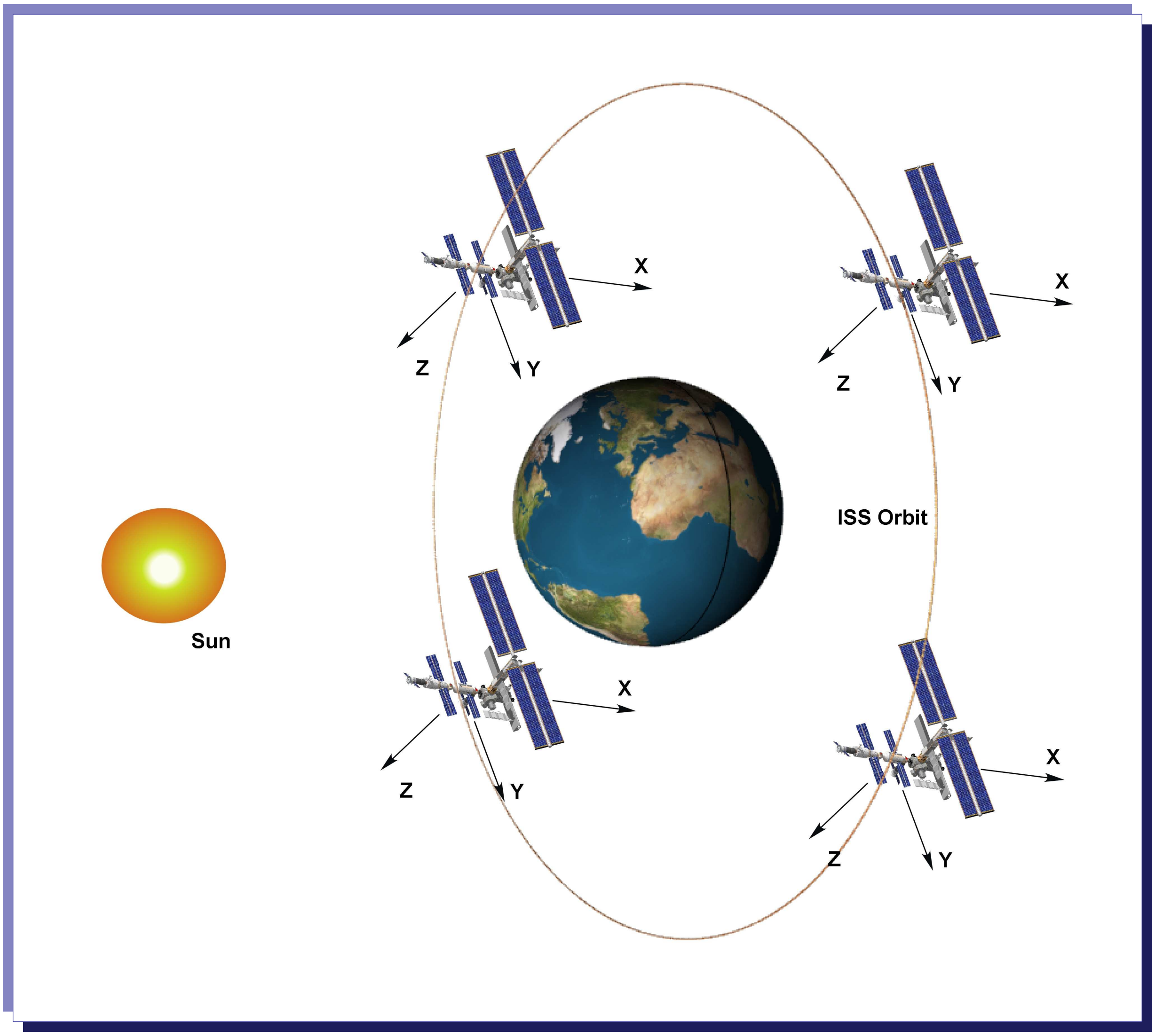

Figure 7-15: XPOP Attitude

7.2.3.4 Y-axis in the Velocity Vector (YVV) Attitude

The YVV attitude (see Figure 7-16) is maintained relative to the Local Vertical Local Horizontal (LVLH) similar to the XVV attitude, but with the ISS body y-axis towards the velocity vector, and the z-axis positive towards the nadir direction. The YVV attitude is the flight attitude required to meet the requirements of Earth viewing payloads. This attitude also serves to keep ISS components from violating high temperature limits while maintaining a lower drag profile.

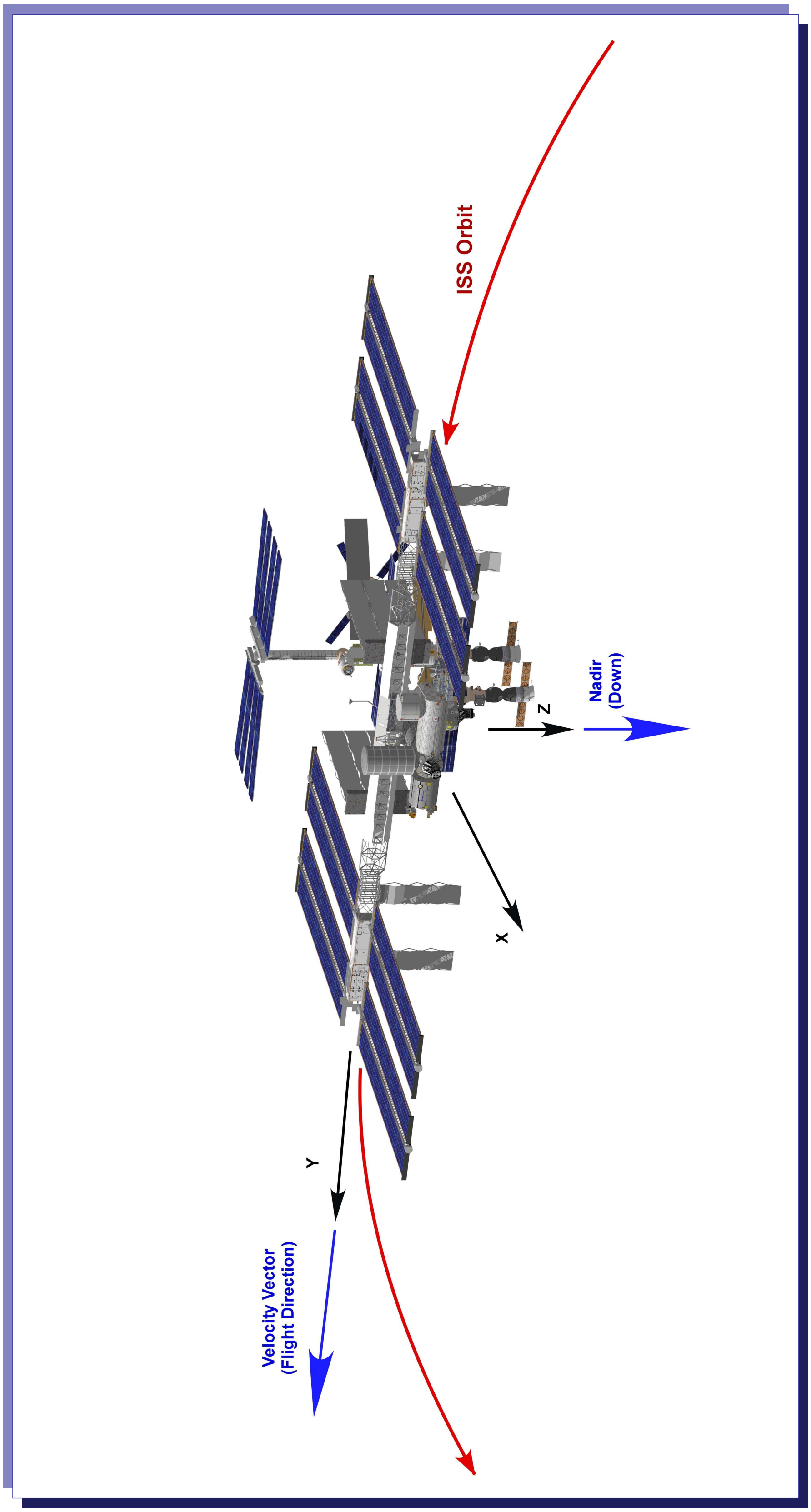

Figure 7-16: YVV Attitude of the ISS

7.2.4 Operational Cycle of the ISS

The ISS is operated according to a number of specific modes, each of which has a specified set of conditions and capabilities. Although most modes support research payload operations at some level, there are others for which payload operations may be sharply curtailed or discontinued.

Microgravity and Standard modes are the primary modes of operation for research. During Microgravity mode the ISS must be operated so as to meet a stringent set of requirements for its microgravity environment (see 7.3). Standard mode has many identical capabilities to Microgravity mode, and provides full support for research payloads. However, Standard mode allows a number of activities that could result in the microgravity environment specifications being exceeded, such as control of the ISS attitude by propulsive means.

In addition to Microgravity and Standard modes, Re-boost mode is necessary for the reasons discussed in 7.2.1. The re-boost period requires 1-2 orbits (1.5 - 3 hours) and represents an assured, but temporary, interruption in the maintenance of the Station's microgravity specification. Table 7-7 provides a brief description of the various ISS operational modes.

Table 7-7: ISS Operational Modes

MODE	DESCRIPTION	COMMENTS
Standard	❑ Represents core operations when tended or preparing to support human presence ❑ Provides "shirt sleeve" environment ❑ Internal and external operations supported, monitored and controlled	Similar to the Microgravity mode, but allows a number of operational activities that could result in the microgravity specifications being violated, e.g., propulsive control of attitude. Use of control moment gyroscopes for attitude control during normal operations, minimises vibration disturbances. Nominal payload operations may be performed.
Re-boost	❑ Used to obtain additional altitude while maintaining a habitable environment and supporting internal and external user payload operations ❑ Altitude controlled propulsively	Required to raise the orbit, occurring once every 10 to 80 days and having a duration of 1.5 to 3 hours (i.e., one to two orbits). Microgravity specifications will be exceeded during these periods. Payload operations not requiring stringent microgravity conditions may be performed.
Microgravity	❑ Consists of capabilities required for microgravity research by user payloads in a habitable environment ❑ Does not include effects of crew activity, but does include effects of crew equipment (e.g., exercise devices)	The ISS is operated to meet stringent Microgravity requirements (see 7.3). Schedulable Extra Vehicular Activity and Intra Vehicular Activity servicing events, re-boosts and Shuttle (or Proton or Soyuz) operations should occur outside of these quiescent periods. Nominal payload operations may be performed.
Survival	❑ Initiated upon command or when a warning of imminent threat (e.g., loss of attitude control, loss of thermal conditioning, available power out-of-range) is not acknowledged by the on-orbit crew, the Orbiter crew, or the ground ❑ Autonomously attempts to correct the threatening condition and provides keep-alive utilities to Station's crew/core systems ❑ Precludes support or commanding of external or internal operations	By its nature, this is an unplanned activity, and as the safety of the crew is paramount in this scenario, payload operations may be compromised. Nominal automated payload operations may be performed. Crew may not be available for interactive payload operations.
Proximity Operations	❑ Provides capabilities related to supporting safe operations with other vehicles while maintaining a habitable environment and supporting internal and external user payload operations ❑ Vehicle is actively determining and controlling attitude non-propulsively	Payload operations may be compromised. Along with the re-boost mode, docking of for example the Shuttle, will cause the greatest disturbance to the microgravity level. Payload operations not requiring stringent microgravity conditions may be performed.

Assured Safe Crew Return	❑ Provides mitigation capability for life threatening illness, unrecoverable loss of Station habitability, or extended problem requiring re-supply/servicing, which is prevented from occurring due to launch problems ❑ Consists of actions, operations and functions necessary to safely populate a crew rescue vehicle, separate, return to earth, and egress the crew rescue vehicle upon recovery on the ground	This is likely to be a planned mode, although the planning timescale could be quite short (i.e., days or even hours). Nominal automated payload operations may be performed, but they may be compromised.
External Operations	❑ Utilises functionality related to supporting ISS-based external operations while maintaining a habitable environment and supporting internal and external payload operations ❑ Vehicle actively determining and controlling its attitude non-propulsively	Nominal payload operations may be performed, but they may be compromised.

7.2.4.1 Example Operational Modes Timeline

An example timeline with respect to altitude of the ISS operational modes (defined in Table 7-7), showing the modes interspersed with each other, is given in Figure 7-17 (both the timeline and altitude are not to scale). The timeline begins with the start of an increment, i.e. the arrival of a new increment crew, which in this case is on-board the Space Shuttle. For a definition of Increment, refer to 7.12. The timeline shows the duration of each mode as well as the cumulative increment duration in days. As can be seen in the figure, a visiting vehicle will usually rendezvous with the ISS when its orbit is relatively low. The increment terminates with the arrival of the new increment crew (again on-board the Shuttle), which in this case is at about 185 days. Excluding increment start and end, a further two vehicles will rendezvous in the example given: a Progress re-supply vehicle at 51 days and a Soyuz vehicle at 160 days. Two extravehicular activity periods (EVAs) are shown in the example at 56 days and 114 days. In this example, 3 microgravity periods of 30 days each are foreseen, which fulfils the requirements defined in 7.3. It should be kept in mind, that this example refers to ISS operations at assembly complete, and assumes Space Shuttle flights for crew exchange.

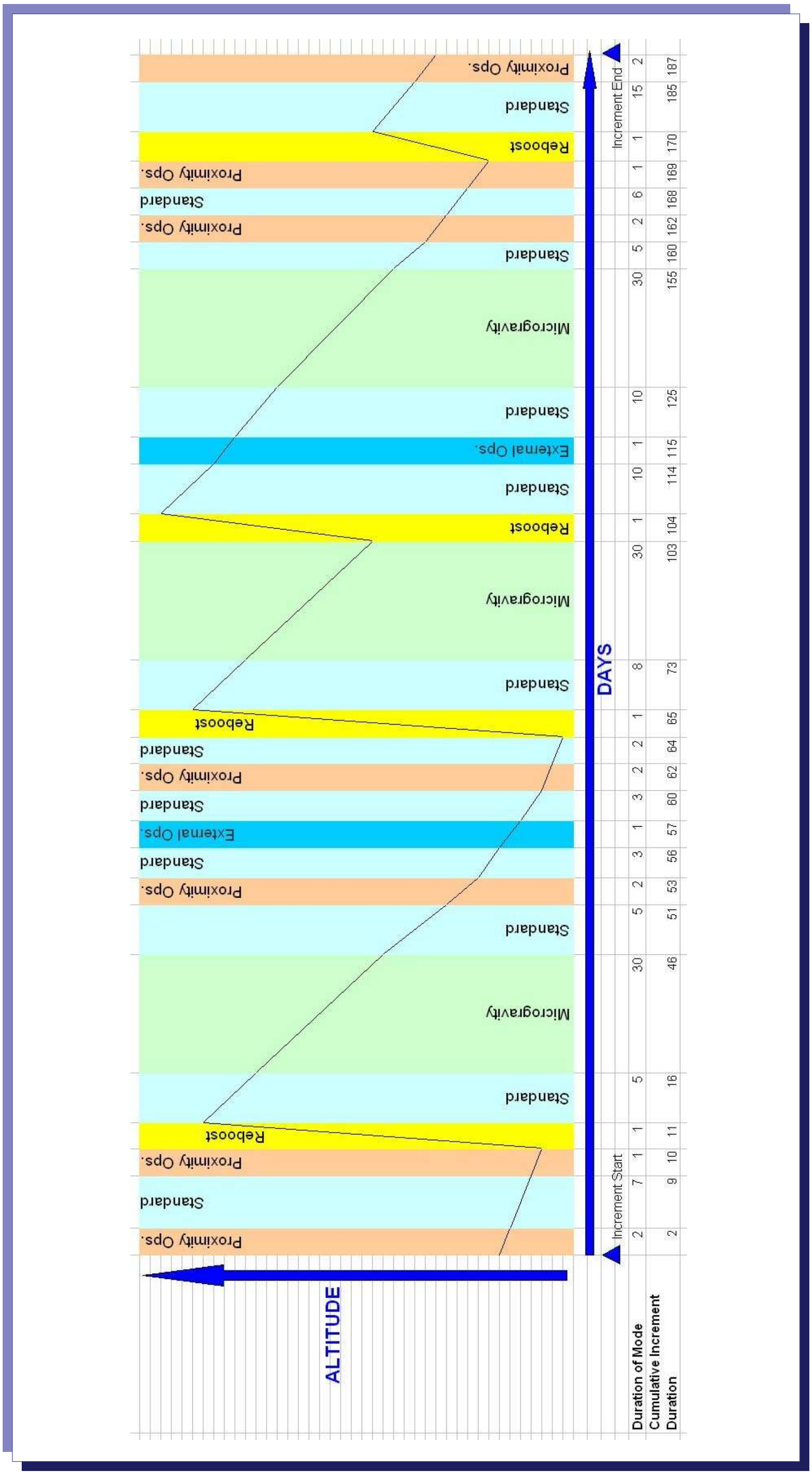

Figure 7-17: Example Operational Modes Timeline

7.3 Physical Environment

7.3.1 Gravity Levels

Inside the ISS a "microgravity" environment exists in which the acceleration of objects and persons relative to their surroundings is reduced to one-millionth of the value measured on the Earth's surface (9.81 m/s^2 or 1g). The microgravity environment experienced on the ISS and other orbiting spacecraft is actually due to two principal classes of residual accelerations:

- Quasi-steady acceleration;
- Vibratory accelerations.

The levels of both quasi-steady and vibratory accelerations on ISS are of interest to microgravity researchers whose investigations cover the effects of reduced gravity on a large range of physical, chemical and biological phenomena. For this reason, the ISS has been designed, is being assembled, and will be operated to meet a set of requirements for both its quasi-steady and vibratory microgravity environment. The requirements specify not only allowable levels of acceleration, but also where on the ISS and for how long such acceleration limits must be obeyed.

7.3.1.1 Quasi-Steady State Accelerations

Quasi-steady accelerations are accelerations whose magnitude and direction vary relatively slowly, on a timescale greater than 100 seconds (i.e. with a frequency < 0.01 Hz). Accelerations are considered quasi-steady if at least 95 % of their power lies below 0.01 Hz as measured over a 5400-second period (the approximate time of one orbit). Generally these accelerations have a magnitude of approximately 1 µg. Quasi-steady accelerations are caused mainly by two factors:

1. The aerodynamic drag that the ISS experiences due to the residual atmosphere at low Earth orbit. This drag causes the Station to lose altitude, and consequently to accelerate along its orbital velocity vector;
2. Gravity gradient effects: any point not exactly at the ISS centre of mass will tend to want to follow its own orbit. Such points, however, because they are physically part of the ISS are subject to accelerations from the structural forces that keep them attached to the Station as it orbits.

A set of formal design requirements regarding the ISS quasi-steady acceleration environment during the Microgravity Mode (see 7.2.4) at Assembly Complete (AC) have been laid out in the ISS programme, which state that:

"50 % of the International Standard Payload Rack (ISPR) locations within the U.S. Destiny, European Columbus and Japanese Kibo Laboratories must have quasi-steady accelerations less than 1 µg (10^{-6} g) for periods of at least 30 continuous days, on 6 occasions per year."

NASA has developed several analytical (system) models for the AC configuration when the microgravity design requirements become applicable. This system model development is an evolutionary process called Design Analysis Cycles (DAC), with each cycle reflecting the current assembly sequence and the updated component models. The last cycle was DAC-9, completed in March 2002. The drag, gravity gradient and other secondary effects can be incorporated into calculations that reveal the level of gravity as a function of coordinate position relative to the Station's centre of mass. These gravity contours are shown in Figure 7-18 and Figure 7-19. The results of the DAC-9 have shown that 14 of the 32 ISPRs analysed (i.e. ~ 44 %) in Destiny, Columbus and Kibo are subject to peak quasi-steady acceleration magnitudes of less than 1µg. This compares favourably with the 50 % figure laid out as a design requirement.

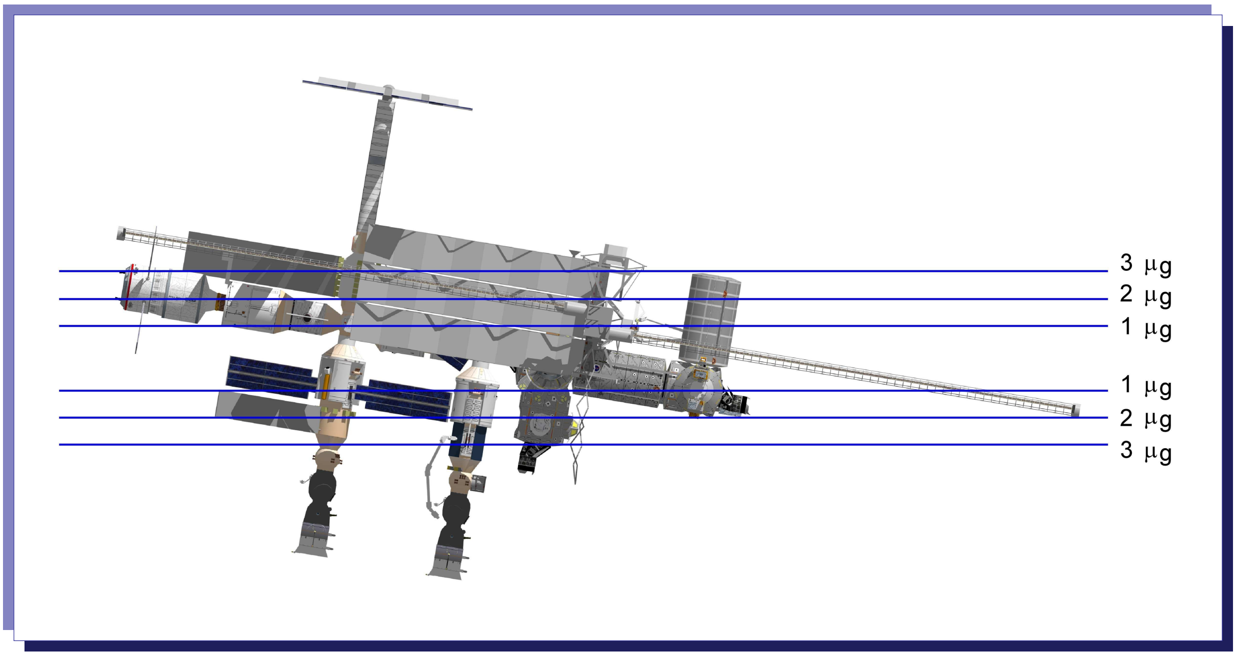

Figure 7-18: ISS "iso-g" contours - XZ plane

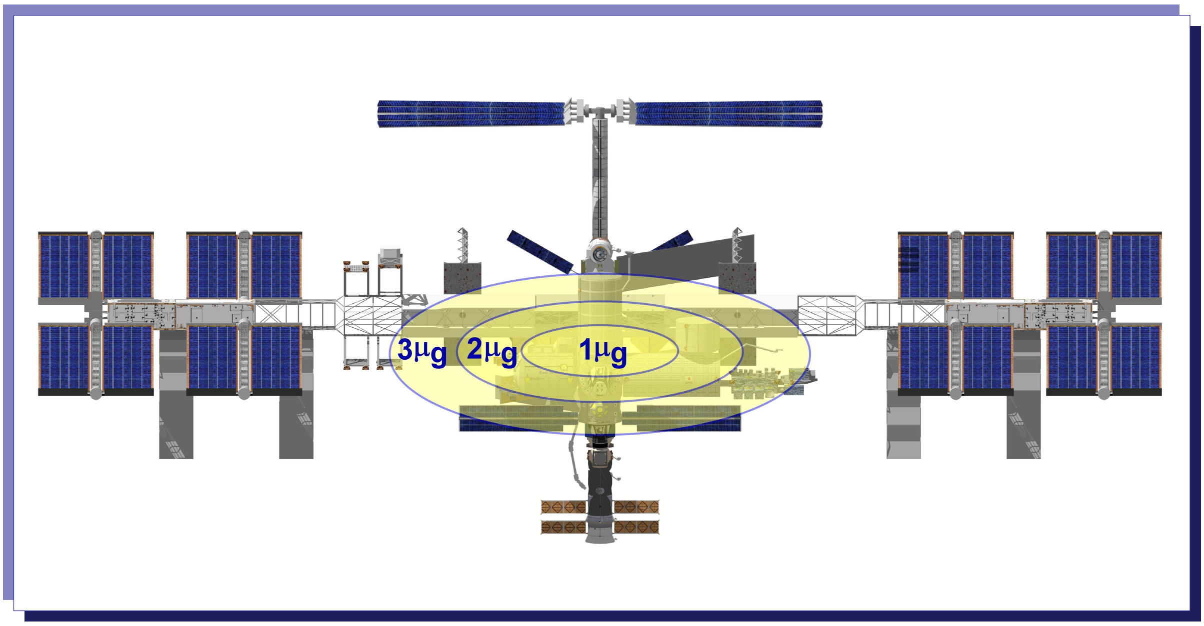

Figure 7-19: ISS "iso-g" contours - YZ plane

7.3.1.2 Vibratory Accelerations

The requirements for the vibratory microgravity environment on ISS are defined in terms of a "spectrum" of allowed root-mean-square (RMS) acceleration as a function of vibrational frequency from 0.01 Hz to 300 Hz. The total vibrational level experienced by the station arises from the combined effects of the payload and vehicle systems. The vibratory microgravity requirements are therefore defined using an RMS acceleration vs. frequency curve for the allowed contribution to the total system vibration by the vehicle alone, with a separate curve for the allowed contribution by the entire complement of payload systems.

In similarity with the quasi-steady state situation, the Microgravity Mode ensures that:

*"the **vibratory acceleration** levels will not be exceeded for 50 % of the International Standard Payload Rack (ISPR) locations within the European Columbus, Destiny and Japanese Kibo laboratories for at least 30 days continuously, on six occasions each year".*

The vibratory acceleration limits (vehicle + payloads) apply at the structural interface between the laboratory module and the ISPRs, and are defined as follows:

- *For frequencies (f) $0.01 \leq f \leq 0.1$ Hz*: the Root Mean Square microgravity disturbance should be less than 1.8 x 10^{-6} g;
- *For $0.1 < f \leq 100$ Hz:* the disturbance must be less than the product of [1.8 x 10^{-5} (g) * frequency (Hz)];
- *For $100 < f \leq 300$ Hz*: the disturbance should not exceed 1.8 x 10^{-3} g.

The above limits are represented in the graph in Figure 7-20.

The fact that a payload complement vibratory requirement exists should be noted by any user considering development of a payload for ISS, because the requirement has implications for placing constraints on how much vibration an individual payload can produce.

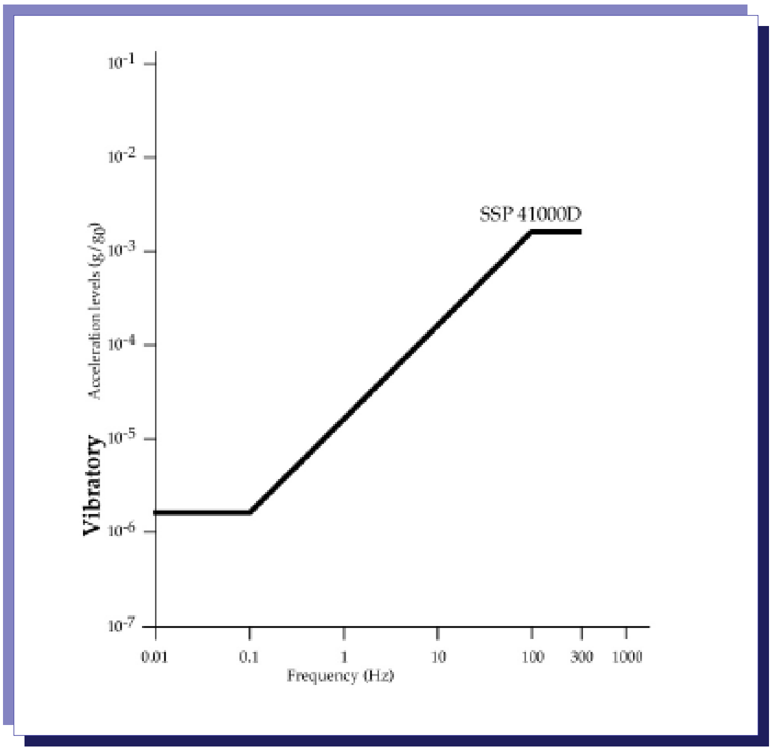

Figure 7-20: Payloads + Vehicle Vibratory Acceleration limits

7.3.1.2.1 Rack Level Isolation Systems

7.3.1.2.1.1 Active Rack Isolation System (ARIS)

In parallel to efforts to further reduce the perturbations by timelining and reduction at the source, NASA has also developed the Active Rack Isolation System (ARIS). The ARIS has been designed to attenuate vibratory

disturbances at selected user payload locations in support of United States On–orbit Segment (USOS) requirements for the microgravity environment, such that the on-rack environment will meet the system vibratory specifications. The ARIS is an active electromechanical damping system attached to an International Standard Payload Rack (ISPR – see 7.6.1.1) that imparts a reactive force between the payload rack and module in response to sensed vibratory accelerations, thereby reducing disturbances to user payloads within the rack.
In addition to attenuation, the ARIS measures vibratory disturbances within the ISPR. The ARIS reports ISPR acceleration measurements to a payload controller for evaluation of ISS microgravity performance, analysis of microgravity effects on payloads, and analysis of disturbance–related anomalies. The ARIS is designed for compatibility with the EXPRESS (EXpedite the PRocessing of Experiments to Space Station) and non–EXPRESS payload racks. Both configurations are based on the ISPR.
More information regarding the ARIS can be found in the document SSP 57006 Rev. A, "Active Rack Isolation System (ARIS) User's Handbook", November 2002.

7.3.1.2.1.2 Passive Rack Isolation System (PaRIS)

The PaRIS is a passive rack vibration isolation system intended for use in the United States Laboratory "Destiny" and Centrifuge Accommodation Module (CAM), with some capability within the Japanese Experiment Module "Kibo" and the Columbus Lab Module. By suspending the integrated payload rack from the ISS module structure using passive dampers, it will attenuate vibratory accelerations above 1 Hz to the user payloads.
The combination of integrated rack and PaRIS provides vibration isolation in both dynamic load path directions (i.e., attenuating vibrations imposed on the rack by the ISS vehicle as well as attenuating vibrations induced on the ISS vehicle by the rack) without consuming any ISS power, thermal, or data/command system resources.
For more information users can consult the following document: SSP 57058 "Passive Rack Isolation System (PaRIS) to International Standard Payload Rack (ISPR) Interface Control Document (ICD)", January 2002.

7.3.1.2.2 Sub-Rack Isolation Systems

7.3.1.2.2.1 Microgravity Isolation Mount (MIM)

This facility was developed by the Canadian Space Agency (CSA) to help isolate experiments from the g-jitter present on all spacecraft. The MIM provides a significant improvement in the acceleration environment for critical experiments that are extremely sensitive to vibrations. The MIM is also capable of imparting vibrations of known frequency and amplitude to an attached experiment.
The MIM consists of a magnetically levitating plate called the Flotor upon which small experiments can be mounted. Sensors inside the MIM detect incoming vibrations and then cancel them out with equal and opposite vibrations to the Flotor. Vibration levels on the Flotor are attenuated by a factor of 10 or more. The MIM can also create known vibrations of up to 100 Hz for experiments mounted to the Flotor. This is most useful for studying the free-surface response of fluids to a known input. Fluids are extremely sensitive to vibrations at or near their natural frequency and typically respond by visible agitation.
An isolation system derived from the MIM technology, known as the Microgravity Vibration Isolation Subsystem (MVIS) has been developed by the CSA for ESA's Fluid Science Laboratory (FSL), in exchange for 5 % of the utilisation rights of the FSL. Its purpose is to isolate an Experiment Container together with the optical bench in which it is accommodated from the support systems of the laboratory. This approach has the advantage of necessitating minimum mass, volume and power for the isolation system. MVIS is the third generation of the MIM technology.

7.3.1.3 Measuring the ISS Microgravity Environment & Accessing Data

As discussed previously, the ISS microgravity acceleration environment consists of two regimes: the quasi-steady environment and the vibratory environment. Currently, the measurement of the microgravity acceleration environment is accomplished by two NASA accelerometer systems, through its Principal Investigator Microgravity Services (PIMS) project at the Glenn Research Center. These 2 systems on-board of the ISS are:

- *The Space Acceleration Measurement System-II (SAMS-II):* The vibratory environment covering the frequency range 0.01 – 400 Hz, is measured by the SAMS-II. Due to the localised nature of these vibrations, this frequency range requires measurement of the environment near the experiment hardware of interest. SAMS-II provides this distributed measurement system through the use of Remote Triaxial Sensor systems (RTS);

- *The Microgravity Acceleration Measurement System (MAMS)*: The MAMS will record the quasi-steady microgravity environment (f < 0.01 Hz), including the influences of aerodynamic drag, vehicle rotation, and venting effects.

The data obtained from the above systems is managed, processed and archived by the PIMS, which has set up an ISS operations website (http://pims.grc.nasa.gov/pims_iss_index.html) that allows researchers and payload developers to:

- *View the current locations of accelerometers* – this allows users to view the current location of accelerometer hardware. Figure 7-21 shows an example for stage 11A (http://pims.grc.nasa.gov/html/CURRENT_LOCATIONS.htm);
- *View real time plots* – users can view real-time plots of data coming from the accelerometers. This information can be viewed directly from a menu on the PIMS ISS operations page, or by clicking on the rack location of interest (see Figure 7-21). The various display formats and data analysis techniques are summarised in Table 7-8;
- *Request archived data* – users can, via an on-line form, request archived data.

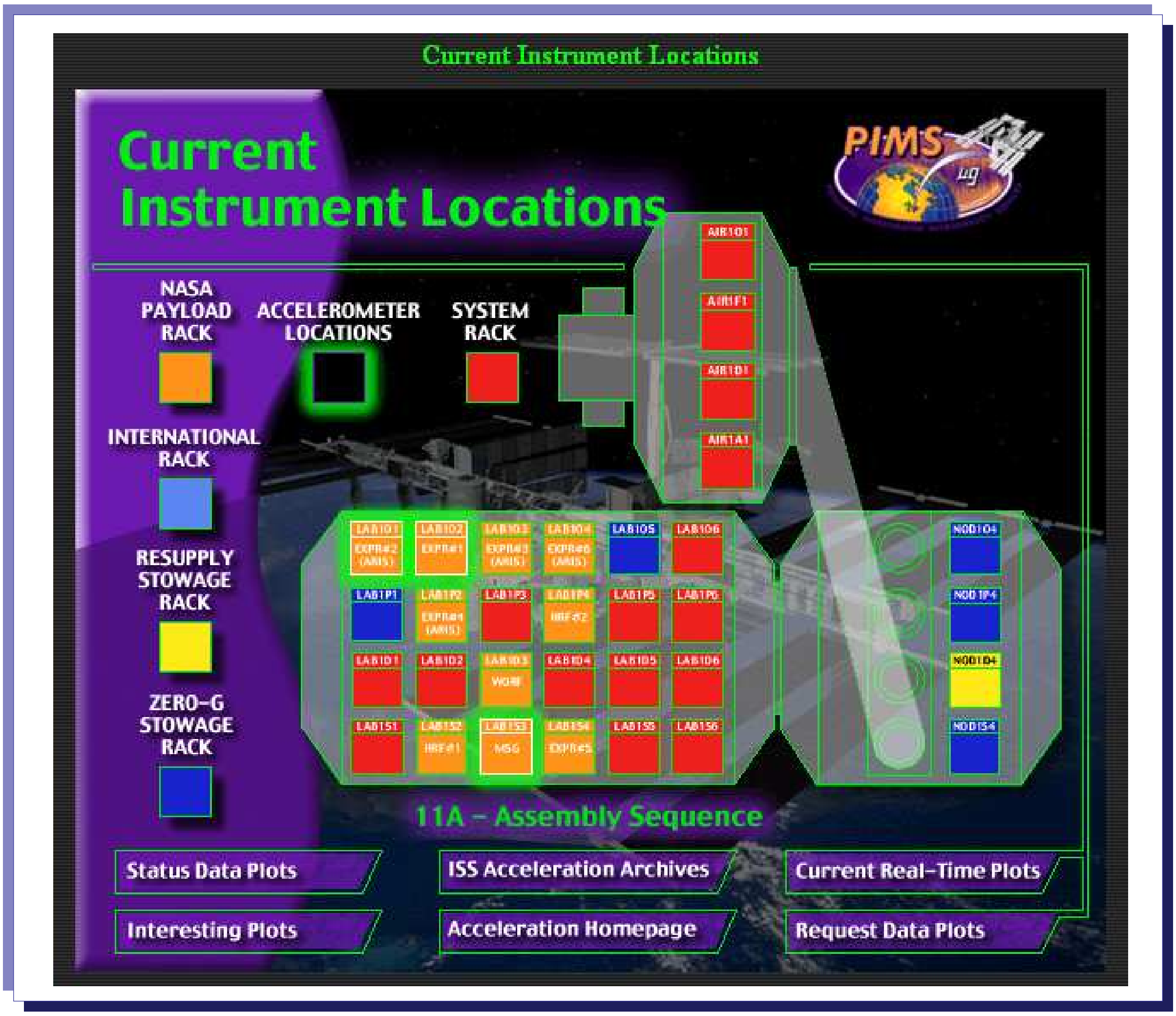

Figure 7-21: Accelerometer locations for stage 11A of the assembly sequence **(Image: NASA)**

Table 7-8: PIMS acceleration data analysis techniques

DISPLAY FORMAT	REGIME (S)	NOTES
Acceleration vs. Time	Quasi-steady, Vibratory	❑ Precise accounting of measured data w.r.t. time ❑ Best temporal resolution
Interval Min/Max Acceleration vs. Time	Quasi-steady, Vibratory	❑ Displays upper and lower bounds of peak-to-peak excursions of measured data ❑ Good display approximation for time histories on output devices with resolution insufficient to display all data in time frame of interest
Interval Average Acceleration vs. Time	Quasi-steady, Vibratory	❑ Provides a measure of net acceleration of duration greater than or equal to interval parameter
Interval Root Mean Square (RMS) Acceleration vs. Time	Vibratory	❑ Provides a measure of peak amplitude
Trimmed Mean Filtered Acceleration vs. Time	Quasi-steady	❑ Removes infrequent, large amplitude outlier data
Quasi-Steady Mapped Acceleration vs. Time	Quasi-steady	❑ Use rigid body assumption & vehicle rates and angles to compute acceleration at any point in the vehicle
Quasi-Steady 3D Histogram (QTH)	Quasi-steady	❑ Summarise acceleration magnitude and direction for a long period of time ❑ Indication of acceleration "centre-of-time" via projections onto three orthogonal planes
Power Spectral Density (PSD) vs. Frequency	Vibratory	❑ Displays distribution of power w.r.t. frequency
Spectrogram (PSD vs. Frequency vs. Time)	Vibratory	❑ Displays power spectral density variations with time ❑ Identify structure & boundaries in time and frequency
Cumulative RMS Acceleration vs. Frequency	Vibratory	❑ Quantifies RMS contribution at and below a given frequency ❑ Quantitatively highlights key spectral contributors
Frequency Band(s) RMS Acceleration vs. Time	Vibratory	❑ Quantify RMS contribution over selected frequency band(s) as a function of time
RMS Acceleration vs. One-Third Frequency Bands	Vibratory	❑ Quantify RMS contribution over proportional frequency bands ❑ Compare measured data to ISS vibratory requirements
Principal Component Spectral Analysis (PCSA)	Vibratory	❑ Summarise magnitude and frequency excursions for key spectral contributors over a long period of time ❑ Results typically have finer frequency resolution and high PSD magnitude resolution relative to a spectrogram at the expense of poor temporal resolution

From the above data, a general characterisation of the ISS microgravity environment can be obtained that affords scientists and hardware developers the pre-flight ability to anticipate the acceleration environment available for experimentation. A handbook of acceleration disturbance sources for the ISS can also be viewed at the PIMS web site, which provides a concise visualisation of the ISS disturbance sources.

The Glenn Research Center is also currently developing a Microgravity Analysis Cycle (MAC) interactive web page, which aims to:

- Provide data that can be utilised to make operational decisions based on the predicted microgravity environment for specific payloads. This would allow payload operational decisions to be made based on planned ISS operations;
- Better predict the microgravity environment for science payloads;
- Merge analytical predictions with on-orbit experience/data.

Users will be able to view predicted data based on different selected ISS configurations and modes.
Figure 7-22 shows the current MAC demo page (http://microgravity.grc.nasa.gov/mac_website/tutorial.html) for the ISS UF5 configuration, in which the Combustion Integrated Rack (CIR) and Fluids Integrated Rack (FIR) are active.

Figure 7-22: NASA MAC demo page for ISS UF5 configuration (Image: NASA)

7.3.2 Internal Environment

7.3.2.1 Cabin Atmosphere

The characteristics of the ISS cabin atmosphere are summarised in the following table (Table 7-9).

Table 7-9: Characteristics of internal cabin atmosphere

PARAMETER	OPERATIONAL VALUE
Normal Total Cabin Pressure Range	97.9 – 102.7 kPa
Contingency Total Cabin Pressure Range	95.8 – 97.9 kPa
Normal Composition of Atmosphere	21 % Oxygen; 78 % Nitrogen
Maximum Allowable % Oxygen in Atmosphere	24.1 %
Maximum N_2 Partial Pressure	80 kPa
O_2 Partial Pressure Range	19.5 – 23.1 kPa
CO_2 Levels	The medical operations requirement, and the ISS specification, for CO_2 level is a 24-hour average of 0.7 % or less, although a 24-hour average exposure as high as 1 % is allowable during crew exchanges. The ISS programme has agreed to maintain the cabin CO_2 level to 0.37 % (with the goal of reaching 0.3 %) for two 90-day periods each year. Modelling has shown that with two U.S.- and one Russian-segment CO_2 scrubbers a level closer to 0.2 % can be expected.
Average CO_2 Partial Pressure during normal operations	0.71 kPa
Air Temperature	17 – 28 °C
Dew Point	4.4 – 15.6 °C
Relative humidity	25 – 75 %
Ventilation velocity	0.076 – 0.203 m/s
Airborne microbial growth	≤ 1000 Colony Forming Units (CFU)/m^3
Atmosphere Particulate level	Class 100 000 (i.e. less than 100 000 particles/ft^3, for particles less than 0.5 microns in size)

7.3.2.2 Illumination

The internal lighting of the ISS consists of:

- *General illumination*: Produced by a number of Module Lighting Units distributed throughout the station, which may be controlled either remotely or locally (i.e., a manually-operated switch on each unit). The general illumination of the Space Station in the aisle will be a minimum of 108 lux (10–foot candles) of white light. This illumination will be sufficient for ordinary payload operations performed in the aisle (e.g., examining dials or panels, reading procedures, transcription, tabulation, etc.);

- *Portable lighting*: A number of portable lighting units are available for temporary crew use (e.g., to increase the local illumination in particularly inaccessible areas);
- *Emergency lighting*: An emergency lighting system is common throughout all pressurised modules of the ISS.

Additional illumination for payload tasks must be taken into account following the set of requirements listed in Table 7-10.

Table 7-10: Payload required illumination levels

TYPE OF TASK	REQUIRED LUX (FOOT-CANDLES)*
Medium payload operations (not performed in the aisle) (e.g., payload change-out and maintenance)	325 (30)
Fine payload operations (e.g., instrument repair)	1075 (100)
Medium glovebox operations (e.g., general operations, experiment set-up)	975 (90)
Fine glovebox operations (e.g., detailed operations, protein crystal growth, surgery/dissection, spot illumination)	1450 (135)

* As measured at the task site

7.3.2.3 Interior Colour

A common interior colour scheme is used throughout all pressurised modules (excluding those in the Russian segment) to ensure a consistent environment for the crew. Depending on the type of hardware, the principal surface colours and finishes adopted are:

Table 7-11: Interior hardware colours and finishes

COLOURS	FINISHES
White	Lustreless
Black	Semi gloss
Off-white	Gloss
Nickel plate	
Medium grey	
Tan	

Label colours will include red (emergency use items only), yellow (Caution & Warning items only), green, blue and orange. No more than 9 colours, including black and white, should be used in a coding system.

7.3.2.4 Internal Contamination

The control of contamination within the pressurised modules is crucial to maintain an efficient working environment for the crew, equipment and user payloads. Contamination can affect the health of the crew, reduce the operational lifetime of equipment, and increase required maintenance activities. Typical sources of contamination are the crew, equipment, materials, experiment processes – all of which combine to produce trace gases, carbon dioxide, particulates and microbial contaminants. The microbial growth and particulate level within the living and working environment of the ISS will be monitored and controlled according to the limits specified in Table 7-9.

7.3.2.5 Noise

The ISS interior will be subject to various noise levels caused by pumps, fans and other operating systems and subsystems. Stringent limits have been set regarding noise in the interior of the ISS. The maximum allowable continuous broadband sound pressure levels (SPLs) produced by the summation of all the individual SPLs from all operating systems and subsystems considered at a given time shall not exceed the values shown in Figure 7-23 for work periods and sleep compartments, respectively. Noise of constant sound levels of 85.0 dB and greater are considered hazardous regardless of the duration of exposure. Hearing protection devices are provided for crew to use during exposure to noise levels of 85.0 dB or greater.

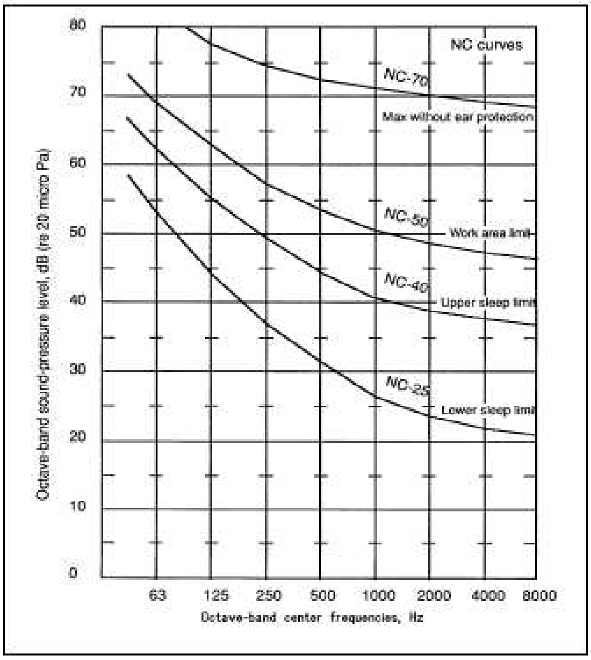

Figure 7-23: ISS Interior Noise Criteria Curves

7.3.2.6 Touch Temperatures

In order to avoid endangering the crew or damaging sensitive equipment, exposed surfaces within the habitable areas of the ISS are subject to requirements regarding minimum and maximum temperatures:

- Surfaces that are subject to *continuous* contact with a crewmember’s bare skin and whose temperature exceeds 45 °C, are required to be provided with guards or insulation to prevent crewmember contact;
- Surfaces which are subject to *incidental* or *momentary* contact (30 seconds or less), with a crewmember’s bare skin and whose temperatures are between 45 and 50 °C, are required to have warning labels that will alert crewmembers of the temperature levels;

- Surfaces that are subject to *incidental* or *momentary* contact (30 seconds or less), with a crewmember's bare skin and whose temperatures exceed 50 °C, are required to have guards or insulation;
- Surfaces which are subject to *continuous* or *incidental* contact with a crewmember's bare skin and whose temperatures are below 4 °C, must provide crew with protective equipment and warning labels must be provided at the surface site.

7.3.3 External Environment

Users should be aware of the ISS external environment for two reasons:
1. It may affect the design and operations of external payloads; and
2. It may be the object of investigation for external experiments.

The ISS external environment consists of:
- *The Induced External Environment* – this is the space environment that exists as a consequence of the presence of the ISS and its related operations;
- *The Natural External Environment* – this is the space environment that exists even if the ISS were not in orbit. This includes neutral atmosphere, plasma, charged particle radiation, electromagnetic radiation, meteoroids, space debris, magnetic field, and gravitational field.

7.3.3.1 Induced External Environment

7.3.3.1.1 Quiescent Periods

The ISS Programme specifications have imposed the following regarding the induced external environment during quiescent periods, i.e. Standard and Microgravity modes.

7.3.3.1.1.1 Molecular Column Density

The contribution to the molecular column density created by the presence of the ISS contamination sources along any unobstructed line of sight will not exceed $1x10^{14}$ molecules/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.

7.3.3.1.1.2 Particulate Background

The release of particulates from the ISS is limited to one particle, 100 microns or larger, per orbit per $1x10^{-5}$ steradian field of view as seen by a 1 metre 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 excludes particulates in the natural environment and their effect on ISS hardware (e.g., their impact on ISS surfaces).
Attached payloads must limit any active venting release of particulates to less than 100 microns in size.

7.3.3.1.1.3 Molecular Deposition

The flux of molecules emanating from the ISS is limited such that the 300K mass deposition rate on sampling surfaces is limited to $1x10^{-14}$g/cm^2/sec (daily average). The sampling surfaces are typically located at the solar arrays, thermal radiators, observation windows, truss attached payloads, and the JEM Exposed Facility.
Contamination requirements directed specifically at effects on attached payloads and the ISS vehicle by other attached payloads specify that an attached payload shall not deposit material at a rate greater than $1x10^{-14}$ g/cm^2/sec on other attached payloads and $1x10^{-15}$ g/cm^2/sec on ISS vehicle elements.

7.3.3.1.2 Non-Quiescent Periods

7.3.3.1.2.1 Molecular Deposition

Total deposition at 300K on the sampling surfaces will not exceed $1x10^{-6}g/cm^2/yr$.

7.3.3.2 Natural External Environment

7.3.3.2.1 Pressure

A natural high-quality vacuum exists outside of the ISS, providing numerous experimental possibilities for a number of research fields. The ISS external on-orbit minimum pressure environment is $3.6x10^{-11}$ kPa.

7.3.3.2.2 Thermal Environment

ISS external elements and payloads will be exposed to:

- Thermal solar constants, albedo, and Earth Outgoing Long-wave Radiation (OLR) environments as defined in Table 7-12;
- A space sink temperature of 3 K;
- The induced thruster plume environment and induced thermal environments from vehicle(s) docking and docked with the ISS;
- Thermal interactions with other on-orbit segments.

Table 7-12: Hot and Cold Natural Thermal Environments

CASE	SOLAR CONSTANT (W/M^2)	EARTH ALBEDO	EARTH OLR (W/M^2)
Cold	1321	0.2	206
Hot	1423	0.4	286

The thermal environment results in maximum and minimum external surface temperatures of ~ +120 °C and –120 °C, respectively.

7.3.3.2.3 Humidity

ISS external elements and payloads will be exposed to an external environment of 0 % relative humidity during on–orbit operations.

7.3.3.2.4 Atomic Oxygen

At Low Earth Orbit altitude, the ISS will encounter the Earth's low-density residual atmosphere, which at this altitude is primarily composed of oxygen in an atomic state (molecular bonds being broken by the solar Ultra Violet rays). Although the particle density is low, the flux (i.e., combined product of density, relative velocity and surface area) is high. The incidence of this neutral oxygen flux can result in significant erosion of certain surfaces depending on their nature. External surfaces may be exposed to fluxes of up to $4.4x10^{19}$ atoms/cm^2/day.

7.3.3.2.5 Electromagnetic Radiation

Important sources of electromagnetic noise exist over the entire frequency spectrum from direct current (dc) to X–ray at the ISS orbit altitudes. These noise sources broadly separate into four categories:

- Galactic;
- Solar;
- Near–Earth natural plasma;
- Man–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. Other effects of electromagnetic radiation to be considered include radio noise and the effects of field strengths from the natural sources at the ISS. Field strengths produced from quasi–static field structures in the plasma have typical values around 25 mV/m, but can be larger. These values generally occur at latitudes greater than 50°.

7.3.3.2.6 Plasma

Plasma is a quasi–neutral gas consisting of neutral and charged particles that exhibit collective behaviour. From approximately 80 km altitude to about 1000 km altitude, a plasma environment about the Earth is designated as the ionosphere. A plasma environment extends further from the Earth into a region designated as the magnetosphere and still further into the solar wind. A primary interaction of plasma with a spacecraft is the accumulation of an electrical charge by the spacecraft until electrical equilibrium is reached between the spacecraft and the local plasma environment. Because electrons have greater thermal velocities than do ions at similar temperatures, a spacecraft tends to reach equilibrium potential at a few volts negative with respect to the plasma at ISS altitudes. However, active components and their associated structure (such as solar arrays) may accumulate sufficient negative potential to produce arcing to other elements of the spacecraft.

7.3.3.2.7 Ionising Radiation

The ionising radiation environment results from the natural radiation in Low Earth Orbit (LEO) due to trapped electrons, trapped protons, and solar, anomalous, and galactic cosmic rays. The contribution of other LEO environmental constituents such as neutrons and x–rays are negligible and are not considered by the ISS Programme. The ionising radiation environment interacts with devices and materials to produce radiation dose effects and single event effects (SEE).

7.3.3.2.7.1 Radiation Dose Environment

Dose effects are ionising radiation–induced changes in devices and materials resulting from exposure to the trapped proton and electron environment during the orbital lifetime. Dose effects are usually manifested as degradation of electronic device and material performance and are cumulative with exposure to the ionising radiation environment.

7.3.3.2.7.2 Single Event Radiation Dose Environment

SEE are ionising radiation–induced effects produced when single, ionised particles interact with electronic devices to change the electrical states or characteristics of the devices. These effects include single event upset, transients, latchup, burnout, and gate rupture. The ionising radiation environment for SEE is divided into a nominal environment and an extreme environment

- *Nominal SEE* – The nominal SEE design environment is the environment, which the Space Station will typically experience, and consists of trapped protons and cosmic rays. The SEE trapped proton environment represents daily average proton fluxes. The trapped proton flux is a maximum during passes through the South Atlantic Anomaly (SAA), where fluxes are more severe than the daily average environment. The ISS will pass through the SAA on 50 % of its orbits and will spend 5–10 minutes of these orbits in the SAA. Cosmic ray particles originate from outside the solar system and although the fluxes are low, they include heavy energetic ions for which it is difficult to shield against. Cosmic rays are known to result in Single Event Upset and “latchup” in electronic components and an uncertain radiobiological effect on biological organisms;

- *Extreme SEE* – The extreme SEE environment consists of protons and heavy ions emitted during the most intense solar flares in a solar cycle. The extreme environment occurs once over an 11 year solar cycle period, and lasts for approximately 24 hours. Three different aspects of this environment are defined:
  - peak proton flux,
  - peak heavy ion flux,
  - orbit–averaged heavy ion fluency for the worst-case flare event.

7.3.3.2.8 Plume Impingement

External payloads and exposed secondary structures (e.g. Multi-Layer Insulation – MLI – blankets) will be exposed to the maximum effective normal pressure of 0.16 kPa and shear plume impingement pressure of 0.038 kPa.

7.3.3.2.9 Meteoroids and Orbital Debris

In orbit, the ISS will encounter meteoroids and orbital debris. Either type of object can pose a serious threat of damage or decompression to the ISS upon impact. Meteoroids are natural in origin, and debris is the result of man–made material remaining in Earth orbit.

7.4 Utilisation Fields Applicable to the ISS

The following sections provide users with a guideline to the various utilisation fields that apply to the ISS.

7.4.1 Life and Physical Sciences

In 2000, ESA prepared a comprehensive Research Plan defining the scientific priorities in the life and physical sciences for a 5-year period, with a horizon of 10 years. The compilation of this Research Plan was initiated by a bottom-up analysis of all the research proposals received at that time by ESA. As a next step, ESA asked the European Science Foundation (ESF) to assess the research priorities in a dedicated user consultation meeting, which took place in Bischenberg, France in November 2000. At this meeting and in the subsequent ESF recommendations, the concept of Research Cornerstones was defined.

The Research Cornerstones describe areas of research where concerted efforts at the European level have already produced, or are promising to lead to, eminence if not a leading position on a global level. They provide therefore, an excellent basis for ensuring that new proposals will address issues that have been recognised as constituting a particular strength in Europe.

A particular advantage of this will be that the research objectives of the ESA programme will be better harmonised with those of other research funding agencies or entities in Europe, leading to a more efficient and complete coverage of the research efforts involved. It will also further promote the teaming of research groups at European level, thus combining strengths and increasing European knowledge and competitiveness. Finally, it will allow ESA to streamline and optimise the available and future research infrastructure to sustain those objectives.

Already at Bischenberg it was identified that the Research Plan is by definition a living document. Research priorities may shift, new promising research fields may emerge, or new results taken into account. For that reason, it was envisaged that the process of user consultation should be repeated at regular intervals.
Following this, a second user consultation on Life and Physical Sciences in Space was organised again by ESF at Obernai, France in May 2004. On this occasion a larger number of scientists participated and more time was available to discuss the individual disciplines during two workshops. After this consultation ESF recommended updated Research Cornerstones, which ESA and its advisory committees are still analysing. Once a full investigation has been completed, ESA will produce an updated Research Plan, in which also the new Research Cornerstones will be defined.

The following section presents a summary of the original 14 Research Cornerstones, which were the outcome of the November 2000 meeting.
It should be stressed, however, that the Research Cornerstones are **not** used as a selection criterion in the evaluation of research proposals. In other words, the final selection of projects will be based on scientific quality, regardless of the research topic addressed. This, in the view of ESA, is the only way to ensure that promising new research will be identified and pursued. The Research Cornerstones should therefore be seen as a guideline to potential users who wish to carry out research in the life and physical sciences on the ISS.

7.4.1.1 Life and Physical Sciences Research Cornerstones (2002-2006)

The 14 Life and Physical Sciences Research Cornerstones that have been identified for the period 2002-2006 are defined in the following tables:

Table 7-13: Fundamental Physics Research Cornerstones (2002-2006)

RESEARCH CORNERSTONES	DESCRIPTION	SCIENCE TARGETS	POTENTIAL APPLICATIONS
Complex Plasmas and Dust Particle Physics	Understand the three dimensional behaviour of particles in complex plasmas and aggregation processes that require weightlessness.	Enhance theoretical description of complex plasmas, including self-ordering and phase transition phenomena; Improve modelling of the interaction of protoplanetesimals, their optical properties and of the behaviour of pollutants in the atmosphere.	Develop novel plasma coating techniques; Nucleation and growth of novel substances for solar cells and plasma screens; Improved modelling of Earth climate and environment.
Cold Atom and Quantum Fluids	Study properties and applications of cold atoms, including Bose-Einstein condensates.	Develop and operate a cold atom clock in space; Check limits of validity of theories of relativity and quantum electrodynamics.	Improved accuracy of absolute time measurements; Increased accuracy for navigation and geodesy systems.

Table 7-14: Fluid and Combustion Physics Research Cornerstones (2002-2006)

RESEARCH CORNERSTONES	DESCRIPTION	SCIENCE TARGETS	POTENTIAL APPLICATIONS
Structure and Dynamics of Fluids, Multi-phase Systems	Study of multiphase systems, their phase transitions and related dynamics, critical and supercritical fluids, granular materials. Geophysical fluid flows.	Quantify heat transfer, mass exchange and chemical processes in multiphase systems and supercritical fluids; Measure diffusive processes in mixtures; Study the stability of foams and emulsions; Describe dynamic coupling in granular materials under vibration.	Develop reactors for supercritical oxidation of industrial contaminants; Develop high-efficiency heat exchangers; Improve reactor design in industrial plants; Design improved oil recovery techniques.
Combustion	Study combustion phenomena that are dominated on the ground by buoyancy convection.	Quantify fuel droplet and spray evaporation, autoignition and combustion processes; Detail the process of soot formation in flames and the conditions for flammability of solid fuels.	Improve efficiency of electrical power plants; Reduce emissions of engines; Improved flammability test procedures.

Table 7-15: Materials Sciences Research Cornerstones (2002-2006)

RESEARCH CORNERSTONES	DESCRIPTION	SCIENCE TARGETS	POTENTIAL APPLICATIONS
Thermophysical Properties	Utilise the extended possibilities of containerless processing in space to measure critical properties of highly reactive liquid metals.	Measurements, and with higher accuracy, of the properties of stable and metastable (undercooled) liquid metals.	Increase the reliability of numerical simulation and control of casting facilities in metallurgical industry.
New Materials, Products and Processes	Understand the physics of solidification and crystal growth of metals, organic and inorganic materials and biological macromolecules.	Quantify the influence of the growth conditions on the homogeneity and the defects in crystals, including protein crystals; Enhance numerical models of the microstructure formation in metals and alloys.	Improve and validate models for predicting grain structures in industrial castings; Develop processes towards new metallurgical products; Improve efficiency of production of industrial crystals.

Table 7-16: Biology Research Cornerstones (2002-2006)

RESEARCH CORNERSTONES	DESCRIPTION	SCIENCE TARGETS	POTENTIAL APPLICATIONS
Biotechnology	Investigate in weightlessness transmembrane and intracellular flux of mediators that control cell differentiation.	Improve knowledge of the relation between material flux at the cell-medium interface and gene expression; Improve the properties of recombinant products; Quantify interfacial transfer and especially interfacial turbulence and control of the membrane porosity.	Develop artificial functional tissues and targets for drugs screening; Develop a bioreactor for tissue engineering e.g. cartilage for implantation; Develop novel microencapsulated drugs and cells.
Plant Physiology	Study mechanosensory elements involved in gravitropism.	Identify mechanosensory and signalling elements determining gravitropism; Identify gene interactions important in the gravistimulus response chain.	Improvement of plant growth and mechanical properties of plants; Develop techniques for plant survival and growth in space.
Cell and Developmental Biology	Study the effect of gravity on cell and whole-body development and reproduction.	Study altered gene expression in an altered gravitational environment e.g. micro-arrays; Improve understanding of the impact of the cytoskeleton architecture on signal transduction e.g. functional genomics; Understand the effect of gravity on the development of the vestibular and sensori-motor systems in vertebrates.	Design pharmacological relevant substances for animal and human applications relevant to human development; Develop techniques and pharmacological substances for cell and tissue regeneration e.g. neuronal repair.

Table 7-17: Physiology Research Cornerstones (2002-2006)

RESEARCH CORNERSTONES	DESCRIPTION	SCIENCE TARGETS	POTENTIAL APPLICATIONS
Integrated Physiology	Use the extreme conditions of space to study the impact of gravity and stress on vegetative regulations.	Study cardio-vascular control, e.g. blood pressure regulation, under microgravity; Investigate the influence of sensori-motor and proprioceptive inputs on cardio-vascular control; Study the dependence of energy uptake on exercise and load.	Develop miniaturised, automated devices for medical diagnostics; Improve techniques and devices for medical applications e.g. sports medicine; Improve protocols for post-traumatic rehabilitation; Improve treatment of stress related disease.
Muscle and Bone Physiology	Use absence of or reduced gravity to study the effects of load on the human musculo-skeleton.	Study effects of changes in load on muscle atrophy and plasticity; Understand and quantify bone mass turnover as a function of e.g. local blood perfusion and mechanical stress.	Develop devices and protocols and protocols for medicine; Improve means for diagnostics, prevention and treatment of osteoporosis; Improve rehabilitation after long-term incapacitation, particularly involving bed rest.
Neuroscience	Understand the effects of gravity on control of posture, locomotion and cognition.	Investigate the interaction of the vestibular system with other inputs relevant to locomotion and posture (e.g. vision, proprioception); Understand cognitive strategies in the absence of gravity.	Develop improved approaches for the treatment of neurological diseases involving impaired cognition, control of posture and locomotion (e.g. cerebellar impairment).

Table 7-18: Astro/Exobiology, Planetary Exploration Research Cornerstones (2002-2006)

RESEARCH CORNERSTONES	DESCRIPTION	SCIENCE TARGETS	POTENTIAL APPLICATIONS
Origin, Evolution and Distribution of Life	Study the survivability of organisms under extreme conditions on Earth (extremophiles) and in space.	Investigate the contribution of space conditions including radiation to the formation of prebiotic molecules; Identify the conditions for survivability of micro-organisms from and in space including planetary surfaces; Identify markers and tools to search for extinct and extant life.	Identify novel enzymes and bacteria from extreme physical and chemical environments with industrial application e.g. biocatalysis.
Preparation of Human Planetary Exploration	Study novel aspect of human planetary expeditions.	Quantify radiation risk for human beings and understand the specific biological action of space radiation; Study effects of isolation in high-stress environments; Quantify needs for consumables during missions; Perform simulation tests on in-situ resource utilisation potential.	Develop advanced radiation sensors and countermeasure devices; Develop technology for telemedicine/telesurgery in remote areas; Develop protocols for handling stress effects; Develop methods for in-situ resource utilisation; Develop life-support systems for use in space and other isolated environments; Develop the technologies for identification and utilisation of in-situ resources.

For more details regarding Life and Physical Sciences research on ISS, please contact:

Secretariat HME-GA
Directorate of Human Spaceflight, Microgravity and Exploration Programmes
European Space Agency
Keplerlaan 1
2201 AZ Noordwijk
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7.4.2 Space Science

The International Space Station is a unique platform with multiple exterior attachment points, which provide scientists with complete exposure to, and observation in almost all directions of, outer space. Some specific fields of research include:

7.4.2.1 Solar Physics

Solar physics research can be executed on board the ISS, and is of great importance in the study of the following:

- Origins of the solar system;
- Solar flare mechanisms;
- Solar wind dynamics;
- Sunspot cycle predictions;
- Coronal heating;
- Atmospheric modelling;
- Atmospheric chemistry;
- Climatology.

7.4.2.2 Astrophysics

Some examples of Astrophysics research on ISS are:

- Sky polarisation measurement;
- X-ray astronomy;
- Cosmic ray astronomy;
- Gamma ray astronomy;
- Space plasma physics.

7.4.3 Earth Observation

The orbital characteristics of the ISS allow it to cover more than three-quarters of the surface of the Earth, providing scientists with a window on the world to study various factors that influence our everyday lives. These fields of study include:

- Atmospheric studies;
- Climatology;
- Deforestation;
- Desertification;
- Mineralogy;
- Agriculture;
- Oceanography;
- Hydrology;
- Ice monitoring;
- Volcanology;
- Geology;
- Archaeology;
- Urban planning.

7.4.4 Technology

Space is a unique environment for testing new products and technologies. The weightless environment, vacuum, exposure to harsh radiations, large fluctuations in temperatures, and strict mass and safety constraints all encourage industries to improve their technology, with direct benefits on the technology applications on Earth. Some examples of technology that could gain from testing on the ISS are:

- On-orbit commercial communication systems for telephones, television and the Internet;
- Efficient use of energy;
- Improvement of air and water quality in closed environments;
- Robotics;
- Structures for future manned missions.

7.4.5 Commercialisation

The main ISS goal is to provide unique research opportunities in a number of fields for the progress of human knowledge and the development of technologies and methodologies that could improve the quality of life on Earth. The access to these opportunities and activities has traditionally been limited to “institutional users” mainly performing basic research. However, since 2001, 30 % of all European resources on-board the ISS have been allocated by ESA for “commercial utilisation” and made exclusively available to commercial users, who can purchase from ESA the use of facilities, resources and services on ground or onboard the ISS. In addition, commercial users may acquire marketing rights.
Companies can therefore gain or increase their competitive advantage by using the ISS as a platform for applied Research and Development (R&D) or for other activities in the areas of Technology Demonstration, Sponsorship, Entertainment and Edutainment.
Different from the institutional access, commercial projects are not peer reviewed but are subject to a specific evaluation process, which ensures customers quick access based on the first-come-first-served principle. Furthermore, through the commercial access customers have the opportunity to obtain the exclusive ownership of the Intellectual Property Rights resulting from the ISS project. The exploitation of the marketing rights related to the project is also a unique opportunity available through the commercial route.

7.4.5.1 The Commercial Promotion Office

ESA offers access to the ISS on a commercial basis through its Commercial Promotion Office. This is a specialised team that has been specifically set up to co-ordinate ESA’s activities in the area of commercialisation. As such, it has the key role of being the ESA interface with the Commercial Agents and the Co-operation Agreement Industrial Partners, as well as being the point of reference for the customers at ESA.

7.4.5.2 The Commercial Agents Network

This is a network of ESA selected Commercial Agents responsible for marketing and selling the use of ESA’s facilities of the ISS and the related resources and services provided by ESA and its Co-operation Agreement Industrial Partners within the assigned market sector. The first Commercial Agent (which includes one company as prime agent and three others as sub-agents) was appointed for the Biotechnology, Health, Food and Nutrition market.
The role of the Commercial Agents is to carry out business-to-business marketing; identify and acquire customers; define the required end-to-end services for the customer’s project; help customers drafting commercial proposals; negotiating contractual arrangements and ultimately implementing projects. In market sectors where commercial agents have not yet been selected by ESA, the Commercial Promotion Office remains the only point of contact for potential commercial users.

7.4.5.3 The Co-Operation Agreement

The “Co-operation Agreement” is an agreement signed between ESA and a number of private companies (grouped under the name of “Co-operation Agreement Industrial Partners”) to promote the commercial utilisation of the ISS through two types of activities:

- General Promotion activities, which are devoted to heightening the image and public awareness of the ISS and of its inherent benefits.
- Promotion Support activities, which are devoted to providing contributions, mainly in terms of deferred payment, price reduction or in-kind services, to specific projects that meet the criteria for acceptance. ESA and the Co-operation Agreement Industrial Partners have committed up to a certain amount to

provide different forms of Promotion Support, such as different facilities, resources and services, at promotional rates to help the early customers.

At present, the Co-operation Agreement Industrial Partners are European companies mainly operating in the space sector; however, non-space companies have recently joined and it is the intention of all Parties to continue extending the Co-operation Agreement to incorporate companies offering additional services outside the space sector.

For further information regarding the Commercial Promotion Office, please contact:

Commercial Promotion Office (HME-EC)
Directorate of Human Spaceflight, Microgravity and Exploration Programmes
European Space Agency
Keplerlaan 1
2201 AZ Noordwijk
The Netherlands
Tel: +31 71 565 5068
Fax: +31 71 565 5232
E-mail: issbusiness@esa.int

7.4.6 Education

Education is a fundamental part of the mandate of ESA. The ISS Education Programme makes use of human spaceflight, in particular the ISS, as a means to capture the attention and the interest of students, to attract them to study scientific and technical disciplines, and to appreciate and understand the benefits, challenges, and importance of Space for Europe. The ISS Education Programme focuses on providing a range of educational activities and material for primary, secondary, and university students, and their teachers. This includes the development and dissemination of teaching material, as well as supporting student experiments to be executed on board the ISS and other spacecraft.
The development of products is carried out after consulting with teachers from all ESA Member States, involving them through workshops and conferences.
Development events are usually organised at ESTEC, The Netherlands, and participating teachers are introduced to the ISS through a managed programme of information briefings, videos, and guided tours of relevant facilities and models. These events are used to investigate what the needs of the teachers are, to identify common elements in the European curricula, and to help develop a concept that meets both the aims of Human Spaceflight education, and those of the teachers in the classroom.

For more information regarding Education activities please contact:

ISS Education Team (HME-GS)
Directorate of Human Spaceflight, Microgravity and Exploration Programmes
European Space Agency
Keplerlaan 1
2201 AZ Noordwijk
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E-mail: isseducationteam@esa.int

7.5 ISS Resources and Partner Utilisation Rights

The National Aeronautics and Space Administration (NASA) provides the overall leadership of the ISS programme development and implementation, and together with Russia provides the major building blocks of the ISS. The European Space Agency (ESA), together with the Japan Aerospace Exploration Agency (JAXA) and the Canadian Space Agency (CSA) are providing additional elements, which significantly enhance the Space Station. The overall ISS utilisation rights are divided among the Partners, according to the elements and infrastructure they provide (e.g. Columbus Laboratory for ESA). The main principle is that each International Partner may utilise equipment and facilities in or on each other Partner's elements in accordance with their respective “utilisation rights”. Those rights are defined in the Intergovernmental Agreement (Article 9) and the different Memoranda of Understanding signed by all of the Partners.
European users may very well perform experiments in the American, Japanese and Russian laboratories, in accordance with the European Space Agency's utilisation rights. Those rights comprise three different types of allocations:

- The “user accommodations”, which are the Space Station elements available for utilisation and potential commercialisation (laboratories, external platforms);
- The “utilisation resources”, which are derived from the ISS global infrastructure (e.g. power and communications), once resources for ISS operations are covered (i.e.“housekeeping resources”);
- The utilisation of crew time.

The baseline utilisation allocations at assembly complete in terms of percentages of the on-orbit facilities, resources and services for the five International Partners are summarised in Table 7-19. Each Partner has the right to barter or sell any portion of its respective allocations and resources. An example of this is the Memorandum of Understanding between NASA and the Italian Space Agency (ASI), in which ASI provides NASA with 3 Multi Purpose Logistics Modules (MPLM) in exchange for 0.85 % of all NASA allocations and resources. The terms and conditions of any barter or sale are determined on a case-by-case basis by the parties to the transaction. Each Partner may use and select users for its allocations for any purpose consistent with the object of the IGA. Note that as Russia retains 100 % of its accommodation, resources and services, it is not shown in the table. The translation of these percentages into more detailed global ISS utilisation resources, accommodations and supporting services that are available to users upon completion of the ISS assembly phase (excluding those of the Russian segment), are shown in Table 7-20.

Table 7-19: Baseline International Partner utilisation allocations (excluding Russia)

UTILISATION RESOURCES, ACCOMMODATIONS & SUPPORTING SERVICES	ESA (%)	NASA (%)	CSA (%)	JAXA (%)
Columbus Laboratory (rack locations; external attachment points)	51	46.7	2.3	-
Destiny Laboratory (rack locations)	-	97.7	2.3	-
Centrifuge Accommodation Module (rack locations)	-	97.7	2.3	-
Truss Payload Accommodations	-	97.7	2.3	-
Japanese Experiment Module (rack locations; external attachment points)	-	46.7	2.3	51
Resources (power/crew time)	8.3	76.6	2.3	12.8
Rights to purchase supporting services (upload/download; communications services)	8.3	76.6	2.3	12.8

Table 7-20: Global ISS utilisation capabilities

ACCOMMODATIONS/RESOURCES/SUPPORTING SERVICES	TOTAL ISS
Pressurised accommodation in the research modules: ❑ Columbus Laboratory ❑ Destiny Laboratory ❑ Kibo Laboratory ❑ Centrifuge Accommodation Module ❑ TBD	35 International Standard Payload Racks: ❑ 10 ❑ 11 ❑ 8 ❑ 4 ❑ 2
External (unpressurised) accommodation: ❑ Columbus External Payload Facility ❑ ISS S3 Truss segment sites ❑ Kibo Experiment Module-Exposed Facility	❑ 4, each taking 1 Columbus External Payload Adapter – CEPA ❑ 4. Currently 1 site is planned to be occupied by a single payload (AMS), and 3 by Express Pallets, each of which can have up to 6 Express Pallet Adapters, i.e. 18 Express Pallet Adapters in total ❑ 10 (5 allocated to JAXA payloads, and 5 to NASA payloads)
Power:	❑ 35 kW max
Crew:	❑ ~ 100 hours/week (crew of 6)
Data:	❑ S-Band command uplink: 72 kbps ❑ Ku-Band data/video downlink: 100 Mbits/s

7.5.1 ESA Utilisation Rights and Resources

In return for its contribution, ESA has a resource allocation of 51 % of the internal and external user accommodation of the Columbus Laboratory. Other allocation rights to ESA comprise 8.3 % of the total ISS utilisation resources and 8.3 % of the total crew time. Note that this excludes all of the Russian accommodations and resources, as this is retained by Russia for its own use. This results in the utilisation rights shown in Table 7-21 for European use, *but users should keep in mind that, due to the dynamic nature of the ISS programme, the values reported can be subject to change.*

Table 7-21: European Research and Accommodation Facilities

PRESSURISED (INTERNAL)	UNPRESSURISED (EXTERNAL)	RESOURCES & SERVICES	
Columbus Laboratories: ❑ Biolab ❑ Fluid Science Laboratory (FSL) ❑ European Physiology Modules (EPM) ❑ Materials Science Laboratory (MSL)[2] ❑ European Drawer Rack (EDR) ❑ European Transport Carrier (ETC)	**Columbus External Payloads including:** ❑ European Technology Exposure Facility (EuTEF) ❑ SOLAR ❑ ACES ❑ EXPOSE	**Resources:** ❑ Max. Power ❑ Average Annual Energy[1] ❑ Average crew time per week	 ❑ 35 kW ❑ ~ 22000 kWh ❑ ~ 8 hours (crew of 6)
		Communication Services: ❑ Max. Data downlink rate (Ku-Band) ❑ Yearly downlink data volume[3] ❑ Max. command uplink rate ❑ Yearly uplink command volume	 ❑ 100 Mbps ❑ 250 Tbit/year ❑ 72 kbps ❑ 0.18 Tbit/year
		Transportation services (yearly average)[4]: ❑ Pressurised upload mass ❑ Pressurised download mass ❑ Unpressurised upload mass ❑ Unpressurised download mass	 ❑ 450 - 600 kg/year ❑ 450 - 530 kg/year ❑ 80 - 115 kg/year ❑ 80 - 115 kg/year

1. 30kW*365*24*0.083
2. Located in US Destiny Lab
3. [(100Mbps x 365 x 24 x 3600)/1024^2] x 0.083
4. Due to the probable retirement of the Space Shuttle at Assembly Complete (currently 2010), the post-2010 cargo transportation capabilities are, at the time of writing this document, still under analysis. The values indicated are current *estimates* of utilisation transport capabilities (not requirements), without the Shuttle in service.

7.5.2 ESA Barter Agreements

ESA has engaged in a series of barter arrangements with other space agencies within the framework of the International Space Station (ISS) Programme. These arrangements formalise exchanges of goods and/or services with the other agencies without a corresponding financial transaction, i.e. without an exchange of funds. Different from cooperation schemes where partners provide complementing elements to a joint project, or fulfil obligations by contributions in kind, barter arrangements are characterised by the partners receiving goods or services from each other, which they would otherwise have to provide by themselves. For ESA, such barter arrangements avoid the need to make cash payments to non-Member States, and instead permit such budgets to be invested with European industry. Other advantages are the reduction of technical and financial risks (concerning the elements, which are provided by the other party), contribution to standardisation and commonality throughout the ISS Programme and the strengthening of the ISS cooperation and partnership. It is however to be recognised that barter arrangements by nature also introduce an element of dependence from the other party through the exposure to the programmatic risks (in particular schedule) related to the activities of the partner. For a barter arrangement to be attractive, it must be beneficial to both parties. Such benefit can be, for example, reduction of cost (e.g. compared to the cost which would result for a party if it would have to provide a bartered good or service by its own), or even access to goods and/or services, which would be otherwise out of reach for one party (e.g. the launch of Columbus Laboratory for ESA). Many barter arrangements are based on ESA delivering goods (hardware), while the other party is providing services or access opportunities to its ISS facilities. ESA has concluded ISS-related barter arrangements with Cooperating Agencies (NASA, Roscosmos, JAXA, CSA), and with ASI. The following paragraphs summarise these arrangements.

7.5.2.1 ESA/NASA Early Utilisation Opportunities of the ISS (18 March 1997)

The primary objective of this **“Early Utilisation MOU”** is to ensure that the European user community would gain early utilisation access to the Space Station, prior to the Columbus Laboratory’s availability in orbit. Through this barter agreement, ESA has obtained:

- Access to 50 % of the experiment module accommodation in a NASA payload rack in the US Laboratory for a period of 2 years. Use of this resource is covered by a cooperative research agreement between ESA and NASA, which was concluded on 28 September 1999 identifying ESA’s Material Science Laboratory (MSL) as the experiment module;
- Accommodation of European provided research equipment in a US research facility or facilities for a period of 2 years. The research equipment to be accommodated was defined by a cooperative research agreement, concluded on 9 October 2001, as the European Modular Cultivation System (EMCS);
- Use of one-half of one attached payload accommodation site on the Truss for a period of 3 years;
- Two Space Shuttle flight opportunities for European astronauts prior to the on-orbit assembly of the Columbus Laboratory.

In exchange, ESA delivers the following “Laboratory Support Equipment” to NASA:
Microgravity Science Glovebox (MSG), 3 units of the Minus Eighty Degrees Freezer (MELFI), the Hexapod Pointing System, and an adapted Columbus Mission Data Base (MDB) to be used as part of NASA’s ISS Ground Segment.

Apart from providing Europe the opportunity for early utilisation in predictable economic terms, the MOU avoids cash flow to the USA, and – for the case of MDB - allows a better exploitation of earlier investments made in Europe.

Since the signature of this MOU in March 1997 the following modifications have occurred:

- NASA requested technical modifications to MSG and MELFI;
- ESA and NASA considered in early 2001 on a technical level to attach the Early Utilisation external payloads no longer to the truss site, but on the Columbus External Payload Facility. This consideration was triggered by questions concerning the timely availability of the Express Pallet and associated adapters to be located on the truss sites as well as by payload interference problems.

7.5.2.2 ESA/NASA Super Guppy Transporter Barter Contract (15 August 1997)

This **“Super Guppy Barter”** originated from a NASA request for ESA to support their negotiations with Airbus Industry for the acquisition of a Super Guppy aircraft for ferrying large ISS elements between NASA centres. ESA made all arrangements with Airbus Industry, including the payment of an ESA-negotiated price, for the transfer to NASA of the aircraft plus associated equipment, spares and services. In return, NASA provided to ESA standard Shuttle services for a total of 450 kg ESA payload upmass on Shuttle flights. Thus, the arrangement allowed ESA to avoid cash payments to NASA for Shuttle transportation services by instead spending a fixed amount in Europe.

7.5.2.3 ESA/NASA Columbus Orbital Facility Launch Barter (8 October 1997)

The objective of the **"Columbus Launch Barter"** arrangement for ESA is to obtain the launch of the Columbus Laboratory and its initial payload on the Shuttle without transferring money to NASA. As compensation, the original arrangement foresaw ESA to provide to NASA the fully integrated Nodes 2 and 3, Cryogenic Freezer and Crew Refrigerator/Freezer equipment for ISS, spares and sustaining engineering for the Laboratory Support Equipment items provided by ESA to NASA under the “Early Utilisation MoU”, and hardware/software support for software development and integration in NASA ground facilities for ISS. Since the signature of that arrangement on October 8, 1997, two amendments have been concluded:

(1) “Protocol Amending the Arrangement between NASA and ESA Regarding Shuttle Launch of Columbus Orbital Facility and its Offset by ESA Provision of Goods and Services”, signed on 3 August 2000. The amendment reflects the NASA requested reengineering of Nodes 2 and 3 configuration to include functionalities previously covered by the US Habitation Module. In exchange, NASA took over the responsibility for the procurement of the US sourced outfitting hardware for Node 3 (originally an ESA responsibility). The resulting financial imbalance was accepted by ESA on the basis of having avoided the financial risk of procuring hardware in the US, taking into account indications that such procurement would significantly exceed NASA’s estimate. As a consequence, it was agreed between ESA and ASI to increase the overall financial allocation for the Node 2/3 project.
(2) “Amendment to the Arrangement between NASA and ESA regarding Shuttle Launch of Columbus Orbital Facility and its Offset by ESA Provision of Goods and Services (Amendment 2)”, signed on 22 July 2002. The amendment covers the implementation by ESA/ASI of further NASA directed modifications to the Nodes 2 and 3 requirements and scope of work. Costs of this implementation through ASI were negotiated between ESA and ASI. The principal compensation element of NASA for ESA/ASI’s implementation of the Nodes’ changes are savings to the benefit of ESA resulting from the cancellation of the Crew Refrigerator/Freezer development beyond the development and delivery of a single qualification unit. The original obligation of ESA was development and delivery of 9 flight units, 1 flight spare, training units and related GSE. To “fine-tune” this balance, ESA will implement a number of changes to the Cupola (being an ESA obligation in the frame of the “Cupola Barter”), while NASA will provide (a) a firm fixed credit to ESA to be applied against ESA’s financial obligations for Shuttle Mission Specialist Training, (b) 10 ISS lockers and 10 8-Panel Unit drawers, for accommodation in the ESA European Drawer Rack. Furthermore, formally outside this amendment, but within its overall balance, NASA agreed to cancel its financial claim on ESA, representing the net balance following modification of the “Cupola Barter”, where ESA has to deliver only one cupola instead of two as originally foreseen and on the basis of which the NASA obligations were established.

7.5.2.4 ESA/NASA MOU for Cooperation in the X-38 Project (8 July 1999)

Although not being a classical barter arrangement but rather an ESA/NASA cooperation, the MOU on the X-38 Project was regarded as a key precursor of a planned barter arrangement on the Crew Return Vehicle (CRV). The MOU was motivated by preliminary studies of ESA and NASA, which indicated areas in which performance and cost objectives for the prototype X-38 vehicle could be enhanced through incorporation of specific European design, system integration, and manufacturing capabilities. ESA contributions consisted of hardware, software and engineering expertise provided to NASA in particular for use on the space flight test vehicle V201 and to be integrated by NASA for orbital flight test. NASA’s responsibility was the integration of the European parts in the X-38 V201 vehicle, launch on the US Space Shuttle and giving ESA access to flight data. On 12 August 2002, NASA informed ESA about having terminated the X-38 programme and at the same time notified ESA – pursuant to Article 15 of the MOU – of its intention to terminate the MOU.

7.5.2.5 ESA/NASA Cupola Barter Agreement (3 August 2000)

The main elements of the original **"Cupola Barter"**, which was negotiated between ESA and NASA in autumn 1998, were on the ESA side to deliver to NASA the ISS elements Cupola-1 and Cupola-2, with associated spares and sustaining engineering. Moreover, ESA committed to enhance the Columbus Laboratory payload support concerning thermal control and Ethernet connectivity. NASA agreed to provide ESA with Shuttle transportation services for five external European payloads, and to allocate to ESA 68 kg of additional launch mass on the Columbus Laboratory launch. The barter agreement allowed ESA to avoid cash payments to the USA for Shuttle transportation services and to avoid potential price uncertainties for such services. In September 1999, before this original agreement was signed by the parties, NASA formally directed ESA to delete the second Cupola flight model and implement a modified on-orbit mission as well as related design changes for the remaining Cupola-1. The principal terms of the final arrangement were nevertheless kept identical to the original one, with the exception of the reduction of the number of cupolas to be delivered by ESA from two to one. This implies that the arrangement still foresees NASA providing goods and services corresponding to ESA delivering two cupola flight units. ESA and NASA agreed to compensate for the net value of this imbalance outside the Cupola Agreement. In the meantime, this compensation was settled in the context of the Amendment 2 of the "Columbus Launch Barter", signed by ESA and NASA on 22 July 2002.

7.5.2.6 ESA/Roscosmos Service Module DMS Agreement (1 March 1996)

This arrangement foresees ESA providing the Roscosmos (formerly Russian Space Agency (RSA)) with the Data Management System (DMS-R) comprising flight equipment for the Russian Service Module "Zvezda" plus necessary ground model, support equipment and spares, whilst Russia provides ESA with two flight sets of the active part of the Docking System for ESA's Automated Transfer Vehicle (ATV), including ground model, support equipment and spares. The cooperation set out in this arrangement enhances the operational efficiency of the Space Station whilst avoiding duplication of development activities. It allows ESA to benefit from Russian long-standing experience in space vehicle docking systems. The cost for ESA developing the docking system on its own would have been considerably higher than the cost for the DMS-R, which is the recurring cost of the DMS for the Columbus Laboratory and ATV, with Zvezda-specific adaptations.

7.5.2.7 ESA/NASDA MOU on Hardware Exchange for ISS Utilisation (5 November 1997)

In the spirit of increasing the commonality in utilisation support equipment whilst minimising the respective development and procurement costs, this MOU commits ESA to provide JAXA (formerly NASDA) with one MELFI Freezer identical to those developed by ESA for NASA in the context of the Early Utilisation MOU. In compensation, JAXA provides ESA with 12 International Standard Payload Racks (ISPR) flight units for use on the ISS. This arrangement permits ESA to avoid purchasing the ISPRs in the USA or Japan, and at the same time to better exploit the investments made in Europe for the development of MELFI for NASA.

7.5.2.8 ESA/CSA FSL and MVIS Cooperation (6 February 2001)

The agreement foresees the upgrading of ESA's Fluid Science Laboratory (FSL) by incorporating the Canadian provided Microgravity Vibration Isolation System (MVIS). MVIS will reduce microgravity disturbances to the FSL and thus improve conditions for scientific experiments conducted in FSL. In exchange for MVIS, ESA will provide to CSA access to the FSL for an amount of 5 % of the total time of ESA FSL use (necessary resources for the Canadian use are provided from CSA's allocation as per the NASA-CSA ISS MOU).

7.5.2.9 ESA/ASI MPLM and Columbus Common Features Exploitation Arrangement (17 April 1997)

In the spirit of exploiting common features of the ASI-developed Multi-Purpose Logistics Module (MPLM) and ESA's Columbus Laboratory, this arrangement commits ESA to provide ASI with the Environmental Control and Life Support System (ECLSS) for the MPLM, which is an adaptation of the ECLSS for the Columbus Laboratory, whilst ASI provides ESA with the primary structure of the Columbus Laboratory (derived from MPLM). Besides significant cost benefits (no full development of Columbus primary structure; ECLSS manufacturing basically at recurrent cost), this arrangement provides stronger commonality and standardisation within the ISS programme.

7.5.3 ESA Additional Flight Opportunities

In May 2001, ESA and the then Russian Aviation and Space Agency (Rosaviakosmos), now Roscosmos, signed a Framework Agreement for the provision of Russian ISS flight opportunities. The Agreement documents the principles, terms and conditions for the cooperation between ESA and Roscosmos concerning ISS operations and utilisation, through the provision by the latter of fare-paying ISS flight opportunities in the period 2001-2006, for members of the European Astronaut Corps. The actual commitment for a specific flight opportunity is entered by ESA upon signature of an ISS Flight Order Contract (IFOC) for a specific flight.
The Framework Agreement marks a milestone in the longstanding and increasing cooperation between ESA and Roscosmos. It establishes a solid and stable basis for the strategic planning of the European Astronaut Corps, and it represents an important step towards the further development of operational expertise of the ESA astronauts prior to the full European utilisation of the ISS with the launch of Columbus.

Two types of flight opportunities are considered under the Agreement as ISS flight opportunities:

- ISS “taxi flights” (this term is reported in the original agreement, but is no longer used), which are defined as short duration Soyuz flights to the ISS for the purpose of exchanging the ISS docked Soyuz, including a short duration stay (approximately 7-8 days) on-board the ISS;
- ISS increment flights, which are defined as ISS crew exchange flights, including a 3-6 months (one increment) stay on-board the ISS.

The assignment of ESA astronauts to a specific flight is subject to the approved ISS procedures, pursuant to the provisions of the IGA and ISS MOUs and other applicable ISS documents. Since all flight opportunities covered by the Agreement are flights to the ISS, ESA and Roscosmos ensure that relevant rules and regulations pertaining to the ISS and the space transportation vehicle are applied to all activities related to these flight opportunities. These rules and regulations include the Code of Conduct for the International Space Station Crew (CCOC) and the related Disciplinary Policy.
The assignment of back-up astronauts/cosmonauts for ISS flight opportunities, involving ESA astronauts, is agreed upon between ESA and Roscosmos for each flight.
On-board activities are not restricted to the mandatory system operations and maintenance activities, but also allow for the conduct of activities or experimental programmes in the interest of ESA and national organisations of the ESA Member States. The terms and conditions of such activities are agreed upon in each specific IFOC. The IFOC defines the terms and conditions specific to the implementation of an agreed ISS flight opportunity. Such terms and conditions take precedence over the terms and conditions defined in the Framework Agreement.

The ISS flight opportunities under the Agreement are implemented according to the following procedure:

- Roscosmos, on a priority basis, notifies ESA in writing of an available ISS flight opportunity for the position of flight engineer in increment and visiting crew, identifying, inter alia, its technical, financial and programmatic elements;
- Upon receipt of the Roscosmos notification of the availability of specific ISS flight opportunities, but in any case not later than four weeks thereafter, ESA expresses in writing to Roscosmos its acceptance or rejection for such a specific ISS flight opportunity based on the technical, financial and programmatic elements specified in the Roscosmos notification. In case of an ESA acceptance Roscosmos and ESA discuss all relevant details with the aim to agree on the provision of the specific ISS flight opportunity. In case of ESA not being in a position to fully accept the elements of the Roscosmos notification, then Roscosmos are entitled to negotiate this flight opportunity with other customers;
- A commitment for an agreed ISS flight opportunity is entered into, following the signature by Roscosmos and ESA of a specific ISS Flight Order Contract (IFOC) which defines the specific contractual, financial, technical and management aspects of the agreed ISS flight opportunity, complementary to the principles, terms and conditions set forth in the Agreement. The respective responsibilities of the parties, related to the implementation of the ISS flight opportunities covered by the Agreement, becomes operative upon signature of the corresponding IFOC;
- Roscosmos also, on a non-exclusive basis, notifies ESA in writing of available ISS flight opportunities for the position of flight researchers identifying, inter alia, its technical, financial and programmatic elements.

The following table (Table 7-22) summarises the Russian ISS flight opportunities that have thus far included an ESA astronaut on-board, following the signature of the Framework Agreement in May 2001.

Table 7-22: ESA Russian flight opportunities deriving from ESA/Roscosmos Framework Agreement (May 2001)

ISS MISSION	ESA MISSION NAME	VEHICLE ID	LAUNCH DATE	LANDING DATE	ESA ASTRONAUT	ASTRONAUT NATIONALITY
ISS 3S	Andromede	Soyuz TM-33	21/10/2001	31/10/2001	Claudie Haigneré	French
ISS 4S	Marco Polo	Soyuz TM-34	25/04/2002	05/05/2002	Roberto Vittori	Italian
ISS 5S	Odissea	Soyuz TMA-1	30/10/2002	10/11/2002	Frank De Winne	Belgian
ISS 7S	Cervantes	Soyuz TMA-3	18/10/2003	28/10/2003	Pedro Duque	Spanish
ISS 8S	DELTA	Soyuz TMA-4	19/04/2004	30/04/2004	Andre Kuipers	Dutch
ISS 10S	Eneide	Soyuz TMA-6	15/04/2005	25/04/2005	Roberto Vittori	Italian

7.6 Columbus Payload Accommodation

As part of the ISS, ESA's Columbus module represents an element of a multi–functional, orbital infrastructure that generates and/or distributes the resources required for scientific and technological research in Low Earth Orbit (LEO). Columbus provides the capability for:

- The long–term continuous exposure of payloads to the microgravity environment and the capability for the systematic repetition and evolution of experiments on a more frequent basis;
- Automatic, remotely controlled and interactive investigations involving orbit–based and ground–based crews composed of scientific, engineering and space operations personnel;
- The remote reconfiguration of the Columbus (and potentially the payloads) functional–electrical configuration based on optimised operations and redundancy concepts;
- A successive build–up and complementation of payloads based upon experiment results while using the logistics capabilities of the space transportation systems and the Columbus design features for Orbit Replaceable Units (ORU);
- In–orbit crew intervention for scientific preparatory, technical diagnostic, hardware configuration or recovery purposes when and as required.

Although aimed at basic research in the fields of material, fluid, biological and physiological sciences, the versatility and resources provided makes Columbus a suitable facility for other fields of applied sciences, process engineering and prototyping of automatic experiments.

The Columbus module consists of a cylinder with an inner diameter of 4216 mm and an overall length of 6137.2 mm, closed by a truncated end cone at each end. The cross–section is double symmetric with four identical stand–off envelopes accommodating the routing of utility lines and four identical rack envelopes spaced 90 degrees apart. An overview of the Columbus features and resources are presented in the Columbus Fact Sheet in chapter **9** at the end of the Guide.

In order to simplify the process of preparing and integrating payloads into the Columbus Laboratory, the European Space Agency, for internal purposes only, has defined two classes of user hardware, i.e. Class 1 and Class 2 payloads. Theoretically, the following definitions are applied by ESA to both internal (pressurised) payload hardware and external (unpressurised) payload hardware. For internal payloads the definitions are very clear, but for external payloads however, a precise definition is not so easy to establish. For the latter reason, the Class 1 and Class 2 classification within this guide will only be applied to internal payloads. External payloads will be dealt with in a separate section (see 7.6.3).

Class 1 payloads are large multi-user facilities, which are normally developed by industry for the user(s). Class 2 payloads on the other hand can be provided directly by the user, and range from an individual sample to a complete subrack level payload.
The complete payload lifecycle activities, complexity, cost and development time is significantly different for the two classes of payload - although the general scope and sequence of activities is very similar in each case. The complete payload lifecycle process is generally complex and of long duration for Class 1 (~ 5 years), and simple and of short duration (~ months to a few years) for Class 2.

7.6.1 Class 1 Payloads

Class 1 payloads are any user hardware that interfaces directly with the Columbus laboratory system at the International Standard Payload Rack (ISPR – see 7.6.1.1), or at the Standard Utility Panel interface in case of centre aisle payloads (see 7.6.1.2). In general, the selection of Class 1 payloads is made at Agency Programme level and in close coordination with the Space Station partners in order to avoid duplication of hardware. Once a decision for the development of a Class 1 payload is taken, this payload will be developed by industry under contract and financial coverage of the responsible Agency Programme Directorate. The final technical definition and construction of the Class 1 payload is undertaken in close interaction with the scientific and technical advisory teams of the respective User Programmes.

Within Columbus, pressurised payloads are primarily accommodated in racks. Columbus accommodates 16 racks in four segments of four racks each (Figure 7-24). System equipment requiring access or viewing by the crew is accommodated in the starboard end cone, while the remainder of the system equipment is housed around the perimeter of the port end-cone, and within three of the deck (floor) racks. The remaining 13 racks are available for payloads and storage, 10 have "plumbing and harness" to provide resources to active racks, and 3 provide passive stowage accommodation for payloads and system.

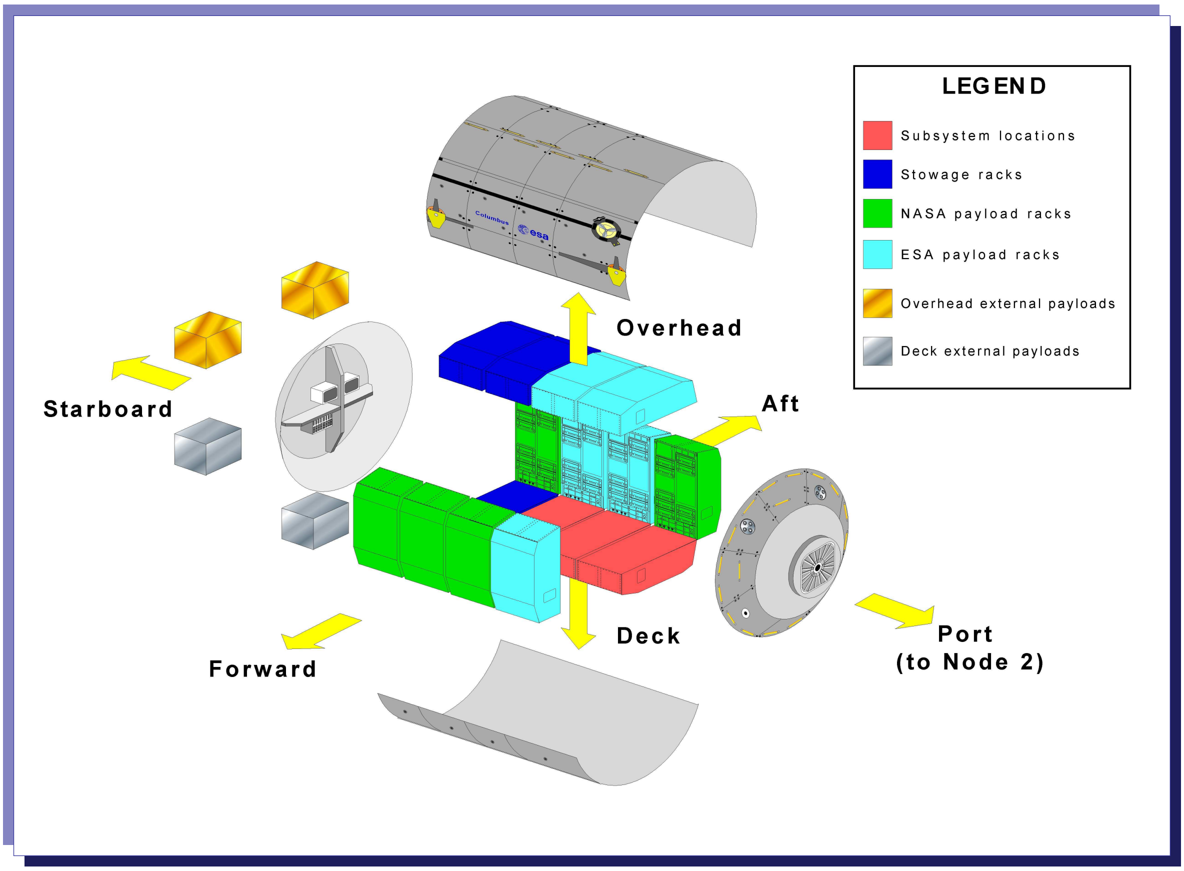

Figure 7-24: Internal layout of Columbus racks

7.6.1.1 The International Standard Payload Rack (ISPR)

To facilitate on-orbit interchangeability between International Partner pressurised modules, internal (or pressurised) payloads are primarily accommodated within an International Standard Payload Rack (ISPR). The exception to this general statement being the Russian segment of the ISS, which does not allow the accommodation of ISPRs. The ISPRs have mechanical mounts at the top and bottom of the rack to enable attachment to the secondary structure of the Columbus Laboratory. The bottom attachment is pivoted, to allow the rack to be tilted forwards approximately 80° for installation, removal or maintenance. Both NASA and JAXA (formerly NASDA) have developed ISPRs that may be utilised by users/payload developers, with interfaces and capabilities that are almost identical. The NASA rack however, has a larger volume for the accommodation of payloads.

The JAXA ISPR (Figure 7-25 and Figure 7-26) is the basic accommodation for European payloads. This is a non-sealed structure made of aluminium. There are removable side and rear panels that may be taken-off during payload integration on the ground or to provide on-orbit access during the payload operations phase. The basic ISPR structure is termed the "six post" configuration, as it has a post at each corner plus one in the centre-front and one in the centre-rear. The centre posts are removable, resulting in a four-post version of the rack. Table 7-23 summarises the major characteristics of the Japanese ISPR for both the 6-post and 4-post versions.

Table 7-23: Characteristics of JAXA International Standard Payload Rack (ISPR)

	6-POST ISPR	4-POST ISPR
Height	2013.4 mm	
Width	1046 mm	
Depth	858 mm	
Payload mass supported	704 kg	418 kg
Internal accommodation volume	1.2 m^3	1.35 m^3

The Japanese ISPR may also be outfitted with standardised components provided by the International Partners – the so-called Standard Payload Outfitting Equipment items (the rack itself is also considered a Standard Payload Outfitting Equipment item).

There are two power ratings of ISPR, a “medium power” 6kW, and a “low-power” 3 kW. The placement of a medium-power rack (6kW) in a low power (3kW) location is not possible, but low-power racks may be placed in any location.

ISPRs are the largest (pressurised) individual entity that can be transported to and from orbit as logistics upload/download. The design of the racks facilitates the ready installation, removal or exchange of sub-rack units on-orbit. The resources available to International Standard Payload Rack payloads are provided through a Utility Interface Panel. This panel (which is part of the Columbus Laboratory) is located beneath the lower front of the ISPR. It is behind the lower stand-off area, and close to the pivot attachment point, only at specific rack locations within the Columbus Laboratory (i.e., the 8 lateral positions and 2 overhead positions). The payload to system interface panel is part of the internal structure of the Columbus Laboratory. The rack utility close-out panel is part of the integrated ISPR. The flexible utility lines (permanently attached to the close-out plate) are mated with the connectors on the Utility Interface Panel during installation of the ISPR in the Columbus Laboratory. These are flexible to provide the capability to tilt the rack for servicing and maintenance without disturbing the interfaces.

The payload/system interface is the Utility Interface Panel itself, so the connectors between the Close-Out Panel and the Utility Interface Panel are payload-provided items. Seat tracks are also present on the front posts of the ISPR, for the temporary attachment of payload equipment, during experiment operations or maintenance activities.

Figure 7-25: International Standard Payload Rack (ISPR): 6-post configuration

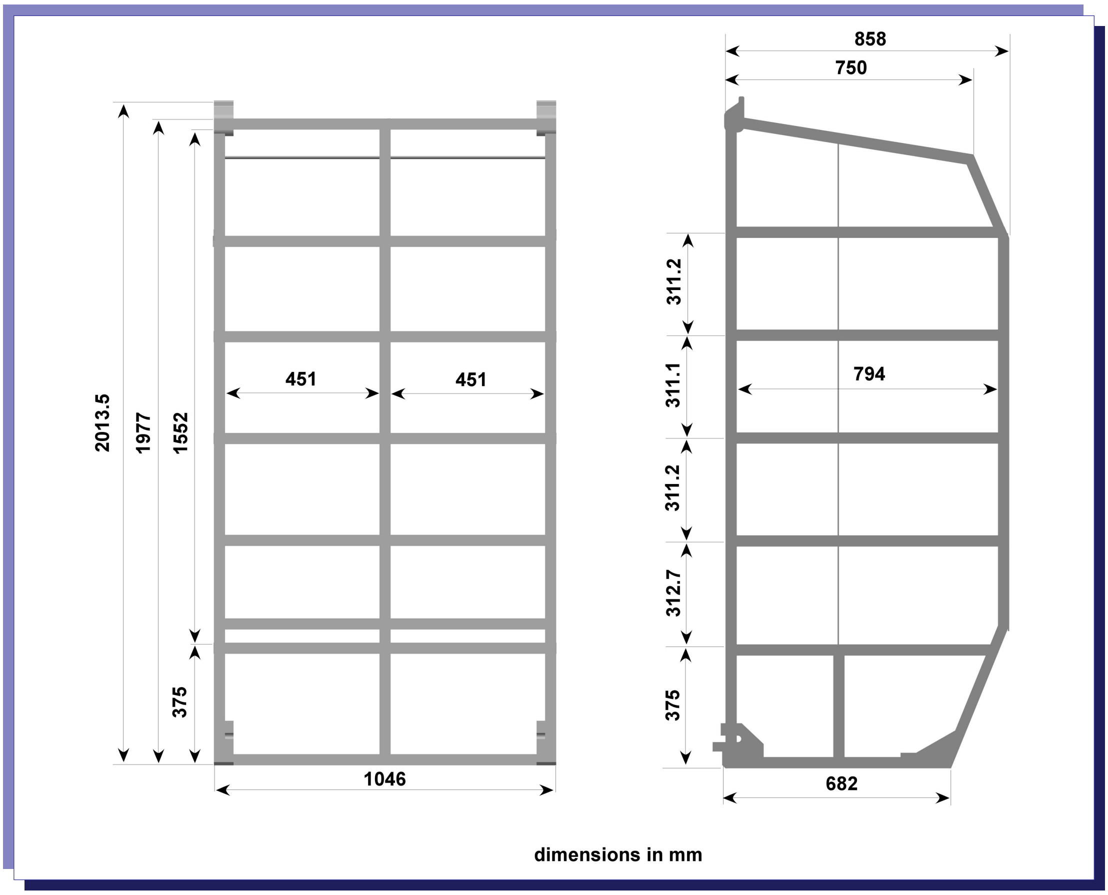

Figure 7-26: ISPR 6-post configuration dimensions – Front and Side View

7.6.1.2 Centre Aisle Payloads

Users have the possibility to mount payload equipment in the centre aisle of the Columbus Laboratory via mechanical attachment to deck rack seat tracks at the location of the deck racks (D1 – D4) of the Columbus floor (see Figure 7-27). The deck panels are removable to allow access to the stowage rack in position D4, or to any of the 3 subsystem racks - D1, D2 and D3 positions, in the underfloor area. Seat tracks are also at the ISPR front post for temporary attachment of payload equipment.

European payloads can be supplied with resources by connection to two Standard Utility Panels (SUPs) located at positions SUP1 and SUP4 in the lower stand-offs. The positions of all four Standard Utility Panels in the stand-off areas adjacent to the deck racks are shown in Figure 7-27.
The Standard Utility Panels include connectors for both payload and system equipment on the same panel. Locations SUP2 and SUP3 are available to American payloads via the United States Payload Bus (as access to the European Columbus payload bus, high rate data and smoke sensor, Emergency Warning and Caution System resources are not available at these positions).

The layout of the Standard Utility Panel is shown in Figure 7-28 and the connector allocations are reported in Table 7-24. Note that there are no water, vacuum, venting or gaseous nitrogen resources provided via the Standard Utility Panel, and any required cooling of aisle-mounted payloads should be performed by the payloads themselves.

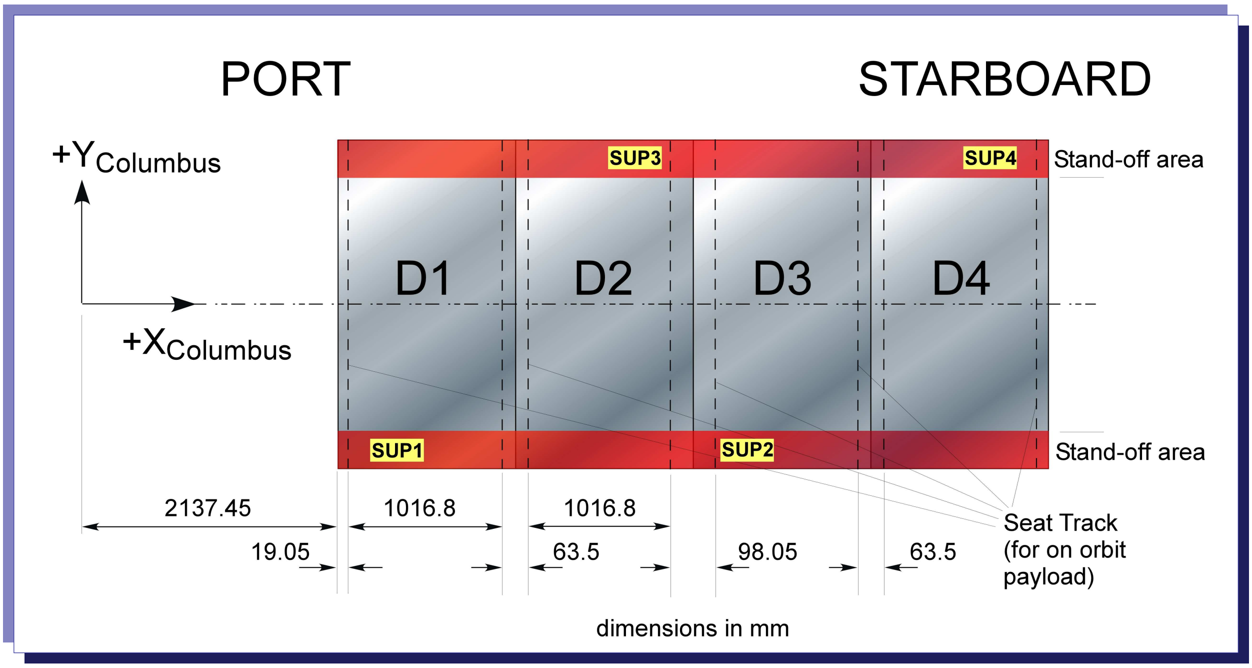

Figure 7-27: Centre Aisle Payload Attachment and Standard Utility Panel (SUP) Locations

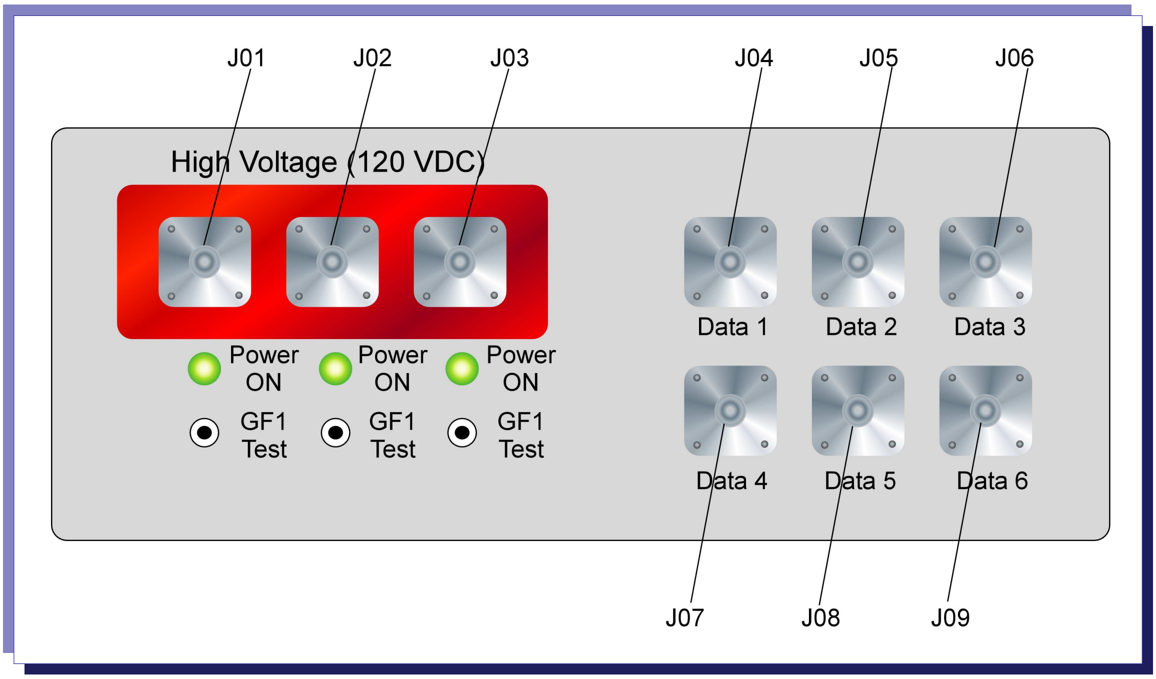

Figure 7-28: SUP panel layout

Table 7-24: Standard Utility Panel connector allocation and function

CONNECTOR	SUP1 & SUP4 LOCATIONS	COMMENTS
J01 – Power	120 Vdc/ Crew Health Care System (CheCS) Bus	Used only by the system
J02 – Power	120 Vdc	Used only by the system
J03 – Power	120 Vdc	Provides power to aisle payloads
J04 – Data 1	Columbus Payload Bus	1533 bus for aisle payload data
J05 – Data 2	Columbus Local Area Network	IEEE 802.3 nominal line
J06 – Data 3	Video/High Rate data	Fibre optic line
J07 – Data 4	Smoke sensor/Emergency, Warning and Caution System	Smoke sensor and Emergency, Warning and Caution System
J08 – Data 5	Video Camera Assembly	This connection is only used by the Columbus system cameras (for 28 Vdc power, sync and video)
J09 – Data 6	Columbus Local Area Network	IEEE 802.3 redundant line

7.6.1.3 Assembly Complete Rack Topology

The following figure (Figure 7-29) shows the overall rack topology at Assembly Complete within all the modules of the non-Russian segment. The different colour codes distinguish between Subsystem, Stowage and Payload Racks. The ESA payload racks in Columbus are also specified. Users must however, keep in mind that due to the dynamic nature of the ISS programme planning, the topology shown represents the situation as at May 2005 and is subject to change.

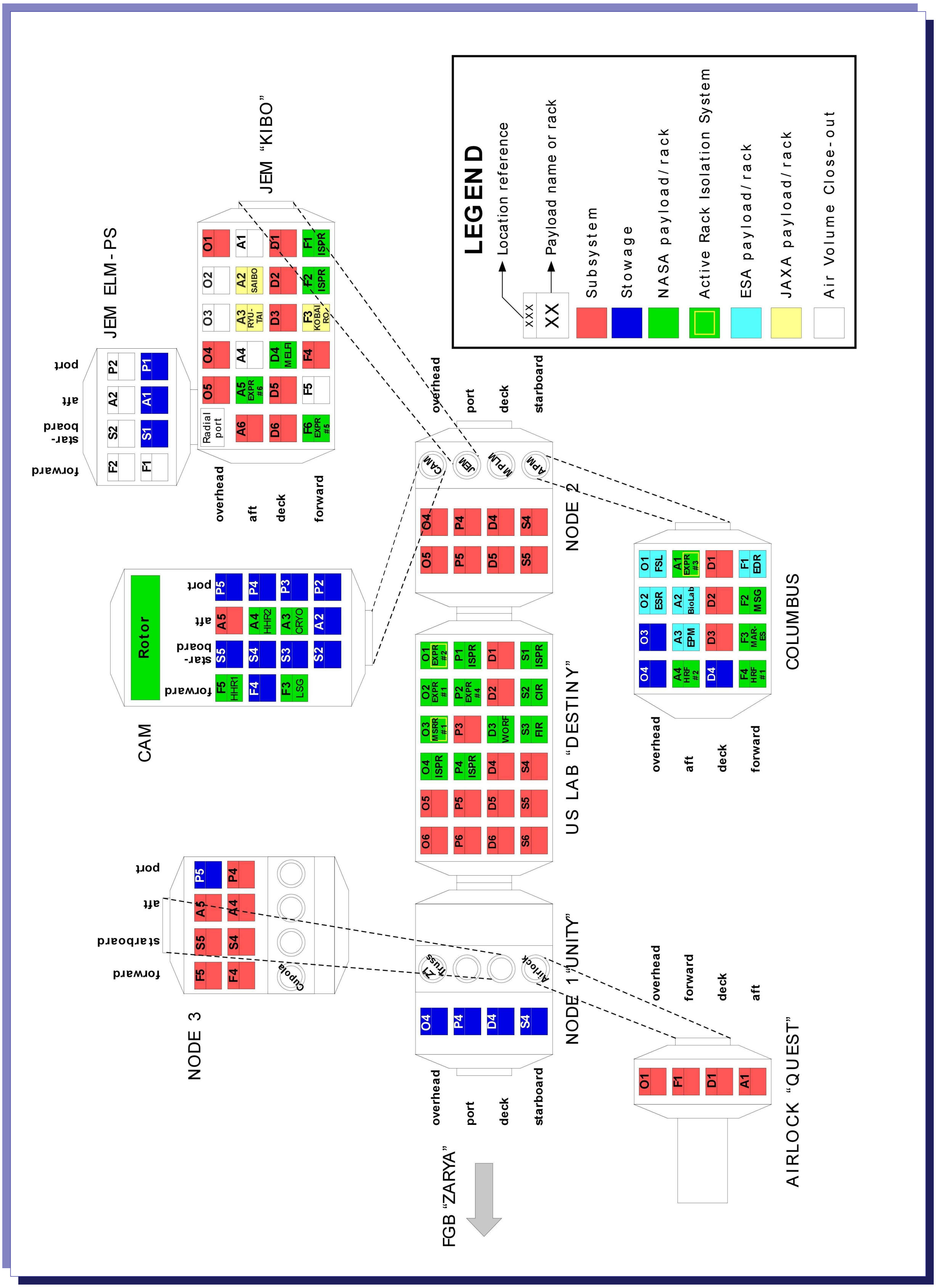

Figure 7-29: Rack configuration at Assembly Complete

7.6.2 Class 2 Payloads

Class 2 payloads are smaller facilities normally provided directly by users (scientists from universities or researchers from industry), which may be sub-units of Class 1 payloads with ISPR internal interfaces, add-on experiments, or smaller instruments accommodated in the European Drawer Rack (EDR). Specific examples of Class 2 payloads would be the Middeck Locker (MDL) and International Subrack Interface Standard (ISIS) drawer used by the EDR for containing experiments or instruments. Other types of Class 2 payloads include experiment samples, dedicated Experiment Containers and Cargo Transfer Bags. The MDL and ISIS drawer are generally referred to as Experiment Container Modules (ECMs). A set of drawers and lockers for the first payload complement will be procured by the European Space Agency, and may be made available to users. Subsequently, users will be required to procure their own drawers/lockers.

The current baseline is that drawers and lockers will normally be transported to the ISS by the Multi Purpose Logistics Module. Lockers requiring power during transportation however, will need to be accommodated in the Space Shuttle middeck area. Conformity to the International Subrack Interface Standard ensures mechanical compatibility with the NASA Express Transport Rack. The American Express Transport Rack can thus be used to upload and download International Subrack Interface Standard drawers. The Middeck Lockers are mechanically compatible with the Space Shuttle Middeck interfaces and the Express Transport Rack, so either the Space Shuttle or the Express Transport Rack can be used to upload and download the Middeck Lockers.

7.6.2.1 Middeck Locker (MDL)

The use of standardised drawers and lockers provides users with a quick turn-around capability, and provides increased flight opportunities for the user community wishing to fly Class 2 payloads. The ISS Middeck Lockers (standard box-shaped containers) were developed by NASA to be compatible with both the Space Shuttle and the ISS. Figure 7-30 shows the basic dimensions and lay out of the MDL, while its characteristics are summarised in Table 7-25.

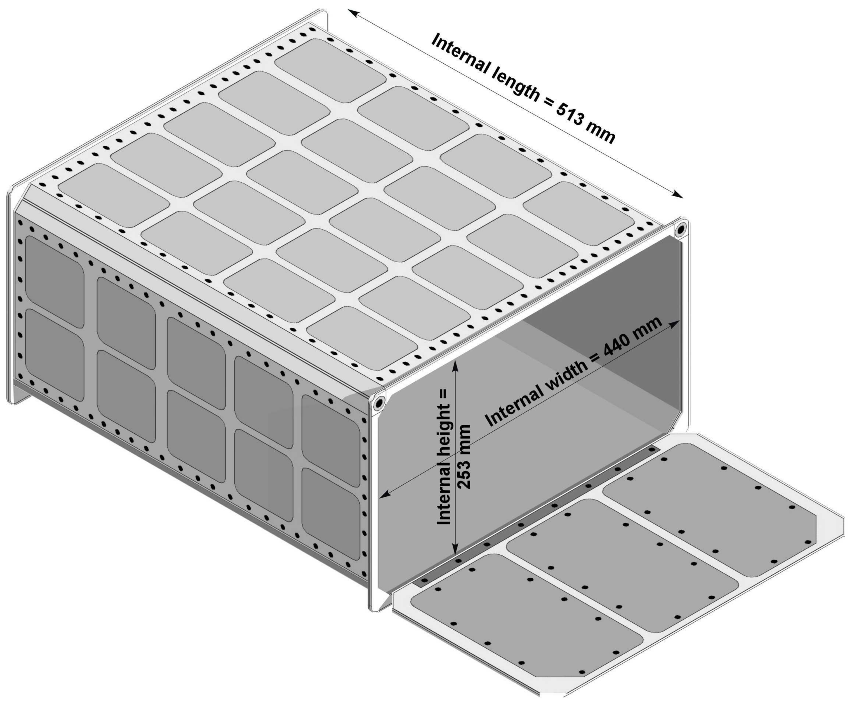

Figure 7-30: Middeck Locker (MDL) Dimensions and Layout

Table 7-25: Middeck Locker Characteristics

PARAMETER	VALUE
Maximum Volume available to users	57 litres
Internal Width	440 mm
Internal Height	253 mm
Internal Length	513 mm
Empty Mass	~ 5.4 kg
Net Mass available to users	28 kg

7.6.2.2 International Subrack Interface Standard (ISIS) Drawer

The ISIS Drawer (Figure 7-31) accommodation is designed to be physically compatible with the drawers of the NASA Express Rack through the adoption of a common rail installation and interface system. In the case of the EDR, the ISIS Drawers are provided by ESA and the baseline foresees the accommodation of 8-PU (8 Panel Unit) ISIS Drawers and the electrical and air cooling interfaces are spaced at 8-PU steps. The Panel Unit is used to determine the height (external) of the drawer, where 1 PU = 44.45 mm. The basic characteristics of the ISIS drawer are given in Table 7-26. The ISIS Drawer receives resources from the EDR system on the rear drawer panel where blind mate connections are implemented for both electrical and air cooling capability; some shared resources will be available in any case from the front of the rack via jumpers.

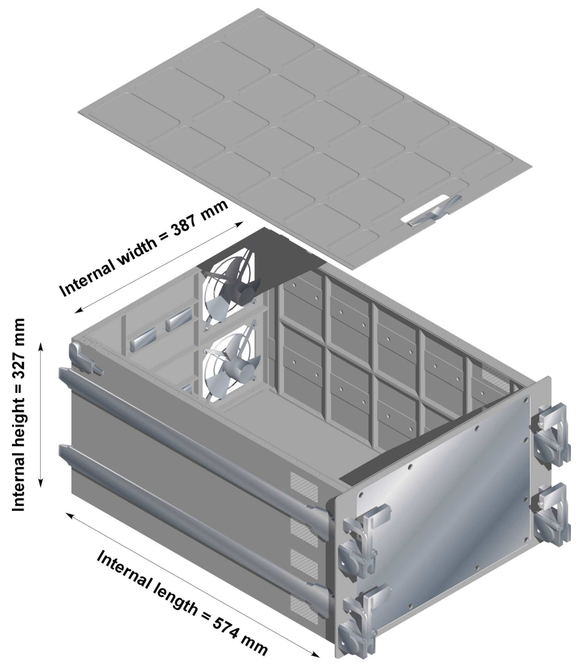

Figure 7-31: International Subrack Interface Standard (ISIS) drawer

Table 7-26: ISIS Drawer Characteristics

PARAMETER	VALUE
Maximum Volume available to users	72.6 litres
Internal Width	387 mm
Internal Height	327 mm
Internal Length	574 mm
Empty Mass (including rails)	~ 18 kg
Net Mass available to users	40 kg

7.6.3 Columbus External Payload Facility (CEPF)

The Columbus module is furnished with attachment locations at the starboard end cone for integrated external payloads requiring space exposure or viewing towards nadir, zenith or the line of flight. The on–orbit attachment locations form part of the Columbus External Payload Facility (CEPF – see Figure 7-32 and Figure 7-33), consisting of two external structures mounted symmetrically and providing a total of four accommodation locations with associated sets of resources.

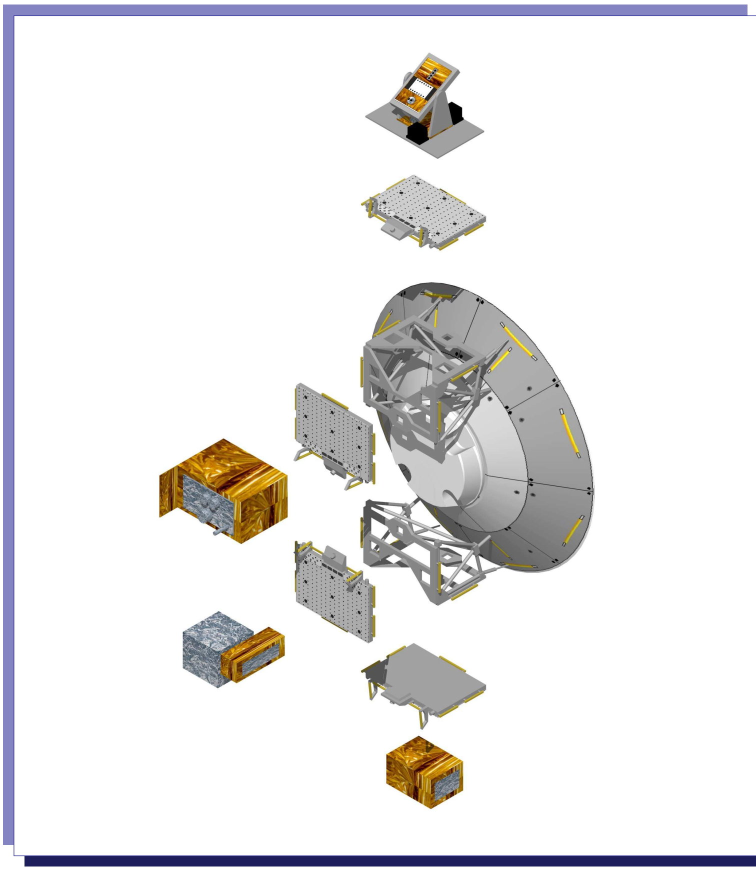

Figure 7-32: Exploded view of Columbus External Payload Facility (CEPF) on the Columbus starboard end cone

The accommodation locations are such that one faces towards the zenith direction (i.e. directly away from the Earth), one towards the nadir direction (i.e. directly towards the Earth), with the remaining two facing towards the starboard side of the ISS (i.e. perpendicular to the ISS velocity vector).
One of the accommodation structures is shown in a simple graphic in Figure 7-34, and consists of the support structure, two Mechanism Support Plates (MSP) and two passive Flight Releasable Attachment Mechanisms (FRAM). Figure 7-35 shows a more detailed view of one CEPF accommodation structure with passive FRAM and MSP.

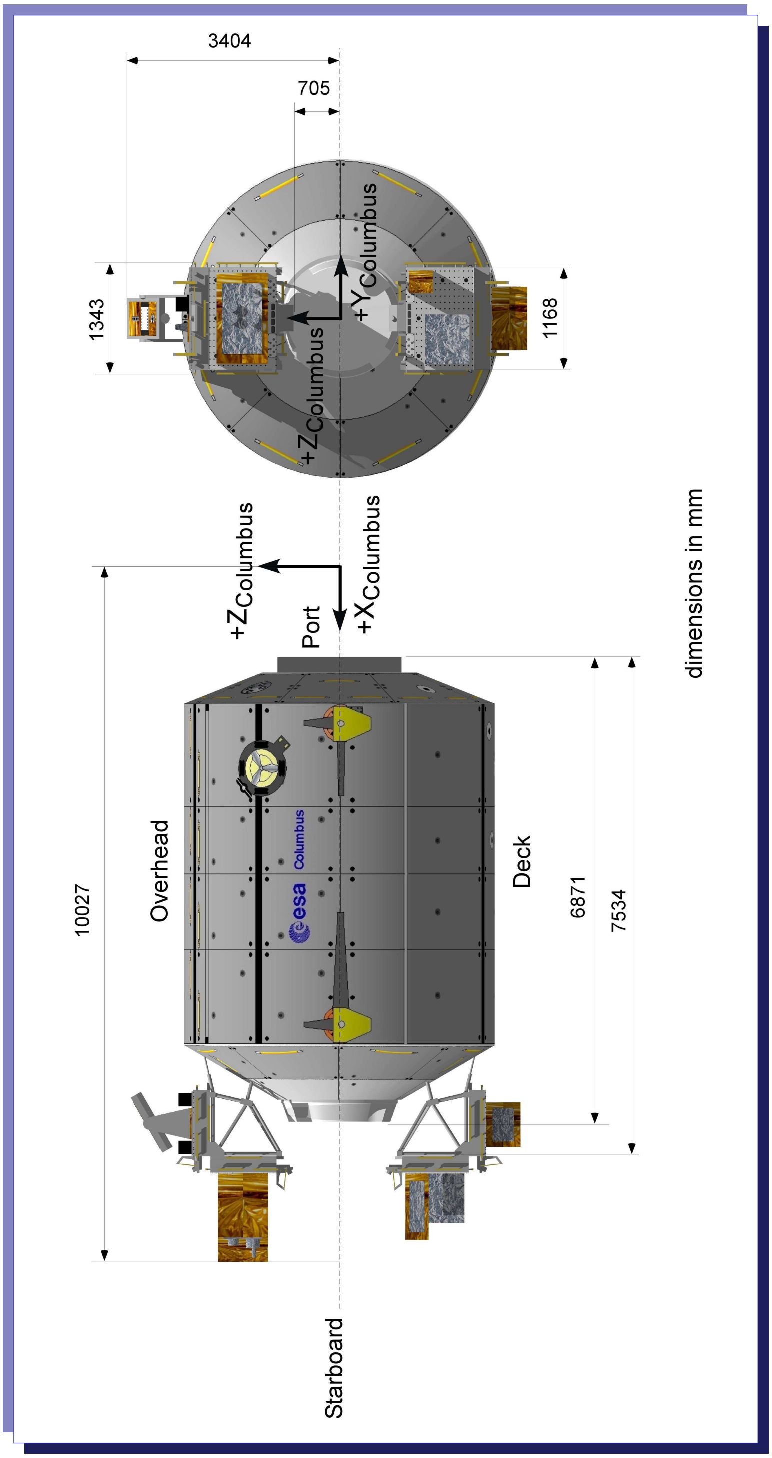

Figure 7-33: Columbus overall envelope with integrated external payloads

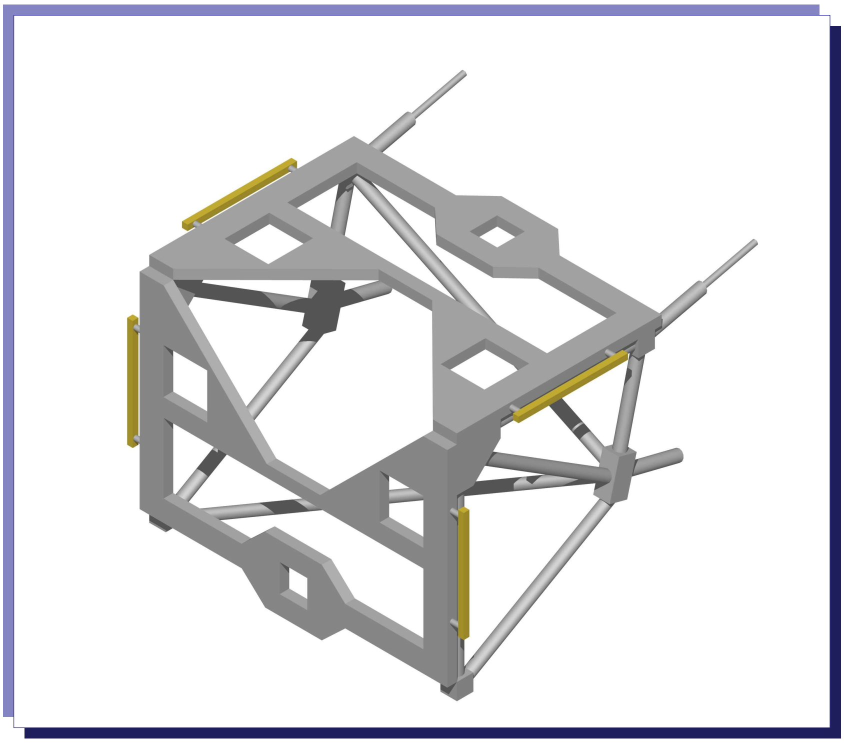

Figure 7-34: CEPF accommodation structure

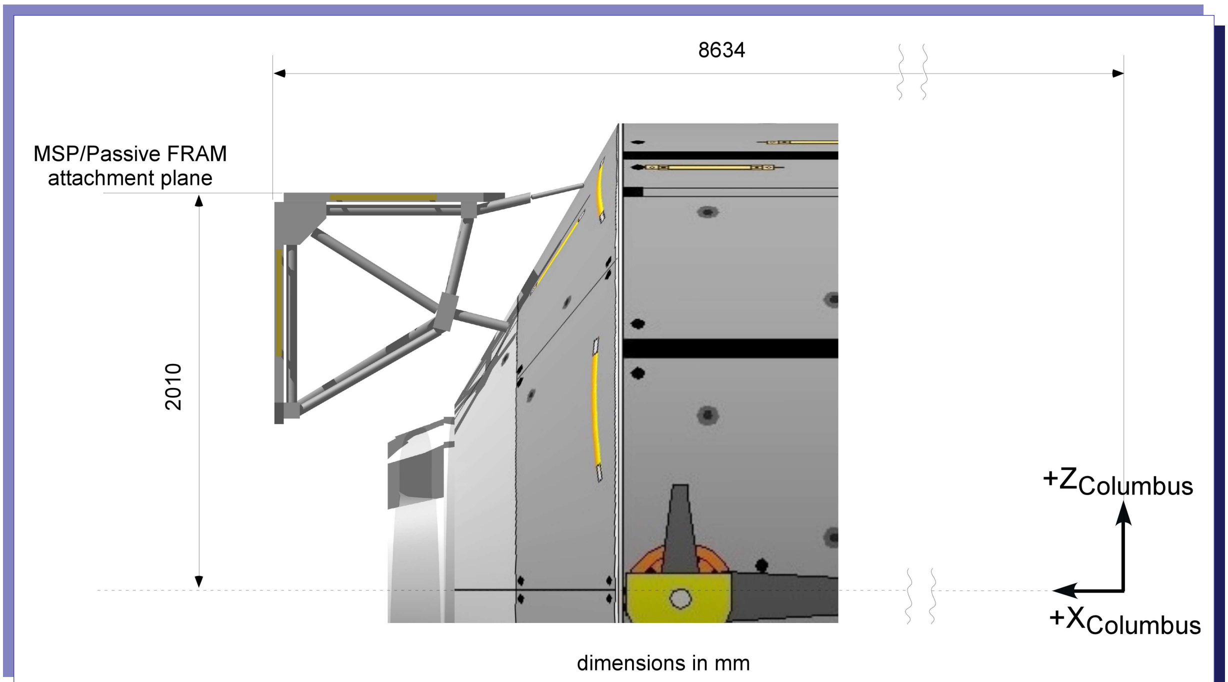

Figure 7-35: Detailed view of CEPF accommodation with passive FRAM and MSP

The primary objective of the FRAM system is to provide a generic means for the accommodation of external payloads. The system consists of an active part and a passive part. The CEPF provides at each of the 4 locations the passive part of the FRAM, while the integrated external payload provides the active part of the FRAM. Figure 7-36 shows the interface plane between an integrated external payload and the Columbus module, with the active and passive FRAM.

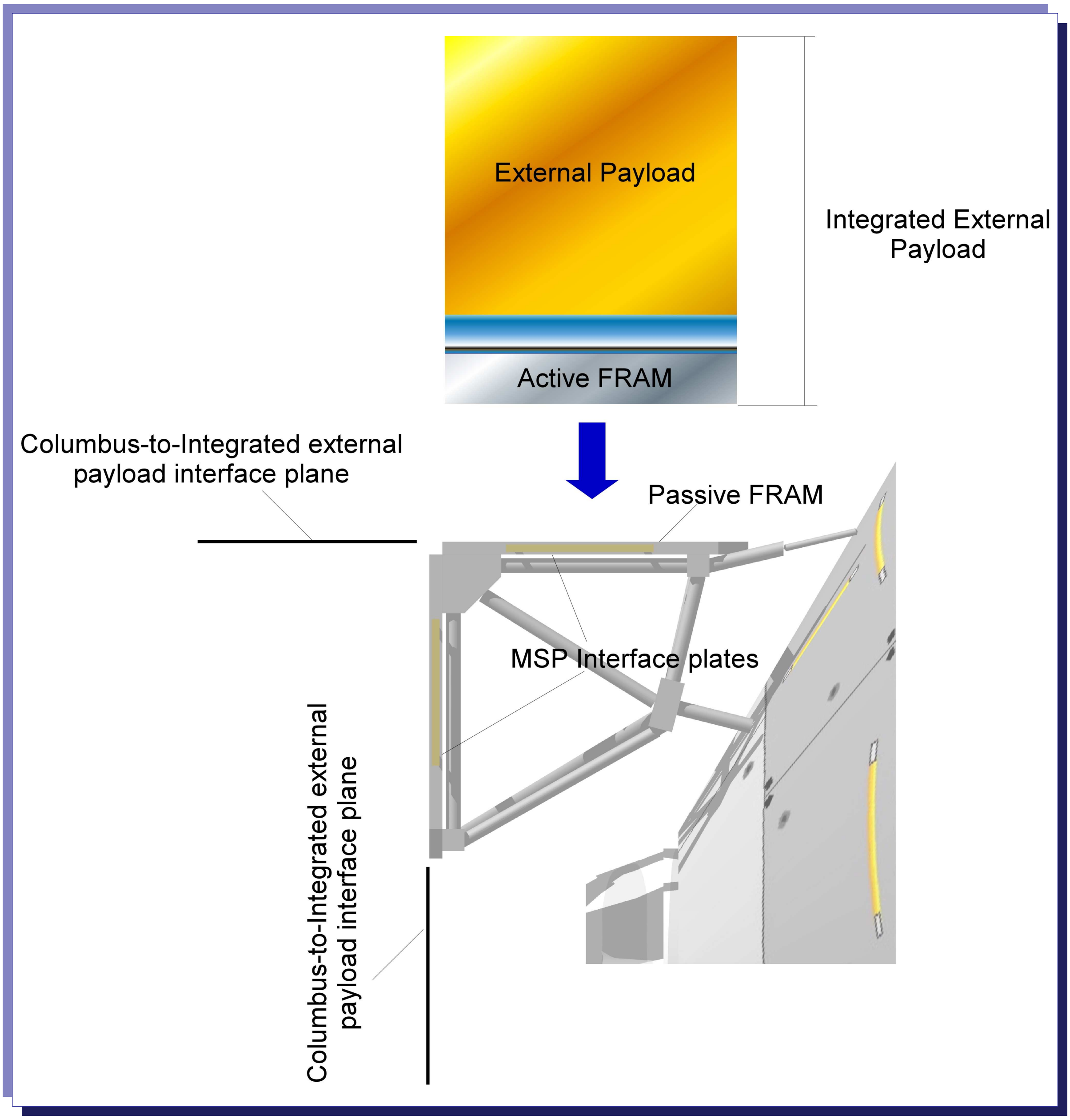

Figure 7-36: External payload/Columbus module interface plane definition

Integrated external payloads will use as a key element, the Columbus External Payload Adapter (CEPA). CEPAs are standardised, removable platforms, which allow the accommodation of external payloads. The CEPA is further described in the next section (7.6.3.1).

7.6.3.1 Columbus External Payload Adapter (CEPA)

The Columbus External Payload Adapter (CEPA) is a mounting plate for Columbus Exposed Facility (CEF) payloads and associated Flight Support Equipment (FSE). It is used in conjunction with the active Flight Releasable Attachment Mechanism (FRAM) to form the CEPA Assembly for transport and stowage aboard the Space Shuttle and Columbus module respectively. Figure 7-37 shows the CEPA Assembly. Each payload with its associated FSE is installed on the CEPA Assembly according to the requirements identified in each payload specification. The CEPA Assembly provides an interface to accommodate a wide variety of CEF payloads for transport to the ISS aboard the Space Shuttle.

In order to accommodate a wide variety of payloads, the CEPA Assembly provides standard mechanical and electrical/data interface features. In addition, the CEPA Assembly provides standardised structural, electrical bonding, and ground support equipment interfaces. The CEPA Plate configuration provides the required interfaces for integration with the active FRAM. Each active FRAM is a moving mechanical assembly which consists of close tolerance, precision machined components, attached to the bottom of an adapter plate. In order to ensure that these components are properly assembled and function as specified, the CEPA Assembly is subjected to acceptance testing consisting of functional, thermal vacuum, and vibration testing. As a result, once acceptance testing is successfully completed, the CEPA Plate should not be disassembled from the active FRAM without successfully repeating the acceptance testing.

Each payload has unique requirements specific to the subject payload. Each CEPA Assembly has a generic interface bolt pattern to allow mounting of payload/payload FSE hardware including EVA aids, heater mats, electrical connector savers and mounting brackets. The payload is integrated to the adapter plate assembly using the payload unique attachments and/or FSE to form the payload integrated assembly. The payload integrated assembly is mounted to a Passive FRAM located on a carrier for launch. Payload specific adapter plates may be developed for use with the active FRAM when it is determined the CEPA Plate configuration cannot meet specified Integrated Payload performance requirements. The CEPA Assembly envelope with dimensions is shown in Figure 7-38.

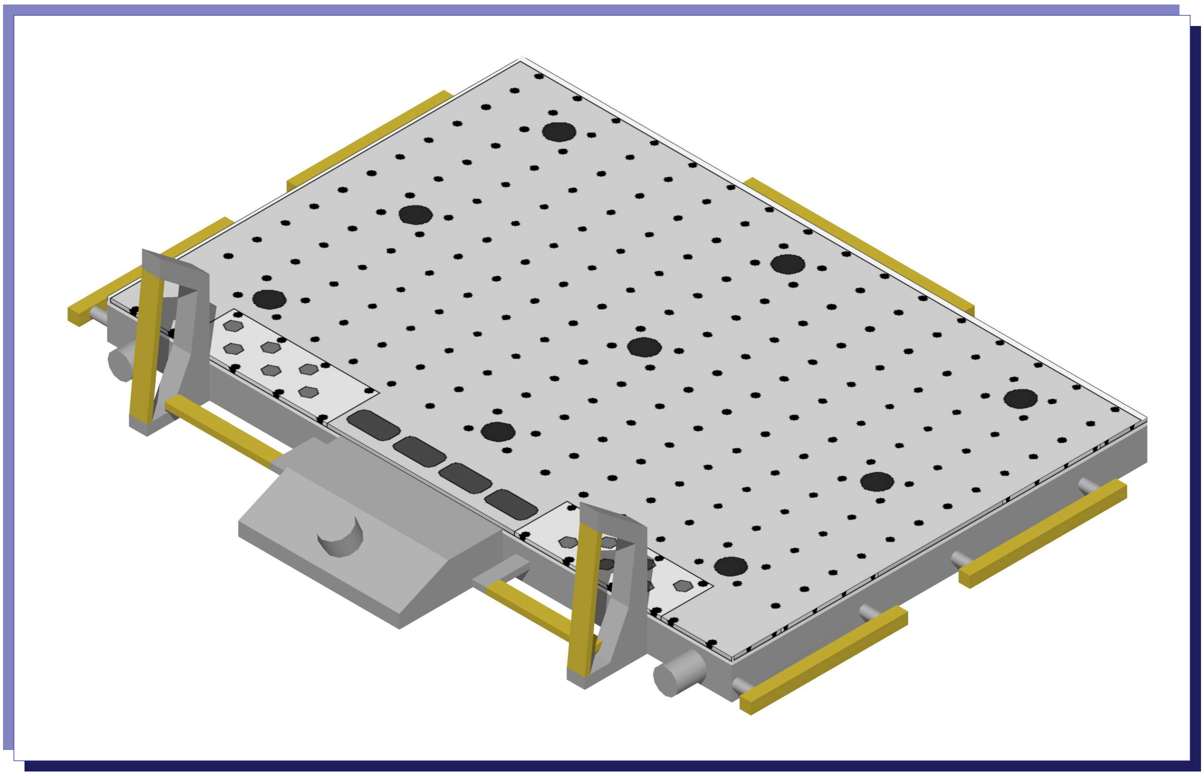

Figure 7-37: Columbus External Payload Adapter (CEPA) Assembly

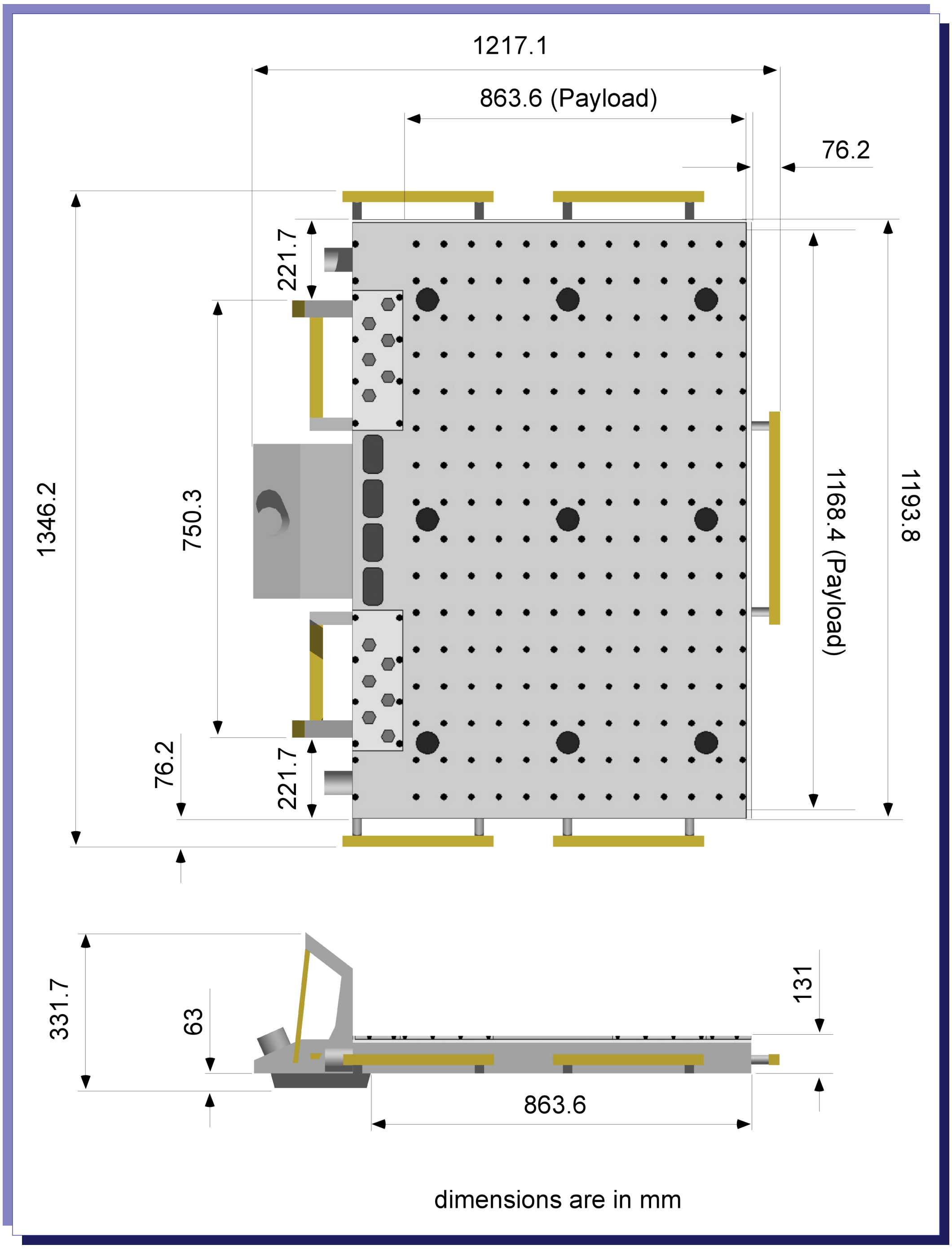

Figure 7-38: CEPA assembly envelope

7.6.3.2 CEPF Integrated External Payload Configuration, Interfaces and Resources

The following table (Table 7-27) summarises the principal Columbus to external payload system interfaces and characteristics. The interfaces of the CEPF include mechanical attach and guidance mechanisms which support the interchangeability by means of Space Station Remote Manipulator System (SSRMS) operations.

Table 7-27: Columbus to external payload system interfaces

INTERFACE/RESOURCE/CONFIGURATION	DESCRIPTION
Integrated external payload on-orbit mass	≤ 290 kg (including CEPA and active FRAM)
Integrated external payload envelope, including active FRAM (Figure 7-39)	1.39 m^3 (width = 1168 mm, height = 1375 mm, depth = 864 mm)
Thermal differences	The integrated external payload shall be thermally conditioned to a temperature in a range between –62 °C to +36 °C to assure the mechanical functionality of the active and passive FRAM design during berthing and unberthing
Power	Columbus will provide a maximum of 1.25 kW per CEPF location; the total for all four external payloads will be limited to 2.5 kW. Each CEPF location is connected to two 120 Vdc power feeders, each with a maximum allocation of 1.25 kW.
Commands to external payload	❑ 3x 28VDC Pulse Command Lines from module per EPF Location ❑ 3x 5VDC Level Command Lines from module per EPF Location
Discrete Data from external payload	❑ 3x Contact status Lines to module per EPF location ❑ 3x Active Driver Inputs to module from each EPF Location
Analogue measurements	❑ 2x Analogue Signals to module from each EPF Location ❑ 2x Analogue Temperature Measurements to module Location from each EPF Location ❑ 2x Analogue Current Measurements to module from each EPF Location
Standard Payload 1553B Bus Interface	Extension of US Lab MIL–STD–1553B payload Data Buses
Specific Columbus Payload 1553B Bus Interface	Extension of Columbus Specific MIL–STD–l553B payload Data Buses supporting 2 remote terminals per payload position
External payload computer serial interface	Connection from Payload Laptop and Programming Panel to External Payload Computer
Columbus specific local area network (LAN)	❑ 2 x TSP (Twisted Shielded Pair cables) connections ❑ ISO/IEC 802–3 (Ethernet standard) ❑ 10Base-T (Twisted Pair wire supporting Ethernet's 10 Mbps) ❑ Columbus Payload Telemetry ❑ Payload–to–Payload communication
US Payload Local Area Network (LAN) (extension into Columbus only, non–redundant)	❑ 2 x TSP (Twisted Shielded Pair cables) connections ❑ ISO/IEC 802–3 (Ethernet standard) ❑ 10Base-T (Twisted Pair wire supporting Ethernet's 10 Mbps) ❑ US Payload Telemetry
Columbus High Rate Data Link	Connection to Columbus Video/Data Processing Unit (VDPU) to transmit payload data with rates up to 100 Mbps

There is no active thermal control capability available to External Payload Facility payloads (such capability must be provided by the payloads themselves). There is also no water, vacuum, venting, gaseous nitrogen (GN2), Emergency Warning and Caution System (EWACS) or NTSC (National Television System Committee) video capability at these locations.

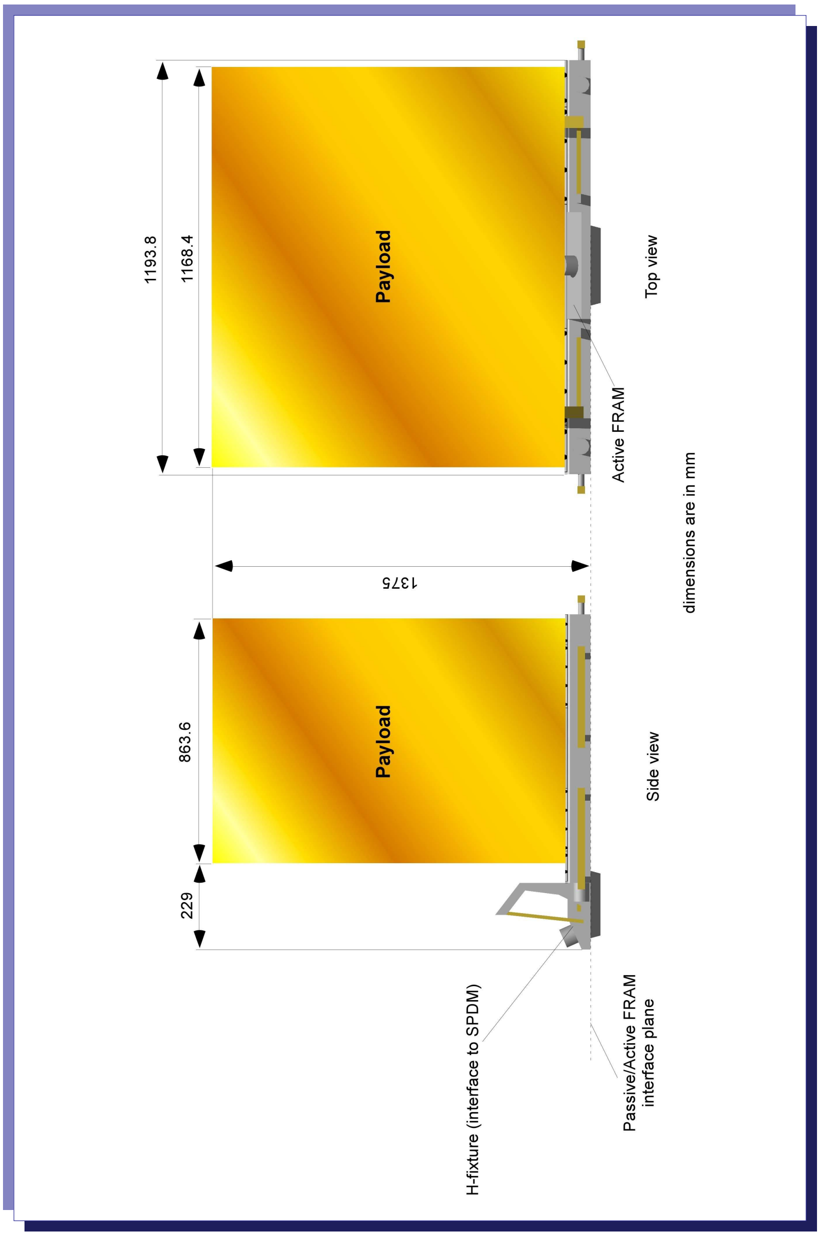

Figure 7-39: CEPF integrated external payload envelope

7.6.4 Other Partner External Accommodations

Besides the European Columbus External Payload Facilities, the ISS also offers other external sites to users. There are a further 14 external sites offered by JAXA and NASA, which are the 10 sites on the Japanese Exposed Facility (F1-F3, A1-A4, U1, U2, O1 – see Figure 7-40) and the 4 sites on the Starboard S3 Truss (S3UI, S3UO, S3LI, S3LO – see Figure 7-41). More information on the JAXA Exposed Facility can be found at the following web site: http://iss.sfo.jaxa.jp/iss/kibo/bakuro_e.html

Users who wish to learn more about the S3 Truss external locations should refer to the following document: SSP57021 Rev. A "Attached Payloads Accommodation Handbook" September 2002.

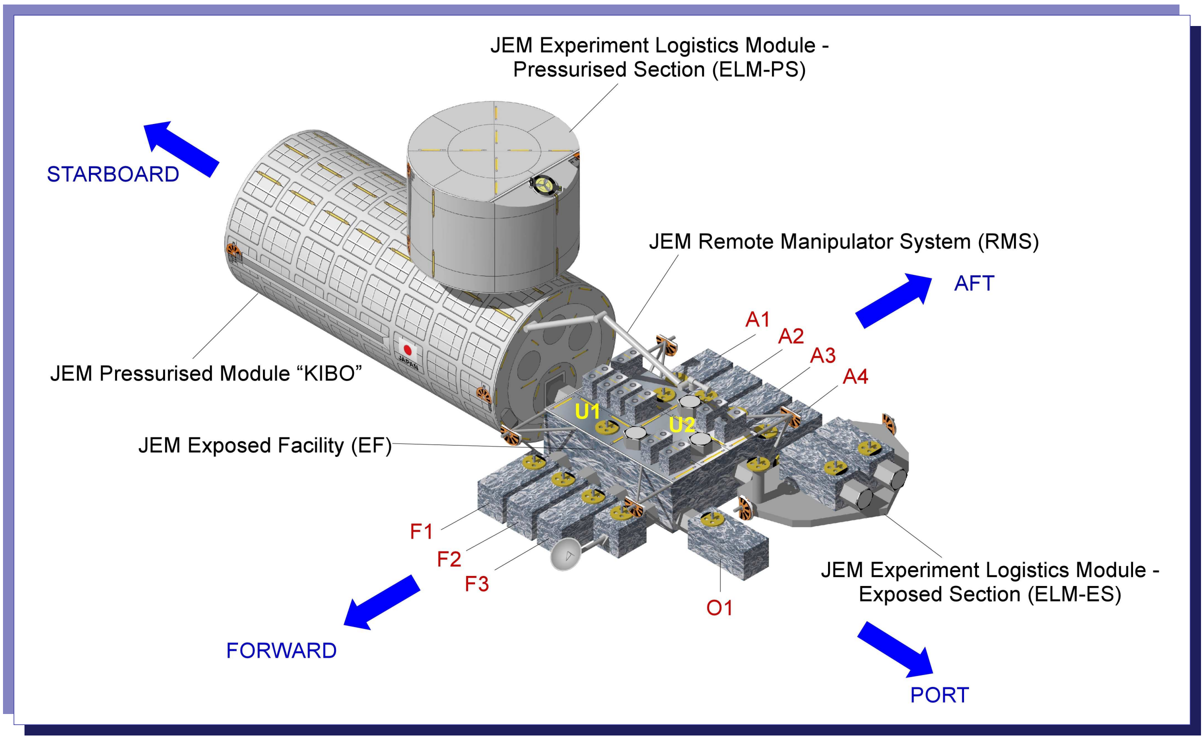

Figure 7-40: External sites configuration on the Japanese Exposed Facility (JEF)

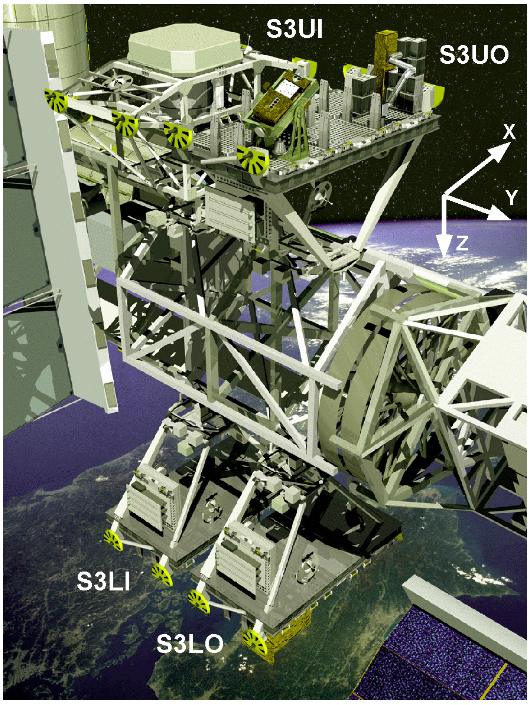

Figure 7-41: External sites configuration on the Starboard Truss (S3) (Image: ESA Ducros)

7.7 ESA Facilities and Payloads

As part of its ISS Utilisation programme, ESA is developing various multi-user facilities, specialised payloads and infrastructural elements. The following tables lists the major facilities, and are divided into three major groups:

- Pressurised (internal) payloads;
- External (unpressurised) payloads;
- Infrastructural support equipment.

Dedicated fact sheets containing overviews and technical data of these facilities can be found in chapter **9** of the Guide. Existing and future fact sheets can be downloaded from the following web site: http://www.spaceflight.esa.int/users/.
In many cases, facilities will be moved from one location to another once new accommodations are made available after the launch of new elements (e.g. Columbus, Kibo), according to the agreements made between NASA and the International Partners. For this reason, only the final location at Assembly Complete is given for each facility.

Table 7-28: ESA Sponsored pressurised (internal) facilities for the ISS Utilisation programme

FACILITY	LOCATION AT ASSEMBLY COMPLETE	ON-ORBIT DATE
BIOLAB	Columbus module	03/2007 (ISS Flight 1E)
European Physiology Modules (EPM)	Columbus module	03/2007 (ISS Flight 1E)
European Drawer Rack (EDR)	Columbus module	03/2007 (ISS Flight 1E)
European Transport Carrier (ETC)	Columbus module	03/2007 (ISS Flight 1E)
Material Sciences Laboratory (MSL)	US Lab “Destiny” module	05/2007 (ISS Flight ULF2)
Fluid Science Laboratory (FSL)	Columbus module	03/2007 (ISS Flight 1E)
European Modular Cultivation System (EMCS)	Accommodated in an EXPRESS rack – US Lab “Destiny” module	09/2005 (ISS Flight ULF1.1)
Muscle Atrophy Research and Exercise System (MARES)	Accommodated in NASA’s Human Research Facility (HRF) – Columbus module	2008
Flywheel Exercise Device (FWED)	Accommodated in NASA’s Human Research Facility (HRF) – Columbus module	TBD
Protein Crystallisation Diagnostics Facility (PCDF)	Accommodated in the EDR – Columbus module	03/2007 (ISS Flight 1E)
Pulmonary Function System (PFS)	Accommodated in NASA’s Human Research Facility (HRF) – Columbus module	07/2005 (ISS Flight LF1)

Table 7-29: ESA Sponsored unpressurised (external) facilities for the ISS Utilisation programme

FACILITY	LOCATION	ON-ORBIT DATE
SOLAR	Columbus External Payload Facility	03/2007 (ISS Flight 1E)
European Technology Exposure Facility (EuTEF)	Columbus External Payload Facility	03/2007 (ISS Flight 1E)
Atomic Clock Ensemble in Space (ACES)	Columbus External Payload Facility	2010
EXPOSE	TBD	TBD
Matroshka	Zvezda external area	01/2004 (ISS Flight 13P)
Global Transmission System (GTS)	Zvezda external area	08/2001 (ISS Flight 5P)

Table 7-30: ESA Sponsored infrastructural support equipment for the ISS Utilisation programme

FACILITY	LOCATION	ON-ORBIT DATE
-80 °C Freezer (MELFI)	Japanese “Kibo” module	09/2005 (ISS Flight ULF 1.1)
Portable Glovebox (PGB)	Various	07/2006 (ISS Flight ATV1)
HEXAPOD	S3 External Location	2010

7.8 Other ISS Partners Facilities

The following sections provides some basic information on the major facilities developed by NASA and JAXA for utilisation onboard ISS. For more details on any of these facilities, users can contact ESA at the following:

ISS Utilisation and Promotion Division (HME-GA)
Directorate of Human Spaceflight, Microgravity and Exploration Programmes
European Space Agency
Keplerlaan 1
2201 AZ Noordwijk
The Netherlands
Tel: +31 71 565 35 17
Fax: +31 71 565 3661

Alternatively, users can directly contact the relative Partner facility responsible at the following:

NASA Facilities

Daniel Hartman
OZ - Space Station Payloads Office Manager
Johnson Space Center
Mail Code AH
2101 NASA Road 1
Houston, TX 77058-3696
USA
Tel: +1 281 244 7048
Fax: +1 281 244-8958
E-mail: daniel.w.hartman@nasa.gov

JAXA Facilities

Kibo Utilization Promotion Office
Japan Aerospace Exploration Agency (JAXA)
E-Mail: kibo-sokushini@jaxa.jp

7.8.1 NASA Facilities

7.8.1.1 Human Research Facility (HRF)

The Human Research Facility (HRF) is a two-rack facility designed to support life sciences investigations using human subjects. HRF Rack 1 was delivered and installed on the ISS during Increment 2 (March 2001). HRF Rack 2 was delivered to orbit during the Return To Flight Shuttle mission to the ISS (LF1) in July 2005.
The HRF 1 is a rack that provides services and utilities to experiments and instruments installed within it. The major pieces of research equipment in HRF Rack 1 are an Ultrasound/Doppler system, a metabolic gas analyser system, a portable computer and a computer workstation for data processing and data communications. A suite of experiment-unique radiation dosimetry equipment will also be stowed in the HRF rack. Investigators using HRF will also have access to the complement of equipment in the Crew Health Care System (CheCS). As an example, the ergometer and treadmill, developed by CheCS for countermeasures, may be utilised in HRF exercise experiments.
For more detailed information users are requested to visit the following website:
http://hrf.jsc.nasa.gov/

7.8.1.2 Microgravity Sciences Glovebox (MSG)

The Microgravity Science Glovebox (MSG), located in International Space Station US Lab Destiny module, is a rack facility enabling scientists from multiple disciplines to participate actively in the assembly and operation of experiments in space with much the same degree of involvement they have in their own research laboratories. Developed by ESA and integrated by NASA, the MSG was launched to the ISS in June 2002. This facility offers an enclosed 255 litre work area and provides a 100,000 level "clean room" sealed glovebox environment that is accessible to the crew through sealed glove ports and to ground-based scientists through real-time data links and video. Because the MSG work area can be sealed and held at a negative pressure, the crew can manipulate experiment hardware and samples without the potential hazard of small parts, particulates, fluids, and gasses escaping into the open laboratory module. Technical data on the MSG can be found in the dedicated fact sheet in chapter **9** of this Guide.
For more information users are requested to visit the following website:
http://msad.msfc.nasa.gov/glovebox/index.html

7.8.1.3 Window Observational Research Facility (WORF)

Installed over the Nadir Research Window, the Window Observational Research Facility (WORF) provides a means of deploying a variety of payloads for conducting geologic, climatologic, atmospheric, and geographic research. The ISS flies over 85 % of the Earth's surface (up to 95 % of the Earth's human population), and flies over a given location approximately every three days, with an identical lighting condition every three months. This pattern provides a tremendous opportunity to observe changes in Earth's surface, oceans and atmosphere on a regular basis.
The WORF design uses existing EXPRESS Rack hardware to minimise both development time and schedule risk. Common EXPRESS hardware includes a Rack Interface Controller box for power and data connection, Avionics Air Assembly fan for air circulation within the rack, rack fire detection, and appropriate avionics to communicate with the ISS data network. The WORF rack provides mounting for payloads, with access to power at 120 or 28 Vdc, uplink and downlink commands at low and medium data rates, and moderate temperature cooling capability for payloads. The interior of the WORF provides for a non-reflective, light-tight environment both to minimise glare off the window, and to allow use of payloads that is sensitive to extremely low energy phenomena such as auroras.
For more information users can visit the following website:
http://eol.jsc.nasa.gov/worf/default.htm

7.8.1.4 Space Station Fundamental Biology Research Facility (SSFBRF)

The Space Station Fundamental Biology Research Facility (SSFBRF) is made up of a series of elements dedicated to on-orbit gravitational biology research, which will be located in the Centrifuge Accommodation Module (CAM). The CAM provides a controlled research environment on the ISS in order to remove any potential interference with vibration-sensitive physical sciences experiments and any impact on living arrangements for the crew. The major elements of the SSFBRF include insect, bird and plant habitats, holding racks, a 2.5 m centrifuge with an artificial gravity range of 0.01 – 2g, a glovebox, and stowage racks.
For more information, users can visit the Space Station Biological Research Project (SSBRP) web site at:
http://brp.arc.nasa.gov/

7.8.1.5 Materials Science Research Facility (MSRF)

The Materials Science Research Facility (MSRF) consists of 3 modular and autonomous Materials Science Research Racks (MSRR-1, MSRR-2 and MSRR-3), which will be the core of materials science research in microgravity on-board the ISS, covering a wide range of fields. The racks will be located in the US Lab "Destiny", and will provide the necessary equipment for both near-term and long-term research. They will contain the common subsystems and interfaces required for the operation of experimentation hardware with full telescience capabilities. The ESA Materials Science Lab (MSL) will be integrated as a part of the MSRR-1.
Users can find more information at the following web sites:
http://msrf.msfc.nasa.gov/msrrfacilities.html and http://msad.msfc.nasa.gov/matsci/msrr1/index.html

7.8.1.6 Fluids and Combustion Facility (FCF)

The Fluids and Combustion Facility (FCF) will made up of two powered racks, the Fluids Integration Rack (FIR) and the Combustion Integration Rack (CIR). The FCF will be located in the US Lab “Destiny” providing a permanent modular, multi-user facility to accommodate sustained, systematic research in the disciplines of fluid physics and combustion science. The two disciplines share racks and mutually necessary hardware within FCF to reduce costs and effectively use ISS resources.

The FIR is designed to be easily reconfigured on-orbit, similar to an optics bench in a scientist's laboratory. The FIR will permit a wide range of fluid investigations from microscopic imaging to particle tracking. The CIR is the only facility on-board the ISS to perform combustion research experimentation.

For further information on the FCF, users can consult the following website:
http://fcf.grc.nasa.gov/

7.8.1.7 Biotechnology Research Facility (BTF)

The Biotechnology Research Facility (BTF) comprises a complement of hardware and science experiments designed to use the unique microgravity environment of low Earth orbit as a tool in basic and applied cell biology research, useful to scientists in fields such as molecular biology, toxicology, pharmacology and bioastronautics. It will be the primary scientific facility for conducting mammalian cell culture, tissue engineering, biochemical separations and protein crystal growth on ISS. The BTF occupies two EXPRESS racks and will be a permanent modular, multi-user facility. The equipment contained by the BTF includes an automated stationary bioreactor, a modular rotating bioreactor, a +4 °C refrigerator, a –80 °C freezer, a –180 °C cryofreezer, a Gas Supply Module, a fluids tray, analytical tools and a high-purity water supply/purification and reagent mixing system.

More information on the BTF can be found at JSCs Biological Systems Office website:
http://slsd.jsc.nasa.gov/bso/collaborate/?viewFile=labfac

7.8.1.8 X-Ray Crystallography Facility (XCF)

The X-ray Crystallography Facility (XCF) is a comprehensive protein crystal analysis facility that incorporates necessary elements for analysing complex macromolecular crystals in the microgravity environment. The XCF supports the preparation of crystals for visual evaluation and mounting, sample freezing, and collection of X-ray diffraction data on selected crystals. As part of its resource allocation the XCF has crystal growth facilities housed in an associated EXPRESS Rack, enabling commercial researchers to grow crystals as well as determine their structures. The integrated capabilities of the XCF enable researchers and scientists to grow samples and obtain structural data on those samples prior to subjecting the crystals to re-entry stress and time-related degradation. Without crew intervention for nominal operations, the proposed system robotically downlinks video of crystal formation to the awaiting scientist. The researcher commands which crystals are to be harvested and prepared for freezing and the X-ray diffraction analysis. The information is stored on board as well as transmitted to the researcher on Earth. The downlinking allows the scientist to review the results and uplink any modifications to the data collection process. Although still manifested to fly on-board ISS, work on the XCF flight project has currently been postponed due to NASA budget shortfalls.

7.8.1.9 Low-Temperature Microgravity Physics Facility (LTMPF)

The LTMPF Facility Class Payload is a complete low temperature laboratory attached to the Japanese External Facility (JEM-EF). There are two identical facilities, each weighing approximately 500 kg and each supporting two experiments in parallel operations. An advanced super fluid helium Dewar maintains a base temperature pre-selected from 1.6 K to 2.0 K for a period of approximately five months. The Dewar insert is configured to best accommodate two experiments. Typically it consists of two sets of thermal-mechanical platforms called the probes. Attached to each probe are the cells and sensors for each experiment. Each probe can have several stages of isolation platforms with separate temperature regulations on each stage to provide the maximum temperature stability. The total allocated weight for both sets of experiment hardware attached to the probes (but excluding the probe mass) is approximately 12 kg or less.

Once on ISS, the experiments simultaneously take data for approximately five months. After cryogen depletion, LTMPF may continue to monitor environments on board the ISS. Each facility is designed to survive five cycles of testing, launch and landing. Taking turns to launch one facility ever 16 months will provide for up to twenty

years of service to experiments that demand an environment of long duration microgravity at low temperature. The LTMPF project is managed by NASA's Jet Propulsion Laboratory (JPL).
For further information regarding the LTMPF, users can visit the following web site:
http://funphysics.jpl.nasa.gov/technical/experiments.html

7.8.2 JAXA Facilities

7.8.2.1 Gradient Heating Furnace (GHF)

The Gradient Heating Furnace (GHF) is a vacuum furnace located in the Kibo module that contains three heating blocks. Their positions and temperatures can be independently controlled, and various temperature profiles can be realised. This facility will be mainly used for high quality crystal growth experiments using unidirectional solidification. GHF has an automatic sample exchange system that can accommodate up to 15 samples to reduce crew operation. The heater temperatures range from 500 °C to a maximum of 1600 °C.
For more information on the GHF, please visit the following link:
http://iss.sfo.jaxa.jp/kibo/kibomefc/ghf_e.html

7.8.2.2 Fluid Physics Experiment Facility (FPEF)

FPEF is a multi-user facility, located in the pressurised Kibo laboratory module, to investigate fluid physics phenomena in a micro-gravity environment. It consists of the core section and the mission section. The core section contains observation equipment, control equipment, and miscellaneous experiment support systems. The mission section, otherwise known as the Experiment Cell, is exchangeable according to the purpose of the experiment. The FPEF's observation capabilities include liquid bridge observation, three-dimensional flow field observations, surface temperature measurement, ultrasonic velocity profile measurement, and surface-flow rate observation.
Technical details of the FPEF are available at the following URL:
http://iss.sfo.jaxa.jp/kibo/kibomefc/fpef_e.html

7.8.2.3 Solution/Protein Crystal Growth Facility (SPCF)

The Japanese Solution/Protein Crystal Growth Facility (SPCF) located in the Kibo Laboratory module is comprised of two modules: the Solution Crystallisation Observation Facility (SCOF) and the Protein Crystallisation Research Facility (PCRF).

The SCOF is an in-situ observation facility containing versatile diagnostics, including a Mach-Zender interference microscope for precise measurements of growth conditions and an amplitude modulation microscope. Interfaces for control and measurement of temperature and pressure, control of the cell stage, evacuation, and N_2 gas supply are available. A Michelson interference microscope and Dynamic Light Scattering are also available as options.
The PCRF contains 6 cell cartridges and allows for 4 different types of protein crystallisation, i.e. vapour diffusion, batch, membrane and liquid-liquid diffusion methods.
Further details on the SPCF can be obtained at the following link:
http://iss.sfo.jaxa.jp/kibo/kibomefc/spcf_e.html

7.8.2.4 Cell Biology Equipment Facility (CBEF)

The Cell Biology Experiment Facility (CBEF), to be integrated in the Japanese Kibo pressurised module, has been developed for various life science experiments such as cell cultivation and plant biology. It consists of an incubator unit and a control and communication unit. The incubator unit includes a µg compartment and a centrifuge that provides gravity control levels between 0.1 and 2.0 g.
Experiment units are placed within containment canisters and installed in the CBEF. The incubator can control temperature, humidity and CO_2 concentration for cultivation, within the following ranges:

Temperature: 15 – 40 °C
Humidity: 20 – 80 % Relative Humidity
CO_2 concentration: 0 – 10 vol %

More technical data relative to the CBEF can be found at the following JAXA link:
http://iss.sfo.jaxa.jp/kibo/kibomefc/cbef_e.html

7.8.2.5 Clean Bench (CB)

The JAXA Clean Bench (CB) provides a closed workspace for aseptic (glovebox) operations with life sciences and biotechnology materials. All materials entering and leaving the work volume pass through a pre-treatment chamber for sterilisation if required. The CB is accommodated in a double ISPR next to the CBEF, and is located in the Kibo module.
For further data relative to the CB users can visit the following web site:
http://iss.sfo.jaxa.jp/kibo/kibomefc/cb_e.html

7.8.2.6 Image Processing Unit (IPU)

The Image Processing Unit (IPU) receives image data from various experiment equipment in Kibo, encodes the data, and then transfers the encoded data to the Kibo system lines. The IPU also records experiment image data on tape when real-time data downlink is not available. The main functions of the IPU are to have various interfaces with the Kibo systems and experiment equipment, to receive and decode 5 channels of independent video signals simultaneously, and to record video signals on tape with five digital VCRs continuously (up to 120 minutes each).
Specific details regarding the IPU can be consulted at the following link:
http://iss.sfo.jaxa.jp/kibo/kibomefc/ipu_e.html

7.8.2.7 Aquatic Habitat (AQH)

The Aquatic Habitat (AQH) is a sub-rack facility that accommodates freshwater and saltwater organisms (such as Medaka fish) inside the Kibo module environment. The facility is designed to accommodate experiments for up to 90 days, making it possible to conduct research ranging from early development and differentiation to individual responses in a microgravity environment.
To read more about the AQH facility users can visit the following JAXA link:
http://iss.sfo.jaxa.jp/kibo/kibomefc/aqh_e.html

7.8.2.8 Space Environment Data Acquisition Equipment/Attached Payload (SEDA/AP)

The SEDA/AP is an external payload, which will be accommodated on the external Kibo Exposed Facility (EF). The objectives of this payload will be to take measurements of the space environment (neutrons, plasma, heavy ions, high-energy light particles, atomic oxygen and cosmic dust) in the ISS orbit. Also, SEDA/AP will be used to study the environmental effects of the space environment on materials and electronic devices on the Kibo EF. In parallel, the SEDA/AP will help verify the JAXA Attached Payload BUS (APBUS) technology, which provides necessary functions to payloads mounted on the Kibo EF.
Further information on the SEDA/AP can be found at the following web site:
http://iss.sfo.jaxa.jp/kibo/kibomefc/seda_ap_e.html

7.8.2.9 Monitor of All-sky X-ray Image (MAXI)

MAXI is an external facility mounted on the Kibo EF and consists of highly sensitive X-ray slit cameras for the monitoring of more than 1000 X-ray sources in space over an energy band range of 0.5 to 30 keV.
More details on the MAXI facility can be consulted at the following link:
http://iss.sfo.jaxa.jp/kibo/kibomefc/maxi_e.html

7.8.2.10 Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES)

The SMILES external facility accommodated on the Kibo EF is a submillimeter-wave limb-sounding spectrometer operating in the 640 GHz band for observing spontaneous radiation emitted by trace gases and particles within the stratosphere. It is aimed at being a demonstration of submillimeter sensor technology based on a superconductive mixer and a 4 Kelvin mechanical cooler.
A more detailed overview of the SMILES payload can be found at the following JAXA URL:
http://iss.sfo.jaxa.jp/kibo/kibomefc/smiles_e.html

7.9 User Support and Operations Centres (USOCs)

The ISS Programme consists of two major components, which are termed “space segment” and “ground segment” respectively. The space segment refers to the on-orbit ISS elements (including the vehicles that service the ISS), and the ground segment includes all of the ground-based facilities that support the activities involved in the Payload Lifecycle. Based on a decision made by the Manned Space Programme Board in 1998, ESA decided to adopt a decentralised infrastructure for the operation of European payloads on board the ISS, based on the concept of User Support and Operations Centres (USOCs).

Under the overall management of ESA, the European USOCs carry out the majority of tasks related to the preparation and in-flight operations of multi-user facilities. USOCs are based on already existing national user centres. This approach makes the USOCs instrumental for the implementation of the ISS ground segment for payload operations preparation, real-time data dissemination and provision of instantaneous experiment command processing. The USOCs will act as a link between the user community and ESA's ISS utilisation organisation. With the discipline-oriented USOCs distributed over Europe (see Figure 7-42), it is ensured that focal points for the preparation and conduct of ESA payload operations are created, which are both very close to the payload operations on board the ISS and the scientific user groups on the ground.

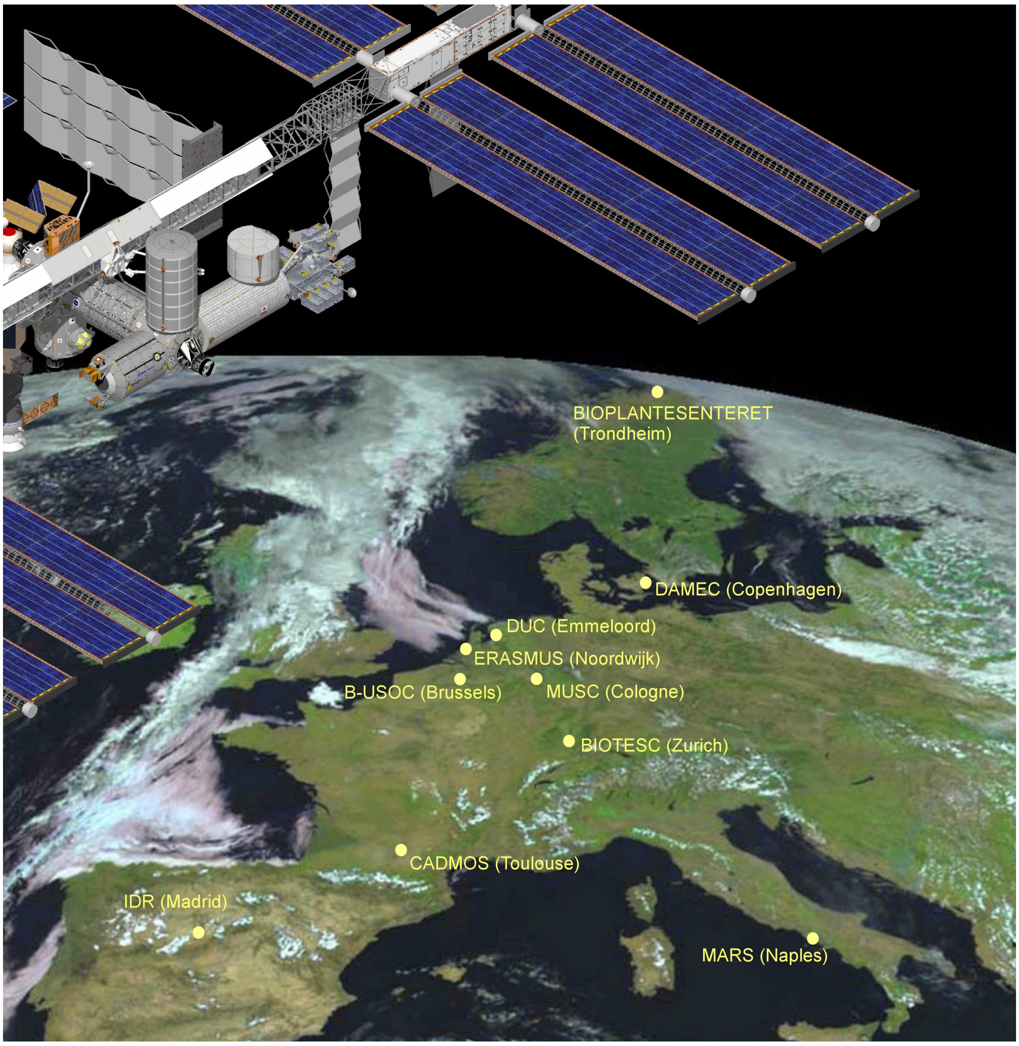

Figure 7-42: Geographical distribution of European USOCs

Depending on the scope of the task assigned to a USOC, there exist three basic levels of responsibility:

- **Facility Responsible Centre (FRC):** A centre that is delegated the overall responsibility for a specific multi-user rack level facility. Its functions focus on payload systems aspects and are related to all phases of payload operations, i.e. pre-flight activities, in-flight operation and post-flight activities. During the on-orbit operations phase, the FRC will operate the facility and assist scientists in their payload operations, and with ground control experiments;
- **Facility Support Centre (FSC):** A centre that is delegated the responsibility for a sub-rack facility (e.g. facility insert, experiment container, drawer payload, a bioreactor);
- **Experiment Support Centre (ESC):** A centre that is delegated the responsibility for single experiments either as self-standing experiments utilising experiment specific equipment or as individual experiments performed in a facility. The ESC mainly focuses on science and experiment operational matters.

The associated Support Centres (FSCs/ESCs) will support FRC payload operations with a defined potential for interactions and collaborations.

In addition, for specific experiment operations, dedicated User Home Bases (UHBs) will be set up if required. UHBs, which are the “home” locations of the scientists, are typically national institutes (e.g. universities), who need to set-up the adequate communication and data processing infrastructures that allow real-time data monitoring and control of the respective experiments (e.g. for remote operations). The establishment and verification of UHBs will typically be done on an increment basis. The FRCs will coordinate and support this setup, and be the focal point for the operations preparation activities for the UHB, in particular for the definition of experiment operations requirements, the specifications of hardware and software, and the connectivity requirements of the UHB to the ISS ground segment.

Apart from its defined technical and operational responsibilities resulting from the assignment to a payload, a USOC – as a national institution – also forms a user information Centre for national users to which central information is supplied by the Erasmus User Centre (EUC) at ESA Noordwijk. In this context a USOC contributes to the identification and familiarisation of potential user groups, with the objective to attract more scientific and commercial users to the ISS.

7.9.1 USOC Assignments

The following table (Table 7-31) summarises the USOCs (FRCs and FSCs only) and their current assignment of facilities as at end 2003:

Table 7-31: Assignment of USOCs to Payloads

FACILITY	FACILITY RESPONSIBLE CENTRE (FRC)	FACILITY SUPPORT CENTRE (FSC)
Pressurised Rack Level Facilities (Class 1)		
BIOLAB	MUSC (Cologne)	BIOTESC (Zurich)
EDR	ERASMUS (Noordwijk)	DUC (Emmeloord) B-USOC (Brussels)
EPM	CADMOS (Toulouse)	DAMEC (Copenhagen)
FSL	MARS (Naples)	Ins. Da RIVA (Madrid)
Pressurised Sub-Rack Level Facilities (Class 2)		
EMCS	BIOPLANTESENTERET (Trondheim)	
MSL-SQF	CADMOS (Toulouse)	MUSC (Cologne)
MSL-LGF	MUSC (Cologne)	CADMOS (Toulouse)
PCDF		B-USOC (Brussels)
PFS		DAMEC (Copenhagen)
External (Unpressurised) Facilities		
SOLAR	B-USOC (Brussels)	
EuTEF	ERASMUS (Noordwijk)	
ACES	CADMOS (Toulouse)	
SPORT	MARS (Naples) MUSC (Cologne)	

7.9.2 USOC Tasks and Responsibilities

The tasks for which the USOCs are responsible can be summarised as follows:

- Facility and experiment operations preparation, validation, and execution;
- Payload increment planning and inputs to the overall mission/increment/partner plan;
- Operations feasibility and science samples bread-boarding with the Scientific Reference Model (SRM), collecting science requirements for experiment and payload upgrades;
- Scientific experiment preparation and operation validation on SRM/EM (Engineering Model) including validation of payload increment timelines, increment procedures and payload data base;
- Consolidated planning in coordination with Industry for ground model utilisation (SRM/EM/EGSE) for increment preparation;
- Provision of science/sample based parts to experiment safety data packages, experiment qualification and validation testing, experiment ground and launch site processing;

- Update of the Payload Operations Data File (PODF), operations scenarios with associated centres (FSCs, ESCs and UHBs), validation and interface testing of ground segment (in particular with the Columbus Control Centre (Col-CC), FSCs/ESCs/UHBs), experiment ground operations products for launch items;
- Experiment training requirements and procedures, astronaut training support for experiment operations (including instructors), familiarisation of scientists;
- Ground rules and constraints, issue of planning and re-planning requests, inputs to short-term-plan, timeline and ground data flows;
- Real-time operations management and re-planning for payload and experiment execution, payload team co-ordination, flight anomalies reporting, console logs, payload data processing, ground based (parallel) experiments on SRM/EM;
- Early retrieval and late access activities, configuration control of experiment ground models (e.g. ground experiment containers), SRM configuration control.

7.10 Legal Aspects

This section summarises the main legal issues concerning the utilisation of the International Space Station.

7.10.1 Legal Framework

7.10.1.1 General Principles

Space law regulates the conduct of the activities of humankind in outer space by both governments and private individuals. Generally speaking, the law of outer space can be divided into two interactive areas:

- The international space law, which governs the activities of States and international intergovernmental organisations;
- The national space law, which governs the activities of individual countries and their nationals.

Since the establishment of the United Nations Committee on the Peaceful Uses of Outer Space in 1958, five major international treaties and conventions have been negotiated and ratified by countries around the world. A growing number of bilateral and multilateral treaties also address space activities.
One of the most important principles of space law is the fact that no part of space is subject to national appropriation. The United Nations space treaties specifically declare space to be open to all countries, similar to the high seas or the deep seabed. This means, in effect, that no one can own any portion of space.
Another important principle of space law provides that any object sent into space (e.g. launcher, station parts, etc.) keeps the nationality of its owner. Each Space Shuttle for instance, is registered as an American object each time a Shuttle is launched.
In the case of the International Space Station, we have a unique assemblage of national objects in space. The American components of the station (e.g. Destiny laboratory) are linked with European, Russian, Canadian and Japanese components, all of which will keep their nationality, according to international space law.

7.10.1.2 Space Station Agreements

The five Space Station Partners - who are the United States, Europe, Canada, Japan and Russia - have come up with a unique legal framework to work together while protecting each other's interests. They have not created a new set of laws applying in outer space, they have rather made links between the Station and their territory so as to authorise the application of their national law to a given situation. The Space Station Partners have created three different types of agreements:

- First, the governments involved in the Space Station project have signed an international treaty on 29 January 1998, formalising their participation (see 7.1.1). The Space Station Intergovernmental Agreement often referred to as "the IGA" establishes "*a long term international co-operative framework on the basis of genuine partnership, for the detailed design, development, operation, and utilisation of a permanently inhabited civil Space Station for peaceful purposes, in accordance with international law*" (Article 1). The Intergovernmental Agreement is the main legal document concerning the International Space Station. It creates a unique legislative regime, constituting a set of rules, which recognise and link the national jurisdiction of the Partner States on the Space Station. National laws can therefore be applied to a given situation, in such areas as liability issues, the protection of intellectual property rights, the exchange of goods and data and even criminal matters.

- A second level of agreements in the Space Station legal framework involves the space agencies of the participating governments. The governments who have signed the Space Station Intergovernmental Agreement have delegated responsibilities to their respective space agencies to do the actual co-operative work of building, operating and utilising the Space Station. NASA as the Space Station coordinator, has signed bilateral agreements with each co-operating Agency (ESA – representing Europe, CSA – representing Canada, RKA (now Roscosmos) – representing Russia, and NASDA (now JAXA) – representing Japan). Those four bilateral agreements, called Memoranda of Understanding (or "MoU"), describe in detail the roles and responsibilities of the agencies in the design, development operation and utilisation of the Space Station. In addition, those documents serve to establish the management structure and interfaces necessary to ensure effectively the operation and utilisation of the Space Station. The space agencies have also agreed to use, when necessary, Bartering Agreements. Those bilateral agreements allow the exchange of Space Station resources between the Partners under certain conditions.

- Finally, the co-operative space agencies have created a third level of Space Station agreements. This level is constituted by various bilateral Implementing Arrangements between the space agencies, which have been created to implement the Memoranda of Understanding. They distribute concrete guidelines and tasks among the national agencies.

7.10.1.3 Extension of National Jurisdiction to the Space Station

As mentioned above, international space law provides that any object sent into space (e.g. launcher, station parts, etc.) keeps the nationality of its owner. For the Space Station the jurisdiction relating to the activities conducted on the Station is determined by the nationality of the module in which the activity takes place. Basically, the Intergovernmental Agreement allows the Space Station Partner States to extend their national jurisdiction into outer space, so the elements they provide (e.g., laboratories) are assimilated into the territories of the Partner States.
The basic rule is that *"each partner shall retain jurisdiction and control over the elements it registers…and over personnel in or on the Space Station who are its nationals"* (Article 5 of the Intergovernmental Agreement).
This means that the five owners of the Space Station are responsible for the respective elements they provide. The extension of the national jurisdiction of the countries they represent, determines what laws are applicable for activities occurring on their elements of the Space Station (e.g. American law in the American Destiny module). The European Partner States are being treated as one homogenous entity, called the European Partner on the Space Station. But any of the European Partner States may extend their respective national laws and regulations to the European elements, equipment and personnel.

7.10.2 Intellectual Property

7.10.2.1 Protection

One of the most delicate legal matters concerning the utilisation of the Space Station is the protection of intellectual property rights. The main objective of the Space Station Partners concerning property rights is to avoid the infringement of rights owned by another Partner or their affiliates (e.g., industrial contractors, customers).
In order to mitigate the risk of potential infringement, the Space Station Partners have agreed to create specific marking procedures to protect the proprietary and confidentiality of each other's data and goods. But the Space Station customers should be aware that those procedures have to take into account the obligation the Partners have to exchange specific technical data and goods, when necessary, to operate and utilise the Space Station in a safe manner (Article 19 of the Intergovernmental Agreement). Therefore, each space agency and its affiliates - any industry or academic institution under contract - have the obligation to mark their technical data or goods with a notice that indicates any specific conditions regarding how those data or goods may be used by other agencies, their contractors and subcontractors.
Basically, a Space Station customer under contract with the European Space Agency has the right to confidentiality and will benefit from the marking procedures. The rules take also into account the protection of third-party intellectual property rights. Any third party proprietary data, which may be required in order for the Partners to carry out their responsibilities, or which may be derived from an experiment, will also be properly marked and protected.
The following guidelines have been agreed on by the Partners in order to protect intellectual property rights:

- Space transportation: each Partner has to respect the proprietary rights and the confidentiality of properly identified and appropriately marked data and goods to be transported on its space transportation systems (e.g., Space Shuttle, Soyuz) (Article 12 of the Intergovernmental Agreement)

- Communications: Each Partner has to respect the proprietary rights of the utilisation data passing through its communication systems, including its ground network and the communication system of its contractors, when providing communication services to another Partner. (Article 13 of the Intergovernmental Agreement)

Regarding crew, a "Crew Code of Conduct" has been agreed on by the Partners in September 2000. It sets specific rules and a chain of command for the astronauts and cosmonauts. Some specific regulations concerning the handling of data and goods by the astronauts have been included in the Code of Conduct, which contribute to protect the intellectual property rights of Space Station customers. According to the Code of Conduct, crew members are required to:

- Protect marked proprietary data;
- Limit the use and disclosure of any technical data and goods to the purpose of performing their assigned tasks;
- Use confidential information obtained in the course of performing their duties only for official purposes and not to further private interest.

If anyhow an infringement of intellectual property were the cause of a claim for damages, legal proceedings would have to be taken against the infringing party. Those claims would be made according to the current international regime for intellectual property and the respective contractual arrangements made between the space agencies and their customers. Because of the particular situation of the European Partner, and to prevent simultaneous claims in multiple European countries, it is provided in the Space Station legal framework that:

- In case an infringement of intellectual property rights relating to a European Space Agency-registered element occurs;
- The owner of that intellectual property has protected his rights in multiple European countries (e.g., through patent and licences);
- He should not be able to recover in more than one European State for the same act of infringement (Article 21 of Intergovernmental Agreement).

7.10.2.2 Ownership and Exploitation

In order to conduct activities using the facilities offered by the Space Station, a contract will be established between the users and the European Space Agency. The ownership of the invention and the type of licensing of any intellectual property - data or product - resulting from the Space Station utilisation will be dependent on the contractual framework.
Generally, the European Space Agency, as an international organisation financed by public funding, is responsible for securing rights for inventions resulting from the contracts it places, and is also responsible for disclosing its own invention to Members States (Article III of the European Space Agency Convention). Therefore whenever an experiment is performed through a contract with the European Space Agency, participants have usually specific obligations concerning patents and licensing issues.
Two main Agency regulations concerning intellectual property that may apply to Space Station customers are:

- **Ownership of invention:** A contractor (e.g., European customer under contract with the European Space Agency) is deemed to be the owner of any invention made in the course of or resulting from work undertaken for the purpose of an ESA contract. He shall be entitled to protect his invention, generally by filing for a patent (Article 37.1 of the General Clauses and Conditions for European Space Agency Contracts);
- **Licensing:** The European Space Agency and its Member States (or Participating States) are entitled to a free of charge, non-exclusive irrevocable licence to use the invention for their own requirements in the fields of space research and technology and their space applications, and are allowed to grant sub-licences for these purposes within the territory of the Member States (or Participating States). (Article 37.2 of the General Clauses and Conditions for European Space Agency Contracts).

Therefore, the ownership of the data resulting from work done on the Space Station and the possibility to get exclusive licenses will be defined by the specific collaboration scheme agreed on by the European Space Agency and its customers.

In the event an invention occurs on the Space Station, the country of inventorship will be determined by the ownership and registry of the Station's element in which the invention has taken place (Article 21 of the Intergovernmental Agreement). For example, an invention made on a US element (e.g., Destiny Laboratory) will be deemed to have occurred in the United States.
This does not impact the ownership of the invention, not does it preclude the right to file for a patent in multiple countries. An inventor may file for a patent in any country he chooses. For example a European researcher inventing a process resulting from his experiment in the Destiny Laboratory (= American territory), may file for a patent anywhere in the world to protect his invention. The purpose of the territorial approach (e.g., American components of the Station = United States territory) is only to determine the location and country where the invention took place.
With respect to the European elements (e.g., Columbus Laboratory), any European Partner State may extend its national law to the European elements and elect to deem the activity to have occurred within its territory. In theory, an invention occurring in the European Laboratory could then be deemed to have occurred in France or Germany. An inventor having used the European Columbus Laboratory facilities may file for a patent anywhere in the world to protect his invention, but he will need to choose one of the European Partner States' territories to determine where his invention originally took place.

7.10.2.3 Liability

Whenever an incident occurs in any field, it is important to be able to determine the responsibilities of the actors involved. Some international legal texts already edict fundamental liability rules concerning space activities (i.e., Liability Convention, 1972), but the Space Station legal framework itself goes a bit further.
The Intergovernmental Agreement establishes a "cross-waiver of liability" which prohibits any of the five Partners or their related entities (contractor, subcontractor, national) to claim against another Partner (or its related entities) for damage sustained as a result of International Space Station activities (Article 16 of the Intergovernmental Agreement).
Each Partner is required to implement this obligation in the contracts with its own contractors and subcontractors. Basically, each Partner and its affiliates, including customers, should assume its own losses with a few exceptions, such as patent infringement.
Any claims arising between a Partner State and its own related entities, will be covered by contracts or subcontracts that will not implicate the other international Partners.
In practice, the Space Station customers will be asked to agree to an inter-party waiver of liability as part of their contract with the European Space Agency, stating that each party will not bring claims in arbitration or sue the other party as a result of International Space Station activities.
In any case, issues such as the applicable law for disputes and the detailed procedures in case of arbitration will be decided mutually by the Space Station customers and European Space Agency. The contract will specify the country where the Arbitration Tribunal shall sit, normally in the country where the customer has his legal seat or where the contract is to be executed.

7.11 Safety And Product Assurance

ESA has established a modular system of Safety and Product Assurance requirements documents for all payloads flying on the ISS. To ensure that safety is designed into the payload the user must perform safety assessments in a systematic and iterative manner beginning in the early project phases. Hazards must be properly identified, classified, controlled and verified for each payload life-cycle stage, including landing, recovery and maintenance. The user must deliver the safety assessment to ESA at the time of the safety reviews and in the form of a technical note complying with the content of the relevant Document Requirement Description (DRD). The initially delivered safety assessment will be progressively detailed and completed as the design proceeds.
As a guideline and reference, users must comply with the fundamental ESA document related to Safety and Product Assurance:

GPQ-010 Issue 2, "Product Assurance Requirements for Payload Projects", June 2003.

The main document is supplemented by specific Annexes that identify unique requirements for:

- Safety and materials;
- Reliability and maintainability.

The requirements applicable in any one instance will depend upon:

- The payload class, i.e. whether at rack or sub-rack level;
- The location of the payload, i.e. whether internal within the pressurised areas, or external, exposed to the space environment;
- The transportation vehicle which carries the payload to/from the ISS (e.g. Space Shuttle, Automated Transfer Vehicle, Soyuz, Progress);
- The relationship between the user and ESA, i.e. whether the institutional or commercial route is followed by the user.

7.11.1 Safety

The payload safety certification process is aimed at ensuring that the payload does not endanger the crew, the ISS, the transportation vehicle/launch vehicle, ground personnel or ground facilities, or any other payload. Successful completion of the associated safety reviews is mandatory to achieve certification of the payload for flight. The main safety and materials requirements documents applicable to internal and external class 1 (rack level) payloads are:

- GPQ-010-PSA-101, "Safety and Material Requirements for ESA Payloads on ISS (internal payloads)";
- GPQ-010-PSA-106, "Safety and Material Requirements for ESA Payloads on ISS (Space Exposed Payloads)".

The safety and materials requirements applicable to internal and external Experiment Flight Equipment (including sub-rack payloads) are:

- GPQ-010-PSA-111, "Safety and Materials Requirements for ISS Experiment Flight Equipment (Pressurised Elements)";
- GPQ-010-PSA-110, "Safety and Materials Requirements for AO Experiment Flight Equipment (Space exposed)".

The complete GPQ series of documents can be downloaded from the website of the Product Assurance and Safety Office of the Department of Microgravity and Space Station Utilisation, within ESA's Directorate of Human Spaceflight, Microgravity and Exploration Programmes. (http://www.estec.esa.nl/gpqwww/home/pasof2.htm).

The user is responsible to implement the safety programmatic and technical requirements and to document compliance. The safety programmatic requirements are defined in the 4 GPQ documents above and in NSTS/ISS

13830 “Payload Safety Review and Data Submittal Requirements for Payloads Using the Space Shuttle/International Space Station”. Safety analyses, including definition of hazard categories, shall be implemented as required by NSTS/ISS 13830.
As a guideline users should also refer to NSTS/ISS 18798B, “Interpretation of NSTS/ISS Payload Safety Requirements”, and JSC 26943, “Guidelines for the preparation of Payload Flight Safety Data Packages and Hazard Reports for Payloads Using the Space Shuttle”.
The Hazard Report form provided in NSTS/ISS 13830 and the “Flight Payload Standardized Hazard Control Report” (JSC 1230), shall be used to document hazard control measures and verifications, as necessary.
The payload safety technical requirements are defined in NSTS 1700.7B, “Safety Policy and Requirements for Payloads Using the Space Transportation System” and NSTS 1700.7B ISS Addendum, “Safety Policy and Requirements for Payloads Using the International Space Station”. Structural designs shall comply with SSP 52005, “ISS Payload Flight Equipment Requirements and Guidelines for Safety Critical Structures”.
All JSC, NSTS and SSP labelled documentation related to safety can be downloaded from the public NASA Payload Safety web site:
http://jsc-web-pub.jsc.nasa.gov/psrp/

Hazard identification and relevant controls must be identified and described in (Ground and Flight) Safety Data Packages. These packages are prepared by the user (or payload developer), with the assistance of the ESA Safety and Product Assurance Office, and submitted for assessment to the safety review process.
Individual payload safety certification reviews are closely associated with the payload design and development milestones. There are three levels of review termed 0/I, II and III, and their development and delivery schedule is linked to the Preliminary Design Review, Critical Design Review and Preliminary Acceptance Review, respectively. During these reviews, the user (or payload developer) presents a brief description of the payload, support equipment and operation, followed by data that is unique to the particular level of review. The depth of the review depends upon the complexity, technical maturity and hazard potential of the payload. In many instances a dedicated meeting is necessary with the Safety Authority (Payload Safety Review Panel).

7.11.1.1 Safety Reviews

The schedule of safety reviews shall be established by the Project Master Schedule approved by ESA, in compliance with the requirements in NSTS/ISS13830. Phase III Safety Reviews shall be completed at least 30 days prior to delivery of flight hardware and/or ground support equipment (GSE). The detailed submittal schedule of safety data packages shall be established by the relevant project review plan. In consideration of the importance of safety both in terms of design compliance with safety requirements and product conformity to the design, the user shall take full responsibility for the following activities:

- Preparation of Flight and Ground Safety Data Packages of good quality and their presentation at Safety Reviews. Corrective measures or action items identified as necessary by the safety review panel shall be readily implemented;
- Performance of the complete safety verification process, including checking and approval of analysis carried out at lower integration level and verification of product conformity to the design and approved configuration. In particular, the user’s PA and Safety Organisation shall witness and/or check the safety related tests and inspections performed either internally or at lower integration level, to ascertain adherence to the requirements, implementation of prescribed conditions and acceptability of results;
- Preparation and submittal of Fracture Control Plan and Structural Verification Plan in accordance with NSTS 14046, “Payload Verification Requirements”, SSP 52005 and ECSS-E-30-01, “Fracture Control”. Delivery at Safety Review Phase III of a Fracture Control Report;
- All safety related tests (e.g. flammability, offgassing, outgassing, etc.) shall be performed at facilities acceptable to ESA;
- The payload design shall allow safe maintenance on ground;
- The ground SDP shall cover flight hardware, GSE and planned ground operations at launch and landing sites. The Ground Safety Data Package shall also cover ground safety for any other site where it is planned to operate the flight hardware and/or its GSE after acceptance by the Agency;
- Performance of the safety assessment of units/models to be operated on ground (e.g. ground unit) and demonstration of compliance with safety regulations that apply at the site of use.

All the ECSS series of documents referred to in the previous paragraphs can be downloaded from the European Cooperation for Space Standardisation (ECSS) website. (http://www.ecss.nl)

7.11.2 Materials

Materials selection is closely associated with safety and key mission assurance requirements. An agreement between ESA and NASA has baselined the process for the selection and certification of materials used in the construction of payload hardware for use on the ISS (and the Space Shuttle). Implementation of this process by the relevant certifying organisation (i.e. ESA or NASA), ensures reciprocal acceptance by the other Agency Safety Review Panels. The certification documentation must contain the following information:

- Specific identification of hardware used (including top-level part numbers);
- Summary of materials and processes used;
- Reference to any relevant ESA Requests For Approval (in case of deviation or use of new materials).

Materials certification will confirm adequacy with, in particular, reference to:

- Stress corrosion;
- Off-gassing;
- Toxicity;
- Out-gassing;
- Thermal cycling;
- Radiation;
- Flammability.

Initial material selection shall be made following the guidelines of ECSS-Q-70-71, “Space product assurance - Data for selection of space materials and processes” and JSC 09604 (MSFC-HDBK-527F), “Materials Selection List for Space Hardware Systems”.

The following materials constitute a safety hazard and are prohibited from being used without prior approval from ESA:

- Beryllium (for structures);
- Beryllium oxide;
- Mercury;
- Cadmium;
- Zinc;
- Polyvinyl chloride (PVC);
- Radioactive materials.

7.11.3 Reliability and Maintainability

While safety remains the top priority for ISS payloads, reliability and maintainability are also now considered of critical importance.
The ESA policy with respect to reliability and maintainability for rack/facility level payloads is summarised as follows:

- Any item or equipment that may potentially malfunction should be made replaceable on-orbit;
- The risk of a potential malfunction occurring that cannot be recovered through on-orbit maintenance should be minimised in the design of the payload;
- Use of Electric, Electronic and Electromechanical components, screened and from qualified manufacturers, should be used in the design of the payload.

The main reliability and maintainability requirements documents applicable to internal and external rack/facility level payloads are:

- GPQ-010-PSA-102, "Reliability and Maintainability for ESA Research Facilities on ISS" (internal payloads)";
- GPQ-010-PSA-107, "Reliability and Maintainability for ESA Payloads on ISS (On-orbit non maintainable)".

The ESA policy for internal sub-rack/experiment level payloads can be summarised as:

- The prevention of failure propagation outside of the experiment;
- Equipment is maintainable on-ground;
- Use of screened Electric, Electronic and Electromechanical components.

The ESA policy for external experiment level payloads may be summarised as:

- The prevention of failure propagation outside of the payload;
- Equipment is maintainable on-ground;
- Use of quantitative reliability targets to guide the payload design;
- Use of screened Electric, Electronic and Electromechanical components.

The main reliability and maintainability requirements documents applicable to internal and external sub-rack/experiment level payloads are:

- GPQ-010-PSA-108, "Reliability and Maintainability for Experiment Flight Equipment (ISS Pressurised Modules)";
- GPQ-010-PSA-109, "Reliability and Maintainability for AO Experiment Flight Equipment (Space Exposed) ".

Users should also refer to the following documents for maintainability aspects:

- GPQ-MAN-04, "Safety Centered Maintainability for ISS Payloads – Maintainability Handbook";
- GPQ-MAN-05, "Safety Centered Maintainability for ISS Payloads – Maintenance Planning Guideline for ISS Payloads".

For any further information regarding safety and product assurance aspects, users should contact the ESA ISS Product Assurance and Safety Responsible:

Tommaso Sgobba
Product Assurance and Safety Office
HME-GQ
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7.12 Payload Planning

The payload planning includes all the preparation activities in which the user's research objectives are defined and coordinated with other research payloads and the ISS systems and operations. ESA is currently consolidating its planning, integration and documentation processes, which are based on the experience gained during Russian flight opportunities as well as the NASA processes in place today. The following represents the latter, but will be updated in future revisions of this Guide with the ESA specific processes once they are finalised.

Before discussing the ISS planning process, it is important to be familiar with the terms that are used to reference planning timeframes. These terms are as follows:

- **Increment (I)** - This is the period of time between the launch of a vehicle carrying an exchange crew to the ISS, and the undocking of a vehicle for return of that crew. The length of an increment ranges anywhere from 3 months to about 6 months.

- **Planning Period (PP)** – This period spans approximately 1 calendar year, but is tied to the beginning and end of ISS increments, so usually does not begin on January 1st. There are usually multiple increments in a Planning Period.

- **Expedition** - This covers the same timeframe as an increment but is used when referring to the ISS crew serving during that increment.

- **Launch (L)** – As it suggests, this refers to the day of launch of a payload.

The ISS planning cycle is made up of 4 phases:

- Multi-Increment Planning (or Strategic Planning);
- Tactical Planning;
- Pre-Increment Planning;
- Increment Execution Planning (or Execute Level Planning).

7.12.1 Multi-Increment Planning

Multi-increment planning (also referred to as strategic planning) provides the long-range planning for the ISS Programme and begins approximately 1 year prior to the release of the Consolidated Operations and Utilisation Plan (COUP). The COUP document is a 5-year plan for the Space Station, which defines the system operations and utilisation activities planned for the ISS. For each planning period, it establishes the amount of resources and accommodations allocated and subscribed to each system and each Partner for utilisation. It also reflects the planned amounts of supporting services from other programs that are available and subscribed. The COUP also provides specific direction and guidance to tactical planning regarding COUP implementation. The COUP includes a high level manifest of major items planned for each planning period and is written by the ISS Programme Office.
Multi-increment planning is the multilateral process responsible for defining the ISS assembly sequence, and the resources and accommodations projected to be available at the Planning Period (PP) level, and for establishing the ISS Programme transportation and crew rotation requirements needed for transportation system planning. The planning process begins by performing integrated traffic planning to define the transportation support to the ISS for crew support, maintenance and logistics, utilisation, and consumables re-supply of the ISS. This information is combined with the PP resources, supporting services, and accommodation capabilities of the ISS to develop the Operations Summary (OS) document. The OS serves as the basis for the development of the Composite Operations Plan (COP) and the Composite Utilisation Plan (CUP). The COP and CUP are then used to develop the COUP. The baselined COUP is implemented via the Multi-Increment Manifest (MIM) Document, and the Integrated Payload Mission Model (IPMM). These two documents, which include flight plans for cargo and payloads, provide multi-increment guidance to tactical planning.

7.12.2 Tactical Planning

Tactical planning and manifesting is performed for each increment in a PP. The multilateral process nominally begins 2.5 years prior to the start of an increment, which is nominally 6 months after the release of the COUP. Tactical planning and manifesting is a multilateral function, which defines the resources, allocations, research objectives, priorities, and manifests for each increment (expedition). It also continues the integrated traffic planning begun in the multi-increment planning phase. These requirements are documented in the Flight Programme (FP) and the Increment Definition and Requirements Document (IDRD) series and annexes for a specific increment. The FP defines the ISS tactical programme content and flight definition required to allow consistent planning and resource control. It also documents ISS FP definition history.

The Increment Definition and Requirements Document for Increment X, defines increment condition, resources and requirements as well as flight and stage objectives. This document also consists of several annexes including Annex 1: Station Manifest, which contains the detailed manifest for all transportation vehicles in the increment, and Annex 5: Increment X Payload Tactical Plan, which provides the increment-specific Payload Tactical Plan (PTP) requirements. IDRD products are used to provide Programme direction and initialise development of the cargo/payload integration and execution planning products.

7.12.3 Pre-Increment Planning

The pre-increment planning process begins around 12 months prior to increment start and takes the increment requirements and mission objectives as defined by the relevant Increment Definition and Requirements Document, and translates them into a number of timelines which govern the on-orbit and on-ground activities associated with a particular increment.

The initial phase of pre-increment planning is the Basic planning cycle, which occurs from I-12 months to I-6 months. The Basic cycle places emphasis on the initiation and integration of operations planning for payloads. The last phase of pre-increment planning is the Final planning cycle, which occurs from I-6 months to I-1 month. The Final cycle places emphasis on the integration of payload and systems operations planning.

The main product of the pre-increment planning process is the On-orbit Operations Summary (OOS), which is a high-level activity plan for an entire increment. High-level activities are planned for a specific day of the increment but are not scheduled for a specific time. The OOS establishes the basis from which actual distribution of ISS resources is to be made by providing expected resource availability and environmental conditions throughout an increment, and by identifying constraints and critical events or time periods during an increment. The OOS is also the foundation for the development of the detailed schedules produced during the Increment Execution Planning process (see 7.12.4).

7.12.4 Increment Execution Planning

The increment execution planning process (also known as Execute Level Planning) begins 1 month to 3 weeks before the start of an increment and consists of three phases:

- Short-term planning;
- Real-time planning;
- Real-time re-planning.

7.12.4.1 Short-Term Planning

This is the process through which weekly and daily schedules of systems and payload operations activities is developed and, if necessary, the long-range plan of activities through the rest of the increment is updated. It is performed by an international team of systems and payload planners. The schedule developed during this process is used to define in detail the activities to be performed during the planning cycle. The long-range plan, which, if necessary, is updated during this process, is used as the basis for generating future detailed plans, and covers the time frame from the end of the next detailed schedule through the end of the increment. The main products of short-term planning are the Weekly Look-ahead Plan (WLP) and the daily Short-Term Plan (STP). The WLP is the detailed integrated schedule of activities to be performed during 1 week of Station operations. The WLP includes all ISS activities, including IP systems and payload activities. The WLP is then further refined into daily schedules called STP. In addition to crew activities, STP timelines also include automated onboard activities and ground controller activities, as well as ancillary data such as Station attitude and communications coverage data. Activities in the STP include all the information necessary for execution, including a reference to the procedure associated with each activity. The STP is developed the week prior to its execution and is based on the OOS that was developed during the pre-increment planning phase, as well as the WLP. Development of the STP is performed by a team called the International Execute Planning Team (IEPT), which consists of planning personnel from the IPs.

7.12.4.2 Real-Time Planning

This is the process through which the onboard and ground detailed schedules are developed. It is performed by the international team of systems and payload planners. The detailed schedules developed during this process are used by the ground crew, the onboard crew, and automated systems to identify and control the segment-specific and stationwide payload and systems activities to be performed during the planning cycle. This process generates the Onboard Short-Term Plan (OSTP), which is the integrated plan that is viewed and executed onboard Station. Since it is derived directly from the STP, the OSTP contains all activities to be executed, including crew, ground, and automated activities for the IP segments. Uplinking of new activities to be included in the OSTP occurs daily.

7.12.4.3 Real-Time Re-planning

This the process through which the detailed schedules are updated in real-time to reflect desired or required changes to systems or payload operations. It is performed by the on-console teams in the Space Station Control Centre (SSCC), the Payload Operations Integration Centre (POIC), the IP Control Centres and the Russian TsUP Control Centre. The detailed schedules developed during real-time planning are updated by the real-time re-planning process in response to required or desired changes. Updates to the schedule will be performed to maintain a safe and functional ISS or in response to desired payload operations changes.

7.13 Payload Life-Cycle and Major Milestones

The integration process of a payload and its accompanying milestones will differ according to whether a payload flies on the Russian segment (using Russian resources) or whether it flies on the United States On-orbit Segment (USOS) (i.e. NASA, ESA, CSA, JAXA). These two processes are discussed separately in the following sections.

7.13.1 Russian Segment Payloads

Since October 2001, as discussed in section 7.5.3, ESA has had several opportunities to fly astronauts and payloads to the ISS by means of the Russian Soyuz and Progress vehicles. In most cases, ESA payloads have also been integrated in the Russian Segment of the ISS. There exist healthy prospects for future collaboration between ESA and Russia with regards to ISS utilisation and therefore it is necessary to provide users with a general overview of the integration process involved, which differs from that implemented in the USOS. The experience gained by ESA during collaborative missions with Russia will pave the way towards full European utilisation once the Columbus module is launched.

Users must however bear in mind that the process presented here represents the situation as of April 2005 and can be subject to minor changes on a mission-to-mission basis. This is a result of changes and improvements applied to the process from the lessons learned after each mission, as well as changing ISS planning which is dependent on the evolution of the ISS.

The general overall process schematically represented in Figure 7-43 and summarised in the following paragraphs, refers to the specific case of ESA entering into a contractual agreement with the Russians for a joint mission. The figure also displays the documentation (see 7.14.1) that accompanies the various reviews and milestones. Users must keep in mind that the timeline given is meant as a guide to users and that it represents a generic case: in most situations the actual milestones will vary on a mission-to-mission basis. The timelines in Figure 7-43 are given in months with respect to both a Progress launch (Lp) and a Soyuz launch (Ls).

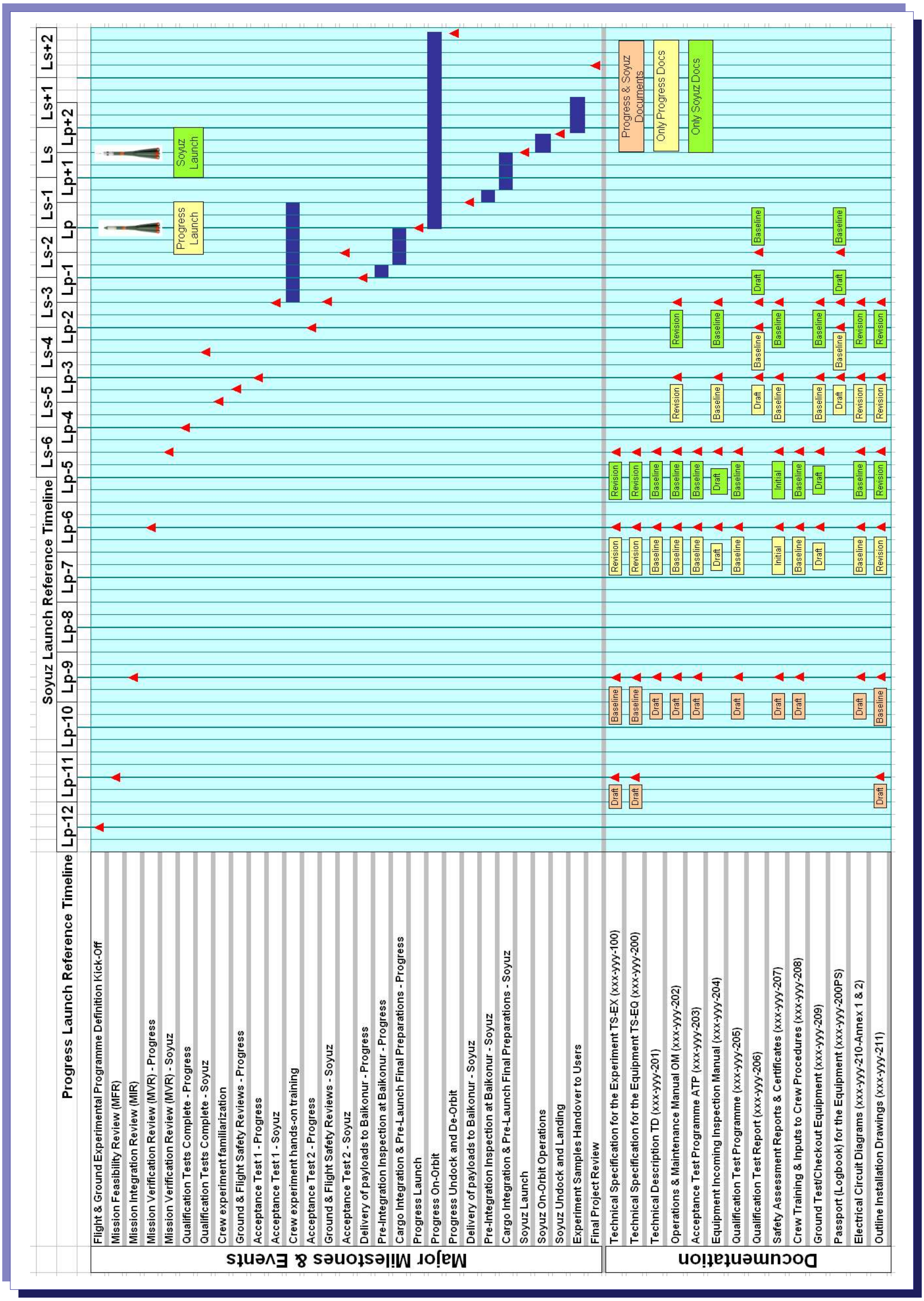

Figure 7-43: Russian Segment Payloads milestones and documentation

The process begins with the Flight and Ground Experimental Programme Definition Kick-Off, where the definition of the individual activities is presented by ESA to the Russian team. The kick-off should generally occur about 12 months before Progress launch, but can, in some cases, occur as late as 6-8 months before launch.

During the entire integration process, the focal points on the Russian and European sides for the integration of the individual activities into the mission are dedicated Payload Integration Managers (PIMs). The PIMs are appointed by ESA and RSC-Energia for the management and control of individual activities. They manage these activities through the mission integration, reviews, verification and certification process.

7.13.1.1 Project Reviews

The project preparation phase is supported by 5 scheduled reviews attended by both ESA and Russian parties to assess technical and programmatic aspects relevant to individual activities and to the overall integrated mission.

7.13.1.1.1 Mission Feasibility Review

Following the Flight and Ground Programme kick-off, the feasibility assessment is conducted by both ESA and the Russian party for all the proposed activities. For each individual experiment the following is achieved:

- Preliminary versions of the documents “Technical Specification for the Experiment” (TS-EX) and “Technical Specification for the Equipment” (TS-EQ) are established and reviewed (see 7.14.1);
- ESA and the investigators/payload developers define and agree the Responsibility and Task Sharing for individual activities. Mission Implementation Agreements are prepared by the ESA PIMs in order to document these agreements. The contents of these agreements include:
    - List of responsible people and contacts
    - Definition of schedule
    - Funding structure
    - Resource requests
    - Assignment of responsibilities
    - Provision of integration equipment
    - Training requirements
- Detailed joint plan of work for both European and Russian parties;
- Finalisation of the Review Plan.

The successful conclusion of the Mission Feasibility Review allows for the development of the preliminary experimental programme, and the finalisation of the ISS Flight Order Contract (IFOC) Annex 6 “Scientific-Technical Programme” and Annex 7 “Basic Data on the Experiments and Equipment”.
The Mission Feasibility Review typically takes place 11 months before the launch of the Progress vehicle, but can in some cases take place as late as 5 months before launch.

7.13.1.1.2 Mission Integration Review

A Mission Integration Review takes place about 9 months before Progress launch, but can be shifted as late as 4 months before the launch. During this review the integration and operation aspects will be reviewed for each individual activity and for the overall integrated mission. The TS-EX and the TS-EQ documents are baselined (see 7.14.1). The Technical Documentation of the equipment is established, while the Crew Training Plan and the Baseline Data Collection Plan are reviewed and finalised.
The successful conclusion of the Mission Integration Review allows for the final manifesting of the individual activities and the continuation of the mission preparation.

7.13.1.1.3 Mission Verification Reviews

The Mission Verification Review is carried out to review and finalise the verification of all the integration and operation aspects for each individual activity for a given flight, while keeping the overall integrated mission in perspective. In addition to the finalisation of the previously established documents, the Equipment Testing Plan is reviewed. Two separate reviews will be held for Progress and Soyuz launches, respectively.
The successful conclusion of these reviews allows the ESA and Russian parties to agree and commit to the testing and acceptance plans and to the continuation of the mission preparation and execution. These reviews are typically

held 6 months before either the Progress or Soyuz launch (depending on the review), but can be shifted as late as 3-4 months before a launch.

7.13.1.1.4 Final Project Review

A Final Project Review is held between 1-2 months after the Soyuz landing. The aims of this review are:

- To determine whether the main objectives stated in the mission specific agreements have been achieved;
- To determine the status of completeness of the mission relevant activities;
- To gather comments, preliminary scientific results and lessons learned from all the parties involved in the mission implementation.

Parties attending this review include:

- The ESA Mission and Integration Team;
- The Russian Team;
- The users;
- The ESA astronaut and back-up astronaut.

7.13.1.2 Equipment Qualification, Testing and Acceptance Processes

For confirmation of conformity to the agreed technical requirements, the equipment intended for installation and operation on board the Russian Segment of the ISS is subjected to a series of pre-flight tests. The test programme includes Qualification Tests and Acceptance Tests, checks of interfaces with other payloads (if necessary), incoming inspection after transportation and, in specially stipulated cases, integrated tests as part of the spacecraft (if necessary), as well as tests at the engineering complex of the Baikonur Cosmodrome before the installation into the launch vehicle. The Flight Models, Training Models and Baseline Data Collection Models are subject to a safety inspection prior to any use by the astronaut/s.

7.13.1.2.1 Qualification Tests

Qualification tests are conducted with the Qualification Model (QM) of each unit of equipment, resulting in the confirmation of their conformity to the requirements laid out in Annex 1 of the IFOC “Description of Complex and General Technical Requirements”. These tests should be completed not later than one month prior to the beginning of Acceptance Test-1 (AT-1) tests (see 7.13.1.2.2).

7.13.1.2.2 Acceptance Tests

Two Acceptance Tests will be carried out during the integration process of equipment for a specific mission. Flight and training equipment is only admitted to the Acceptance Tests if it has successfully passed the Qualification Tests (see 7.13.1.2.1).

- Acceptance Test 1 (AT-1) verifies whether or not the equipment is conformant to the requirements that are specified in the TS-EQ document. Upon completion of AT-1, the consent to ship the equipment to the Russian party will be given. ESA assumes the custodianship of the accepted equipment and takes care of its transportation to Russia as per agreed transportation requirements. Specific transport support equipment will be supplied by the equipment supplier. Separate AT-1 tests will take place 2-3 months before the Progress and Soyuz launches, respectively;
- Acceptance Test 2 (AT-2) applies to the equipment with active interfaces to the spacecraft and to the ISS. It allows the equipment to be tested with the vehicle and Station simulators in order to provide the final verification of those interfaces. The equipment without active interfaces undergo a simplified AT-2, which includes post-delivery inspection. The successful conclusion of the review allows for the acceptance of the flight equipment by the Russian party. The Russians assume custodianship of the accepted equipment and take care of its transportation to Baikonur as per agreed transportation requirements. Specific transport support equipment will be supplied by the equipment supplier. Separate AT-2 tests will take place 1-2 months before the Progress and Soyuz launches, respectively.

The AT-1 and AT-2 results are formalised in Acceptance Tests Certificates.

7.13.1.2.3 Incoming Inspection and Final Preparation

After transportation of the equipment to Moscow and from Moscow to Baikonur, the Incoming Inspection of the equipment is performed in accordance with the requirements specified in the “Equipment Incoming Inspection Manual” (see 7.14.1.6), and will be attended by representatives of all parties involved in the mission. The incoming inspection and final preparation procedure includes:

- Visual inspection of the equipment, including its external inspection and completeness check, and functional check of the equipment procedures. The content of checks for each piece of equipment can be changed, in agreement with the parties, but must include a functional check at rated power supply voltage and a check of electrical insulation resistance;
- Flight readiness check and safety inspection of the equipment directly prior to or immediately after its installation into the spacecraft;
- Completion and signing of the documentation, which reflects the incoming inspection results.

7.13.1.2.4 Pre-Launch Preparation and Final Operations

Upon completion of the ATs, the Russian party conducts activities on the equipment before launch pursuant to the requirements in the documents “Acceptance Test Programme” and “Equipment Incoming Inspection Manual” (see 7.14.1). The Russian party provides the necessary storage conditions for the equipment before and after its installation into the spacecraft.

7.13.1.3 Operations Preparation

The ESA and Russian parties jointly define and implement the experiments execute planning (excluding installation and de-installation activities), which will be based on inputs provided by ESA. ESA, supported by the Russian party, is responsible for the verification of the planning inputs during ground tests and crew training activities against the on-board documentation available at that moment.
Responsibility for coordination with other ISS International Partners and approval of actions and fulfilment of the ISS-adopted planning procedures and rules belongs to the Russian party. For the fulfilment of this task both sides, together with other ISS International Partners, develop relevant Operational Interface Procedures, which define the applicable processes for the execute planning implementation.

7.13.1.4 On-orbit Operations

ESA mission and experiment coordination and support is carried out from the ESA Operations Control Centre located at the Columbus Control Centre (Col-CC) in Oberpfaffenhofen (Germany). Using this infrastructure, ESA performs monitoring and coordination of the flight activity programme and the necessary information exchange with other operations centres. In addition, ESA communication installations at the Mission Control Centre in Moscow (MCC-M) are used for operational data transfers between MCC-M and Col-CC.
During real time operations, an ESA dedicated team is located at the MCC-M in support of ESA activities. The Russian party, in close coordination with ESA operations support, manages the real-time implementation of the Flight Activity Programme from the MCC-M.

7.13.1.5 Post-Flight Handover of Experiment Samples

Post-flight extraction of experiment samples and results from the descent module and delivery to Moscow are performed by the Russian party. An ESA representative may be present at the landing site for the evacuation of urgent experiment results requiring special delivery procedures. The samples and results are then submitted to an ESA representative in Moscow. The hand-over of experiment samples and results from ESA to the scientists will take place no later than 20 days after landing (R+20), but in most cases occurs around R+10.

7.13.2 USOS Payloads

For payloads accommodated in/on the USOS (i.e. NASA, ESA, JAXA, CSA) segment of the ISS, the payload life cycle includes the following:

- Payload integration;
- Payload training;
- Operations preparation and integration;
- Certification of flight readiness;
- Ground processing;
- On-orbit operations;
- Post-flight processing.

The overall process is schematically represented in Figure 7-44 and is summarised in the following paragraphs. The figure also displays the documentation (see 7.14.2) that accompanies the various reviews and milestones. Users must keep in mind that the timeline given is meant as a guide to users and that it represents a generic case: in most situations the actual milestones will vary on a payload-to-payload basis. The timelines in Figure 7-44 are given in months with respect to a Planning Period (PP), an Increment (I) and the Launch (L). This particular example represents a case where the launch date coincides with the increment start date, which in turn begins 4 months after the start of the planning period.

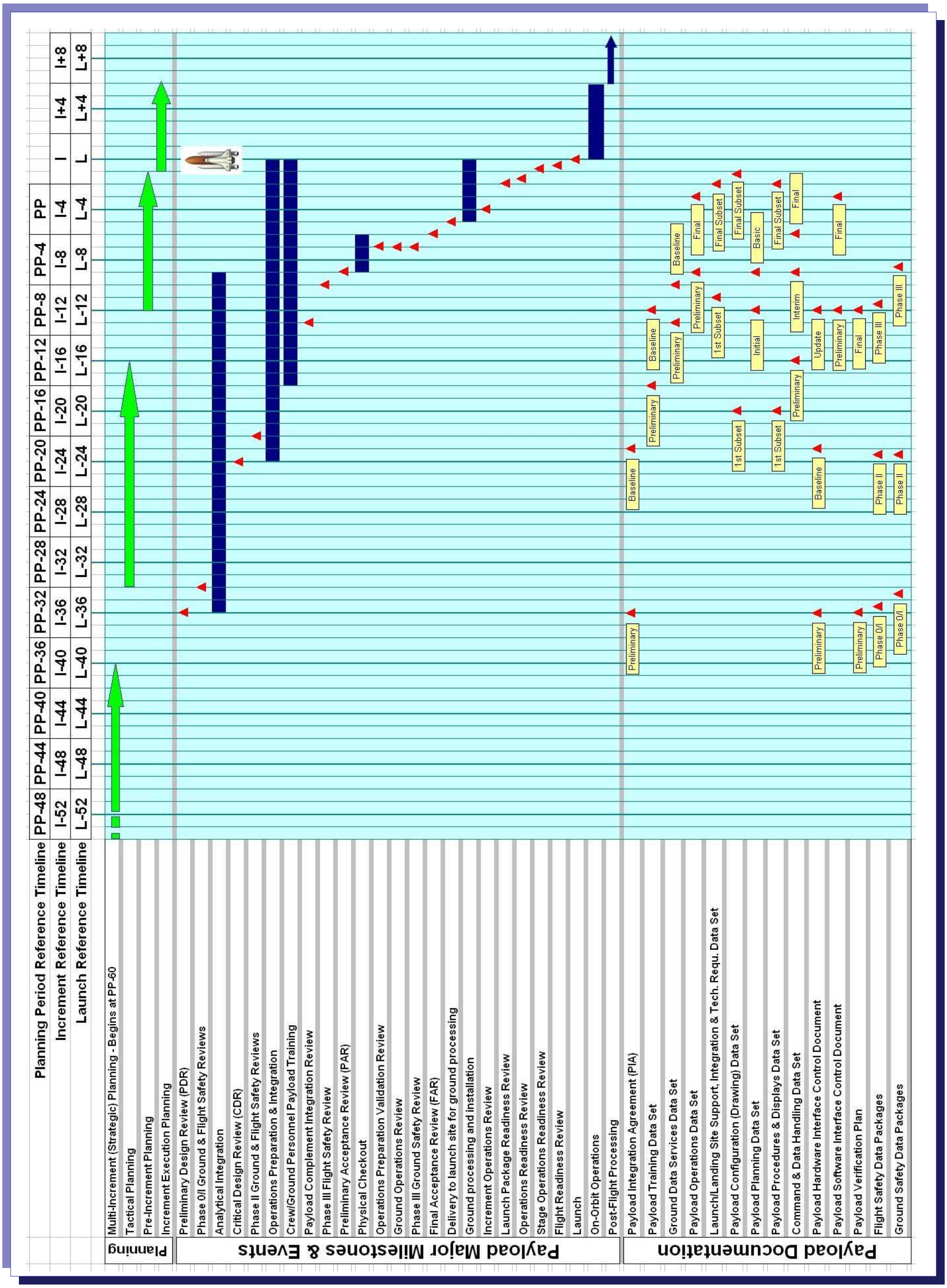

Figure 7-44: USOS Payloads Milestones and Documentation

7.13.2.1 Payload Integration

The term "integration" applies to all the ground-based activities necessary to ensure acceptance of the payload for flight on the ISS. The analytical and physical integration and ground processing of the payload covers all of the activities required to physically interface the payload to the ISS System and Cargo Carriers (e.g. Multi Purpose Logistics Module, Space Shuttle). This process includes verification (part of payload development) and interface and compatibility testing (i.e. physical checkout). The precise activities of this phase depend heavily on the payload class.

7.13.2.1.1 Payload Development

Generally, payload development follows the classical Phase A, B and C/D process, where:

- **Phase A** is the feasibility study phase, to assess the programmatic, technical and financial feasibility of a given payload prior to submission to the relevant committee (e.g. an ESA Programme Board) to become an official ESA project;
- **Phase B** is the detailed system study and design phase;
- **Phase C/D** is the development and manufacturing phase.

The Phase C/D development can start once the payload has been provisionally allocated to an increment. For a Class 1 payload the time between allocation to an increment and actual flight, is approximately 5 years, and for a Class 2 payload approximately 3 years. In the case of a very simple payload, such as a sample, the corresponding timescale will be ~ 1 year.

7.13.2.1.2 Major Reviews

The major reviews associated with payload integration are:

7.13.2.1.2.1 Preliminary Design Review (PDR)

The major focus of the Preliminary Design Review is the assessment of the preliminary design and compatibility of the payload with its external physical and functional interfaces, e.g. Columbus Laboratory, ISS, Cargo Carrier, ground segment. Signature of the Payload Integration Agreement (PIA) document (see 7.14.2.1) defines the payload development schedule, together with the associated Payload Data Sets (see 7.14.2.2) that have to be delivered. For most payload projects, as part of the hardware development effort, a PDR will be conducted when the hardware design reaches ~30 % maturity. The PDR is the completion activity of the classical project development Phase B, and demonstrates and baselines a feasible and credible design that will accomplish the stated goals within the constraints imposed by the fiscal and operating environment. Typically, the PDR takes place at roughly L-36 months.

7.13.2.1.2.2 Critical Design Review (CDR)

During the Critical Design Review, the Payload Data Sets are assessed to demonstrate that the payload is compatible with its external physical and functional interfaces, and to be able to proceed to Analytical Integration. Upon successful completion of the review, the payload Interface Control Document (see 7.14.2.3) and associated Payload Verification Plan (see 7.14.2.4) are baselined and the Payload Data Sets (in preliminary form) are placed under configuration control. For most payload projects, as part of the hardware development effort, a CDR will be conducted when the hardware design reaches ~90 % maturity. The CDR is the completion activity of the classical project development Phase C, and demonstrates a build-to detailed design baseline to fabricate, integrate and verify. The CDR takes place roughly at L-24 months.

7.13.2.1.2.3 Preliminary Acceptance Review (PAR)

The Preliminary Acceptance Review is held following the successful termination of all acceptance tests and just prior to delivery of the payload for further payload interface compatibility checkout. The review consists of an assessment of the performance of the payload compared to the agreed documentation set (i.e. a review of the acceptance test results and payload design as compared to the Interface Control Document, Payload Verification Plan and Payload Data Sets). There should be a matching between the test results and the analysis carried out earlier in the design and development process. Following a successful completion of the Preliminary Acceptance Review, the payload is delivered to the Rack Level Test Facility site for interface verification and Columbus Laboratory compatibility testing. The PAR takes place at roughly L-9 months.

7.13.2.1.2.4 Final Acceptance Review (FAR)

The Final Acceptance Review is held following completion of the verification programme. The test results from the compatibility testing on the Rack Level Test Facility are reviewed for compliance with the payload Interface Control Document. Successful completion of the Final Acceptance Review leads on to transportation to the launch site for integration into the relevant Cargo Carrier, and the review data packages and associated results become part of the Acceptance Data Package for the payload. The FAR takes place roughly at L-6 months.

During these reviews, the user presents a brief description of the payload, support equipment and operation, followed by data unique to the particular review. The depth of the review depends on the complexity, technical maturity and hazard potential of the payload. ESA, through the Payload Integration Manager (PIM), will support users in the preparation of the necessary material for these reviews. The review data packages from these reviews, together with those from the required operations and safety reviews (see 7.13.2.4 and 7.11), become part of the overall Acceptance Data Package for the payload.

ESA also provides the review data to the following ISS Programme reviews:

- Ground Operations Review at 7 months before increment start;
- Increment Operations Review at 4 months before increment start;
- Launch Package Readiness Review at 2 months before increment start;
- Flight Readiness Review at 2 weeks before increment start;
- The Space Shuttle Programme reviews: Flight Operations Review at 4 months before increment start.

7.13.2.1.3 Analytical Integration

In parallel with the initiation of the payload development activities, the analytical integration process can begin. In this process, each payload is analysed in detail to ensure compatibility with the Columbus Laboratory system (or alternative internal or external accommodation sites on the ISS). Compatibility with other payloads within the payload complement being flown on the allocated increment is also verified. ESA, through the Payload Integration Manager, will perform the analytical integration activities in support of the user. For Class 2 payloads, this typically takes place between L-36 and L-9 months.

7.13.2.1.4 Physical Checkout

Following a successful Preliminary Acceptance Review, Class 1 payloads undergo an interface verification and system compatibility test on the Rack Level Test Facility for internal/external payloads. The Rack Level Test Facility is the formal verification tool used for the functional and operational testing of internal payloads. The Rack Level Test Facility may however, be modified to also allow the verification of external payloads and centre-aisle payloads, but this capability does not currently exist. This verification is carried out before installation into the Columbus Laboratory (for the initial internal payload complement), or prior to shipment to the Kennedy Space Centre for installation into the Multi Purpose Logistics Module, for transportation to the ISS.
If the Class 1 payload is already on-orbit, a Class 2 payload is verified against the Class 1 Engineering Model (or Ground Reference Model) normally located at the relevant Facility Responsible Centre (FRC). In this case, the payload will not be subject to testing on the Rack Level Test Facility. The results from the interface and compatibility testing are then input to the Final Acceptance Review of the payload, which if successful, certifies the payload for flight. The payload is now ready for shipment to the designated launch site. The Physical Checkout typically takes place between L-9 and L-6 months.

7.13.2.2 Payload Training

Payload training is aimed at ensuring ground personnel and flight crew involved in payload operations perform safely and effectively under both nominal and off-nominal operations situations. Individual payload facilities training will be performed at the European Astronaut Centre in Cologne, using a training model of the user's payload. In-depth payload training for Class 1 and Class 2 payloads will be carried out at designated Facility Responsible Centres where an Engineering Model and/or Ground Reference Model will be located. During Integrated Training (i.e. the last 6 months prior to increment start), travelling of the crew is restricted. Integrated Training is thus carried out exclusively in either the United States or Russia, depending on the particular launch vehicle being used to transport the crew to the ISS. Dependent upon the precise nature and complexity of the experiment, users may be required to support experiment-specific training activities, most likely, at a Facility Responsible Centre or the user's User Home Base (i.e. institute/company). ESA will prepare all of the necessary training material based on inputs from the user (e.g. from the Payload Integration Agreement document).

7.13.2.3 Operations Preparation and Integration

Operations preparation and integration relates to the development and/or updating of those data products used to operate the Columbus Laboratory and it's payloads. The outputs of pre-increment and increment execution planning (see 7.12.3 and 7.12.4) are used to develop operations products to enable real-time increment operations, and ensure that all involved entities (i.e. ground controllers and facilities, and crew) are adequately prepared for an increment. Operations products refer to all data-related items required to directly operate the Columbus Laboratory and its payloads throughout an increment, under both nominal and contingency conditions. Operations products can be located on-orbit or on ground and may be in electronic and/or physical formats.

Class 1 payloads will normally remain on-orbit for several years, maintained and upgraded as required, so the operations products will likewise be updated to reflect these changes, together with any lessons learned. Class 2 payload operations products are, by their nature, associated with Class 1 operations products, and thus any changes to an existing Class 2 payload or the installation of a completely new Class 2 payload will be reflected in the associated Class 1 operations products. The on-board operations products are part of the Acceptance Data Package required for acceptance by the Payload Integration Manager.

7.13.2.4 Certification of Flight Readiness

The Certification of Flight Readiness (CoFR) process is a formal certification process to ensure the safety and operational readiness of the user payload for flight to the ISS and operation on the ISS. The ESA CoFR Process is a means for ESA management to systematically assess and certify the successful completion of all programme activities required to ensure the success of every ESA-managed ISS activity. This includes (but is not limited to) certification of the safety, integration, and operational readiness of all of ESA's ISS-bound and ISS-supporting hardware and software, facilities, and personnel involved with pre-launch, launch and/or return, on-orbit assembly, operations, and utilisation activities.

ESA (with appropriate support from NASA and other IPs, as necessary) performs a detailed "readiness review," called the Operations Readiness Review (ORR) to demonstrate their readiness to support the launch and/or undock of an ISS Transportation Vehicle, and ESA's subsequent on-orbit activities planned throughout the flight, stage, and when warranted, the Increment. The ORR is chaired by the ESA Mission Manager, and supports the ESA Mission Manager's systematic risk and readiness assessments, and development of the confidence necessary to assure ESA senior management regarding the mission. During the ORR, each ESA Certifying Organisation presents the status of its mission responsibilities according to a pre-defined CoFR presentation template that is clearly related to the Stage-specific ESA CoFR Matrix. At the end of a successful ORR, the ESA Mission Manager and the associated ESA CoFR Board, decide to certify the readiness of all, a portion of, or none of ESA's planned ISS launch, return, and on-orbit activities for the flight, Stage, and/or Increment by signing the ESA CoFR Certificate.

The ORR typically takes place 2 to 3 weeks prior to the Stage Operations Readiness Review (SORR), which in turn takes place about 3 weeks before launch.

7.13.2.5 Ground Processing

Payloads to be transported to the ISS using the Space Shuttle are shipped to the launch site at Kennedy Space Center 5 months prior to the scheduled upload launch. At the launch site (in the case of the Space Shuttle), the NASA Payload Mission Integrator receives the payload and carries out the necessary processing activities to install the payload within the Multi Purpose Logistics Module or on the Express Pallet. Also for the Space Shuttle, users requiring late access (e.g. in the case of life-limited samples) will have access to the Space Shuttle middeck area up until 2 days before launch.

7.13.2.6 On-Orbit Operations

When the payload arrives at the ISS, it is transferred to its allocated internal or external accommodation site or temporary stowage location. It is then installed and a short activation checkout test performed to verify readiness for on-orbit operation. Payload operations include nominal operations to achieve the research objectives of the payload, together with any nominal servicing and maintenance that is required. Users may monitor and interactively control their experiment from a Facility Responsible Centre, User Support and Operations Centre or User Home Base. On completion of on-orbit operations, the payload is removed from its location and returned to Earth.

7.13.2.7 Post-Flight Processing

Users requiring early retrieval access will have access to the Shuttle middeck area after 2 days following landing. The NASA Payload Mission Integrator will deliver the users payload to the ESA point-of-contact following de-integration from the Multi Purpose Logistics Module or Express Pallet, or earlier if agreed between the user and the ISS Programme. The ESA point-of-contact will perform a short checkout of the payload and prepare it for shipment to the user. The User Support and Operations Centre (or Facility Responsible Centre) associated with the operation of the user's payload will also provide to the user a complete history of all the tele-commands sent to, and telemetry data received from the payload during the increment. The final step of the payload lifecycle is the publishing of the research resulting from the on-board operations of the payload on the ISS.

7.14 Payload Documentation

The documentation that will be developed during the integration process of a payload will differ according to whether the payload flies on-board the Russian segment of the ISS or the USOS (i.e. NASA, ESA, JAXA, CSA) segment. The inputs required from the users to develop these documents as well as the format of the documents will be different for the two segments of the ISS. For this reason, this section is split up into two parts.

7.14.1 Russian Segment Payload Documentation

The various reviews and milestones discussed in section 7.13.1 will be accompanied by documents that will serve as inputs for the review process or for the achievement of a milestone, and will be used by the Russians for the development of their own documentation towards the ISS programme. Documentation in support of the reviews will be submitted to the ESA PIMs 4 weeks before the review start date, in order to allow for the translation of the documents into Russian and for the review preparation. The translated documents will then be submitted to the Russian party 2 weeks before the start of a review. The mission joint documentation is produced for the individual experiments, equipment and activities, in support of their preparation, acceptance certification and implementation in the mission. The documentation must be approved by both ESA and Russian parties. The following paragraphs provide a brief description of the documents involved, and the submission milestones of the different versions of the documents are represented in the timeline of Figure 7-43. More detailed information regarding the contents of each document can be found in the mission specific IFOC Annex 4, Appendix A "Documentation Requirements". Note: the 'xxx' and 'yyy' that appear in the document numbers refer to the mission and experiment acronyms respectively, and will therefore be decided on a mission-to-mission basis.

7.14.1.1 Technical Specification for the Experiment: TS-EX (xxx-yyy-100)

This represents the basic technical document on the scientific, technological and methodical realisation of the conduct of an experiment with the proposed payload facility or equipment on-board the Russian segment of the ISS (RS-ISS). It provides the basic information on the tasks to be solved during the experiment implementation, the experiment requirements for programme support, the engineering aspects and the required resources. It also specifies the responsibilities of the experiment participants. A TS-EX will be established for each investigation conducted in the frame of the project, irrespective if this concerns a flight or a ground-based experiment. The document will contain the following sections:

- Introduction;
- Objectives of the Experiment, including:
  - experiment conduct;
  - description, with schematics and drawings;
- Requirements to the Equipment, including:
  - mechanical layout;
- Requirements to Experiment sessions support facilities;
- Requirements to Experiment ground processing and development tests;
- Technical requirements to the ISS Modules for Experiment implementation, including:
  - requirements for consumables and materials to be returned to Earth;
  - requirements for the conditions of the experiment sessions;
  - requirements for the Station crew (a simplified step-by-step procedure);
- Responsibilities of the Experiment Participants.

The following versions of the document will be established:

- **Draft** version at the Mission Feasibility Review (see 7.13.1.1.1);
- **Baseline** version at the Mission Integration Review (see 7.13.1.1.2);
- **Revised Baseline** version at the Mission Verification Review (see 7.13.1.1.3).

7.14.1.2 Technical Specification for the Equipment: TS-EQ (xxx-yyy-200)

Upon approval of the TS-EX document for an experiment, the TS-EQ for the scientific equipment designed for its implementation is developed. The TS-EQ is the basic document that specifies all the requirements, which the equipment has to conform to be launched on Russian spacecraft and to be accommodated on the RS-ISS. The document will contain the following sections:

- Introduction;
- Equipment composition, including:
    - a parts list;
- Technical Requirements for the Equipment, including:
    - requirements for electrical and electromagnetic compatibility;
    - requirements for environmental resistance;
    - requirements for mechanical stability;
    - characteristics of acoustic noises generated by the equipment;
    - safety requirements;
    - reliability requirements;
    - requirements to the equipment to be installed on the external surface of ISS;
    - marking requirements;
    - packing requirements;
    - design requirements / mechanical parameters;
    - requirements for maintainability, repair and storage;
    - transportation requirements;
- Requirements for software and information support;
- Training model requirements and special mock-ups;
- Equipment ground processing requirements and ground test equipment;
- Technical and operational documentation requirements;
- Intellectual property rights and requirements for copyright protection;
- Development phase and delivery schedule;
- Verification requirements, Verification matrix, General Acceptance Test procedure.

The following versions of the document will be established:

- **Draft** version at the Mission Feasibility Review (see 7.13.1.1.1);
- **Baseline** version at the Mission Integration Review (see 7.13.1.1.2);
- **Revised Baseline** version at the Mission Verification Review (see 7.13.1.1.3).

7.14.1.3 Technical Description: TD (xxx-yyy-201)

The Technical Description (TD) is aimed at the description of the equipment study and should contain the design description necessary for operation, as well as general technical characteristics. The document should contain the following sections:

- Introduction;
- Purpose;
- Content of the equipment;
- Technical characteristics;
- Equipment and components design;
- Data interface characteristics;
- Equipment operation description;
- Instrumentation (for incoming inspection);
- Tools and accessories, expendables;
- Marking and sealing;
- Container and packing;
- Appendices (if necessary).

The following versions of the document will be established:

- **Draft** version at the Mission Integration Review (see 7.13.1.1.2);
- **Baseline** version at the Mission Verification Review (see 7.13.1.1.3).

7.14.1.4 Operations and Maintenance Manual: OM (xxx-yyy-202)

The Operations and Maintenance Manual (OM) includes information necessary for adequate operation of the equipment, the rules for handling, maintenance and operation in the technical sequence of their implementation (including both ground and onboard operations during normal operations), the necessary tools, etc. The document will consist of the following sections:

- Introduction (general instructions);
- Safety measure definition (safety instructions);
- Preparation for work;
- Technical condition check prior to the beginning of work;
- Operating procedure;
- Maintenance;
- Off-nominal situations;
- Equipment storage;
- Transportation;
- Appendices.

The following versions of the document will be established:

- **Draft** version at the Mission Integration Review (see 7.13.1.1.2);
- **Baseline** version at the Mission Verification Review (see 7.13.1.1.3).
- **Revised Baseline** version at Acceptance Test 1 (see 7.13.1.2.2).

7.14.1.5 Acceptance Test Programme: ATP (xxx-yyy-203)

The Acceptance Test Programme (ATP) document presents the scope and procedure of the Acceptance Tests (AT-1 & AT-2) of the equipment designed for installation and operation on-board the ISS. The ATP should consist of the following sections:

- Introduction;
- Object and Purpose of tests;
- General Provisions;
- Testing conditions and sequence, including:
    - documents required for the Acceptance Test;
- Acceptance Test performance;
- Location, Date & Duration of ATs;
- Ambient Test Conditions;
- Special Environmental Conditions Required;
- Test Personnel;
- Safety considerations for the performance of specific tests;
- Test Equipment required;
- Scope of Acceptance Tests;
- Acceptance Test Procedures, including:
    - completeness check;
    - visual control;
    - check of overall dimensions;
    - check of mass and centre of gravity;
    - check of electrical resistance and breakdown of insulation;
    - check of amplitude and duration of in-rush current;
    - check of power consumption in the operating mode;
    - functional check;
    - packing check;

  - vibration tests during the insertion phase;
  - safety check;
- Appendices.

The following versions of the document will be established:

- **Draft** version at the Mission Integration Review (see 7.13.1.1.2);
- **Baseline** version at the Mission Verification Review (see 7.13.1.1.3).

7.14.1.6 Equipment Incoming Inspection Manual (xxx-yyy-204)

The Equipment Incoming Inspection Manual contains descriptions of the checkout operations for the Flight Models of equipment after transportation and before launch. The document should consist of the following sections:

- Introduction;
- Preparation for work;
- General provisions;
- Ground processing equipment;
- Visual control procedure;
- Equipment functional check;
- Pre-launch readiness check.

The following versions of the document will be established:

- **Draft** version at the Mission Verification Review (see 7.13.1.1.3);
- **Baseline** version at Acceptance Test 1 (see 7.13.1.2.2).

7.14.1.7 Qualification Test Programme (xxx-yyy-205)

The Qualification Test Programme defines the scope and procedures of Qualification Tests (QT) (see 7.13.1.2.1) of the equipment and consists of the following basic sections:

- Introduction;
- Test object;
- Conditions and order of testing;
- Scope and procedures of Qualification Tests;
- Appendices.

The following versions of the document will be established:

- **Draft** version at the Mission Integration Review (see 7.13.1.1.2);
- **Baseline** version at the Mission Verification Review (see 7.13.1.1.3).

7.14.1.8 Qualification Test Report (xxx-yyy-206)

The Qualification Test Report contains a report (or reports) on the results of Qualification Tests of the equipment conducted by the hardware developers. The document generally consists of the following sections:

- Introduction;
- General provisions;
- Conditions and order of tests;
- Scope of Qualification Tests;
- Test procedures and results;
- Appendices, including:
- Testing Record Sheets (TRS);

- Reports on equipment characteristics non-conformity to TS-EQ requirements;
- Defects/failure analysis;
- Check-list;
- Detailed test procedures;
- Warranties.

The following versions of the document will be established:

- **Draft** version at Acceptance Test 1 (see 7.13.1.2.2);
- **Baseline** version at Acceptance Test 2 (see 7.13.1.2.2).

7.14.1.9 Safety Assessment Reports and Certificates (xxx-yyy-207)

This document, as a rule, does not have a strictly regulated form, however it should contain all necessary data that will allow for a conclusion to be reached about the safety of the equipment, relative to the ISS and the crewmembers in all phases of equipment operation. If the developer of the equipment has data on toxicological safety of the materials used, the appropriate test certificates or reports should be submitted with this document. See also section 7.11. The following sections should be included in the document upon submittal:

- Introduction:
- Description of the equipment (unit by unit);
- Materials safety;
- Electrical safety;
- Structural safety;
- Electromagnetic and other types of radiation;
- Gas bottles handling system (if necessary);
- Noise level;
- Temperature;
- Appendices (mandatory), including:
    - safety check results;
    - equipment toxicological test data;
    - list of non-metallic materials;
    - materials certificates.

The following versions of the document will be established:

- **Draft** version at the Mission Integration Review (see 7.13.1.1.2);
- **Initial** version at the Mission Verification Review (see 7.13.1.1.3);
- **Baseline** version at Acceptance Test 1 (see 7.13.1.2.2).

7.14.1.10 Crew Training Documentation and Inputs to Crew Procedures (xxx-yyy-208)

These documents define the procedures used for crew training for the particular equipment. Crew training documentation should contain only the information that is necessary for training crews. Besides, it should contain requirements for work with the training equipment and for the development of a timetable of training sessions. The document should take into account the fact that the crew training is aimed at successful implementation of a certain scientific experiment, using a certain number of devices. Since several equipment units can be used in one experiment, the given document is developed so that the crew training includes training sessions for all systems that will be used during experiment execution. The following sections should be included in this document:

- Introduction;
- Description of research programme;
- Content (description) of the flight equipment;
- Flight operations, including:
    - general description of operations;

   - functional Objectives;
- Equipment transfer limitations;
- Working operations, including:
   - equipment unpacking (depreservation);
   - accommodation on-board ISS
   - equipment preparation for work (assembly and set-up);
   - equipment activation;
   - termination of use (deactivation);
   - equipment packing (preservation).
- Operating procedure in off-nominal situations;
- Content (description) of the training equipment;
- Operating procedures of the training equipment;
- Safety requirements for training and flight equipment;
- Description of training sessions.

The following versions of the document will be established:

- **Draft** version at the Mission Integration Review (see 7.13.1.1.2);
- **Baseline** version at the Mission Verification Review (see 7.13.1.1.3).

7.14.1.11 Ground Test Equipment/Checkout Equipment (xxx-yyy-209)

This document presents a list and descriptions of the Ground Test Equipment/Checkout Equipment used for all types of tests and checks of the specific experiment equipment under ground conditions. The document consists of the following sections:

- Introduction;
- List of the Ground Test Equipment;
- Description of the Ground Test Equipment;
- Safety of utilisation of the Ground Test Equipment.

The following versions of the document will be established:

- **Draft** version at the Mission Verification Review (see 7.13.1.1.3);
- **Baseline** version at Acceptance Test 1 (see 7.13.1.2.2).

7.14.1.12 Passport (Logbook) for the Equipment (xxx-yyy-200PS)

The Passport for the equipment is the basic document certifying assured main parameters and characteristics of the equipment. Based on data presented in the Passport, the equipment is accepted for installation and operation as a part of the ISS. The Passport should consist of the following sections:

- General instructions;
- General information about the equipment;
- Major technical characteristics;
- Set of deliveries;
- Acceptance certificate;
- Preservation certificate;
- Packing certificate;
- Warranty responsibilities;
- Information about compliance claims;
- Information about storage;
- Incoming inspection note (filled in prior to installation on-board);
- Operation (service life) records;
- Failures in operation;
- Appendices (including special notes).

The following versions of the document will be established:

- **Draft** version at Acceptance Test 1 (see 7.13.1.2.2);
- **Baseline** version at Acceptance Test 2 (see 7.13.1.2.2).

7.14.1.13 Requirements to the Contents of Electrical Circuit Diagrams (xxx-yyy-210-Annex 1 & 2)

The electrical circuit diagrams should contain data on electrical cable connections between separate units of the equipment, as well as between the given equipment and the Power Supply System, Onboard Control System, and Telemetry System of the specific ISS modules.

The following versions of these documents will be established:

- **Draft** version at the Mission Integration Review (see 7.13.1.1.2);
- **Baseline** version at the Mission Verification Review (see 7.13.1.1.3);
- **Revised Baseline** version at Acceptance Test 1 (see 7.13.1.2.2).

7.14.1.14 Requirements to the Contents of Outline Installation Drawings (xxx-yyy-211)

The Outline Installation Drawings (OID) reflect the specifications of equipment accommodation (installation) inside the Russian spacecraft during the insertion phase and during orbital flight.

The following versions of these documents will be established:

- **Draft** version at the Mission Feasibility Review (see 7.13.1.1.1);
- **Baseline** version at the Mission Integration Review (see 7.13.1.1.2);
- **Revised Baseline** version at the Mission Verification Review (see 7.13.1.1.3);
- **Second Revision Baseline** version at Acceptance Test 1 (see 7.13.1.2.2).

7.14.2 USOS Payload Documentation

At the start of the development phase of a payload, a Payload Integration Manager (PIM) is assigned to each user. The PIM provides the user with all of the necessary ISS documentation to design, develop and operate the user's payload safely and successfully on the ISS. The PIM acts as the prime interface with other entities for the user, with respect to specific activities throughout the payload life cycle, up to the successful on-orbit activation of the payload. When this activation has been accomplished, the Payload Operations Manager will become the main point-of-contact, to assist in the operations of the user payload.
Users/payload developers will be supported from the start of the payload life cycle to understand and interpret the ISS requirements and accommodations. Most of the inputs required from users/payload developers will be submitted, for the most part, by implementing so-called Blank Books. These documents are essentially templates that are used to develop a specific document by filling in the necessary payload-unique data by the user/payload developer.

The major documents relevant to users/payload developers are:

- Payload Integration Agreements;
- Payload Data Sets;
- Interface Control Documents;
- Payload Verification Plans;
- Safety Data Packages.

The following paragraphs provide a brief description of the documents to be submitted and when they are submitted. For a schematic representation of the documents and their milestones, refer to Figure 7-44. Users must keep in mind that this information is given for a generic case and must therefore be used as a guide. The required inputs, documentation and submittal dates may vary from payload to payload.

7.14.2.1 Payload Integration Agreement (PIA)

The Payload Integration Agreement (PIA) is the primary management and technical agreement between the user/payload developer and ESA.
The PIA specifies all management and technical activities required for transportation and on-orbit operation of the payload, and will be updated as agreed to by the implementing organisations to meet increment- and flight-specific needs using data provided by the user.
Payload-specific PIAs and any supporting data describe the requirements and the general roles and responsibilities of the parties involved in the integration/deintegration, pre-launch/post-landing processing, transportation, and the on-orbit operation of the payload. More specifically, they contain information pertaining to reviews, schedules, hardware commitments, and protocols required to manifest the payload. The PIA also documents the tactical parameters, dynamic requirements, schedules, and commitments associated with specific transportation flights and on-orbit increment operations. Supporting data containing engineering, integration, and operational details is also required.

In general, two versions of the PIA will be submitted:

- **Preliminary** version – this is submitted around the same time as the Preliminary Design Review (PDR).
- **Baseline** version – this is typically submitted 1 month after the Critical Design Review (CDR).

7.14.2.2 Payload Data Sets

The Payload Data Sets represent the detailed technical requirements relative to the engineering, integration and operational aspects of a payload, as agreed upon by the payload developer and the implementing organisations. The following paragraphs provide a basic overview of the major data sets.

7.14.2.2.1 Payload Training Data Set

The payload training data set contains the requirements for user-provided, user/ESA provided and ISS Programme-provided payload training for the ISS crew and ESA ground personnel, together with the ESA requirements for the training of user personnel. This data is used to develop the payload increment training plans.
Two versions of the Payload Training Data Set will be developed and submitted:

- **Preliminary** version – this is submitted approximately 6 months after the Critical Design Review (CDR);
- **Baseline** version – this is submitted 12 months before the start of the Increment to which the payload has been assigned (I-12).

7.14.2.2.2 Ground Data Services (GDS) Data Set

The Ground Data Services Data Set contains the requirements for ground systems and communication services to support the on-orbit operations of the payload. This data is used to prepare the ground communications plan. Two data sets will be submitted at different times during the integration process:

- **Preliminary** version – this version of the data set is submitted 13 months prior to the start of the Increment to which the payload has been assigned (I-13);
- **Baseline** version – the preliminary version of the data set is baselined 3 months later, i.e. at I-10 months.

7.14.2.2.3 Payload Operations Data Set

The Payload Operations Data Set contains the requirements to prepare, conduct and support the execution of the on-orbit payload operations. This data set is comprised of 3 sub-sets containing information relative to payload flight operations actions, decisions, and constraints; payload operational flight rules; and payload regulations. These sets are used to develop lower-level operations products, and are delivered during a timeframe ranging between 9 months before launch (L-9) and 3 months before launch (L-3).

7.14.2.2.4 Launch/Landing Site Support, Integration and Technical Requirements Data Set

This data set contains the requirements for integration and ground processing, together with launch/landing-site requirements, and include verification, inspection/test activities, assembly, installation and test requirements, payload physical integration, site interfaces and resources, deliverable items lists, support services and equipment, ground processing, access and contingency activities. Also included here are any payload equipment items that are to be launched/returned from the relevant increment, and any late-access or post-landing early retrieval requirements. Typically, the first preliminary subset of this data set is submitted approximately 6 months prior to the payload being on-dock, i.e. delivered to the launch site, while the last baselined subset will be submitted around 2 months before launch (L-2).

7.14.2.2.5 Payload Configuration (Drawing) Data Set

The primary purpose of this data set is to document the payload configuration. The configuration is defined by listing the current configuration drawings with all revisions. The configuration data set (CDS) also documents agreements made between the ISS Programme and the user concerning the hardware configuration of the payload and the use of selected resources. Configuration data includes sketches and drawings, electrical interface schematics, thermal interface schematics, mass properties, and stowage requirements. The purpose of the CDS is also to collect data for supporting engineering analysis and payload analytical integration to ensure the safety and compatibility of the entire payload complement. This data includes thermal requirements, power profiles, use of selected consumables and structural data. The various subsets of this data set will be submitted during an interval spanning from 4 months after the Critical Design Review (CDR+4) to 5 weeks before the launch of the payload (L-5 weeks).

7.14.2.2.6 Payload Planning Data Set

The Payload Planning Data Set provides the detailed pre-increment and real-time planning and payload resource requirements for the International Space Station (ISS) Programme. The user/payload developer provides the detailed payload planning and resource requirements specifications to the ISS planners based on the types of inputs described within the Payload Data Sets Blank Book.

The payload planning requirements are used for modelling the user’s requirements for onboard activities, and also defines the products, activities, roles, responsibilities, and interfaces required for the provision of payload planning during Payload Operations.

The Payload Planning Data Set collects detailed planning requirements for ascent/descent, and Station onboard resources such as crew time, power, thermal, commanding, and data and video downlink requirements. The ISS Mission Planners utilise these requirements to develop planning products such as the On-Orbit Operations Summary (OOS), Weekly Look-Ahead Plans, Short-Term Plan (STP) and the Onboard Short-Term Plan (OSTP).

Typically, 2 versions of the Planning Data Set are submitted:

- **Initial** version – this first version of the planning data set is submitted approximately 12 months before the start of the payload increment (I-12);
- **Basic** version – this is submitted around 3 months after the initial version, i.e. at I-9 months.

7.14.2.2.7 Payload Procedures and Displays Data Set

The Payload Procedures and Displays (PPD) Data Set includes the requirements for crew, automated, and ground command procedures and related information, onboard crew displays, and payload messages, supporting on-board operations. There are several subsets of the PPD data set that are submitted during the life-cycle of a payload, the first subset being delivered around 4 months after the CDR, and the final subset submitted 2 months before the launch of the payload.

7.14.2.2.8 Command and Data Handling Data Set

The Command and Data Handling (C&DH) data set is the method by which a user/payload developer defines the payload requirements for use of the International Space Station (ISS) flight and ground C&DH systems. Three versions of this data set will be submitted during the life cycle of a payload:

- **Preliminary** version – delivered around 16 months prior to the launch of a payload (L-16);
- **Interim** version – submitted 9 months before launch (L-9);
- **Final** version – submitted 6 months before launch (L-6).

7.14.2.3 Interface Control Documents

7.14.2.3.1 Payload Hardware Interface Control Document

The unique payload hardware Interface Control Document (ICD) defines and controls the design of the interfaces between the payload and the system that accommodates it, including unique interfaces, constraints, definition of selectable parameters, and stage unique constraints. The unique ICD provides specific design data and defines the engineering analyses applicable to the interfaces and optional/special services identified in the PIA.
A user will implement the Payload Hardware ICD Template to produce the Payload-unique hardware ICD, together with the Payloads Interface Requirements Document (IRD). The IRD defines the physical and functional interface requirements between payload and system, and acts as a guideline to establish commonality with the respect to analytical approaches, models, test methods and tools, technical data and definitions for integrated analysis.
The payload unique hardware ICD will contain design implementation and module specific interface information, an applicability matrix that provides traceability back to the requirements and corresponding verification requirements contained in the IRD.
Typically, 3 versions of the Payload Hardware Interface Control Document will be submitted during the development and integration phase:

- **Preliminary** version – submitted approximately at the same time as the Preliminary Design Review (PDR);
- **Baseline** version – submitted around 1 month after the Critical Design Review (CDR);
- **Updated** version – submitted approximately 12 months before the launch of the payload (L-12).

7.14.2.3.2 Payload Software Interface Control Document

The Payload Software Interface Control Document (ICD) is developed to define the flight unique software interface requirements between the payload systems and the ISS flight data handling elements (low, medium and high rate data links). The user will determine the number and type of interfaces based on the requirements of the unique payloads. To develop the Software ICD a user will implement the Payload Software Interface Control Document (ICD) Template together with the Payloads Interface Requirements Document (IRD) (see 7.14.2.3.1).
In general, 2 versions of the Software ICD will be submitted in the process of payload development and integration:

- **Preliminary** version – submitted approximately 12 months before the launch of the payload (L-12);
- **Final** version – the final version of this document will be submitted about 3 months prior to launch (L-3).

7.14.2.4 Payload Verification Plans

A payload unique Payload Verification Plan (PVP) is developed together with the Payload ICDs, and is used to define the complete set of verification activities necessary to ensure compliance with the payload design requirements identified in the ICDs. The PVP will contain Verification Data Sheets (VDS) providing instructions, definitions, references and guidelines for the verification activities associated with each payload design requirement. The submission of the PVPs will take place together with that of the Payload Hardware ICD, i.e. a preliminary version around the PDR and a final version approximately 12 months before launch.

7.14.2.5 Safety Data Packages

A description of the safety data packages is given in 7.11.1. Typically, the milestones for the submission of the data packages are as follows:

7.14.2.5.1 Flight Safety Data Packages

- Phase 0/I Data Package – approximately 45 days prior to the Phase 0/I Safety Review, which takes place about 2 months after the PDR;
- Phase II Data Package – approximately 45 days prior to the Phase II Safety Review, which takes place about 2 months after the CDR;
- Phase III Data Package – approximately 45 days prior to the Phase III Safety Review, which takes place about 10 months before launch (L-10).

7.14.2.5.2 Ground Safety Data Packages

- Phase 0/I Data Package – approximately 45 days prior to the Phase 0/I Safety Review, which takes place about 2 months after the PDR;
- Phase II Data Package – approximately 45 days prior to the Phase II Safety Review, which takes place about 2 months after the CDR;
- Phase III Data Package – approximately 45 days prior to the Phase III Safety Review, which takes place about 7 months before launch (L-7).

7.15 Operational Cycle of an ISS Payload

7.15.1 Russian Segment Payload Operational Cycle

The following table provides a general outline of the major events that take place during the operational cycle of a payload flying to and being accommodated on the Russian segment of the ISS. Scientists should use this as a reference and should keep in mind that the list below may vary from payload to payload. For a generic case, the table refers to the timeline of a Soyuz launch campaign. ("L" refers to the time of launch of the Soyuz spacecraft and "R" refers to the time of landing of the Soyuz capsule). Figure 7-45 graphically summarises the sequence of events during a Soyuz launch campaign.

Table 7-32: Major events in the operational cycle of an ISS Russian Segment payload

TIME	EVENT
L-1 month	Payloads delivered to Baikonur launch site
L-30 to L-20 days	Pre-integration inspections at Baikonur (in most cases scientists and payload developers will be present)
L-20 to L-12 days	Payload physical integration into Soyuz spacecraft
L-8 to L-5 days	Spacecraft integration with launcher. Upon request, final stowage of limited additional cargo is possible
L-1 days	Soyuz launcher rolled-out to launch pad
L-7 days to L-12 hours	"Late Access" of limited size kits possible through side hatch of Soyuz spacecraft
L	Launch of Soyuz vehicle
L+2 days	Spacecraft docks with ISS
L to L+10 days	Execution of scientific programme of mission
L to L+10 days	Users located at: the User Support and Operations Centres (USOC) or a User Home Base (UHB)
L+10 days	Undocking and landing of spacecraft
L+10 days	Payload and data retrieval
R to R+15 days	Payloads and experiment data handover to scientists/payload developers
R+40 days	Final project review

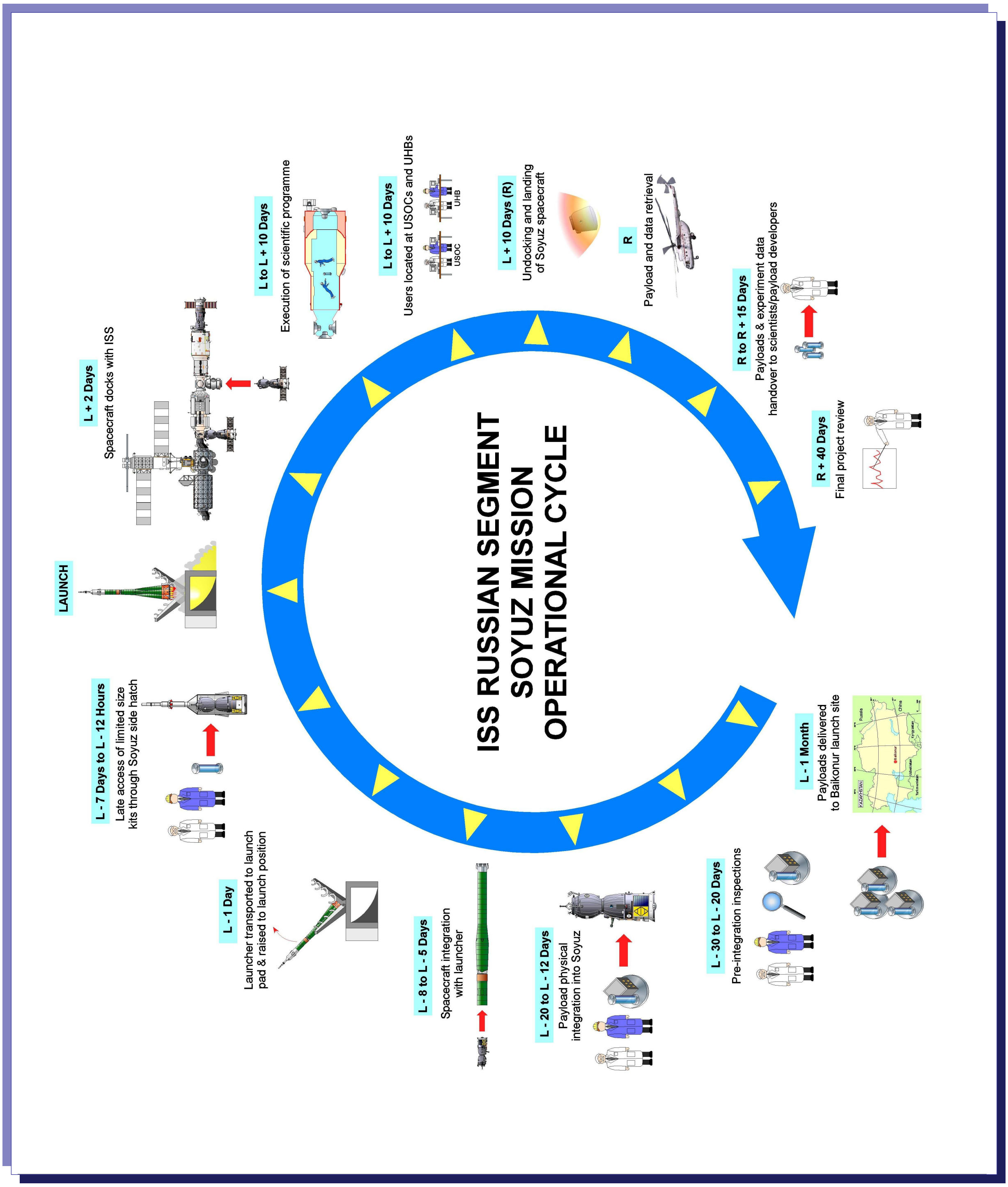

Figure 7-45: Schematic of the operational cycle for a Soyuz-transported ISS payload

7.15.2 USOS Payload Utilisation/Operational Cycle

The timeline and utilisation/operational cycle of payloads accommodated on the USOS of the ISS will vary from payload to payload and from mission to mission. Providing users with a specific example of an operational cycle for each possible case would be beyond the scope of this guide. For this reason, the following figure (Figure 7-46) is meant to present users with a very generic operational cycle for payloads flying to and from the ISS. It is aimed at providing users with an overall view of the elements and flow involved.

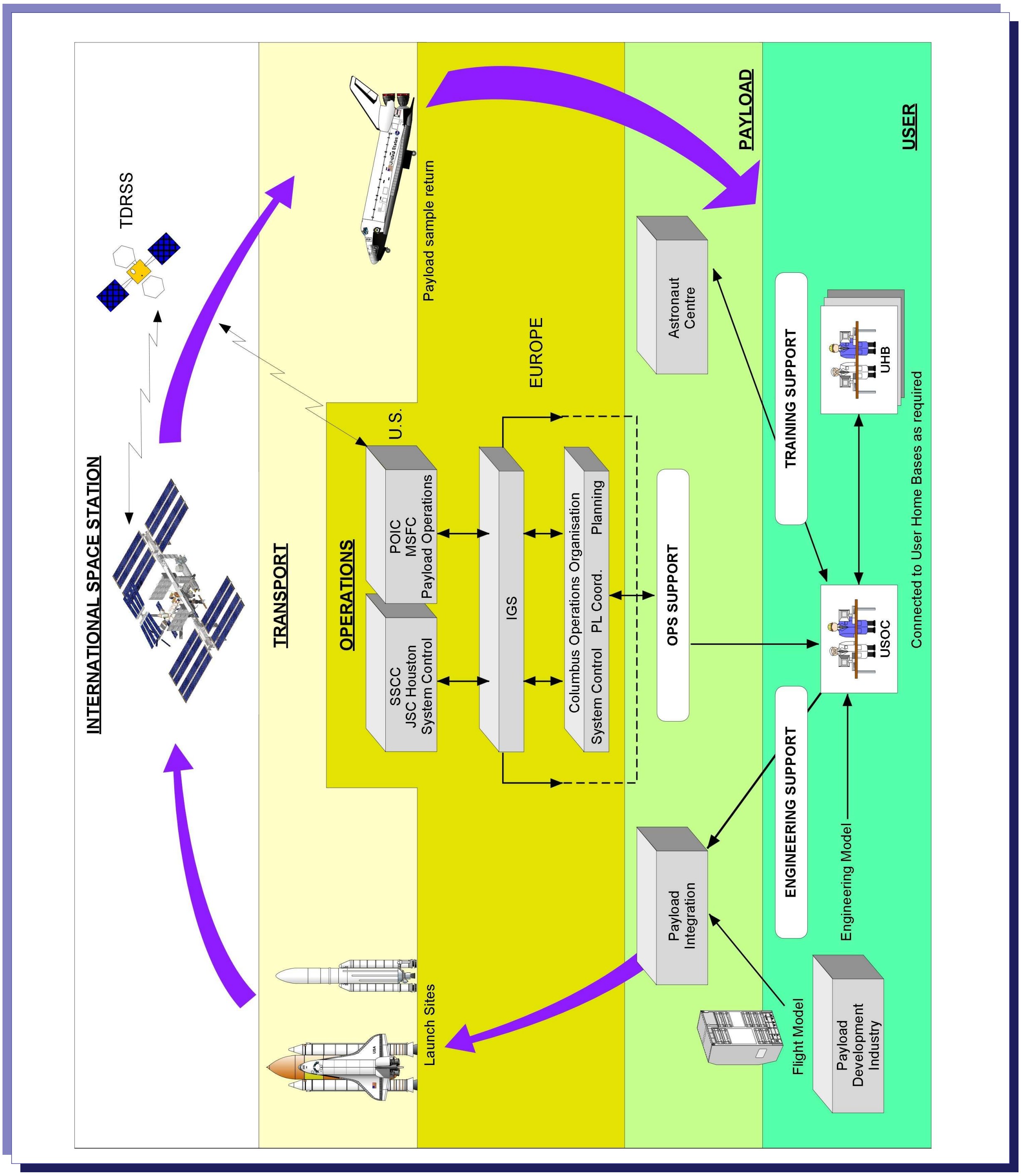

Figure 7-46: Schematic of a generic USOS ISS payload utilisation/operational cycle

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