S.P.Korolev Rocket and Space Corporation Energia

ISS Russian Segment

User Manual

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This document is the second updated revision (v.2) of the ISS RS User Manual for integration of scientific equipment intended for principal investigators and payload developers.

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Contents

1 Introduction

This Manual provides basic information that designers of experiments and payloads that are proposed to be conducted and installed in the Russian Segment of the International Space Station (ISS RS) need to know in order to correctly state specifications when drawing up statements of work for space experiments and scientific equipment, as well as to conduct a preliminary feasibility analysis of the experiments proposed for ISS RS.

It provides general information about ISS RS resources at different stages of its deployment, as well as about resources of its individual elements. Special attention is given to the issues related to payload delivery and in-orbit operation and returning experimental results to earth.

All the payloads installed on ISS RS (Scientific Equipment (SE)) are included into the Mission Payload Facility (MPF). The Manual describes the ISS RS MPF architecture and provides a brief description of its components.

It provides a description of workstations for accommodating scientific equipment, mission payloads that support the conduct of space experiments, resources provided for SE, the principles of SE control, and methods of downlinking data from the SE.

It describes the SE operational environments within the ISS RS modules and within the transportation vehicles Soyuz and Progress.

2 Groundrules

To meet the necessary requirements for SE development, testing, delivery, accommodation and functioning, a Mission Payload Facility (MPF) is established onboard ISS RS. Included in the MPF are:

- scientific equipment;
- mechanical adapters;
- science support equipment;
- cables.

In order to achieve the most efficient use of resources provided by the space station for conducting research throughout its life (during which time some research objectives may become irrelevant, the research methodology may change, and scientific equipment may fail or become obsolete), the MPF is based on the principles of unification and integratedness.

The unification principle calls for the use of replaceable payload technology which implies that virtually any kind of scientific equipment can be delivered and put into operation immediately in orbit. In order to implement such technology, the MPF supports installation and adaptation of delivered SE (built to meet the relevant requirements) from the standpoint of mechanical, electrical, data and other interfaces.

SE control, data support, temperature control and vacuumization onboard ISS RS are provided by the onboard support systems that are not included into MPF.

3 General data on the ISS RS resources at different stages of its deployment

3.1 ISS RS consisting of SM, DC1, MRM2 and MRM1

Resources allocated to the MPF include:

- allocated working volume of : up to 1 m^3 on SM, up to 0.2 m^3 on MRM2 and up to 3 m^3 on MRM1;

- power supply:

- - on SM and DC1 up to 0.3 kW (daily average) and up to 1 kW for 2 days with continuous additional normal power supply to ISS RS from the US segment in accordance with operational documentation;
- - on MRM2 up to 0.1 kW (daily average);
- - on MRM1 up to 0.1 kW (daily average);

- heat rejection capacity:

- - on SM, DC1 and MRM2 up to 0.3 kW (daily average) (the balance is achieved taking into account the heat loss through the SM hull);
- - on MRM1 up to 0.1 kW (daily average);

- the number of workstations on the outer surface:

- 4 pcs. on the SM (8 pcs., when deliverable Multi-Purpose Workstations (MPWs) are taken into account);
- 5 pcs. on MRM2 (7 pcs., when deliverable Multi-Purpose Workstations (MPWs) are taken into account);

- payload data downlink capacity (maximum, via RF system for data transmission): up to 4 GB per a session;

- ISS attitude control mode (nominal): Orbital Coordinate System (OCS);

- ISS OCS attitude control accuracy : ± 10 angular minutes;

- ISS angular rate stabilization accuracy: 0.005 deg/s;

- the number of telemetered parameters: up to 212 (SM), up to 50 (MRM2) and up to 36 (MRM1);

- the list of electrical interfaces available for MPF:

- RS-232;

- RS-422 (only on SM);
- RS-485 (only on SM);
- Ethernet;
- USB;

- HF with wave impedance of 75 Ohm and 50 Ohm (only on SM);
- discrete control commands (on SM and MRM2);
- the number of vaccumization interfaces for MPF: 1 pc on MRM2 and 1 pc on MRM1.

The MPF cargo traffic to ISS RS is planned based on the following assumptions:
- delivery of cargo to ISS RS onboard Progress MS logistics spacecraft: on average up to 600 kg per year;
- return from ISS RS in the descent vehicle of the Soyuz MS crew transportation spacecraft of up to 110 kg of payloads per year.

The external appearance of ISS RS in the above configuration is shown in Figure 3.1

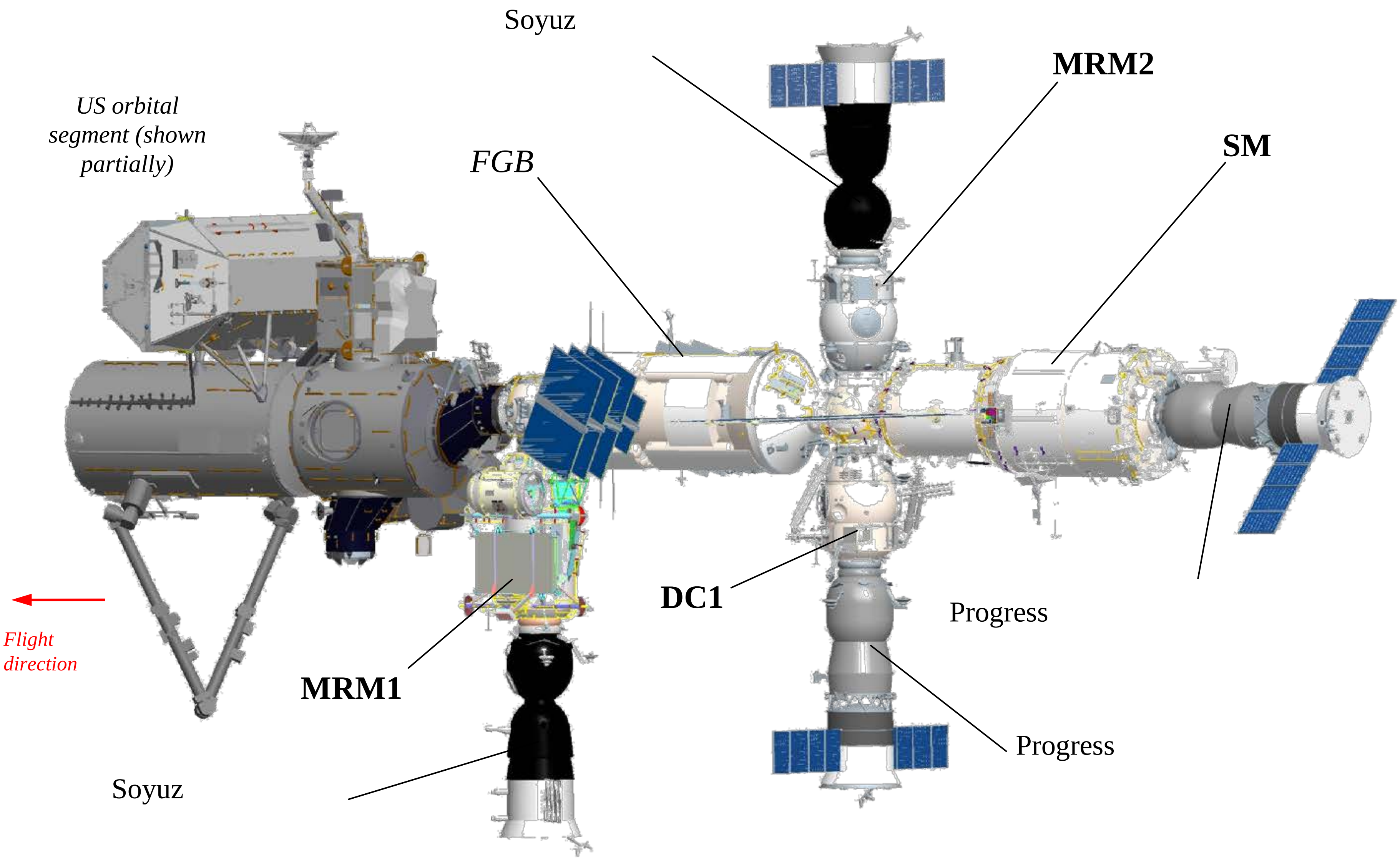


Fig. 3.1 – ISS RS configuration consisting of SM, DC1, MRM2 and MRM1

3.2 ISS RS consisting of SM, MRM2, MRM1 and MLM

After MLM module is launched in late 2017 and attached to the ISS RS, and the airlock and the radiator are relocated from MRM1 to MLM using the ERA robotic arm, the ISS RS configuration will be as shown in Fig. 3.2.

Resources allocated to the MPF include:

- allocated working volume of : up to 1 m^3 on SM, up to 0.2 m^3 on MRM2, up to 3 m^3 on MRM1, and up to 6 m^3 on MLM;

- power supply:

- on SM up to 0.3 kW (daily average) and up to 1 kW for 2 days with continuous additional normal power supply to ISS RS from the US segment in accordance with operational documentation;
- on MRM2 up to 0.1 kW (daily average);
- on MRM1 up to 0.1 kW (daily average);
- - on MLM up to 1.0 kW (daily average) inside the pressurized cabin and up to 1.5 kW (daily average) outside the pressurized cabin;

- heat rejection capacity:

- on SM and MRM2 up to 0.3 kW (daily average);
- on MRM1 up to 0.1 kW (daily average);
- on MLM up to 1.0 kW (daily average) after deployment of an additional radiative heat exchanger;

- the number of workstations on the outer surface:

- 4 pcs. on the SM (8 pcs., when deliverable Multi-Purpose Workstations (MPWs) are taken into account);
- 5 pcs. on MRM2 (7 pcs., when deliverable Multi-Purpose Workstations (MPWs) are taken into account);
- 9 pcs. on the MLM (13 pcs., when deliverable Multi-Purpose Workstations (MPWs) are taken into account);

- payload data downlink capacity (maximum, via RF system for data transmission): up to 4 GB per a session;

- ISS attitude control mode (nominal): Orbital Coordinate System (OCS);

- ISS OCS attitude control accuracy : ± 10 angular minutes;

- ISS angular rate stabilization accuracy: 0.005 deg/s;

- the number of telemetered parameters: up to 212 (SM), up to 50 (MRM2), up to 36 (MRM1), up to 323 (MLM);

- the list of electrical interfaces available for MPF:

- RS-232;
- RS-422 interface channels per EIA RS422A standard with maximum data exchange rate of 115 Kbps (on SM and MLM);
- CAN interface channels per requirements of EIA RS485 standard for electrical parameters of the signal. The logical level of the protocol shall be compliant with the specification CAN 2.0 B, ISO/DIS 11898. The maximum data rate is 1 Mbps (on SM and MLM);
- Ethernet 10/100 Base T interface channels per requirements of standards IEEE 802.3 and IEEE 802.3u. The maximum data rate is 100 Mbps;
- USB;
- local data highway interface of the multiplexed data exchange channel per national standard GOST 26765.52-87 (MIL STD 1553B). The maximum data rate is 1 Mbps (only on MLM);

- HF with wave impedances of 75 Ohm and 50 Ohm (on SM and MLM);

- discrete control commands (on SM, MRM2 and MLM);

- the number of vaccumization interfaces for MPF: 1 pc on MRM2, 1 pc on MRM1, 2 pcs on MLM;

- the number of thermostatting interfaces for MPF: 2 pcs. on MLM.

The MPF cargo traffic to ISS RS is planned based on the following assumptions:

- delivery of cargo to ISS RS onboard Progress logistics spacecraft: on average up to 600 kg per year;

- return from ISS RS in the descent vehicle of the Soyuz crew transportation spacecraft of up to 110 kg of payloads per year.

The external appearance of ISS RS in the above configuration is shown in Figure 3.2.

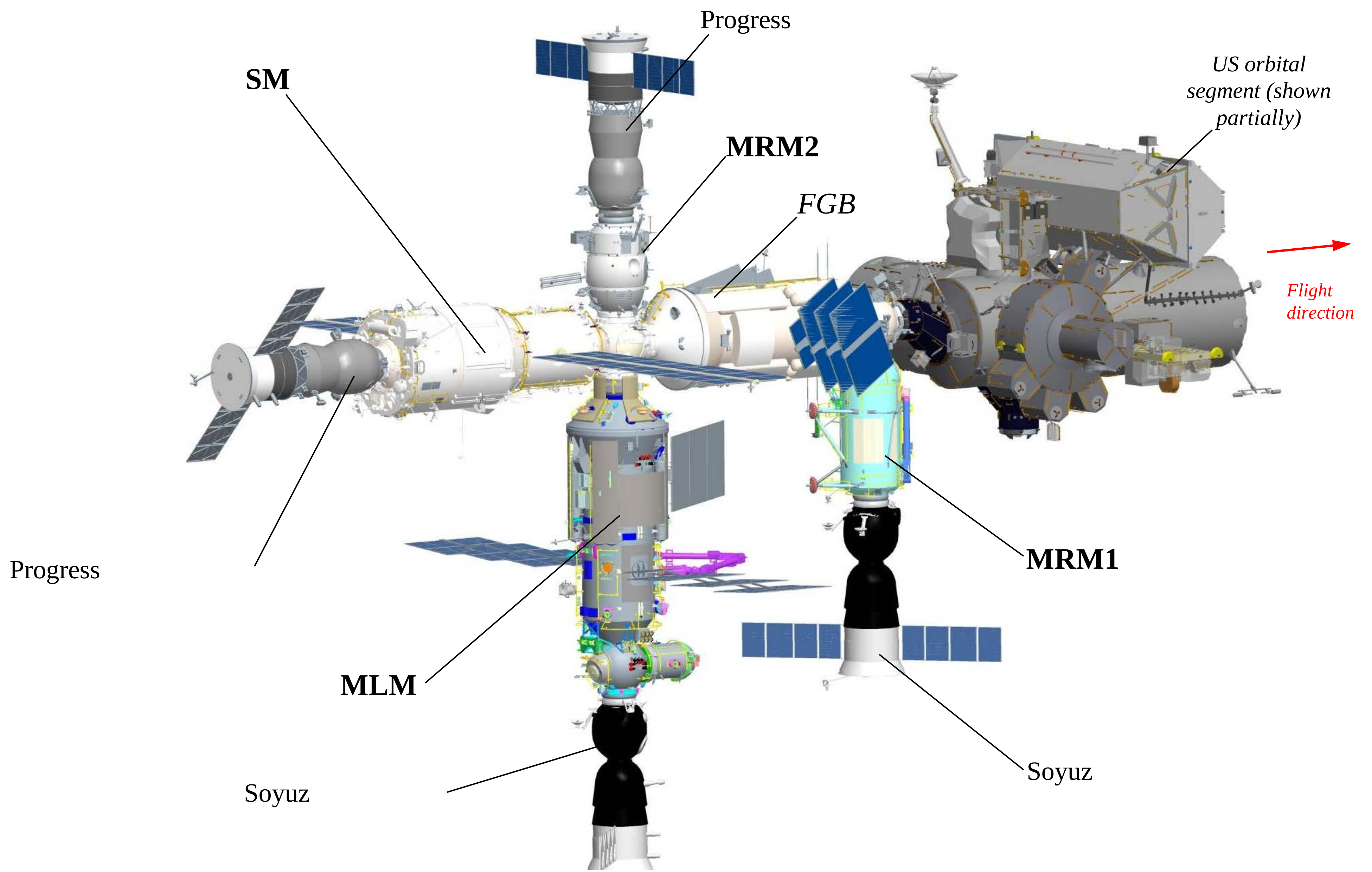


Fig. 3.2 – ISS RS configuration consisting of SM, MRM2, MRM1 and MLM

3.3 ISS RS consisting of SM, MRM2, MRM1, MLM-U and NM

After the Node Module (NM) is attached to the ISS RS and the MLM module is outfitted during an EVA with a LOAD platform, the ISS RS configuration will be as shown in Fig. 3.3.

Resources allocated to the MPF include:

- allocated working volume of : up to 1 m^3 on SM, up to 0.2 m^3 on MRM2, up to 3 m^3 on MRM1, and up to 6 m^3 on MLM-U;

- power supply:
  - on SM up to 0.3 kW (daily average);
  - on MRM2 up to 0.1 kW (daily average);
  - on MRM1 up to 0.1 kW (daily average);
  - on MLM-U up to 1.0 kW (daily average) inside the pressurized cabin (after deployment of an additional radiation heat exchanger) and up to 1.5 kW (daily average) outside the pressurized cabin;

- heat rejection capacity:
  - on SM and MRM2 up to 0.3 kW (daily average);
  - on MRM1 up to 0.1 kW (daily average);
  - on MLM up to 1.0 kW (daily average) after deployment of an additional radiative heat exchanger;

- the number of workstations on the outer surface:
  - 4 pcs. on the SM (8 pcs., when deliverable Multi-Purpose Workstations (MPWs) are taken into account);
  - 5 pcs. on MRM2 (7 pcs., when deliverable Multi-Purpose Workstations (MPWs) are taken into account);
  - 9 pcs. on the MLM-U (16 pcs., when deliverable Multi-Purpose Workstations (MPWs) are taken into account);

- payload data downlink capacity (maximum, via the 2nd RF system for data transmission): up to 50 GB per a session;

- ISS attitude control mode (nominal): Orbital Coordinate System (OCS);

- ISS OCS attitude control accuracy   : ± 10 angular minutes;

- ISS angular rate stabilization accuracy: 0.005 deg/s;

- the number of telemetered parameters: up to 212 (SM), up to 50 (MRM2), up to 36 (MRM1), up to 323 (MLM);

- the list of electrical interfaces available for MPF:

- RS-232;
- RS-422 interface channels per EIA RS422A standard with maximum data exchange rate of 115 Kbps (on SM and MLM);
- CAN interface channels per requirements of EIA RS485 standard for electrical parameters of the signal. The logical level of the protocol shall be compliant with the specification CAN 2.0 B, ISO/DIS 11898. The maximum data rate is 1 Mbps (on SM and MLM);
- Ethernet 10/100 Base T interface channels per requirements of standards IEEE 802.3 and IEEE 802.3u. The maximum data rate is 100 Mbps;
- USB;
- local data highway interface of the multiplexed data exchange channel per national standard GOST 26765.52-87 (MIL STD 1553B). The maximum data rate is 1 Mbps (only on MLM);

- HF with wave impedances of 75 Ohm and 50 Ohm (on SM and MLM);

- discrete control commands (on SM, MRM2 and MLM);

- the number of vaccumization interfaces for MPF:

- 1 pc. on MRM2,
- 1 pc. on MRM1,
- 2 pcs. on MLM;

- the number of thermostatting interfaces for MPF: 2 pcs. on MLM.

The MPF cargo traffic to ISS RS is planned based on the following assumptions:

- delivery of cargo to ISS RS onboard Progress logistics spacecraft: on average up to 600 kg per year;

- return from ISS RS in the descent vehicle of the Soyuz crew transportation spacecraft of up to 110 kg of payloads per year.

The external appearance of ISS RS in the above configuration is shown in Figure 3.3.

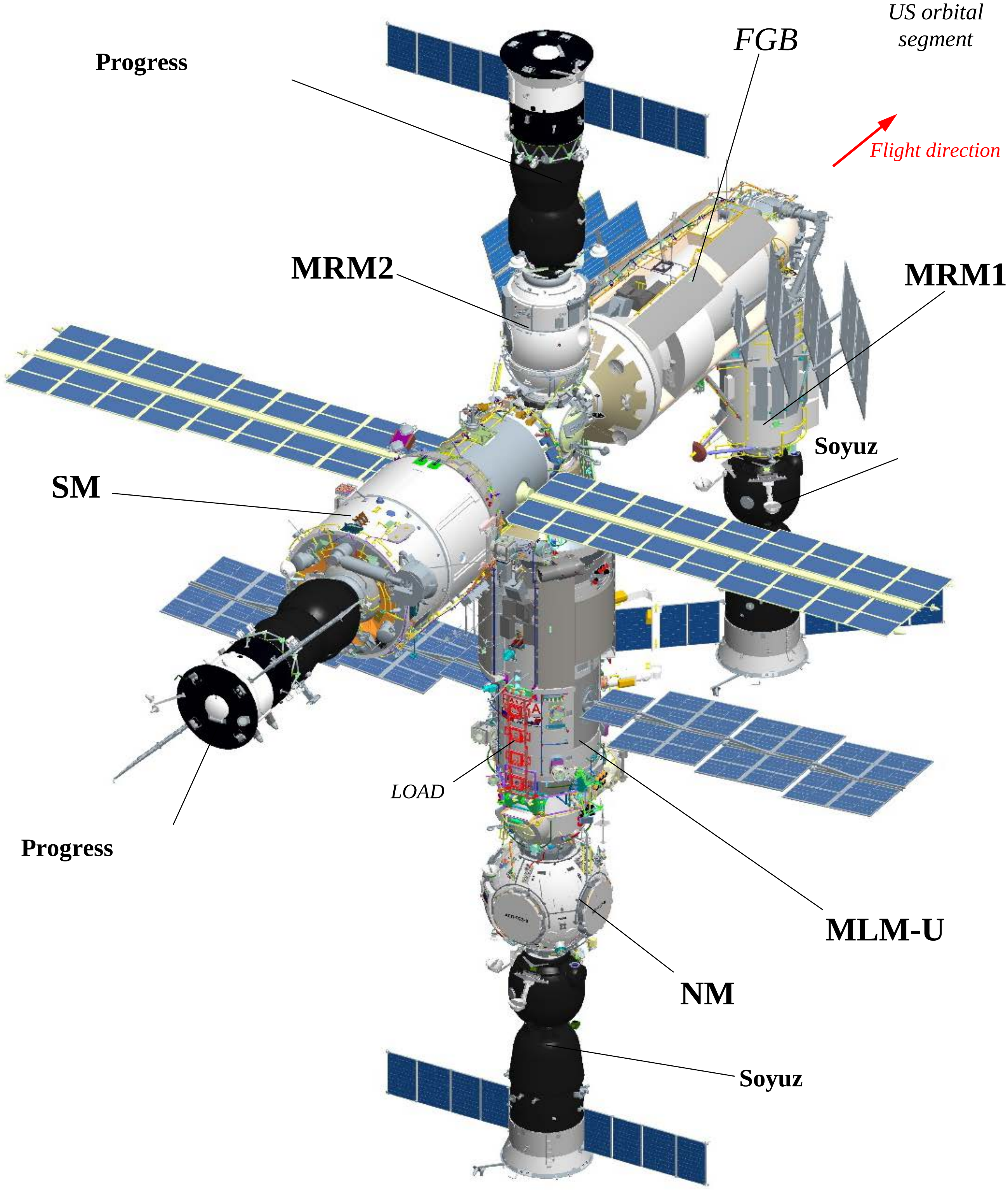


Fig. 3.3 – ISS RS configuration consisting of SM, MRM2, MRM1, NM, MLM-U

3.4 Characteristics of communication links and downlinking

ISS RS has several channels for downlinking data from science payloads. Among them the main downlinking channels are the ones that go:

- via the radio link of the RF system for data transmission with data rate of up to 100 Mbps (up to about 4 GB per a communications session);
- via the TM IU unit and the radio link of telemetry system OI&TS2-12 (in the data file transmission mode) with data rates of up to 50 Mbps (up to about 2 MB per a communications session);

3.5 Trajectory and navigation support for space experiments

ISS, together with the ISS RS, is continuously (normally) operated in the Equilibrium Orbital Coordinate System (EOCS or TEA). EOCS axis at each specific phase in the ISS mission (depending on the current ISS configuration), slightly deviate (through 1÷5 degrees) from the Orbital Coordinate System (OCS or LVLH).

The attitude of the EOCS axes is selected in such a manner as to achieve the minimal integrated disturbance torque for an orbit when ISS flies in this coordinate system.

The Orbital Coordinate System OCS is defined as follows:

- Y-axis is pointing along the radius-vector connecting the center of Earth's geoid with the ISS center of mass;
- X-axis lies in the orbital plane and is pointing toward the ISS velocity vector;
- Z-axis is perpendicular to axes X, Y and completes the right-handed coordinate system.

The accuracy and stability of maintaining the ISS in the coordinate system are:

- ISS OCS attitude control accuracy : ± 10 angular minutes;
- ISS angular rate stabilization accuracy: 0.005 deg/s.

Additional requirements for payload accuracy and stabilization during a space experiment shall be met through the use of additional specialized (or multipurpose) equipment working in conjunction with the operating mission payload equipment, such as two-axial rotating platforms.

ISS can perform programmed pitch and roll maneuvers within ± 15 degrees (this constraint is imposed due to the lighting conditions of the thermal control system panels on the US orbital segment).

3.5.1 Trajectory and navigation display program Sigma

Currently installed on on-board crew support laptop computers is the Sigma program for displaying the trajectory and navigation flight environment, which enables the crew to independently perform the following tasks:

- continuous real-time display on the laptop computer screen of the ISS position, ground track of the current orbit, coverage areas of the nearest ground stations, the start and end times of the next communications session with Earth, lighting environment in orbit, mission elapsed time, etc.;
- provide real-time simulations of the future (prediction) or the past position of the space station;
- automatically determine on the electronic maps the name of the region, the country, the body of water;
- promptly calculate (predict) when and how well a specified area on the Earth surface is going to be visible from the space station within the interval of time covering the next 16 orbits to a week;
- simulate in real time a segment of the Earth surface and/or of the celestial sphere which is visible through the specified porthole.

To assure normal operation of the trajectory and navigation support software, provisions have been made for daily uplinks of the orbital trajectory data predictions.

3.6. The list of photographic and video equipment onboard ISS RS

Currently available onboard ISS RS is equipment (still photo/video cameras), which can support the conduct of space experiments and record the process of conducting the space experiments.

Tables 3.6.1 and 3.6.2 provide the lists of photographic and video equipment onboard ISS RS, respectively.

Table 3.6.1 The list of photographic equipment onboard ISS RS

Equipment name	Major accessories *(see table)
Still camera Nikon D3X	Nikkor autofocus lenses
Still camera Nikon D3	Nikkor autofocus lenses
Still camera Nikon D800	Nikkor autofocus lenses
Still camera Nikon D4	Nikkor autofocus lenses
Flash lamp Nikon SB-800	
Binoculars 20x50	

Table 3.6.2 The list of video equipment onboard ISS RS

Equipment name	Major accessories
Video system LIV	Telescopic lens Fujinon A16x9 BRM-28A
HDTV videosystem	Telescopic lens HJ15x8B IAS
HDV videocamera (Sony HVR-Z1 and Sony HVR-Z7)	The camcoder contains a high-resolution video camera with 3 CCD matrices and HDV video recorder
Video camera Sony DSR PD150P	12x zoom lens matches the 1/3-inch CCD system Optical stabilizer - Super SteadyShot™

A more detailed description, characteristics and external appearance of the above equipment are given in sections 3.7 and 3.8.

3.7. Equipment for still photography

Specifications.

Currently available onboard ISS RS are still cameras Nikon D3X, Nikon D3, Nikon D800 and Nikon D4 (see Table 3.7.1.1), which make it possible to take high-resolution photos of the Earth surface and other objects through ISS portholes.

The still cameras come with accessory lenses which are listed below and are intended for different tasks.

20× power binoculars with image stabilization are intended for visual observation of remote objects. The binoculars are pressure-sealed and moisture-proof.

An enclosure for camera Nikon D3 is intended for shooting photos during extravehicular activities.

The Nikon D3 enclosure with a Nikon D3 camera inside shall support EVA photography for seven hours with the maximum number of pictures in RAW format of no less than 200. The complete set of the Nikon D3 enclosure may include the following equipment:

- The enclosure wit a port for the lens;
- Nikon D3 camera with storage battery Nikon EN-EL4a;
- camera lenses: AF-NIKKOR 24mm f/2,8D, AF-NIKKOR 28mm f/2,8D, AF-NIKKOR 35mm f/2D;
- Protective cover made of MLI ;
- a bracket for attachment to the spacesuit

Table 3.7.1.1 Lenses for the Russian photographic equipment onboard SM

#	Name
1	Lens AF-S Nikkor 14-24 mm f/2.8
2	Lens AF-S Nikkor 17-35 mm f/2.8
3	Lens AF-S Nikkor 24-120 mm f/3.5-5.6
4	Lens AF-S Nikkor 24-120 mm f/4
5	Lens AF-S Nikkor 28-70 mm f2.8
6	Lens AF-S Nikkor 70-200 mm f/2.8
7	Lens AF VR Nikkor 80-400 mm f/4.5-5.6
8	Lens AF SIGMA 300-800 f/5.6
9	Lens AF-S Nikkor 14 mm f/4
10	Lens AF Nikkor 28 mm f/2.8
11	Lens AF-S Nikkor 35 mm f/2.0
12	Lens for ultra close-up photography AF-S Nikkor 60 mm f/2.8
13	Lens AF-S Nikkor 85 mm f/1.4
14	The lens for ultra close-up photography Micro-Nikkor f = 105 mm f/2.8
15	Telephoto lens AF-S Nikkor 600mm f/4
16	Telephoto lens AF-S Nikkor 400mm f/2.8
17	Extender Nikon TC-14E
18	Extender lens Nikon TC-20E
19	Extender Nikon TC-17E
20	Sensor clear lens

Photographic equipment is self-contained and is not connected to the onboard power supply line. Chargers for storage batteries of the Nikon camera are hooked up to connectors on the LIV video system.

Photographic equipment specifications (tables 3.7.1.2, 3.7.1.3, 3.7.1.4, 3.7.1.5), the external appearance is shown in Fig. 3.7.1.1, 3.7.1.2, 3.7.1.3, 3.7.1.4.

Fig. 3.7.1.1 External view of still camera Nikon D3 (Nikon D3X)

Table 3.7.1.2

Digital still camera Nikon D3 (Nikon D3X)	
CCD matrix dimensions	36.0x23.9 mm (35.9x24.0 mm)
Image size	4288x2848 (6048x4032)
Light sensitivity	Equivalent to 200÷6400 ISO speed 25600 ISO (100÷1600)
Recording medium	Compact Flash memory cards
Compression	RAW (NEF) and JPEG formats.
LCD display	3-inch, with 920000 pixels, with adjusted brightness, 100% frame coverage
Lenses	Nikkor auto focus lenses
Optical exposure	Automatic (software controlled with time of exposure or aperture having higher priority) and manual

Optical exposure measuring area	Matrix-based, centrally-weighted, spot measurement
Exposure time range	1/8000÷30s
Bracketing mode	2-9 frames with incremental steps of 1/3, 2/3 or 1 EV
Synchronization with the flash	5 modes
Power	Li-Ion battery EN-EL4a (11.1V)
Dimensions	159.5x157x87.5 mm
Mass	1.24 kg (1.22 kg)

Fig. 3.7.1.2 External view of still camera Nikon D800

Table 3.7.1.3

Digital still camera Nikon D800	
CCD matrix dimensions	35.9 × 24.0 mm
Image size, pixels	7360 × 4912
ISO light sensitivity	100-6400
Recording medium	Compact Flash memory cards
Compression	RAW (NEF) and JPEG formats
LCD display	3.2-inch
Lenses	Nikkor auto focus lenses
Optical exposure	Automatic (software controlled with time of exposure or aperture having higher priority) and manual
Optical exposure measuring area	Matrix-based, centrally-weighted, spot measurement

Exposure time range	1/8000÷30s
Bracketing mode	2-9 frames with incremental steps of 1/3, 2/3 or 1 EV
Power	Li-Ion storage battery EN-EL15, 7V (EN-EL18)
Dimensions	146 × 123 × 81 mm
Mass	0.9 kg
Video mode	1920 × 1080

Fig. 3.7.1.3 External view of still camera Nikon D4

Table 3.7.1.4

Digital still camera Nikon D4	
CCD matrix dimensions	36.0 × 23.9 mm
Image size, pixels	4928 × 3280
ISO light sensitivity	100-12800
Recording medium	Compact Flash memory cards
Compression	RAW (NEF) and JPEG formats
LCD display	3.2-inch
Lenses	Nikkor auto focus lenses
Optical exposure	Automatic (software controlled with time of exposure or aperture having higher priority) and manual
Optical exposure measuring area	Matrix-based, centrally-weighted, spot measurement
Exposure time range	1/8000÷30s

Bracketing mode	2-9 frames with incremental steps of 1/3, 1/2, 2/3 or 1 EV
Power	Li-Ion storage battery EN-EL18 (10.8V)
Dimensions	160 × 156 × 91 mm
Mass	1.18 kg
Video mode	1920 × 1080

Fig. 3.7.1. External view of binoculars БКСШ 20x50

Table 3.7.1.5

Specifications of binoculars БКСШ 20x50	
Magnifying power	20×
Field of view angle, deg.	4.1 ± 0.2
Dioptric adjustment of eye-lens, diopters	-5 to +5
Pupil distance adjustment range, mm	56 ÷ 74
Overall dimensions, mm	215×164×76
Mass, kg	1.3

3.8. Video equipment

The video equipment is intended for live event filming and creating a video record of experiments inside the ISS RS, and for filming during EVA. Video and audio produced by the crew can be downlinked via the Station-to-MCC channel both in real time and in the dump mode. Video equipment includes:

- video system LIV;
- video system Glisser-M;
- HDTV equipment.

3.8.1 Video system LIV

The LIV video system is intended for performing the following tasks:

- filming live and recorded TV broadcasts inside the station and through portholes;
- video recording of experiments;
- video recording with audio inside station modules and through portholes, including high-definition video;
- receiving and recording video from TV system;
- sending video into TV system in analog and digital format, including high-definition video;
- monitoring audio and video signals;
- filming videos from Soyuz crew transportation spacecraft during re-docking operations.

3.8.1.1 Inventory

List of equipment

#	Name
1.	28V/12V voltage converter UN-941
2.	Switch Sony VCS-63A
3.	Camcorder Sony PMW-EX1R
4.	Camcorder Sony PMW-200
5.	Hard disk drive Sony PHU-220R
6.	Battery charger Sony BC-U1
7.	Battery charger Sony DC-V700 with cable SM-LIV-59
8.	Storage battery Sony BP-U60
9.	Sound mixer Sony MX-P42

#	Name
10.	Microphone Sony F-115
11.	Microphone Sony ECM-55S
12.	Microphone Sony ECM-77B
13.	Earphones Sony MDR-7506/1
14.	Monitor Sony LPM-770BP
15.	Plug-in transmitter SKP 100 G3
16.	Microphone Sennheiser E 835-S
17.	Miniature transmitter SK 100 G3
18.	Clip-on microphone ME4
19.	On-camera receiver EK 100 G3
20.	Multi-purpose portable bracket
21.	Consumables: Memory cards and their adapters, AA batteries

Fig. 3.8.1.1 External appearance of camcorder Sony PMW-EX1R

Table 3.8.1.1 Specifications of camcorder Sony PMW-EX1R

Mass	About 2.8 kg
Dimensions	178 × 176 × 311.5 mm
Continuous running time	About four hours with battery BP-U60 About two hours with battery BP-U30
Recording format	Video MPEG-2 Long GOP. HQ mode: VBR (Variable Bit Rate), maximum rate: 35 Mbps, MPEG-2 MP@HL SP mode: CBR (Constant Bit Rate), 25 Mbps, MPEG-2 MP@H14 Audio Linear PCM (2 channels, 16 bit, 48 kHz)
Recording framerates	NTSC settings HQ mode: 1920 × 1080/59.94i, 29.97P, 23.98P, 1280 × 720/59.94P, 29.97P, 23.98P SP mode: 1440 × 1080/59.94i PAL settings HQ mode: 1920 × 1080/50i, 25P, 1280 × 720/50P, 25P SP mode: 1440 × 1080/50i
Recording/playback time	HQ mode About 50 min with memory card SBP-16 (16 GB), about 25 min with memory card SBP-8 (8 GB) SP mode: About 50 min with memory card SBP-16 (16 GB), about 25 min with memory card SBP-8 (8 GB)

Camcorder PMW-EX1R has a ½-inch professional 14x power HDTV zoom lens Fujinon and a unique mechanism with two focusing modes.

The front lens in the lens system is protected with a hood and a shutter.

Fig. 3.8.1.2 External appearance of camcorder Sony PMW-200

Table 3.8.1.2 Specifications of camcorder Sony PMW-200

Mass	About 2.7 kg
Dimensions	172 × 164 × 317 mm
Running time	About 6 hours with battery BP-U90
Recording format	Video: UDF: - HD422 mode: CBR (Constant Bit Rate), max. rate: 50 Mbps, MPEG-2 422P@HL - HD420 mode: VBR (Variable Bit Rate), 35 Mbps, MPEG-2 MP@HL; - DVCAM mode: DVCAM; FAT: - HQ 1920 mode: VBR (Variable Bit Rate), 35 Mbps, MPEG-2 MP@HL; - HQ 1440 mode: VBR (Variable Bit Rate), 35 Mbps, MPEG-2 MP@HL; - HQ 1280 mode: VBR (Variable Bit Rate), 35 Mbps, MPEG-2 MP@HL; - SP 1440 mode: CBR (Constant Bit Rate), 25 Mbps, MPEG-2 MP@H-14; - DVCAM mode: DVCAM. Audio: UDF: - HD422 mode: Linear PCM 24 bits, 48 kHz, 4

	channels; - Alternative mode: Linear PCM 16 bits, 48 kHz, 4 channels; FAT: - HD mode: Linear PCM 16 bits, 48 kHz, 4 channels; - SD mode: Linear PCM 16 bits, 48 kHz, 2 channels.
Recording frame rates	NTSC settings HQ mode: 1920 × 1080/59.94i, 29.97P, 23.98P, 1280 × 720/59.94P, 29.97P, 23.98P SP mode: 1440 × 1080/59.94i PAL settings HQ mode: 1920 × 1080/50i, 25P, 1280 × 720/50P, 25P SP mode: 1440 × 1080/50i
Recording/playback time	HQ 1920/HQ 1440/HQ 1280 mode: About 200 min with memory card SBP-64/ SBS-64G1A (64 GB); About 100 min with memory card SBP-32/ SBS-32G1A (32 GB); About 50 min with memory card SBP-16 (16 GB); SP 1440 mode: About 280 min with memory card SBP-64/ SBS-64G1A (64 GB); About 140 min with memory card SBP-32/ SBS-32G1A (32 GB); About 70 min with memory card SBP-16 (16 GB); DVCAM mode: About 260 min with memory card SBP-64/ SBS-64G1A (64 GB); About 130 min with memory card SBP-32/ SBS-32G1A (32 GB); About 65 min with memory card SBP-16 (16 GB).
Inbuilt microphone	Omni-directional condenser electret microphone.

Camcorder PMW-200 has a wide-angle 14x power zoom lens with focal length variable from 31.4 to 439 mm (equivalent to 35 mm lens) and

SteadyShot™ image stabilization function. Camcorder PMW-200 has with a large 3.5-inch color WVGA display.

Fig. 3.8.1.3 External appearance of Sony LPM-770BP monitor

Table 3.8.1.3 Specifications of Sony LPM-770BP monitor

Type	Active TFT matrix
Resolution	800 × 480 pixels
Effective size of the image (W×H)	152.4 × 91.5 mm, 177.8 mm diagonal
Format	15:9
Requirements for power supply	7.2 V DC, battery Sony NP-F970/F770, 12 V DC, type XLR, 4-contacts, plug

3.8.2 Stand-alone video system Glisser-M for a crewmember to record activities outside the pressurized cabin.

3.8.2.1 Purpose

A standalone video system for a crewmember is intended for recording onto a memory card the process of extravehicular activities (EVA) with the distance to the subject varying from 0.3m to ∞. The system includes two camcorders GoPro Hero 3 in spcial enclosures.

Key specifications of the camcorder

- the number of pixels – 4000 × 3000 (12 MP);
- Horizontal viewing field angle – about 170 deg.;
- usable resolution – 1920 × 1080;
- recording duration, min – up to 180;
- Average time required to charge one storage battery, hours – 1.5.

Key specifications of camcorder GoPro Hero 3

- the number of pixels – 4000 × 3000 (12 MP);
- - horizontal viewing field angle – about 170 deg.;
- -usable resolution – 1920 × 1080;
- - recording duration, min – up to 180;
- - average time required to charge one storage battery, hours – 1.5.

Fig. 3.8.2.1 External appearance of camcorder for a crewmember Glisser-M

3.8.3 HDTV equipment

3.8.3.1 Purpose

The HDTV equipment is intended for carrying out the following tasks:

- video recording of experiments;
- video shooting inside the SM to provide information to general public;
- video filming of the Earth

3.8.3.2 Inventory

The complete set of HDTV equipment includes camcorders Sony HVR-Z1U and Sony HVR-Z7E of the HDV digital format. Using an adapter to the bracket LIV/106/20, the camcorders can be installed on the bracket in order to fasten them to the SM handrails. The HDV kit also includes a wide-angle attachment x0.8 Sony VCL-HG0872, Sony batteries NP-F970, lights Sony HVL-LBP, a set of cables and adapters.

The list of essential HDTV equipment onboard the ISS RS

#	Name
1.	Camcorder Sony HVR-Z1U
2.	Camcorder Sony HVR-Z7E
3.	Lens Fujinon HAs18x7.6BRM 137mm
4.	Adapter ACM-17
5.	Camera light Sony HVL-LBP
6.	Wide-angle attachment x0.8 Sony VCL-HG0872

Fig. 3.8.3.1 Exterior view of camcorder Sony HVR-Z1U

The camcorder works in the HDV1080i format, which uses 1080 effective scanning lines in HDV standards, and records the video at the data rate of about 25 Mbps. The i.LINK is adopted as the digital interface enabling a digital connection with HDV-compatible TV sets and personal computers.

Fig. 3.8.3.2 Exterior view of camcorder Sony HVR-Z7E

Camcorder Sony HVR-Z7E has tape path specifications similar to Sony HVR-Z1U.

Camcorders Sony HVR-Z1U and Sony HVR-Z7E are professional-grade HDV equipment. The camcorders can work in PAL and NTSC systems, as well as in HDV, DV and DVCAM formats. The draw their power from the storage battery Sony **NP-F970**. The camcorder has a wide-angle zoom lens. The camcorder Sony HVR-Z1 has a wide-angle attachment x0.8 Sony VCL-HG0872 to increase the viewing angle. The camcorders have a system of color filters and the white-balance system, as well as an amplifier and an electronic shutter.

4 Capabilities provided in support of scientific equipment operation onboard the ISS RS modules

4.1 Service module (CM)

Characteristics:

- pressurized volume: 75 m^3,

- storage volume for cargoes and scientific equipment: 3.3 m^3,

- in particular, for scientific equipment: 0.03 m^3,

- power for scientific equipment: 0.3 kW

- maximum daily average rejection of heat from the hardware included in the MPF through the air loop of the thermal control system:

The following interfaces with the module are used for integration of the scientific equipment into the SM:

- mechanical interface;
- electrical interfaces, including power interface, telemetry interface, data interfaces;
- thermal interface;
- vacuum interface (connection to external environment).

The SM design provides for a number of areas for installing scientific equipment in orbit, which have structural support for mechanical attachment and connection of scientific equipment to the ISS support systems.

Such areas on the outside of the SM are:

- the MPWS-N1 workstation, located on the SM outer surface along plane III of the Working Compartment 1 between frames 3, 4. Installed on an adapter plate on the SM hull as a mechanical device for attachment of scientific equipment is a Passive Base Point (PBP). Scientific Equipment is installed by an operator during EVA onto the PBP using an adapter, which includes an Active Base Point (ABP);
- workstation MPWS-N2 formed by a system of handrails 25x25 mm in cross-section on the body of the SM Working Compartment 2 between planes I and II in such a way that the normal to the line connecting the centers of cross-sections of

the two central handrails is slanted at an angle of 47° from plane I towards plane II. The scientific equipment is fastened onto the handles with special locks;

- each of the workstations MPWS-N3 (MPWS-N4) is formed by four threaded M12 holes with the base of 400×x200 mm, located in the payload fairing supports on the outer surface of the SM along planes II and IV between frames 8, 8a, respectively. Scientific equipment is installed using adapters;
- the Deliverable Multi-Purpose WorkStation (DMPWS) is installed on MPWS-N3. DMPWS consists of a base with a PBP and a platform with three payload adapters for active scientific equipment and a mating device for installation onto the PBP. Normals of the three passive adapters installed on the platform shall be aligned with axes $\pm Y_{SM}$ and $+Z_{SM}$.

Installed on MPWS-N4 is a DMPWS which is similar in design. Normals of the three adapters are aligned with axes $\pm Y_{SM}$ and $+Z_{SM}$.

The following volumes are reserved for installation and connection of scientific equipment inside the pressurized cabin of the Service Module:

- on the backside of panel 407 (УРМ4-3 zone) for scientific equipment with dimensions of up to 175x400x60 mm;
- behind panel 305 (УРМ4-2 zone) for scientific equipment with dimensions up to 220x350x300 mm.

The SM external appearance is shown in Figures 4.1.1 and 4.1.2.

External multi-purpose workstations on the SM for installing units of scientific equipment are shown in Figures 4.1.3 and 4.1.4.

SM interior view, locations of portholes, laptops and mission payloads are shown in Figures 4.1.5, 4.1.6 and 4.1.7.

SM resources used for integration of scientific equipment are listed in Table 4.1.1.

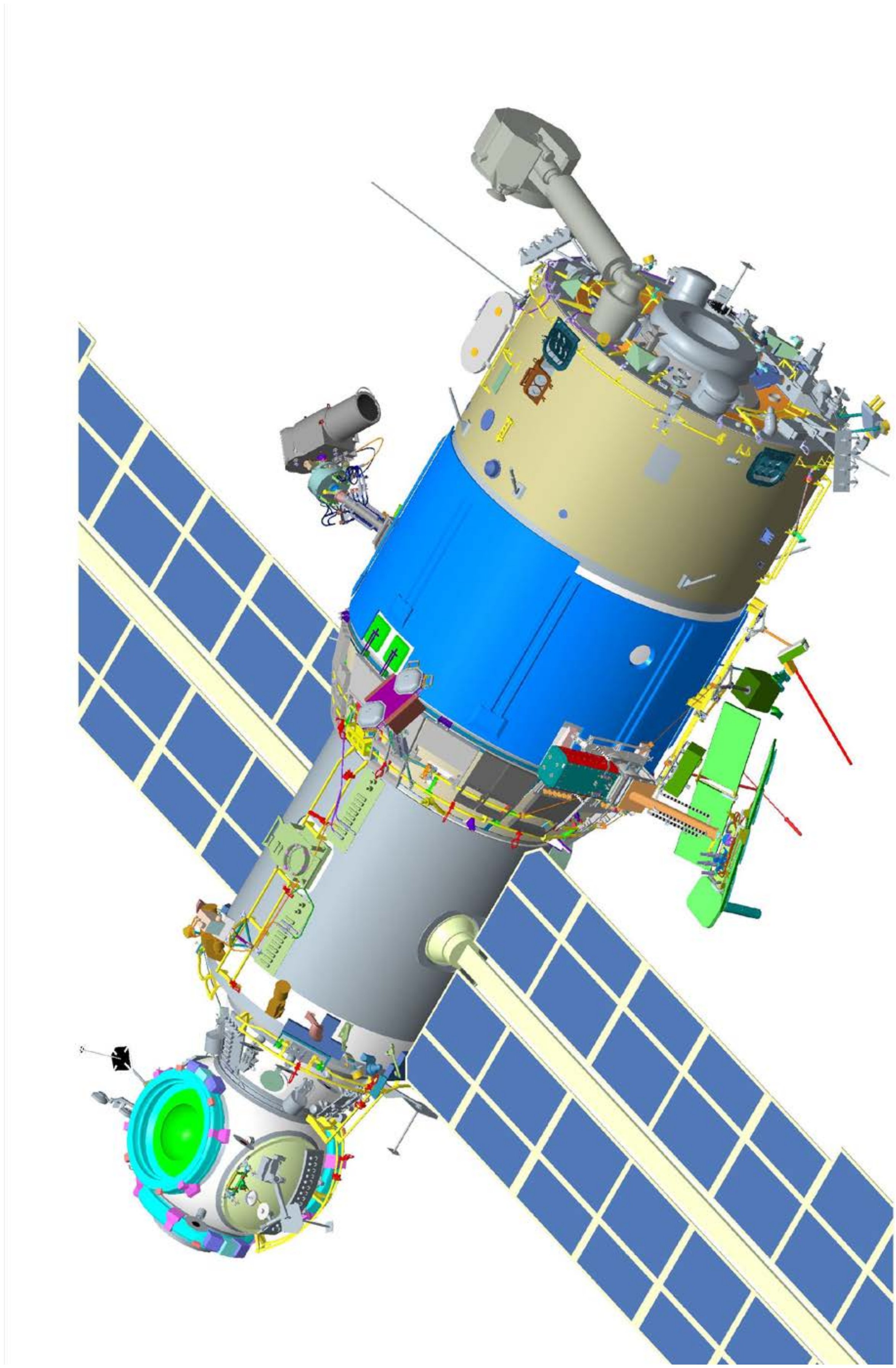


Fig. 4.1.1 – SM external view

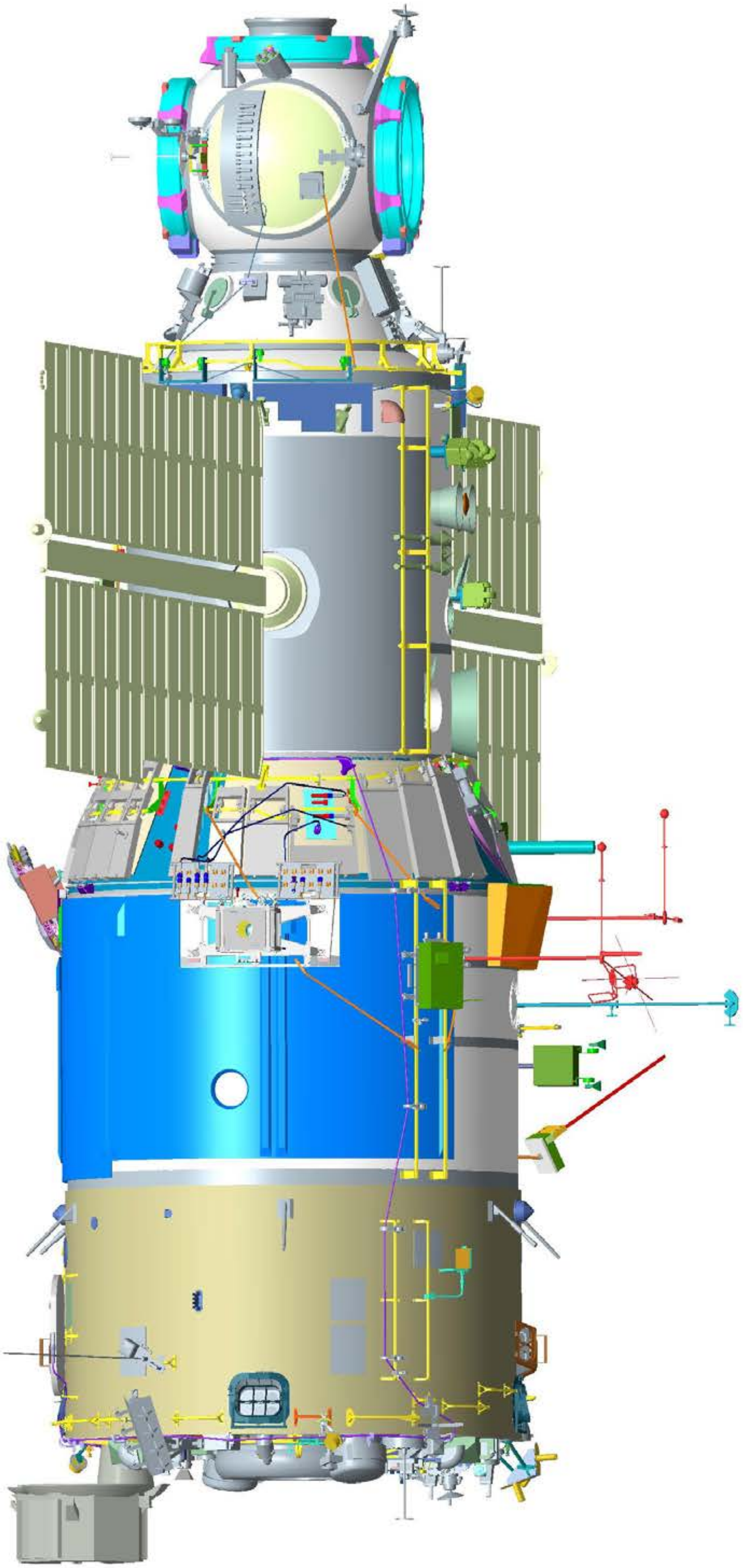


Fig. 4.1.2 – SM external view (starboard view)

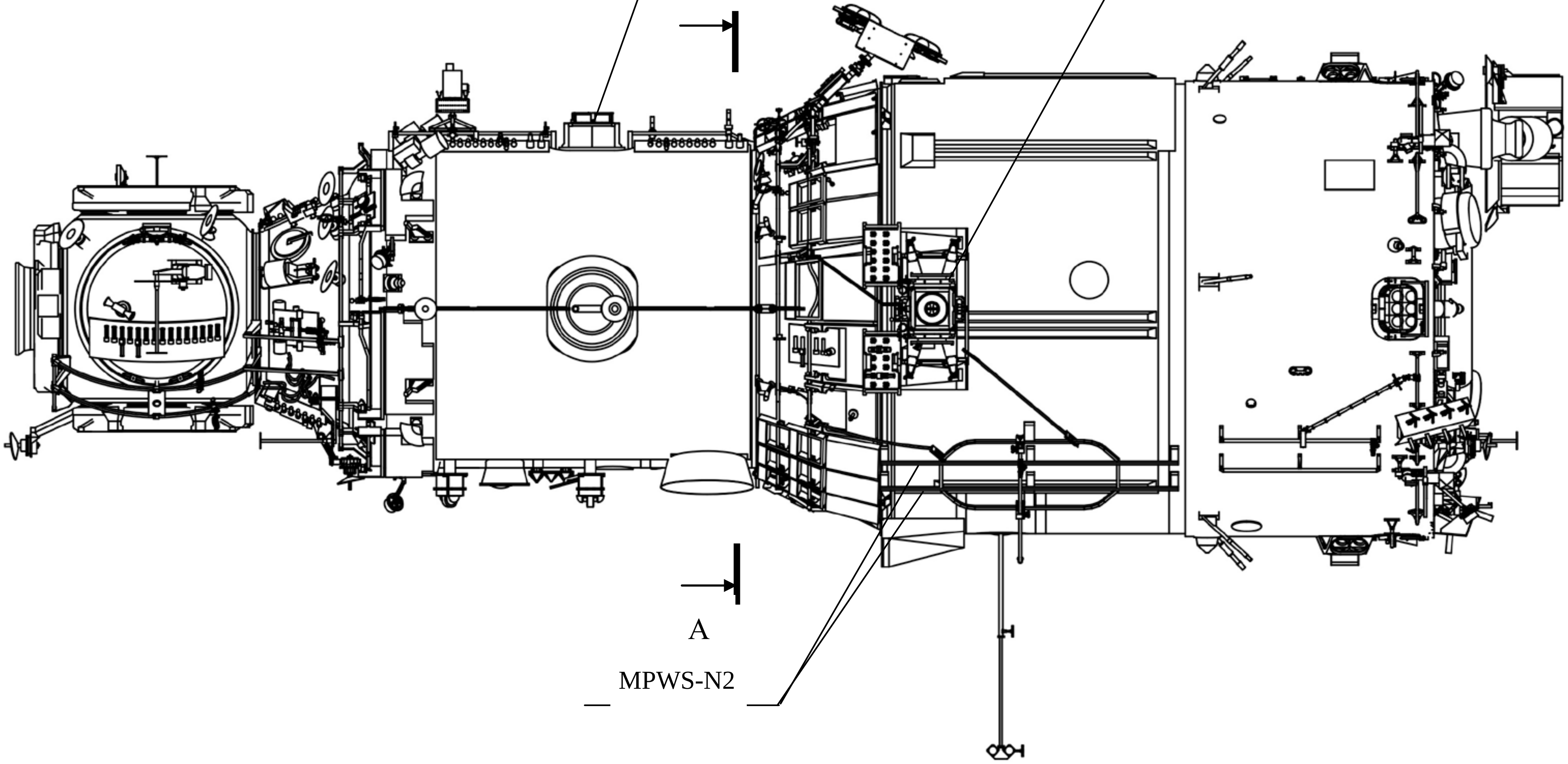


Fig. 4.1.3 – External MPWS for installing scientic equipment units on SM (portside view)

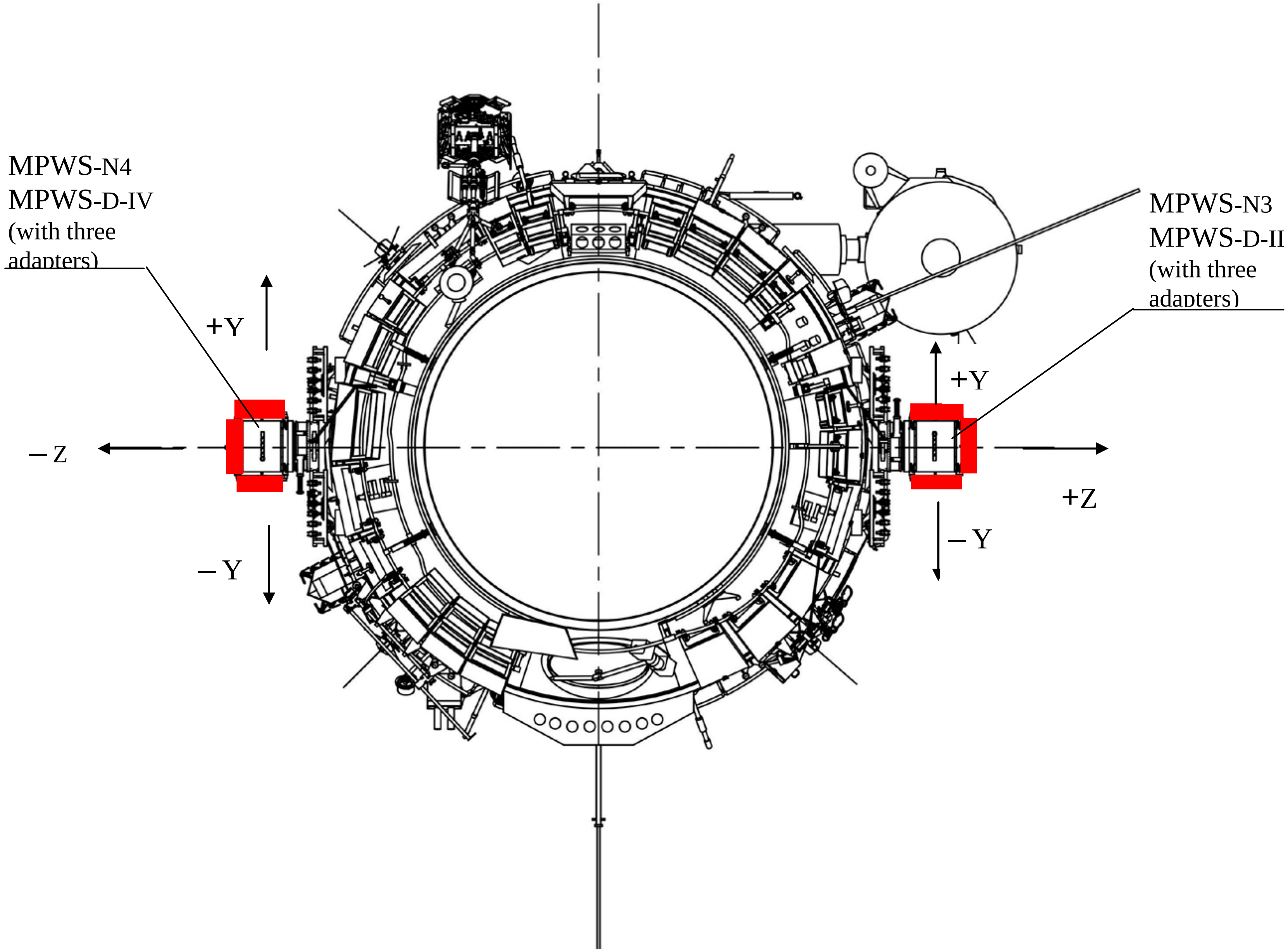


Fig. 4.1.4 – External MPWS for installing scientific equipment units on SM

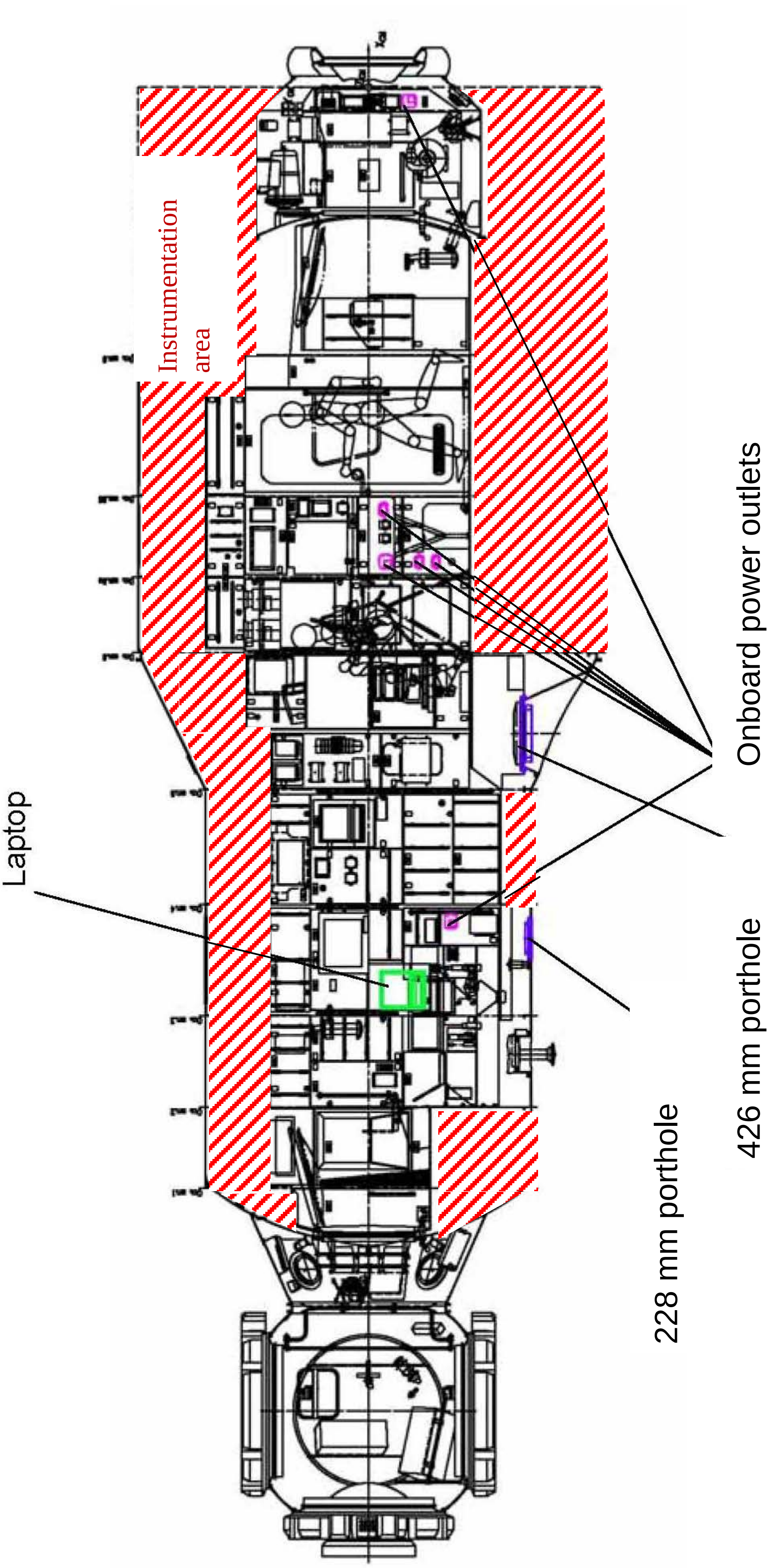


Fig. 4.1.5 – SM interior view (starboard)

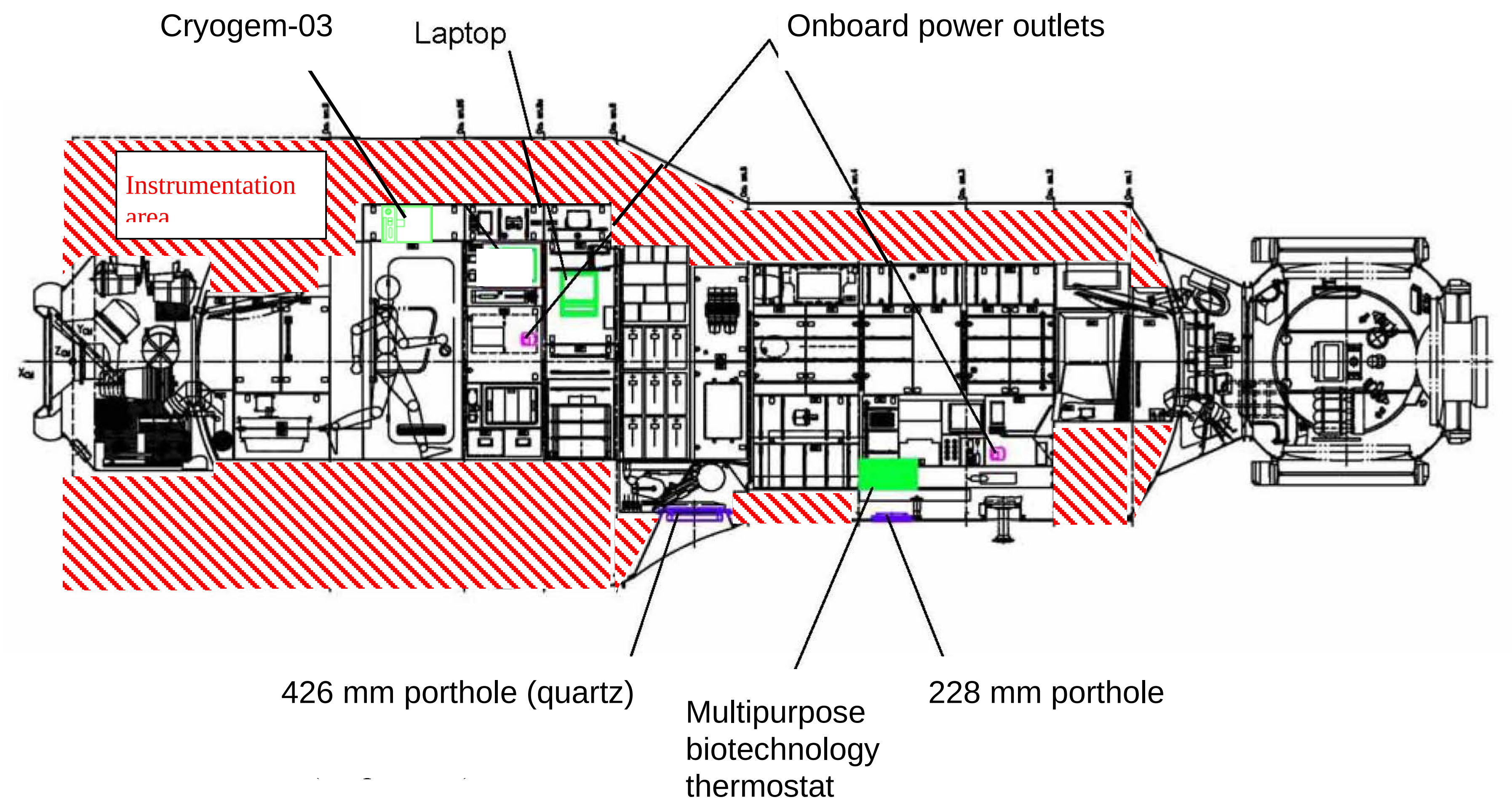


Fig. 4.1.6 – SM interior view (port side)

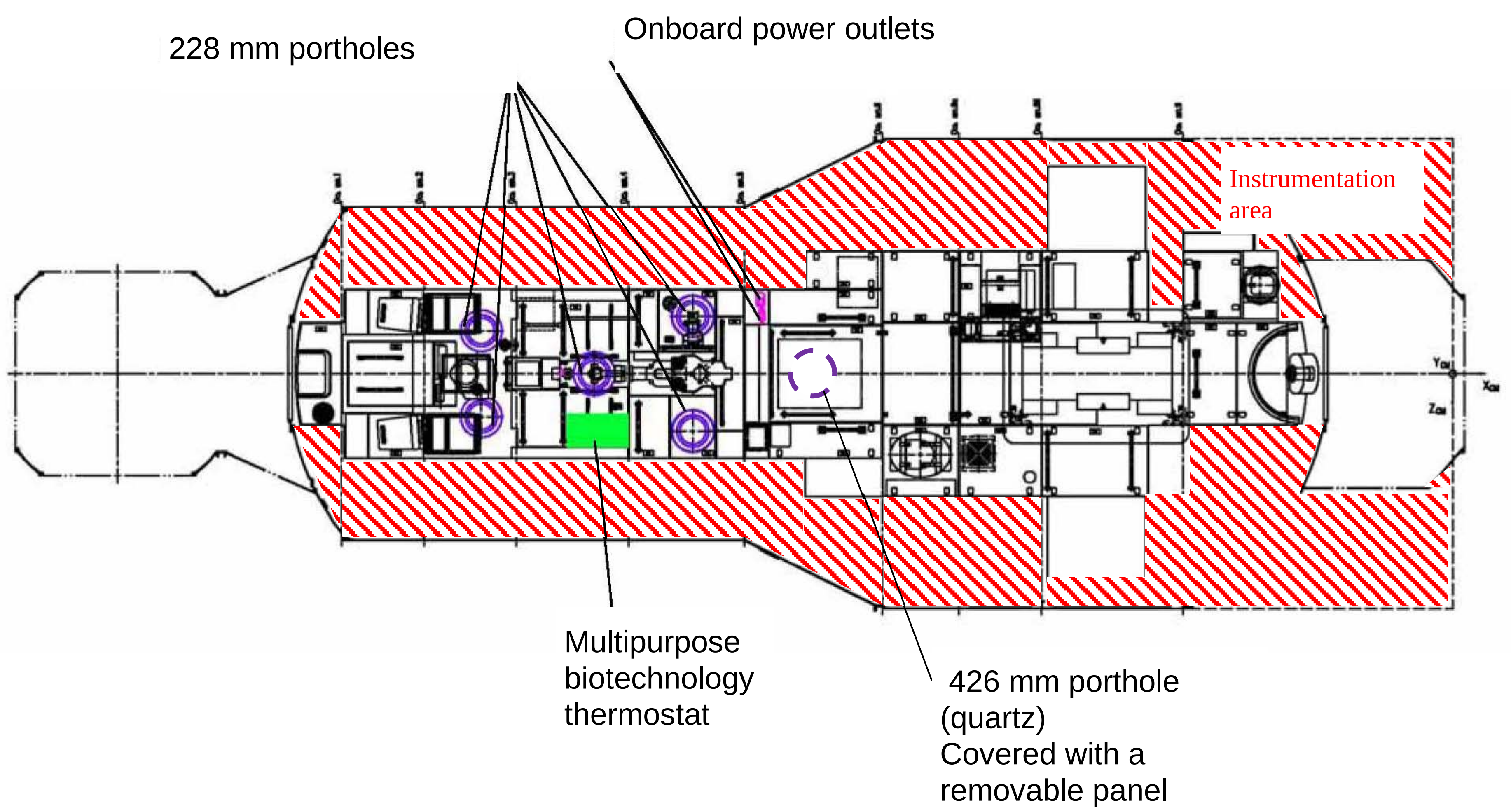


Fig. 4.1.7 – SM interior view (floor)

Table 4.1.1 – SM resources for integration of scientific equipment

Name	Multipurpose workstations	
	Internal	External
Number of multi-purpose workstations	3	4
Power consumption, W - daily average	300	
Heat released in the atmosphere, W	up to 300	-
Total volume of the hardware, m^3	no less than 1.5	-
Information interfaces	RS-422, RS-485, Ethernet, RS-232, USB	RS-422, RS-485
Television channels	No less than 2	1 (it is possible to use communications line for EVA TV camera)
Vacuum interface	1 (before MRM2 docking)	-
High-frequency channels (500 m) from pressurized cabin to outside	2	-

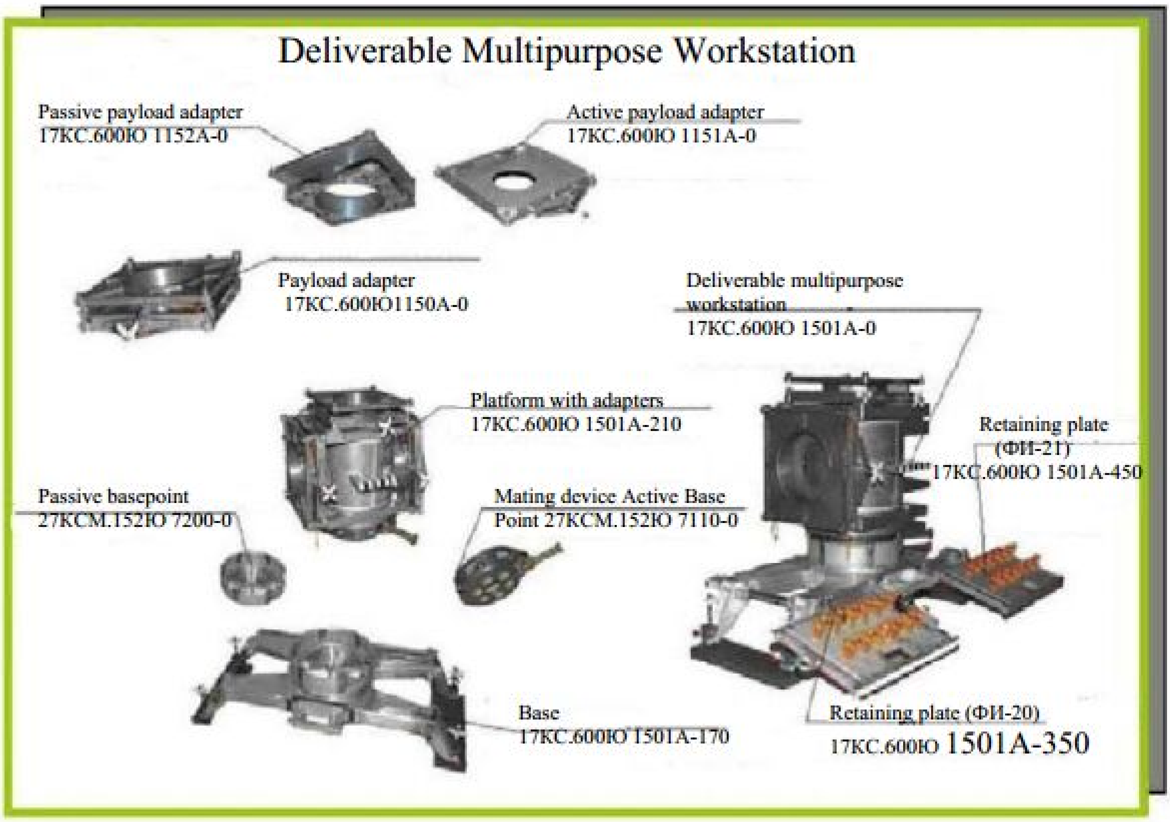
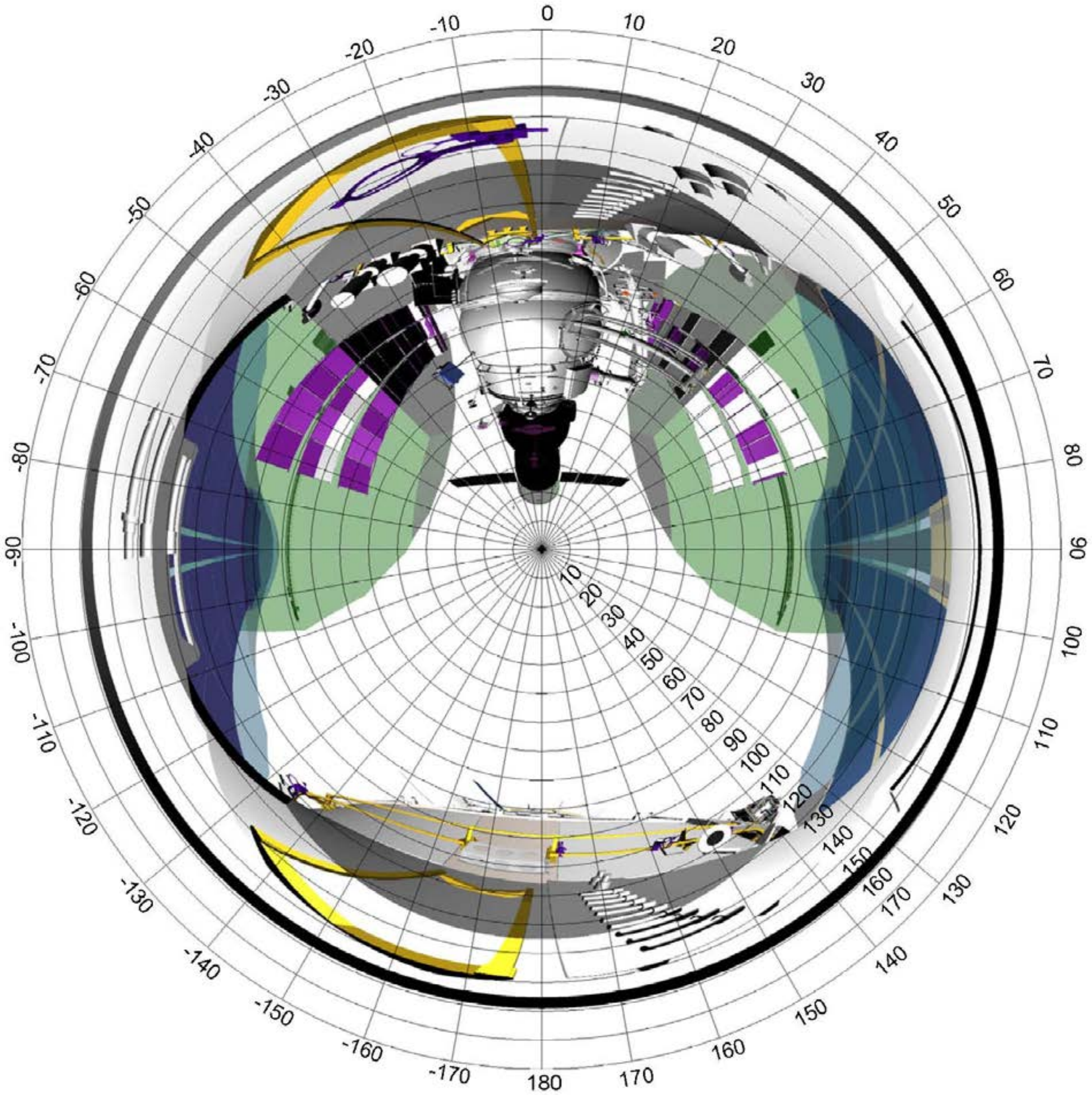


Fig. 4.1.8 – Deliverable multipurpose workstation

Sample fields of view of scientific equipment installed on the SM multipurpose workstation are given in the following figures:

- Fig. 4.1.9 – field of view of scientific equipment installed on the MPWS-N1 (axis of sight aimed at zenith +Y);
- Fig. 4.1.10 – field of view of scientific equipment installed on the MPWS-N3 (axis of sight pointed at zenith +Y);
- Fig. 4.1.11 – field of view of scientific equipment installed on the MPWS-N3 (axis of sight pointed towards nadir -Y);
- Fig. 4.1.12 – field of view of scientific equipment installed on the MPWS-N4 (axis of sight pointed at zenith +Y);
- Fig. 4.1.13 – field of view of scientific equipment installed on the MPWS-N4 (axis of sight pointed towards nadir -Y);



- Fig. 4.1.9 – field of view of scientific equipment installed on the MPWS-N1 (axis of sight aimed at zenith).

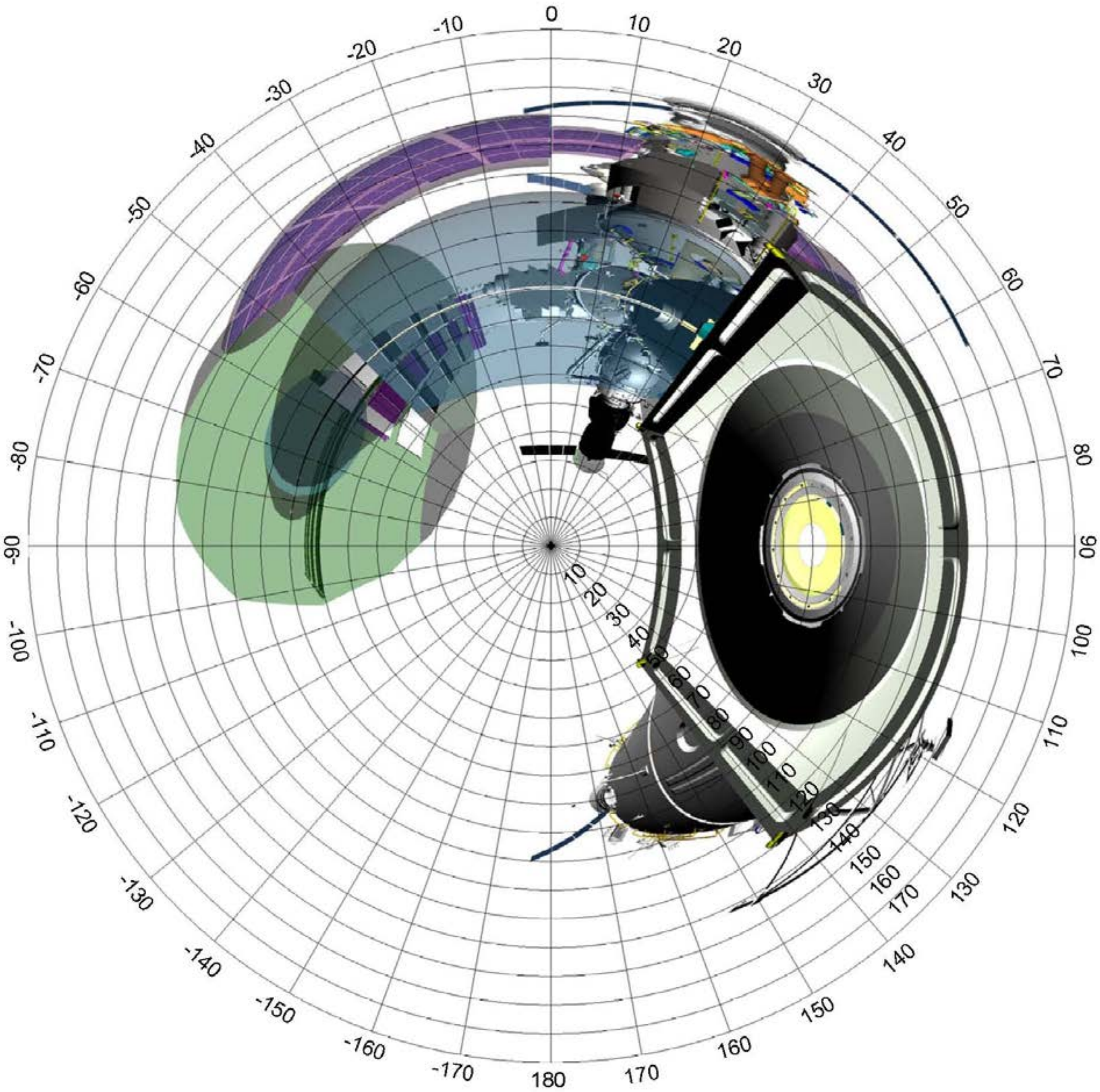
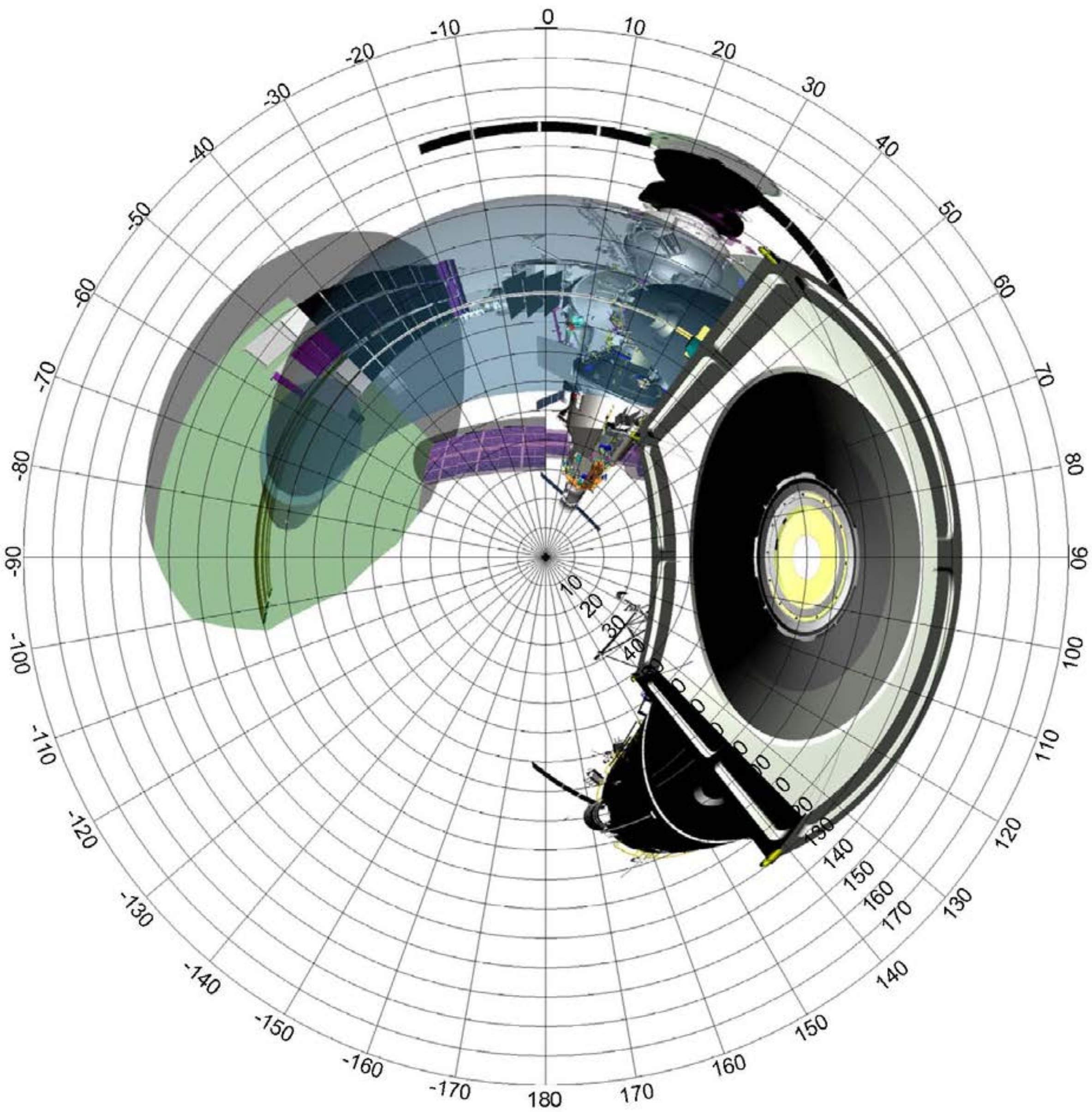


Fig. 4.1.10 – field of view of scientific equipment installed on the MPWS-N3 (axis of sight pointed towards zenith)



4.2 Docking compartment No.1 (DC1)

Characteristics:

- launch mass, kg: 7900
- pressurized volume, m^3: 17.4
- power for scientific equipment, kW: 0.1

Special features that DC1 provides for conducting scientific experiments are:

- capability to install hardware on the outer surface of DC1 for observing the plane of the local horizon;
- availability of a porthole with capability to sight the hardware in the horizon plane;

- capability to place hardware inside pressurized cabin for short periods of time for conducting space experiments and to store it only for the periods between EVAs;
- on-board systems resources for scientific equipment on the external surface are mostly borrowed from the SM.

On the DC1 external surface, possible areas for deploying payloads are:
- magnetomechanical latches, located on the cylindrical part and on the central sphere.
- passive base points (2 pcs.), located on te cylindrical part.
- brackets for the latch of the outboard workstation located (4 pcs. each) on the flange of the exit hatches.

Locations on DC1 of external multipurpose workstations based on electromechanical latches are shown in Fig.4.2.1.

Locations on DC1 of windows and electrical outlets are shown in Fig.4.2.2.

DC1 resources used for integration of scientific equipment are listed in Table 4.2.1.

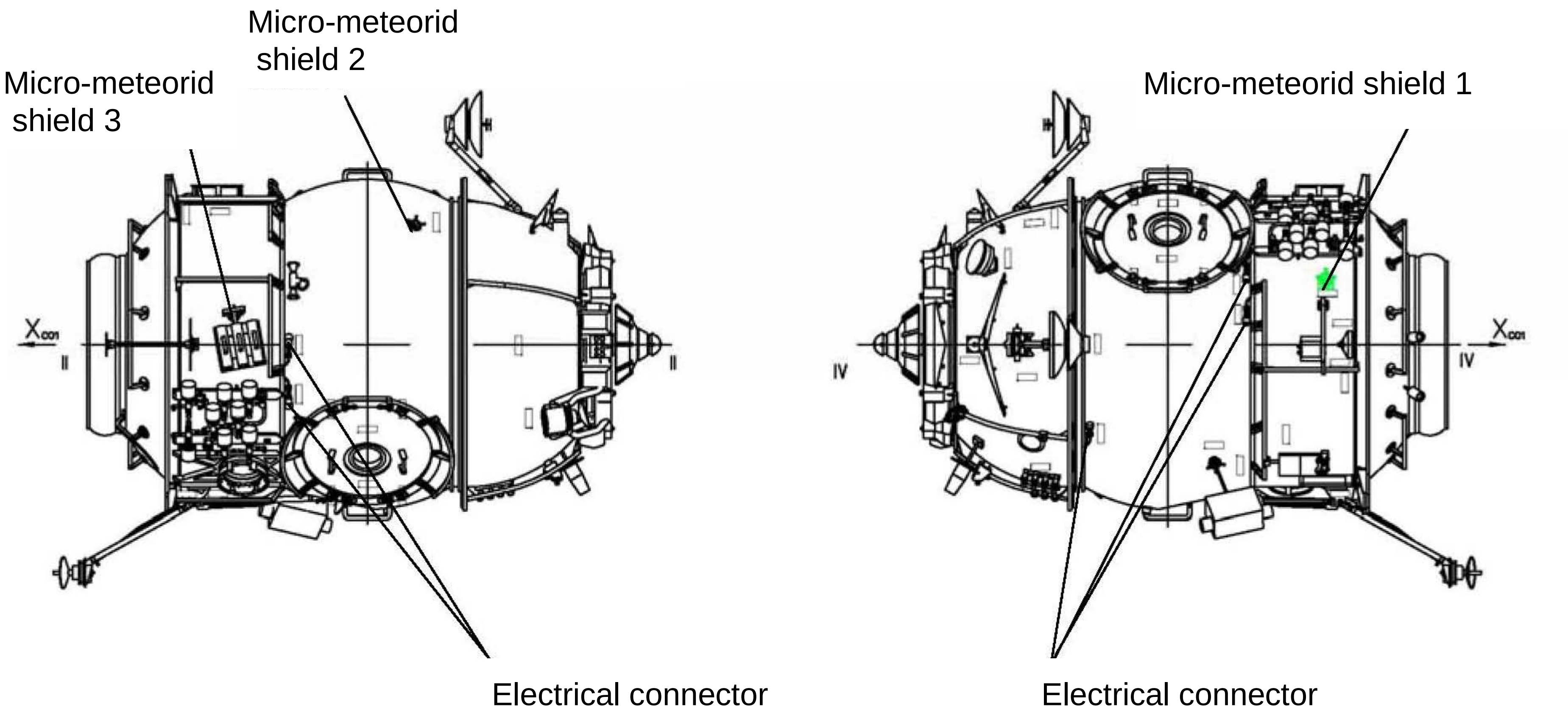


Fig. 4.2.1 – Locations of external MPWS on DC1

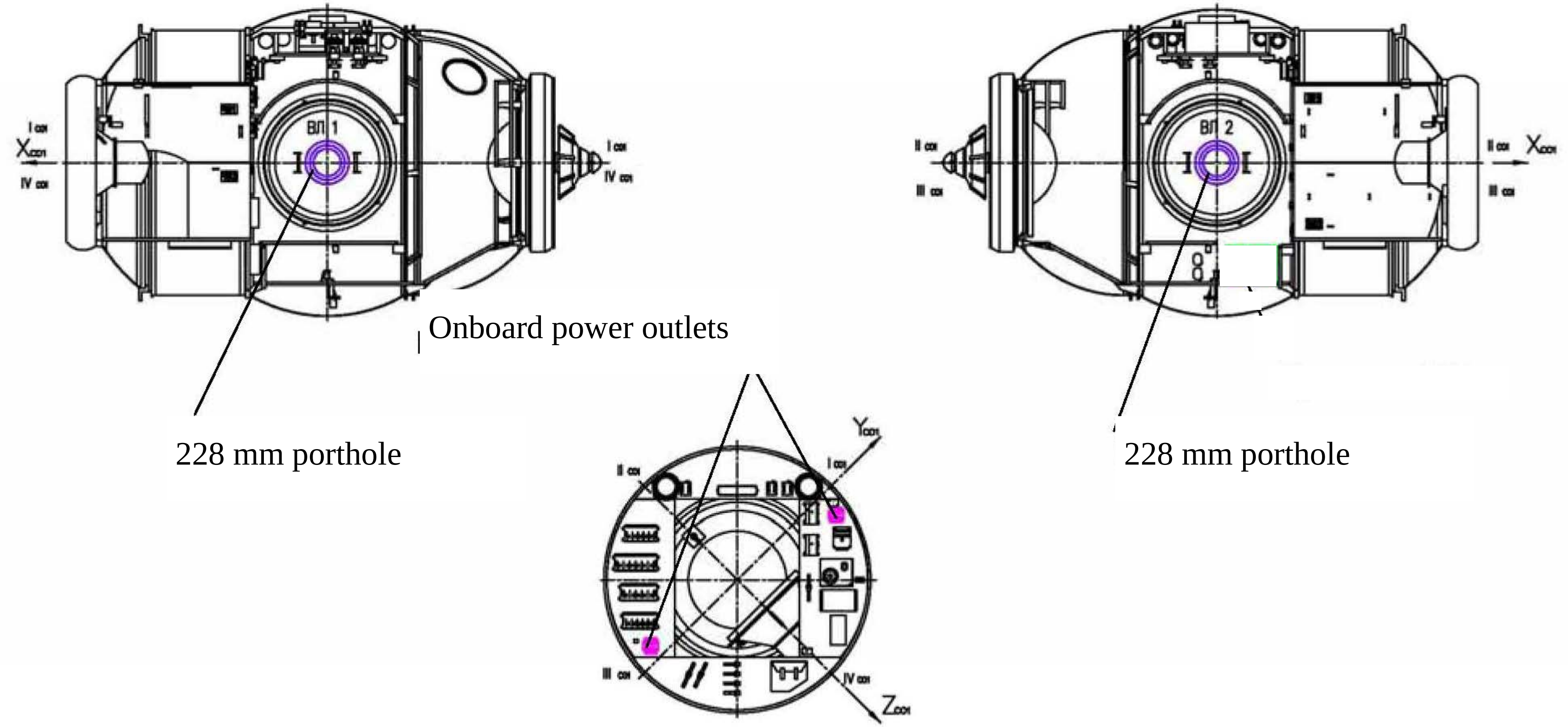


Fig. 4.2.2 – Locations of payload equipment, portholes and outlets of the onboard power grid on DC1

Table 4.2.1 – DC1 resources for integration of scientific equipment

Name	Multipurpose workstations	
	Internal	External
Number of multi-purpose workstations	-	3
Power consumption, W - daily average	300 (together with SM SE)	
Heat release, W - in the atmosphere, up to	300 (together with SM SE)	-
Information interfaces	RS-232, USB	-
Television channels	-	1

4.3 Mini Research Module 2 (MRM2)

Characteristics:

- launch mass, kg: 3670±50 kg;
- pressurized volume, m^3: 12.5;
- storage volume for cargoes and scientific equipment, m^3: 0.2;
- in particular, for scientific equipment, m^3: 0.1;
- power for scientific equipment, kW: up to 0.1;
- maximum daily average rejection of heat from the hardware included in the MPF through the air loop of the thermal control system: up to 0.1;
- launch vehicle: Soyuz-FG

MRM2 external appearance is shown in Fig. 4.3.1

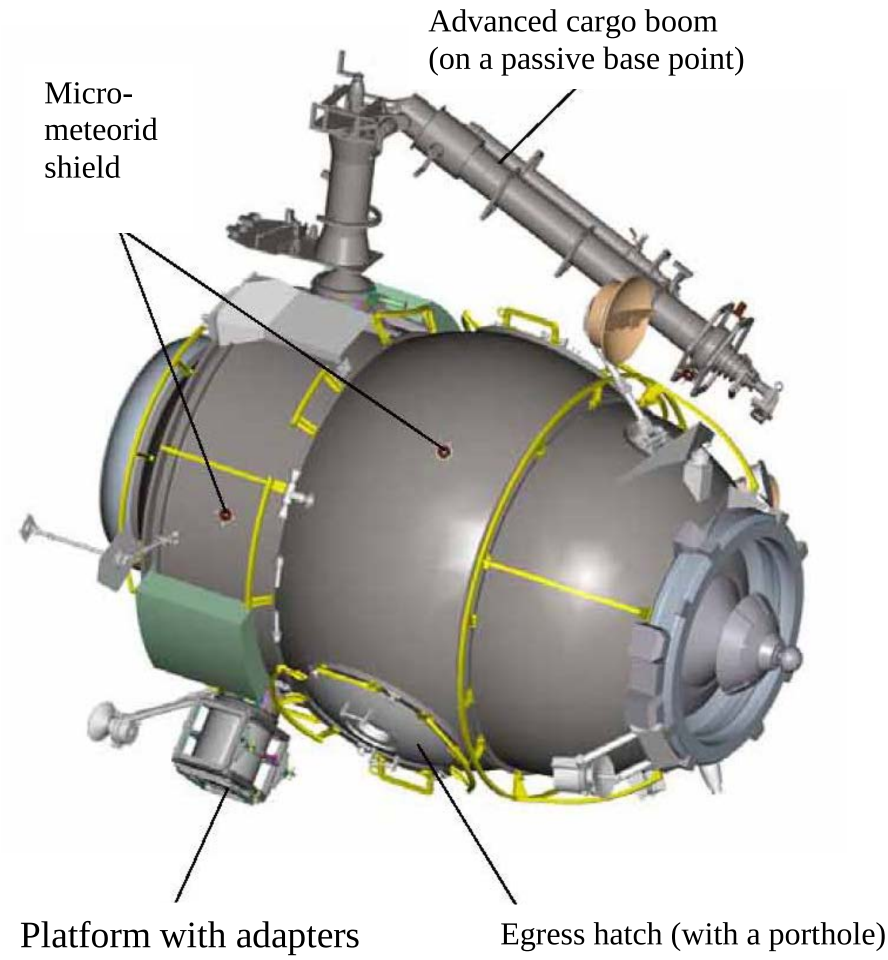


Fig. 4.3.1 – MRM2 external appearance.

Special features that MRM2 provides for conducting scientific experiments are:

- capability to install hardware on the outer surface of MRM2 for observations of the upper hemisphere and the plane of the local horizon;
- availability of a porthole with capability to sight the hardware in the horizon plane;
- capability to place hardware inside pressurized cabin for short periods of time for conducting space experiments and to store it only for the periods between EVAs;
- on-board systems resources for scientific equipment on the external surface are mostly borrowed from the SM.

Passive basepoint:		
Payload mass, kg	200	It is used for installing SE or a platform with adapteers
Quantity, pcs.	1	

Platform with adapters		
Payload mass, kg	150	The use of the platform with adapters makes it possible to increase up to three the number of work stations for installation of SE
Quantity, pcs.	1	

Fig. 4.3.2 – Characteristics of standard adapters for installing scientific equipment units.

Location and configuration of the platform with adapters on MRM2 are shown in Fig.4.3.3.

MRM2 resources used for integration of scientific equipment are listed in Table 4.3.1.

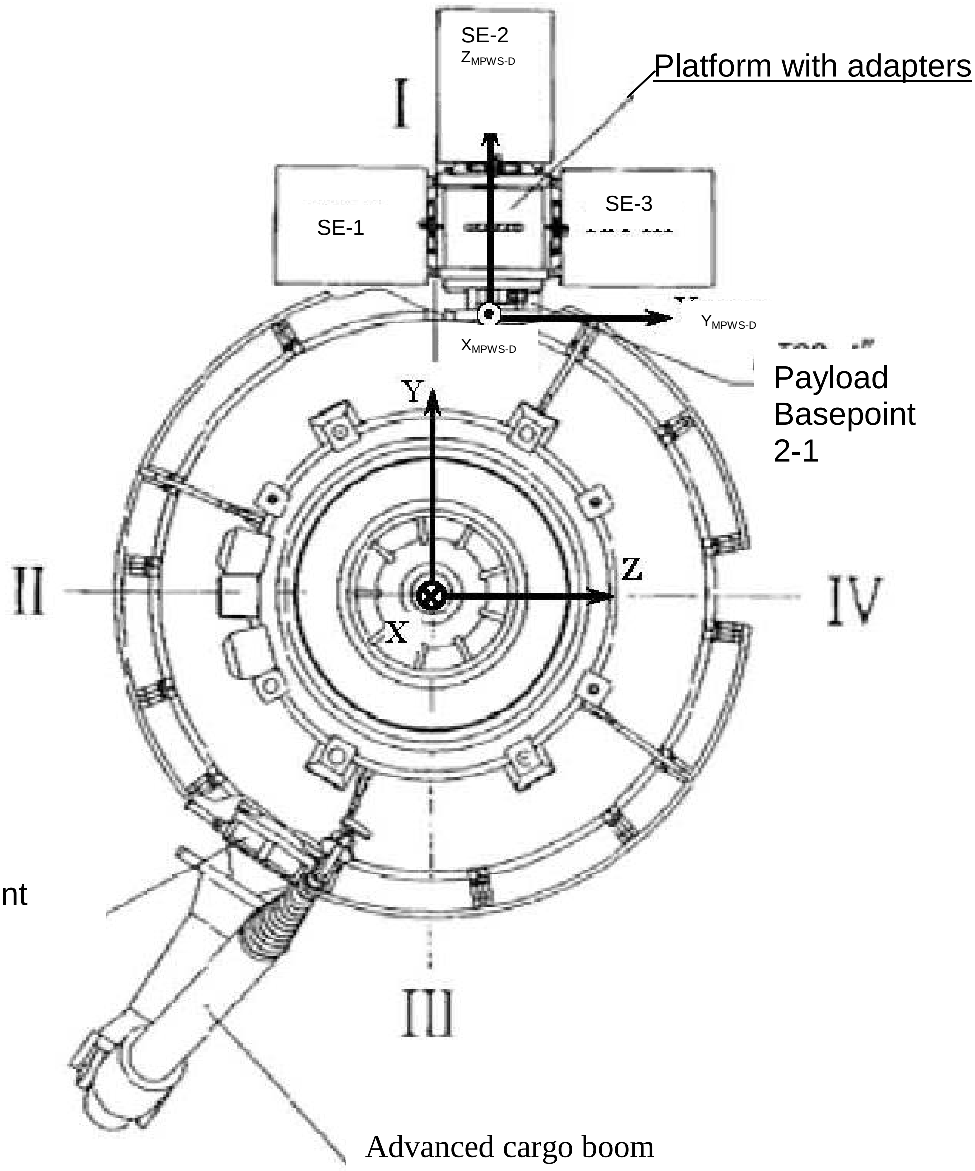


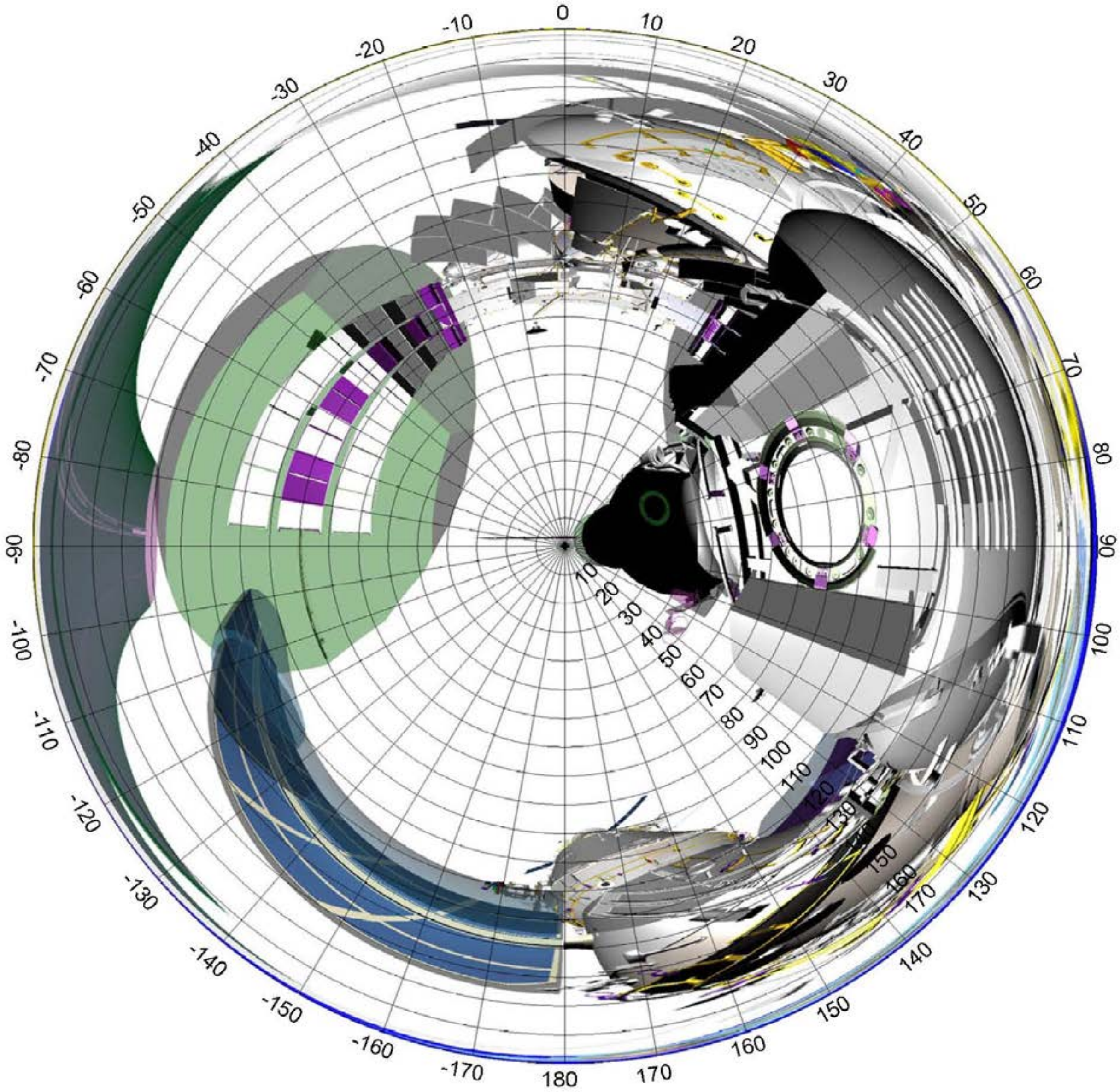
Fig. 4.3.3 – Location of the platform with adapters on MRM2 and its configuration

Table 4.3.1 – MRM2 resources for integration of scientific equipment

Name	Multipurpose workstations	
	Internal	External
Multipurpose workstations (MPWS), pcs.	up to 3	Platform with adapters, up to 4 (based on micrometeoroid sheild)
Daily average power consumption, W	85	Resources for SE are provided from SM via external cables
Total volume of the hardware, m^3	up to 1.0	
Number of discrete control commands	30	
Power supply feeders: - remote control, pcs. - onboard power outlets РБС10/3	6 2	
Number of telemetry parameters: - discrete, - analog, - temperature	20 20 10	
Information interfaces	Ethernet	
Number of television channels	1	
Vacuum interface, 10^{-2} mm Hg	1	
The total mass of scientific equipment, kg	more than 240	

Sample fields of view of scientific equipment installed on the MRM2 BPB multipurpose workstation are given in the following figures:

- Fig. 4.3.4 – field of view of scientific equipment installed on the PBP1 (axis of sight aimed at zenith);
- Fig. 4.3.5 – field of view of scientific equipment installed on the PBP2 (axis of sight aimed at zenith);



- Fig. 4.3.4 – field of view of scientific equipment installed on the PBP1 (axis of sight aimed at zenith);

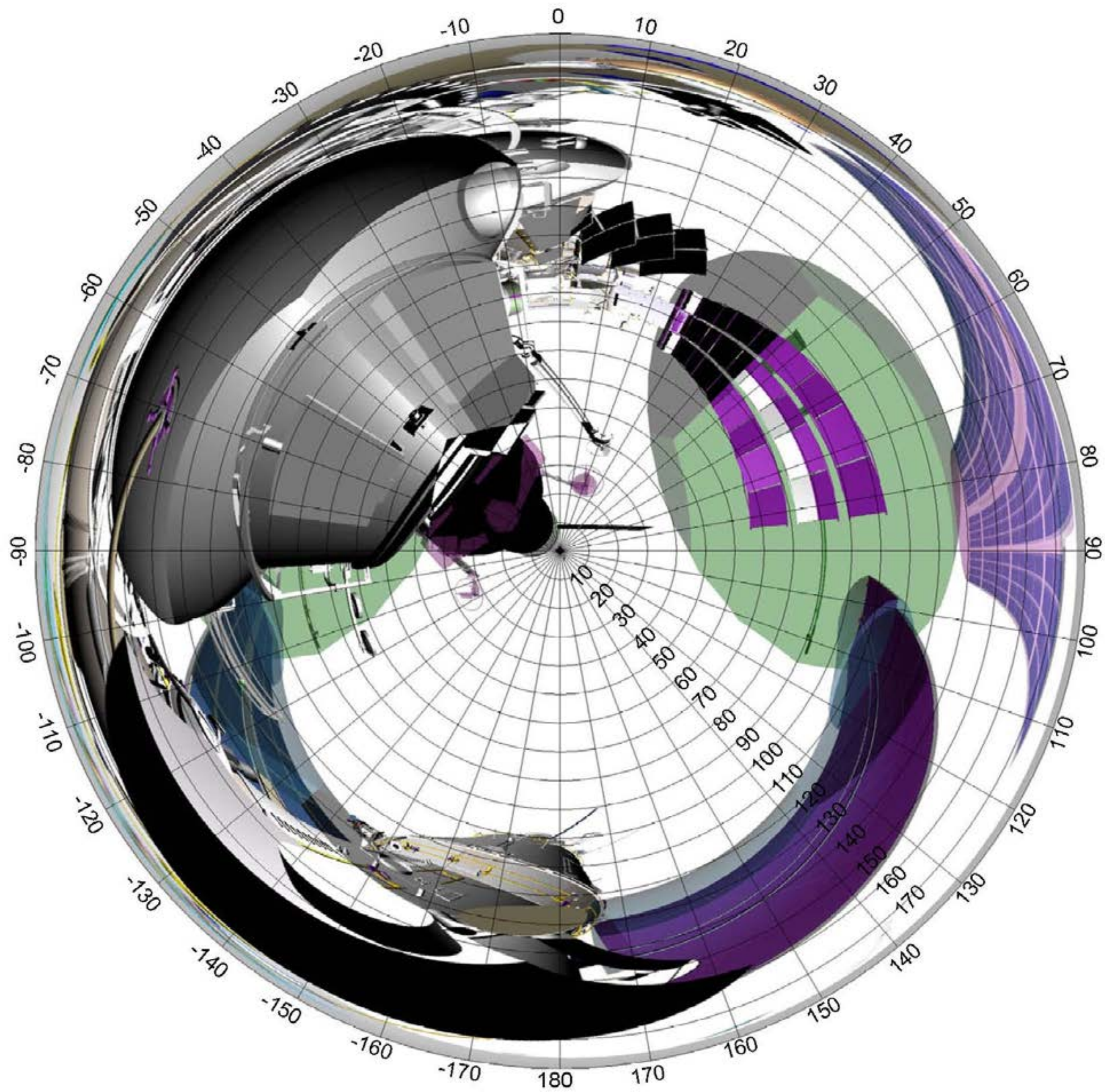
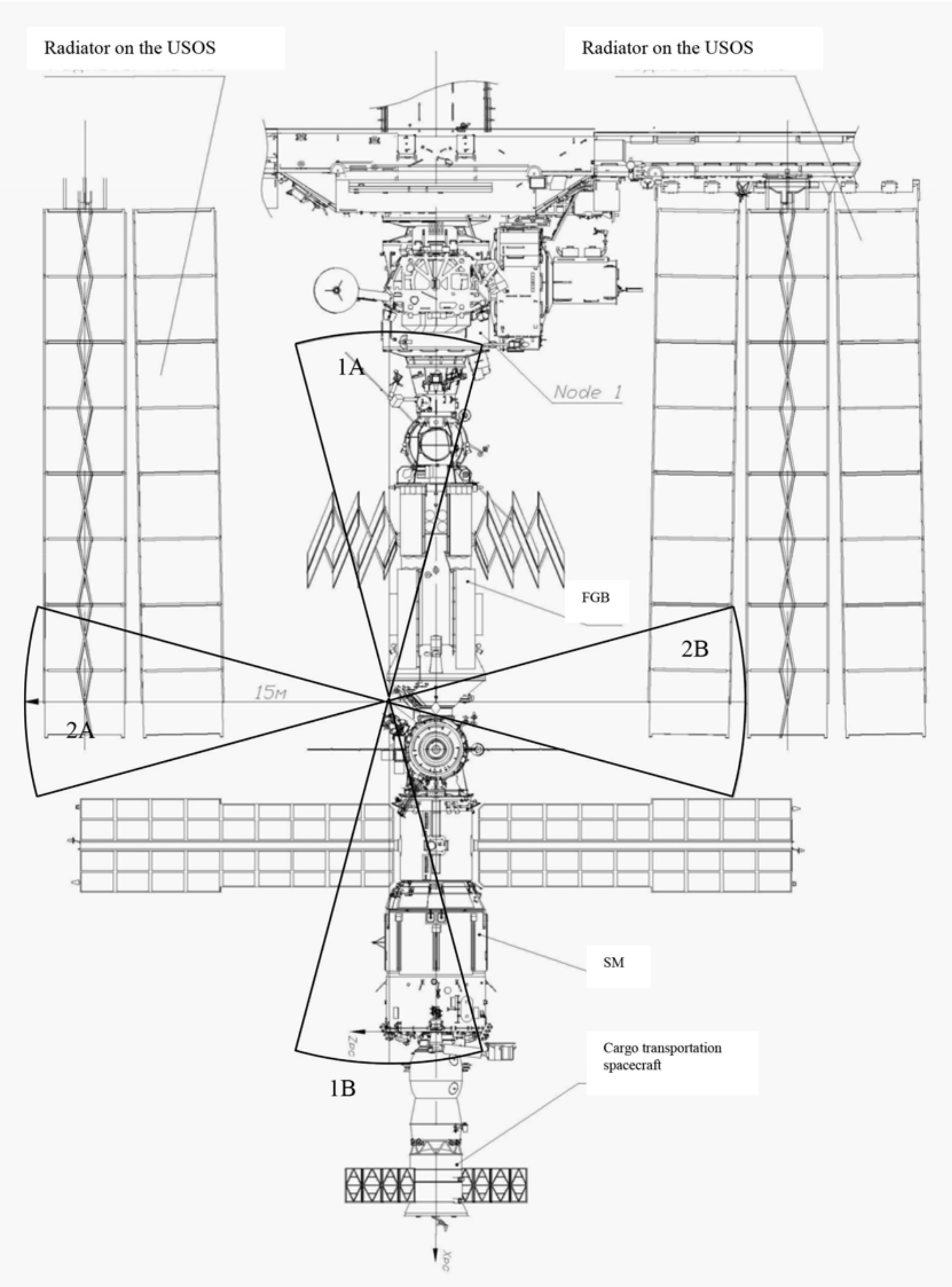


Fig. 4.3.5 – field of view of scientific equipment installed on the PBP2 (axis of sight aimed at zenith)

In addition to MPW, structural elements (handrails) can also be used for scientific equipment integration on the outer surface of MRM2.

Examples of scientific equipment installation on MRM2 handrails extension boom, and fields of view for scientific equipment are shown in Figures 4.3.6, 4.3.7.



Gig. 4.3.6 – An example of scientific equipment installation on MRM2 handrails

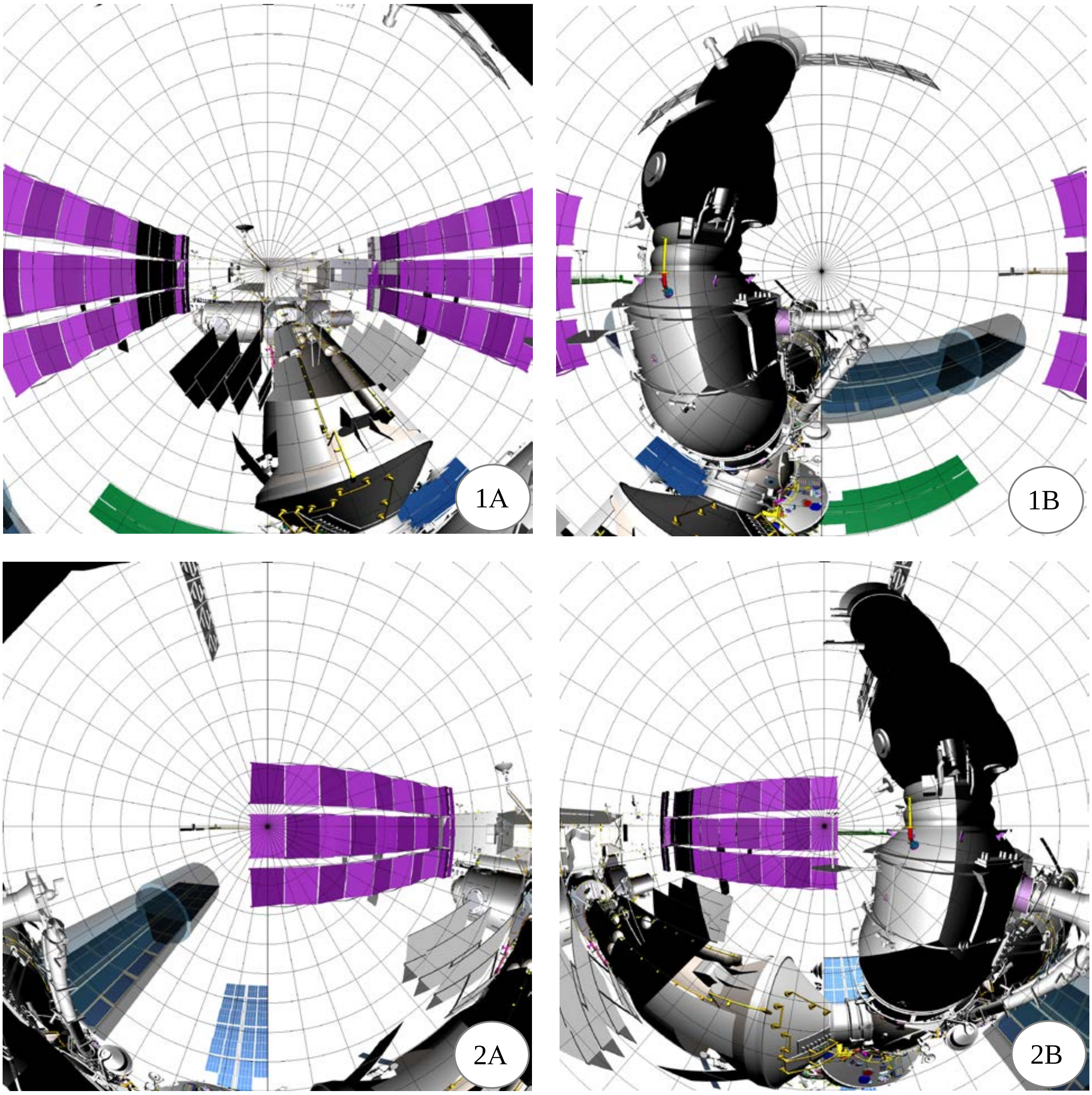


Fig. 4.3.7 – Fields of view of scientific equipment installed on MRM2

4.4 Mini Research Module 1 (MRM1)

Characteristics:

- launch mass, kg: 7900;
- pressurized volume, m^3: 17.4;
- storage volume for cargoes and scientific equipment, m^3: 4,4;
- in particular, for scientific equipment, m^3: 3.0;
- power for scientific equipment, kW: up to 0.1;
- maximum daily average rejection of heat from the hardware included in the MPF through the air loop of the thermal control system, kW: up to 0.1;

MRM1 external appearance is shown in Fig. 4.4.1

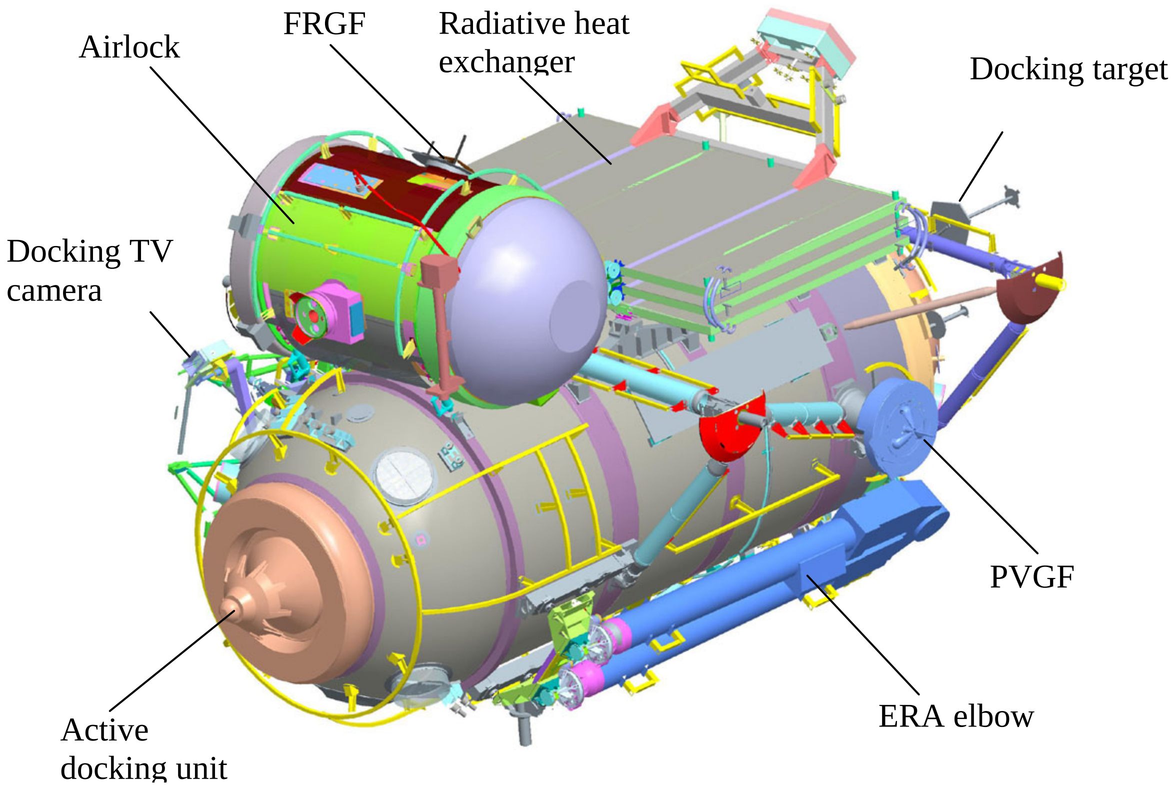


Fig. 4.4.1 – MRM1 external appearance (the airlock, the radiative heat exchanger, and the ERA elbow are to be relocated to MLM).

Included in the MRM1 MPF is the mission payload equipment necessary for providing onboard MRM1 an extended range of services in support of Russian and commercial experiments.

Set up in the pressurized cabin are 5 multi-purpose workstations (MPWs) equipped with mechanical adapters and mission payload equipment:

- modular shelves (up to 4 pcs.);
- Glovebox-C hardware with retractable glove box shelf;
- MBLTT thermostat;
- MBHTT thermostat;
- multipurpose vibration isolation platform MVIP.

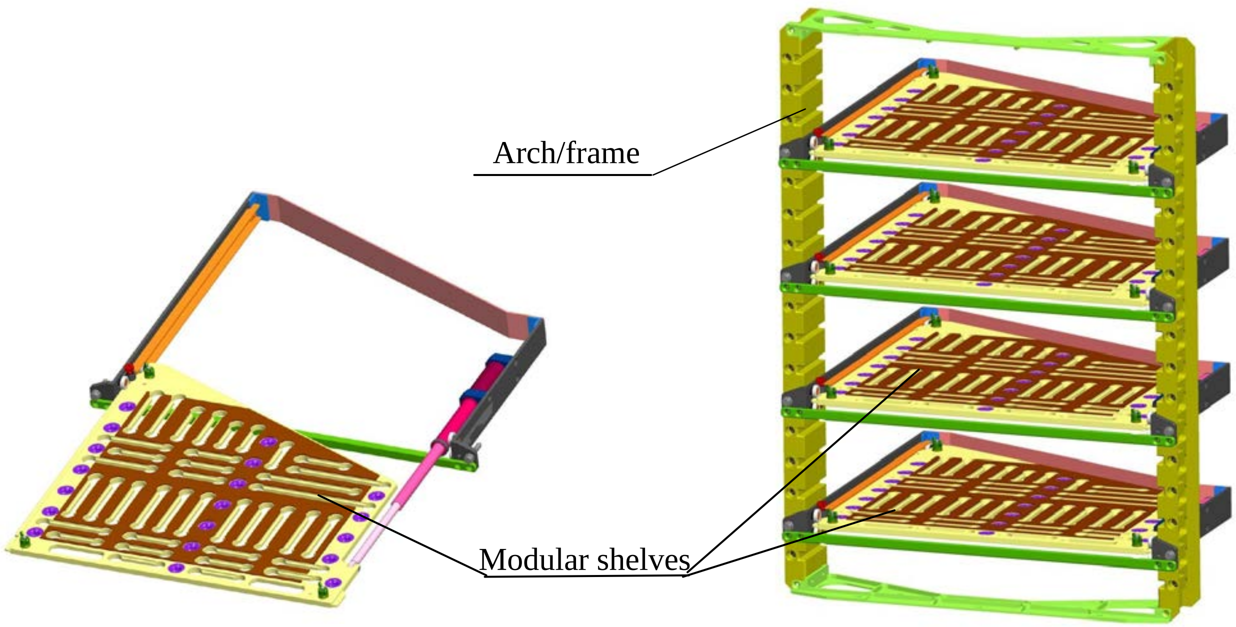


Fig 4.4.2 – Mechanical payload adapter.

Key specifications:

- maximum payload unit dimensions 600x400x600 mm;
- maximum number of retractable shelf modules - 4
- payload attachment to shelf modules:
- anchor bolt attachment;
- elastic fasteners;
- Velcro fastener.

Table 4.4.1 – Specifications of MRM1 utilization support equipment

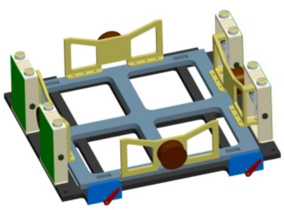
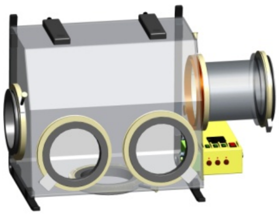
External appearance	Name	Purpose	Characteristics
	vibration isolation platform Universal	SE protection against background vibrations	SE mass of up to 50 kg, overall dimensions up to 488x488x300 mm, vibration insulation factor at the frequency of 0.4 to-250.0 Hz of no less than 20 dB
	Multi-purpose high-temperature biotechnology thermostat	Creating thermal environments necessary for handling biologicals	Useful volume of 10 liters Thermostatting temperature 2 to 37°C
	Multi-purpose low-temperature biotechnology thermostat	Creating thermal environments necessary for handling biologicals	Useful volume of 10 liters Thermostatting temperature of minus 20°C
	Glove box	Creating an environment for working with sterile, hazardous or loose substances	Airlock and means of cleaning and sterilization available. The volume of 0.15 m^3

Table 4.4.2 – MRM1 resources available for SE integration

Name	Value
Internal multipurpose workstations (MPWS), pcs.	5
Daily average power consumption, W	100
Total volume of the hardware, m^3	up to 3.0
Power supply feeders: - manual control, p[illegible] - onboard power outlets РБС10/3	 [illegible] 2
Number of telemetry parameters: - discrete, - analog, - temperature	 20 10 6
Information interfaces	Ethernet
Number of television channels	1
Vacuum interface, 10^{-2} mm Hg	1
Heat release into the air loop of the thermal control system, W	100

4.5 Multipurpose laboratory module (MLM)

Characteristics:

- launch mass, kg: 20700 kg;
- pressurized volume, m^3: 70.0;
- volume for scientific equipment, m^3: 6.0;
- power for scientific equipment, kW: - up to 1.0 kW (daily average) inside the pressurized cabin and up to 1.5 kW (daily average) outside the pressurized cabin;
- maximum daily average rejection of heat from the hardware included in the MPF, kW: up to 1.0;
- launch vehicle: Proton M.

To support scientific equipment itegration, MLM has provisions for:

- installation of payloads inside pressurized cabin of MLM (9 internal multipurpose workstations) with the total volume of the accommodation areas of no less than 6 m^3 (including a workstation equipped with a porthole for installing units of scientific equipment);
- simultaneous installation outside the MLM pressurized cabin of no less than 13 payloads (taking into account two platforms with active payload adapters);
- mechanical interfaces;
- vacuum interfaces;
- interfaces to provide thermostatic control for scientific equipment;
- interfaces to supply scientific equipment with power from the MLM On-board Equipment Control System;
- command and data interfaces between scientific equipment and the MLM On-board Equipment Control System;
- payload operating conditions in required modes when conducting space experiments;
- storing original materials and obtained results.

In addition to this, to support a long-term program of scientific and applied research, MLM provides the following equipment:

- vibration isolation platform;
- glove box;
- thermostats.

In order to minimize EVAs when installing scientific equipment on external workstations, the following robotic equipment is provided:

- ERA robotic arm;
- automatic airlock (AL).

The MLM external appearance is shown in Figures 4.5.1 and 4.5.2.

External view of the airlock is shown in Fig. 4.5.3.

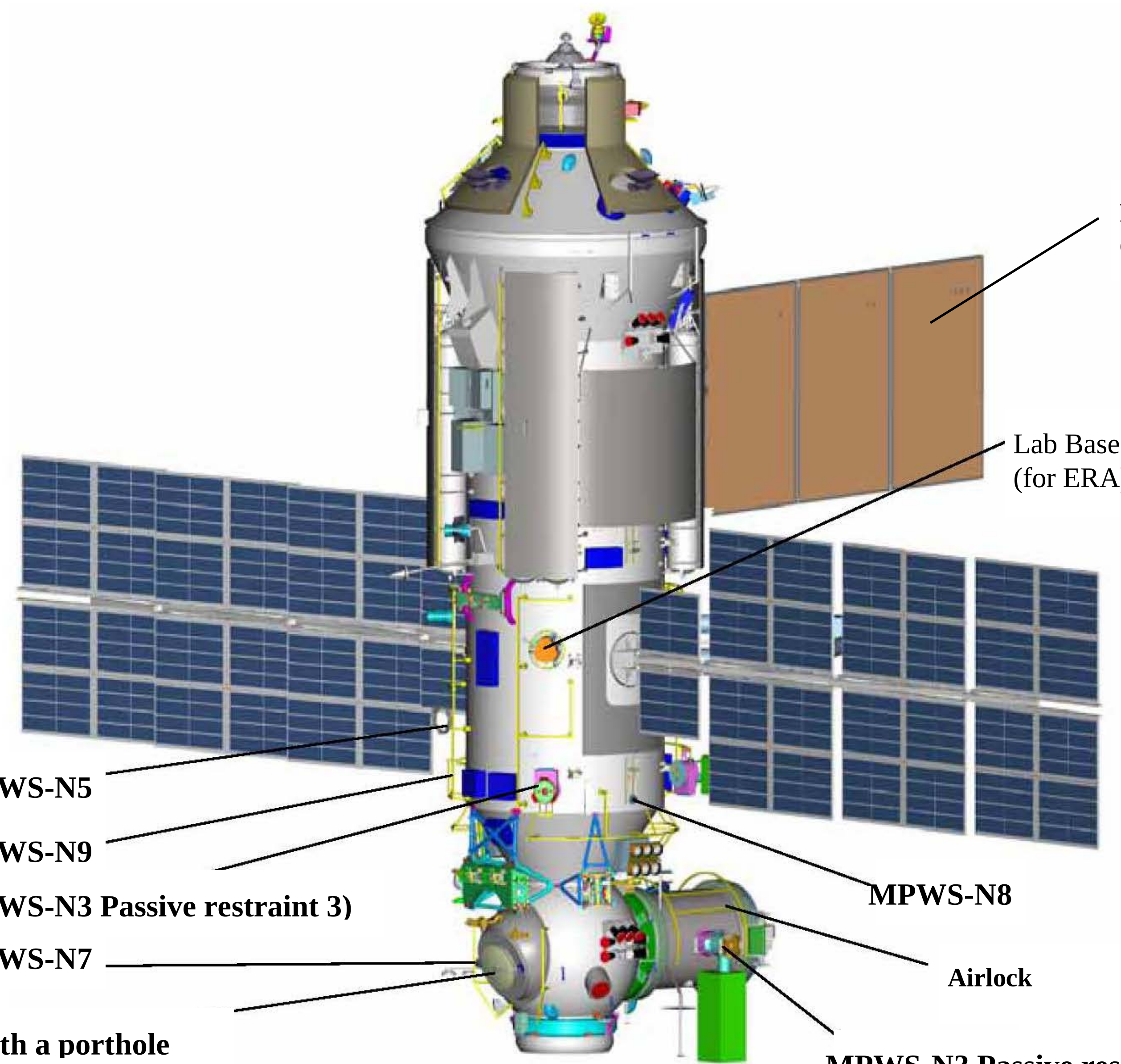


Fig. 4.5.1 – MLM external appearance

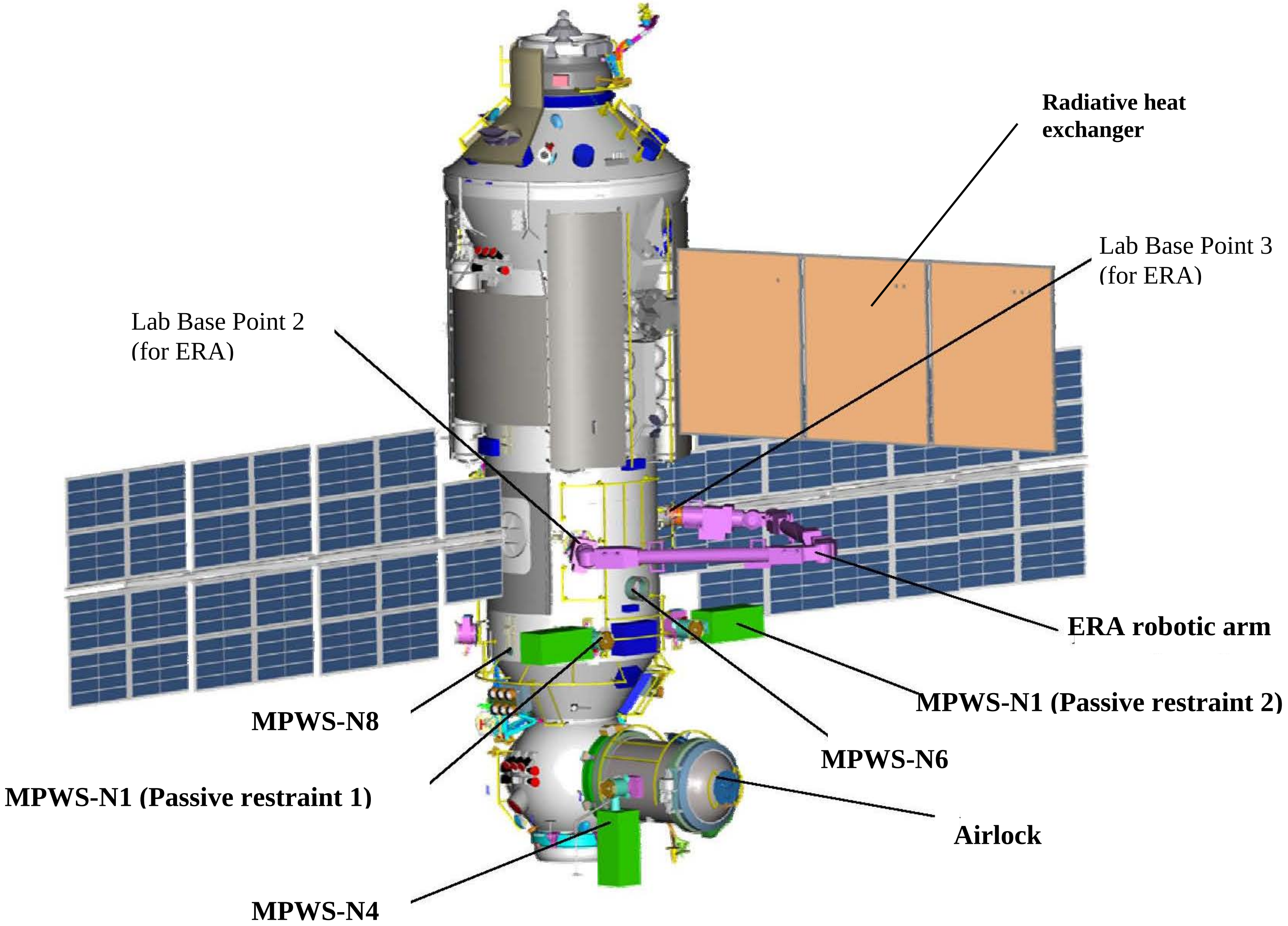


Fig. 4.5.2 – MLM external appearance (SE zones highlighted in green)

For installing scientific equipment outside the MLM pressurized cabin, the following External Multi-Purpose Workstations (EMPWS) are provided:

- EMPWS1, EMPWS2 based on passive fasteners located outside the MLM instrumentation and cargo compartment-3 along Plane I. Installation of scientific equipment onto EMPWS1, EMPWS2 is effected by means of payload adapter;
- EMPWS3 based on a passive fastener located outside the MLM instrumentation and cargo compartment-3 between Plane II and III. Installation of scientific equipment onto EMPWS3 is effected by means of payload adapter;
- EMPWS4 based on a passive fastener located outside the airlock. Installation of scientific equipment onto EMPWS4 is effected by means of payload adapter;
- EMPWS5 based on a passive fastener located outside the MLM instrumentation and cargo compartment-3 along Plane III. Used for installing scientific equipment onto EMPWS5 is a mating device ABP.

It is possible to install onto EMPWS5 a multipurpose platform with active adapters, allowing simultaneous installation of three payloads. Used for installing scientific equipment onto the platform are passive payload adapters;

- EMPWS6 based on a passive fastener located outside the MLM instrumentation and cargo compartment-3 along Plane I. Used for installing scientific equipment onto EMPWS6 is a mating device ABP.

It is possible to install onto EMPWS6 a multipurpose platform with active adapters, allowing simultaneous installation of three payloads. Used for installing scientific equipment onto the platform are passive payload adapters;

- EMPWS3 based on a support located outside the MLM pressurized adapter between Plane III and IV. Installation of scientific equipment onto EMPWS7 is effected by means of a base for installing the scientific equipment onto a support;
- EMPWS8 based on a support located outside the MLM instrumentation and cargo compartment-3 along Plane II. Installation of scientific equipment onto EMPWS8 is effected by means of a base for installing the scientific equipment onto a support;

- EMPWS9 based on a support located outside the MLM instrumentation and cargo compartment-3 along Plane IV. Installation of scientific equipment onto EMPWS9 is effected by means of a base for installing the scientific equipment onto a support;

- EMPWS based on a passive fastener located on the airlock in-and-out table. Installation of scientific equipment onto EMPWS4 is effected by means of payload adapter. The in-and-out table of the airlock also provides structural elements for securing payloads when conducting experiments in the extended position of the table.

Sample fields of view of scientific equipment installed on the MLM multipurpose workstation are given in the following figures:

- Fig. 4.5.3 – field of view of scientific equipment installed on the EMPWS1 (axis of sight pointed towards nadir);
- Fig. 4.5.4 – field of view of scientific equipment installed on the EMPWS3 (axis of sight aimed at zenith);
- Fig. 4.5.5 – field of view of scientific equipment installed on the EMPWS3 (axis of sight pointed towards nadir);
- Fig. 4.5.6 – field of view of scientific equipment installed on the EMPWS4 (axis of sight aimed at zenith);
- Fig. 4.5.7 – field of view of scientific equipment installed on the EMPWS5 (axis of sight pointed towards nadir).
- Fig. 4.5.8 – field of view of scientific equipment installed on the EMPWS6 (axis of sight pointed towards nadir);
- Fig. 4.5.9 – field of view of scientific equipment installed on the EMPWS7 (axis of sight aimed at zenith);
- Fig. 4.5.10 – field of view of scientific equipment installed on the EMPWS8 (axis of sight pointed towards nadir);
- Fig. 4.5.11 – field of view of scientific equipment installed on the EMPWS9 (axis of sight pointed towards zenith);

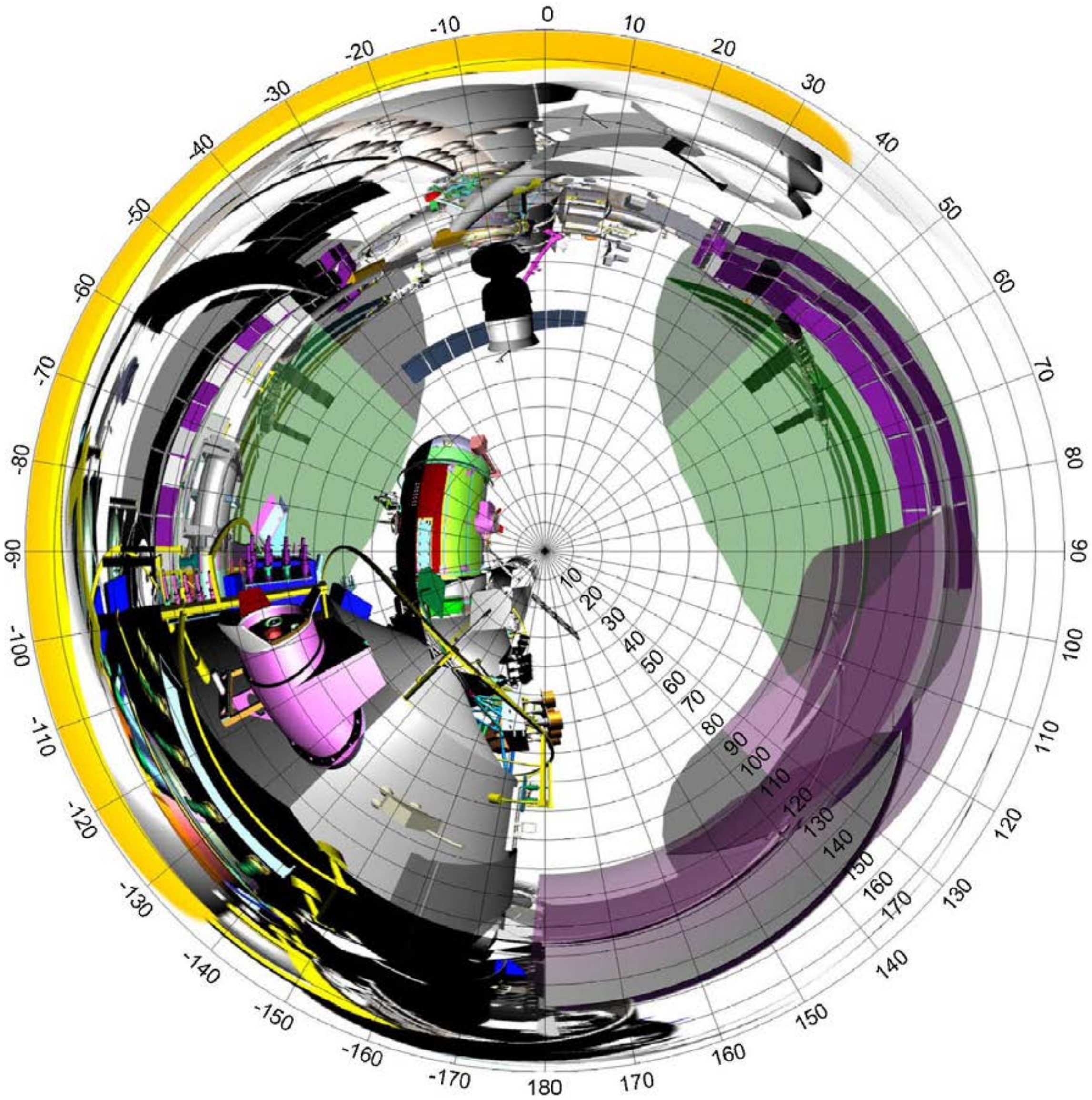


Fig. 4.5.3 – field of view of scientific equipment installed on the EMPWS1 (axis of sight pointed towards nadir)

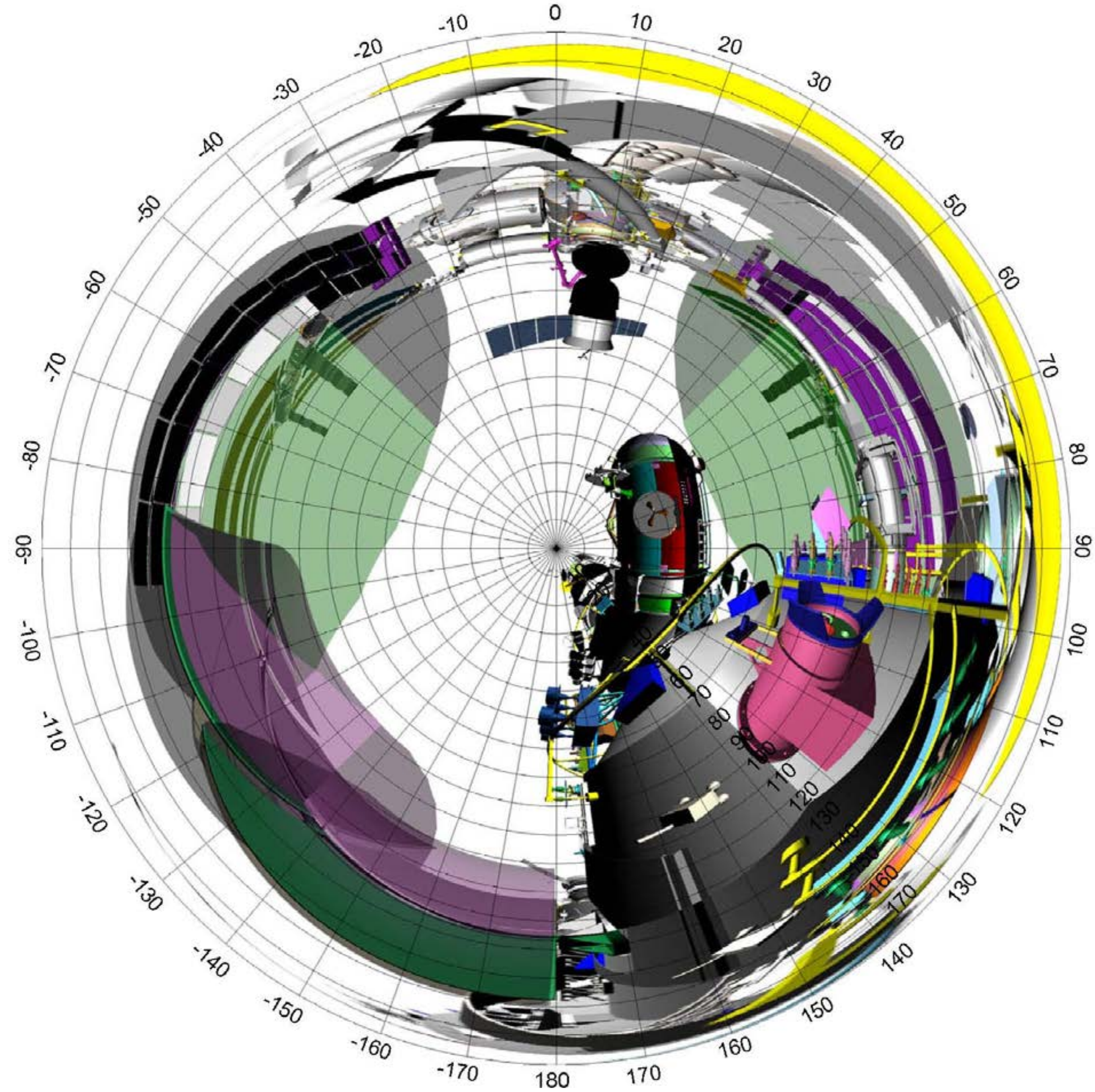


Fig. 4.5.4 – field of view of scientific equipment installed on the EMPWS2 (axis of sight pointed towards nadir)

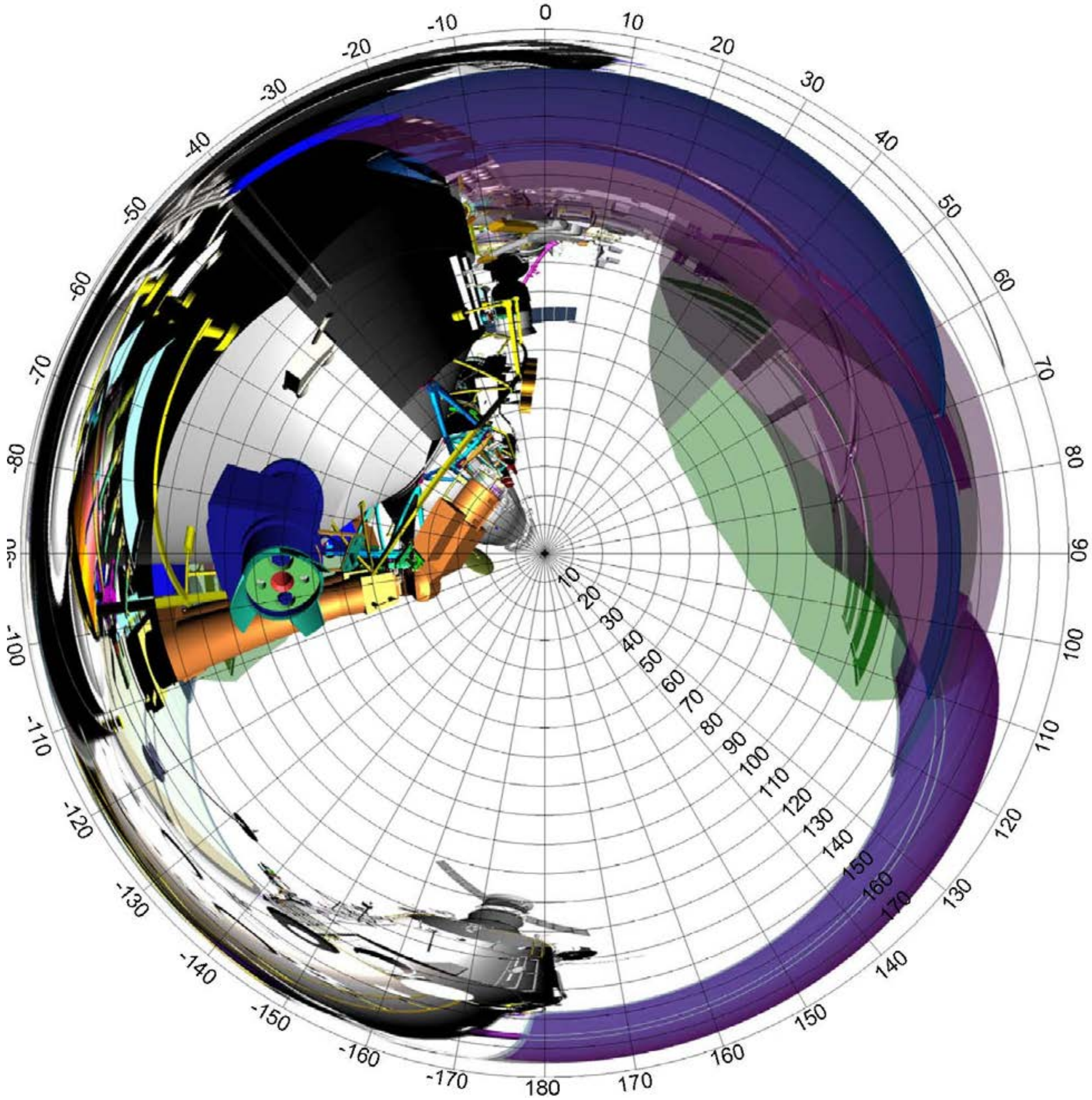


Fig. 4.5.5 – field of view of scientific equipment installed on the EMPWS3 (axis of sight pointed towards nadir)

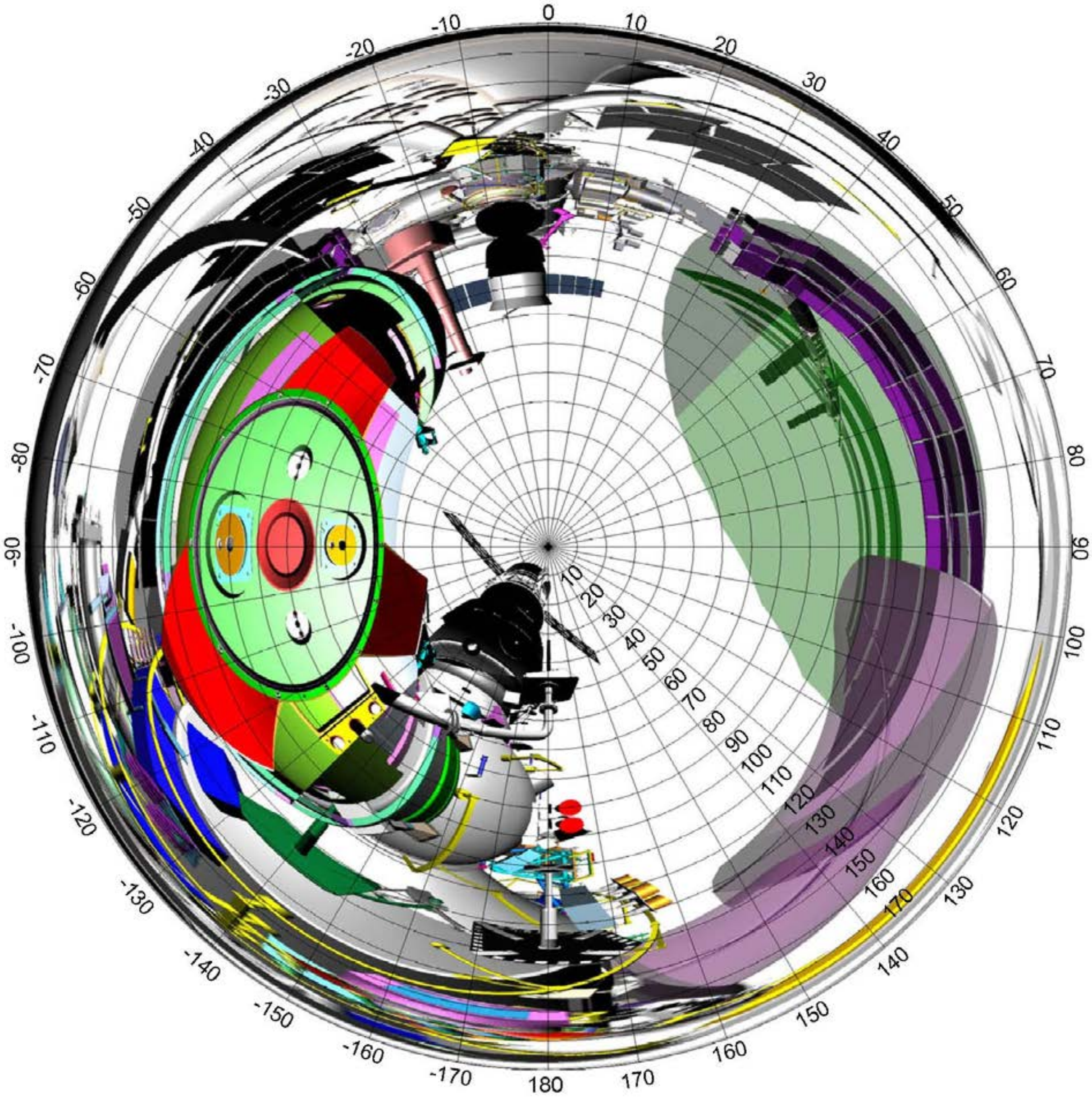


Fig. 4.5.6 – field of view of scientific equipment installed on the EMPWS4 (axis of sight pointed towards nadir)

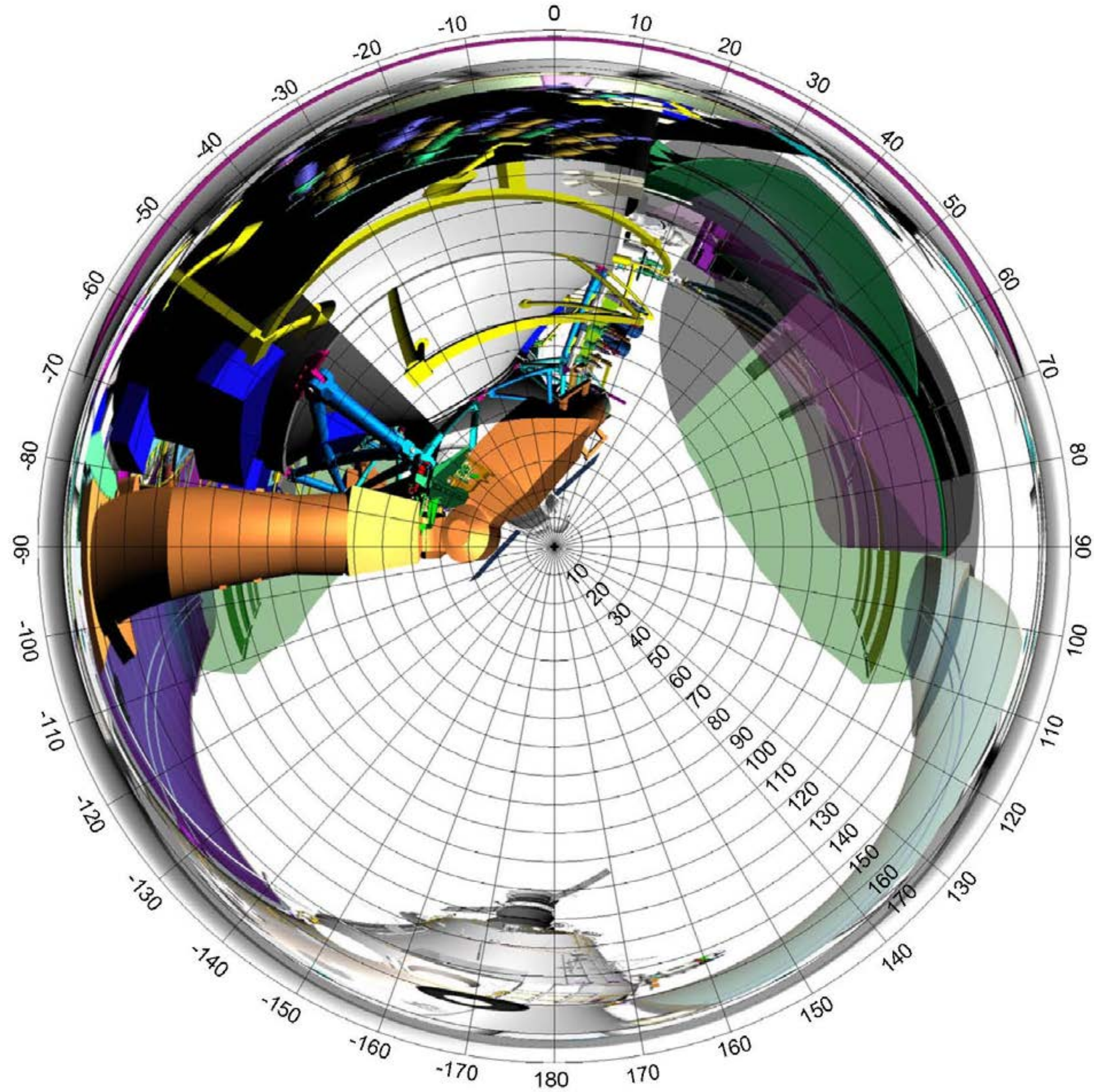


Fig. 4.5.7 – field of view of scientific equipment installed on the EMPWS5 (axis of sight pointed towards nadir)

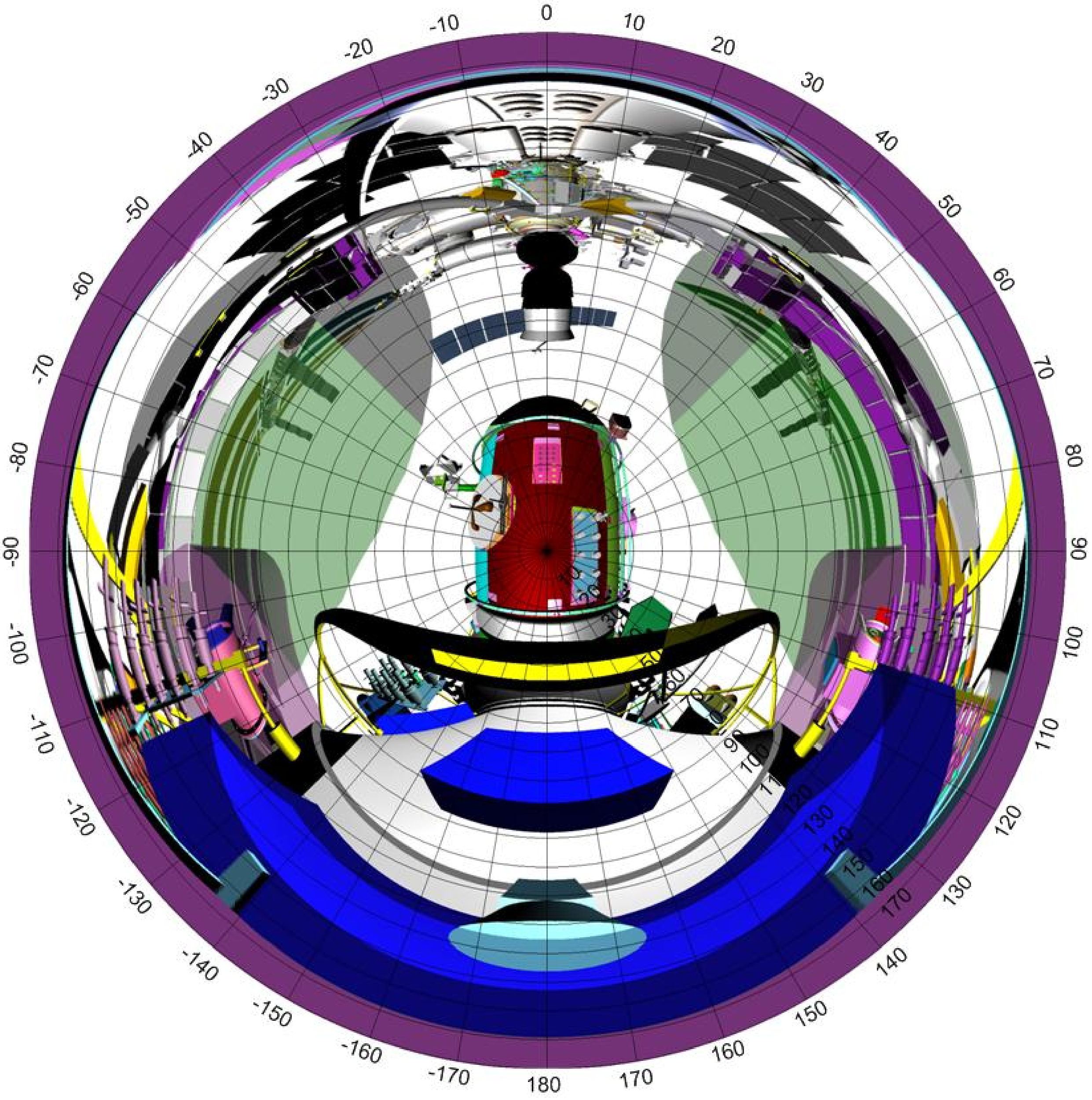


Fig. 4.5.8 – field of view of scientific equipment installed on the EMPWS6 (axis of sight pointed towards nadir)

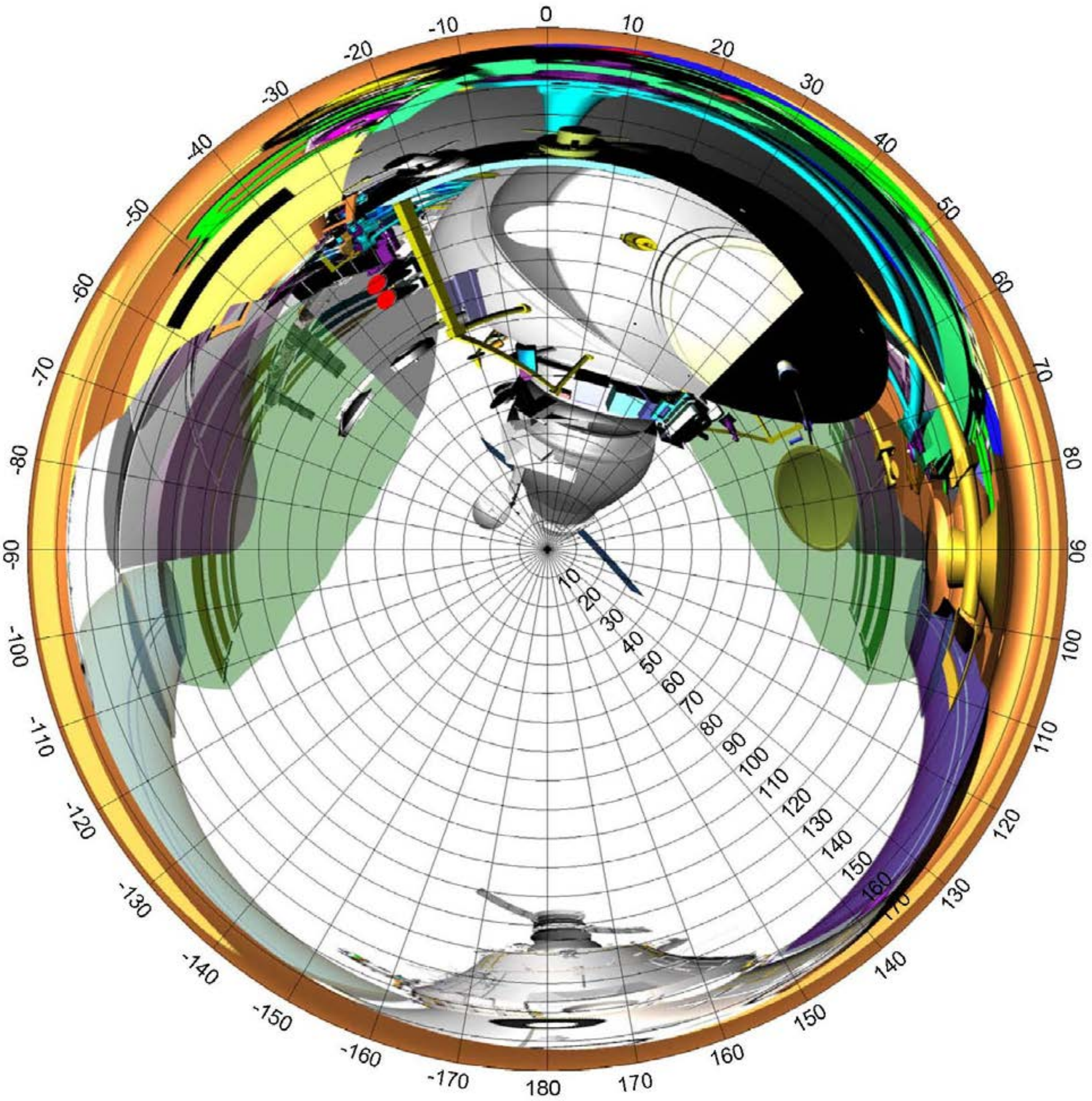


Fig. 4.5.9 – field of view of scientific equipment installed on the EMPWS7 (axis of sight pointed towards nadir)

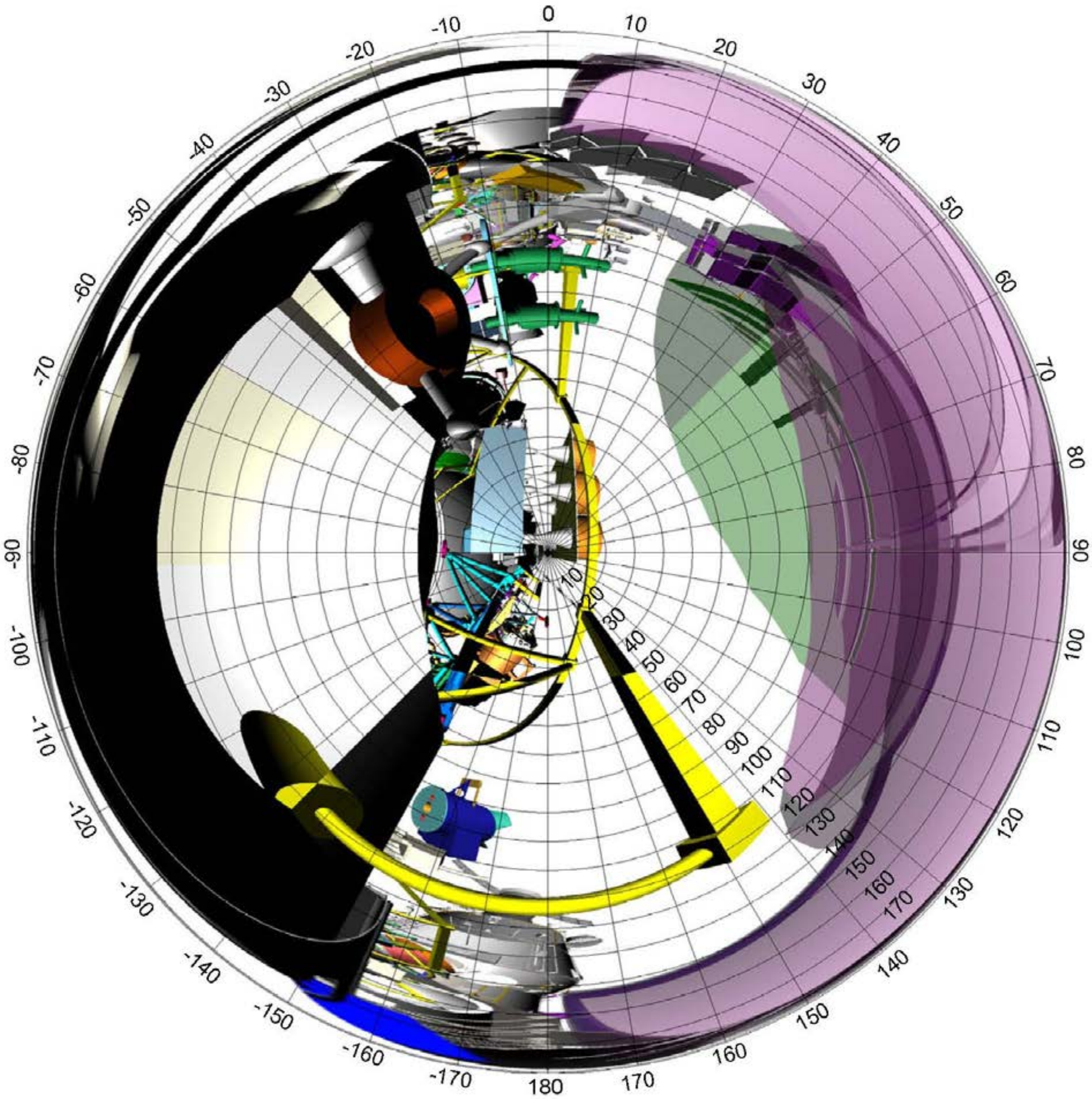


Fig. 4.5.10 – field of view of scientific equipment installed on the EMPWS8 (axis of sight pointed towards nadir);

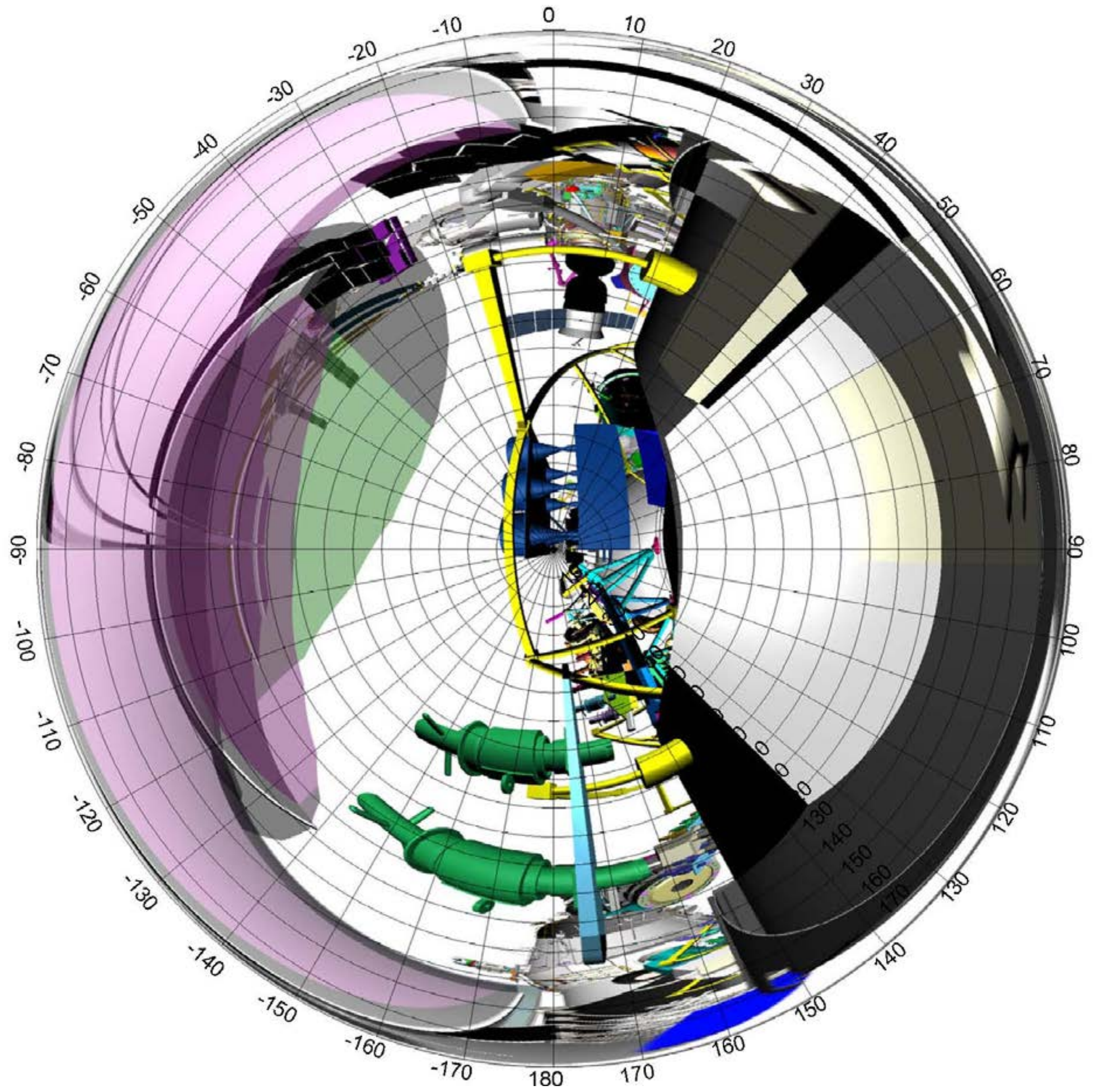


Fig. 4.5.11 – field of view of scientific equipment installed on the EMPWS9 (axis of sight pointed towards nadir)

Automatic airlock is intended for:

- removing payloads from the MLM pressurized adapter and placing them on the outer surface of the space station;
- receiving payloads from ERA robotic arm and moving them into the internal volume of the airlock and on to the MLM pressurized adapter;
- conducting scientific experiments in the internal volume of the airlock;
- conducting scientific experiments outside the airlock on the extended table and at a specially prepared station.

Key specifications of the airlock:

- airlock mass, kg: up to 1050;
- maximum power consumption with a payload, kW: 1.5;
- gas volume, m^3: 2.1;
- maximum payload mass on the payload handling device, kg: 150;
- maximum payload dimensions, mm: 1200x500x500;
- the number of vacuum pumping cycles during flight tests, no less than: 200;
- allowable internal pressure, kg/cm^2: 1,3;
- residual pressure after vacuum pumping, mm Hg: 10^{-4};

External view of the airlock is shown in Fig. 4.5.3.

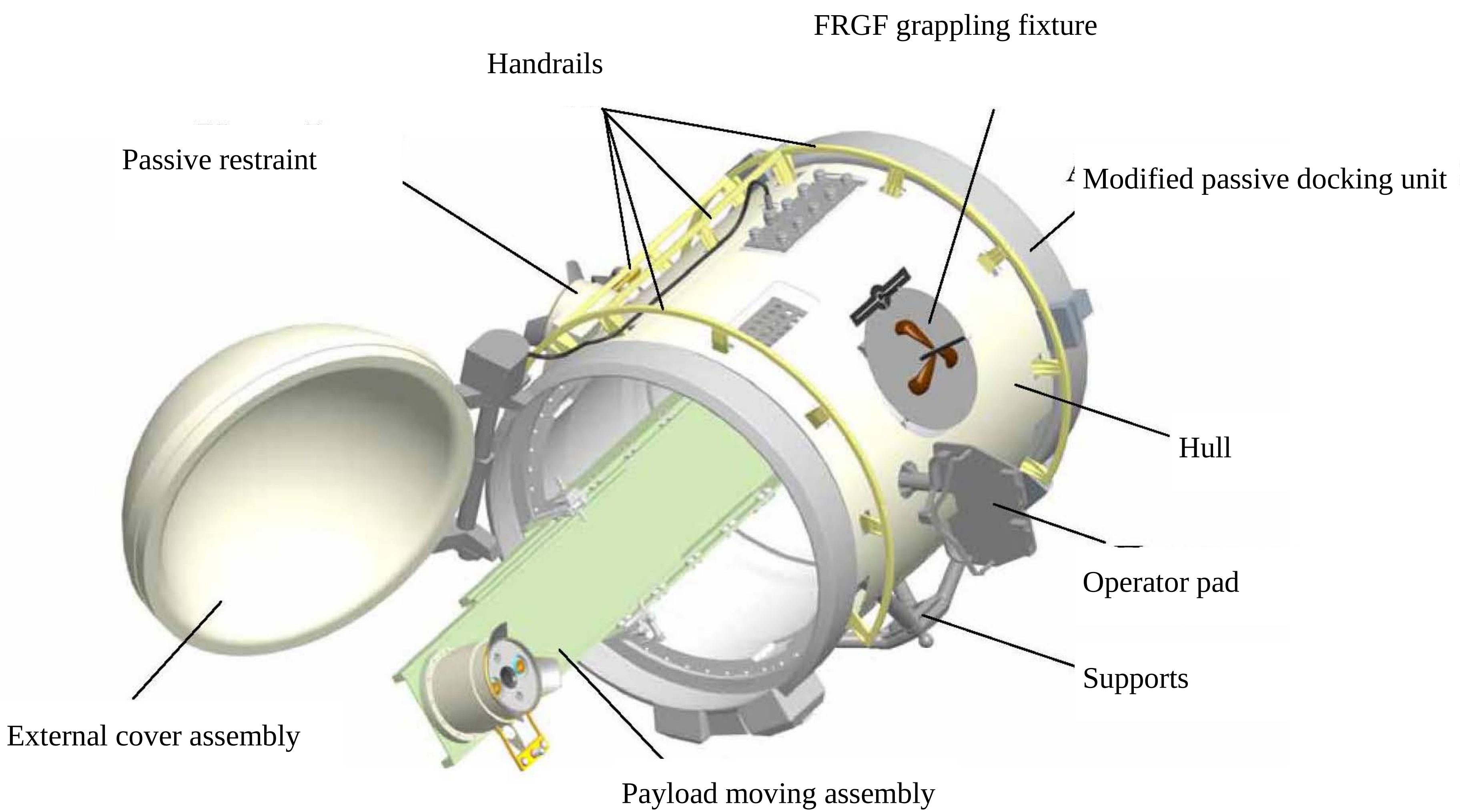
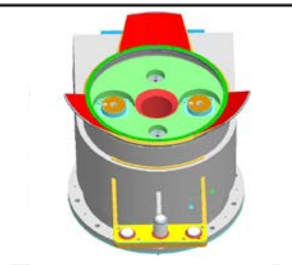
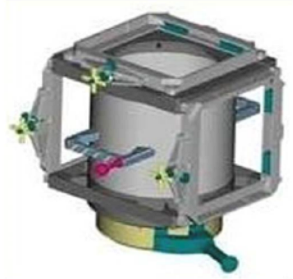


Fig. 4.5.12 – Airlock external appearance

Table 4.5.1 – MLM resources for SE integration

Name	Multipurpose workstations	
	Internal	External
Multipurpose workstations (MPWS), pcs.	16	9, taking into account deliverable MPWS - 13
Daily average power consumption, kW	up to 1.0	up to 1.5
Total volume of the hardware, m^3	up to 8.0	
Number of discrete control commands	150	
Remotely controlled power feeds, pcs. Manually controlled power feeds, pcs.	49 38 (+14- onboard power outlets)	Provided via external cables
Number of telemetry parameters: - discrete, - analog, - temperature	180 78 65	
Information interfaces	Ethernet, RS-422, RS-485, MILSTD 1553B, RS-232, USB	
Number of television channels	**6**	
RF interfaces, pcs.	2	
Vacuum interface, 10^{-2} mm Hg	2	-





Passive restraint
(installed on MPWS-N1, MPWS-N2, MPWS-N3, MPWS-N4)

Payload mass, kg:	150
Qty, pcs.: (including 1 on the airlock)	4

It is used to install SE with the ESA robotic arm.

Passive Base Point (PBP) *(installed on MPWS-N5, MPWS-N6)*

Payload mass, kg:	150
Qty, pcs.:	2

It is used to support installation of SE units or platforms with adapters by an operator during EVA.

Platforms with adapters:
(installed onto PBP on MPWS-N5, MPWS-N6)

Payload mass, kg:	150
Qty, pcs.:	2

It is used to support installation of SE by an operator during EVA. When platforms are installed on both PBPs, the number of SE units that can be installed goes up from 9 to 13 *(1 platform can accommodate up to 3 SE units)*

Support *(installed on MPWS-N7, MPWS-N8, MPWS-N9)*

Payload mass, kg:	50
Qty, pcs.:	3

It is used to support installation of SE units by an operator during EVA.

Table 4.5.2 (continued)– Characteristics of adapters for external MPWS (counterparts)

Payload adapter 77КМЛ.600Ю2200-0 *(for installing SE units on the passive restraint)*

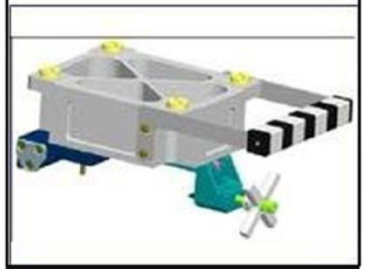
Payload mass, kg:	150	It is used to support installation of SE units with the use of the ESA robotic arm. Interface with the payload - a 1166x500 mm pad.
Qty, pcs.:	Up to 4	

Mating device of the Active Base Point 27КСМ.152Ю7110-0 *(for installing a SE unit on PBP)*

Payload mass, kg:	150	It is used to support installation of a SE unit or a platform with adapters by an operator during EVA. Interface with the payload - 12 M8 holes on a 340 mm diameter.
Qty, pcs.:	Up to 2	

Passive payload adapter 17КС.600Ю1152А-0 *(for installing a SE unit on the platform)*

Payload mass, kg:	150	It is used to support installation of a SE unit by an operator during EVA. Interface with the payload - 4 M10 holes on a square 370 mm on a side.
Qty, pcs.:	Up to 6	



Base 77КМЛ.600Ю1006-200 *(for installing a SE unit on the support)*

Payload mass, kg:	50	It is used to support installation of a SE unit by an operator during EVA. Interface with the payload - 4 M8 holes on a 124 mm x 162 mm rectangle
Qty, pcs.:	Up to 3	

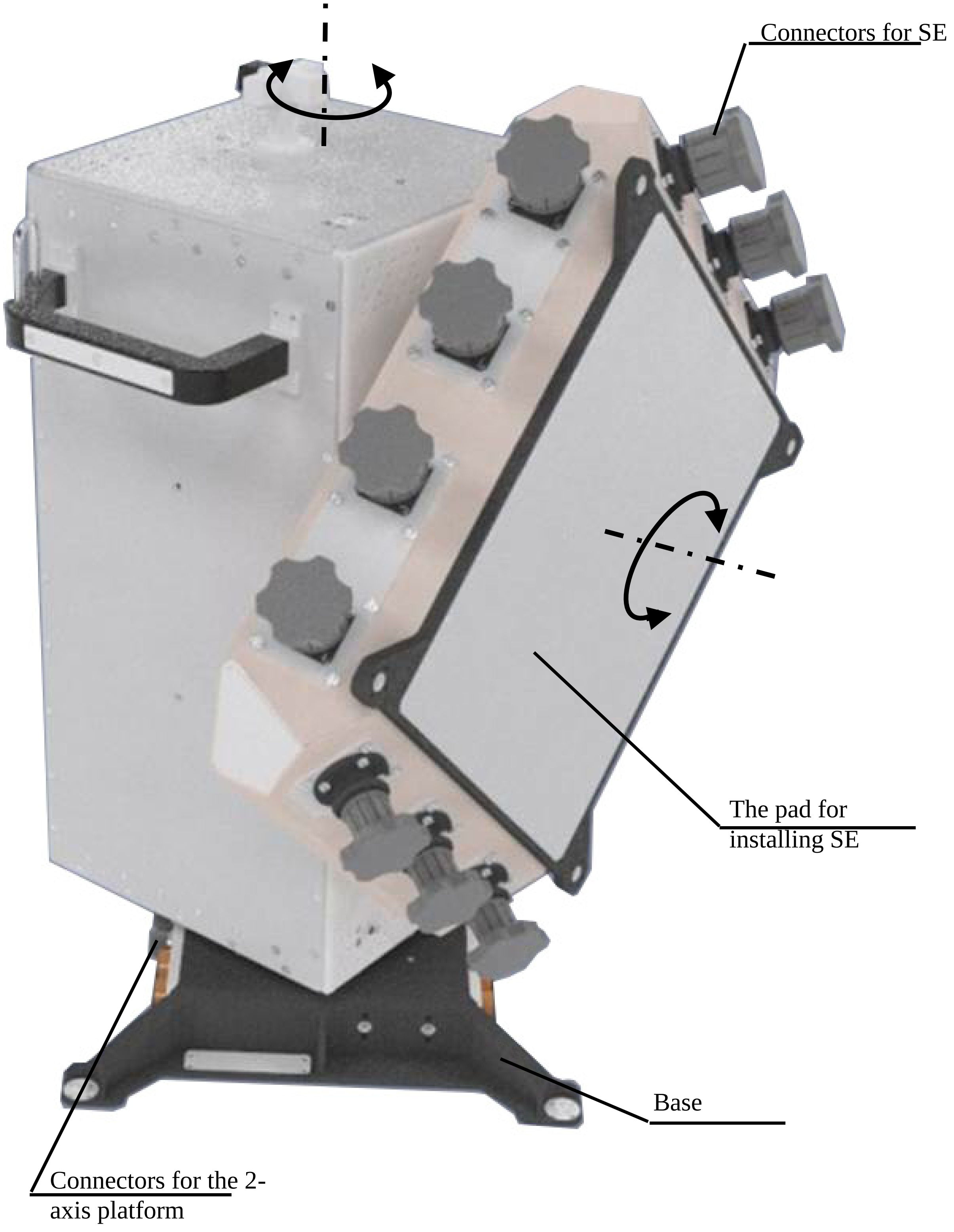


Fig.4.5.13 Two-axis rotating platform

4.6 Multipurpose laboratory module with upgraded performance (MLM-U)

In order to improve its operational performance, the MLM is to be additionally outfitted during an EVA by means of installing a specialized structure – Large Objects Attachment Device LOAD 374УУ01.

After installation of the LOAD, which holds three EMPWS (see Fig.), and after installation on these EMPWS of deliverable multi-purpose workstations having three payload adapters each, the total number of places for accommodating scientific equipment on the external surface of the MLM-U taking into account the deliverable MPWS will be 16.

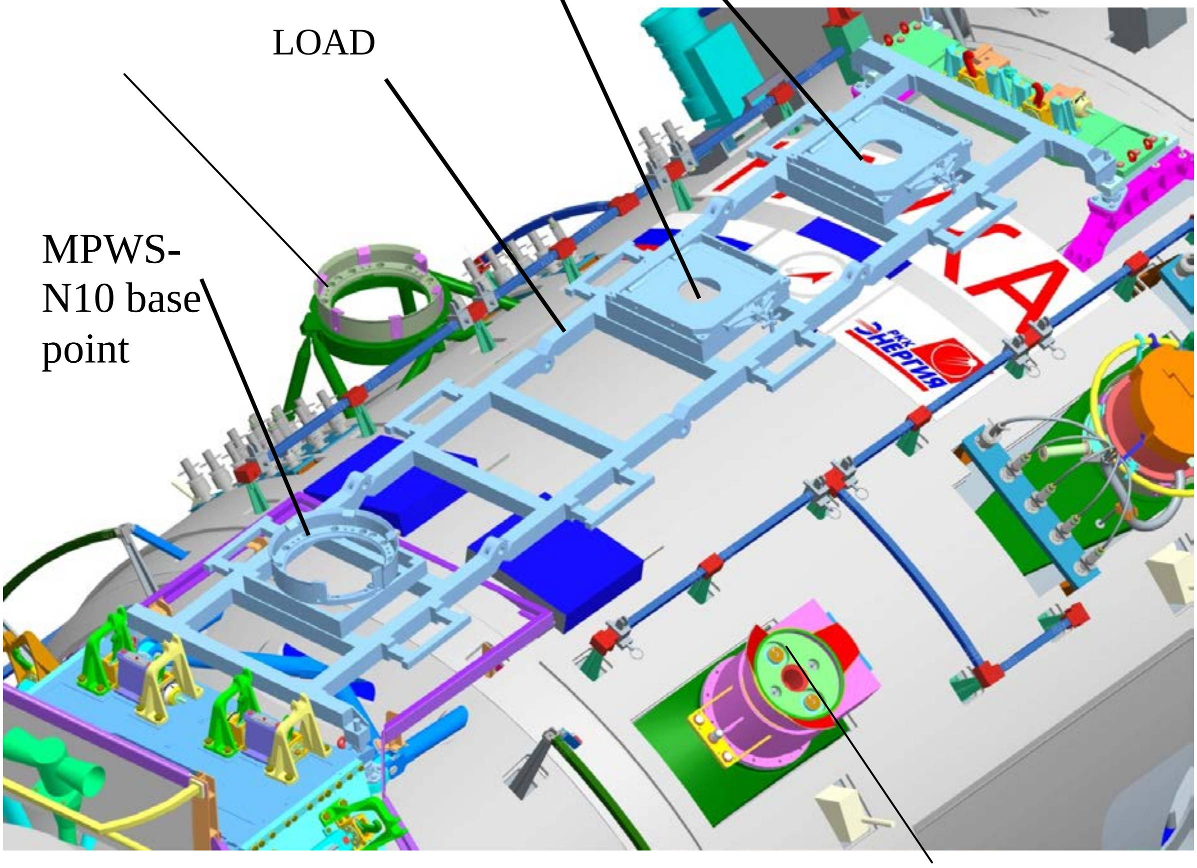


Fig.4.6.1 External appearance of MLM-U

The total mass of equipment installed on the LOAD shall not exceed 400 kg.

Used for attaching the equipment are:
- a passive base point
– an active payload adapter.

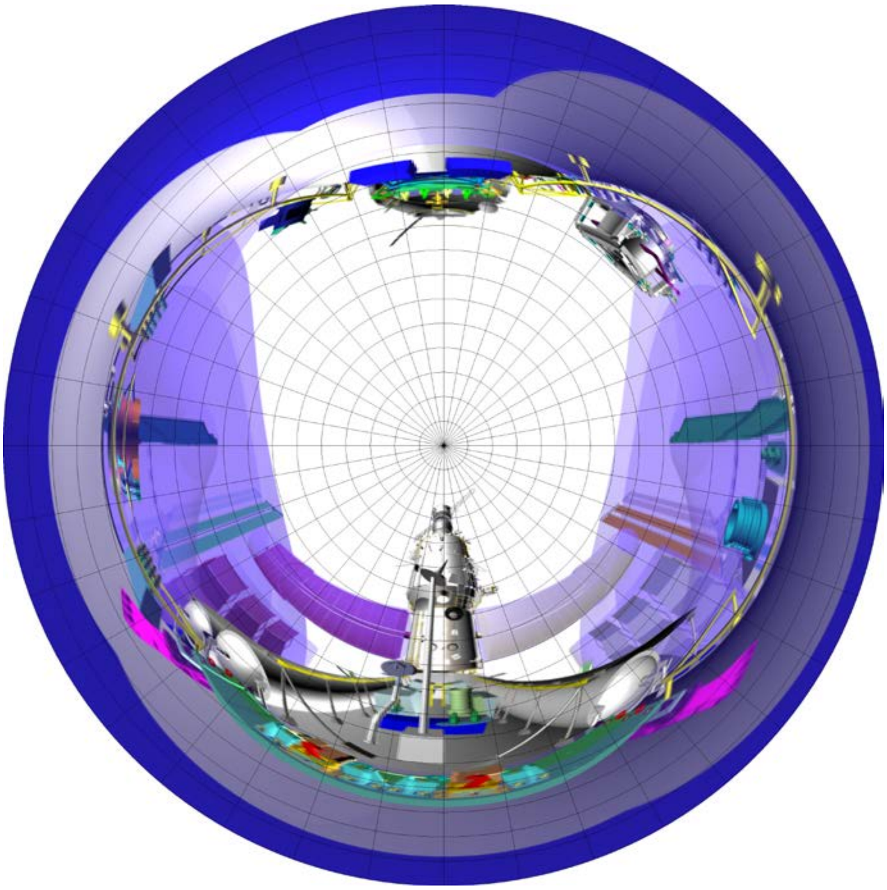
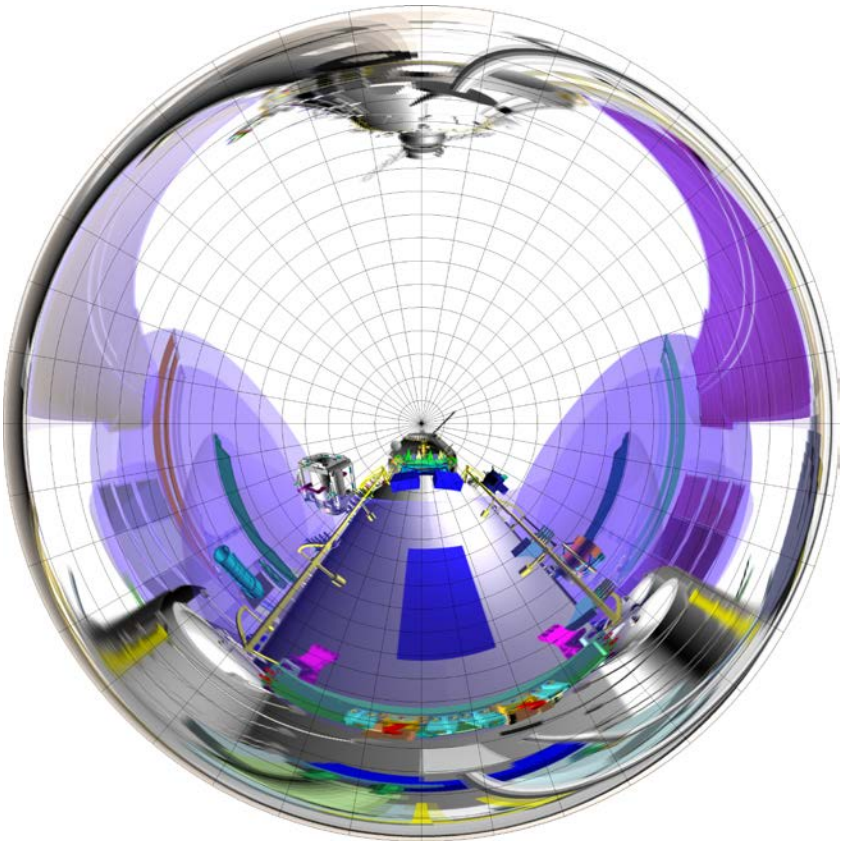


Fig. 4.6.1 Fields of view of scientific equipment installed on the LOAD Axis of sight pointing towards zenith



- Fig. 4.6.2 Field of view of scientific equipment installed on the LOAD. Axis of sight pointed towards nadir

4.7 Node Module NM

Characteristics:

Launch mass: 4650±100 kg

Pressurized volume: 19 m^3

Method of delivery to the ISS: Logistics vehicle Progress M-NM

There are no plans to conduct scientific experiments in the NM.

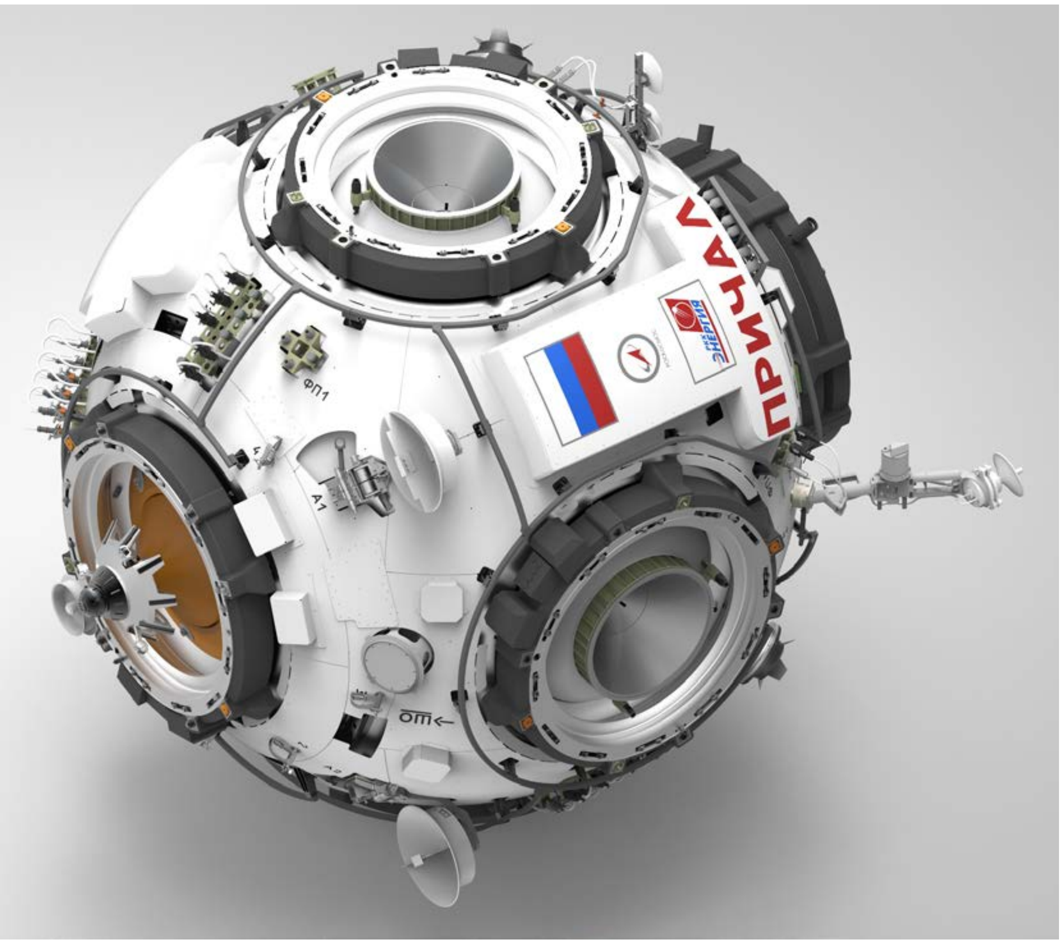


Fig. 4.7.1 External appearance of the Node Module NM

5 Cargo certification

One of the essential conditions for integrating scientific equipment into Russian spacecraft and ISS RS is to certify the scientific equipment.

All the scientific equipment hardware delivered by Russian transportation spacecraft to ISS RS shall be certified for transportation/functioning onboard the spacecraft and use onboard ISS RS, that is, the hardware shall comply with the current requirements levied upon the hardware by the Russian spacecraft and ISS RS.

All the activities on the implementation and verification of compliance with the current requirements for the scientific equipment and on proving its flightworthiness are subdivided into the following groups, which correspond to the step-by-step process of development, verification and certification of the scientific equipment:

a) development of scientific equipment to meet the specified requirements;

b) verification of the scientific equipment to check and confirm that requirements specified for the equipment have been met. Verification includes tests, calculations, analyses, etc. Requirements for hardware tests are given in paragraph 5.5.;

c) analysis of verification results: verification of equipment characteristics compliance with the specified requirements; evaluation of hardware flight readiness; development and publication of certification documents.

A Russian organization develops scientific equipment in accordance with requirements of HA-99, a foreign organization follows contract requirements for conducting the space experiment.

Scientific equipment certification is conducted in order to verify its following integral properties:

- safety (strength, fire safety, electrical safety, toxicological safety, radiation safety, acoustic noise, etc.);

- equipment compatibility with spacecraft and the ISS RS systems;
- equipment compliance with requirements in the Specifications.

Depending on the specific kind of equipment, certification is performed as follows:

- safety and compliance with the specified requirements are verified for all types of equipment;
- equipment compatibility with the spacecraft and ISS RS systems are verified for the equipment that has interfaces (mechanical, electrical, software, telemetry) with the spacecraft and operating on-board the spacecraft.

5.1 Documents used in the course of certification

5.1.1 Documents used in certification of scientific equipment are defined in Russian technical standards documents used for the development of rocket and space technology products. Certification documents attesting to certification of an individual piece of equipment are:

- logbook, data sheet, label (hereinafter referred to as logbook) included in the accompanying documents;
- flightworthiness statement;
- safety certificate.

5.1.2 Logbook

The logbook is intended for identifying a piece of equipment, recording its key characteristics, and contains a flightworthiness statement for that particular unit.

The logbook is published for each piece of equipment by its manufacturer (vendor) in accordance with the current requirements for shop-floor documentation. In some particular cases (for example, for certain foreign-made equipment, purchased items), when there is no logbook meeting the established requirements, the organizational unit in charge of that item publishes a document functionally similar to a logbook.

5.1.3 Flightworthiness statement.

Flightworthiness statement is intended as an assertion by the developer (supervisor) company (organizational unit) that the current requirements of the Specification or a document which replaces it (supplement to a contract, etc) are met. The Statement shall attest to the completion of the scheduled developmental testing, to the fulfillment of the current requirements for scientific equipment, and contain a permission to fly the equipment. The Statement is the primary certification document published by the developer based on the results of a series of activities aimed at analyzing, developmental testing and confirmation of the scientific equipment readiness for flight/flight testing per requirements of Russian technical standards.

The Statement is published for the scientific equipment for which a permission to fly is sought for the first time (newly developed or structurally modified equipment), and which is used under the Russian program of scientific and applied research.

The Statement’s scope shall cover the flight of scientific equipment inside a particular type of a transportation spacecraft and its use within an ISS RS module.

5.1.4 Safety Certificate

The Certificate attests to the scientific equipment compliance with the current safety requirements. The Certificate is published based on the results of analysis of the equipment safety characteristics and measures taken to prevent hazardous situations. The results of such an analysis are presented in the form of a report (attachment to the certificate), which, together with the certificate constitute a single Safety Data Package (SDP).

The safety certificate is published:

- for scientific equipment of foreign organizations: for the phase of its transportation on a Russian spacecraft and for the phase of its use and storage on-board ISS RS;
- for Russian scientific equipment: for the phase when it is used and stored onboard ISS RS, and the phase when it is transported onboard a foreign spacecraft.

If the scientific equipment is a re-flight item for a particular phase (a certificate was published for an earlier successfully completed flight), safety certificate is not published for that item for that particular phase.

5.2 Scientific equipment tests

5.2.1 Generally, scientific equipment is subjected to the following kinds of tests:

- qualification/stand-alone developmental tests (QT);
- acceptance tests (AT);
- tests at checkout and testing facility within the flight model of the spacecraft/ISS RS module;
– tests in the integrated testing facility for the modules that have already been launched;
- incoming inspection;
- tests at the processing facility within the flight model of the spacecraft/ISS RS module, or within the integrated testing facility (electrical mockup) of the ISS RS module;

All the tests and operations to service and process the scientific equipment at RSC Energia and the processing facility are only conducted per RSC Energia-approved instructions and under supervision of its responsible representatives. The instructions shall contain all the information that is necessary to handle the equipment.

5.2.2 Qualification tests are conducted by the equipment developer on the qualification model of the equipment, which is not intended for operation, but which is built per documentation for the flight model of the equipment.

The prime task of qualification tests is to check the equipment against specification or contract requirements under exposure to environments which are as close to operational environments as possible, and, if need be, under heavier duty test modes.

5.2.3 Acceptance tests on contract equipment are done to check the equipment against the requirements of the documentation approved by RSC Energia. The procedure for conducting acceptance tests is determined by the contract requirements.

5.2.4 Tests at the checkout and testing facility within the flight model of the spacecraft/ISS RS module are conducted in order to check mechanical, electrical and software interfaces between the equipment and the spacecraft/module.

The interfacing of the scientific equipment with an ISS RS module is checked in the course of tests of the scientific equipment in the integrated testing facility (electrical mockup) of the module.

Tests within the flight model of the spacecraft at checkout and testing facility and at the processing facility are conducted when interfaces are available, if so agreed with RSC Energia.

5.2.5 Incoming inspection of the equipment is conducted per agreed procedure after its delivery to RSC Energia.

Incoming inspection operations include:

- inspection of external appearance and a check for missing items;
- equipment operational integrity check (if need be).

5.2.6 Program of qualification and acceptance tests

Requirements for the scientific equipment tests are defined in OCT 92-5100-89.

The list of tests on the Russian scientific equipment is defined in the Integrated Developmental Testing Program for the scientific equipment.

A typical list of tests and verification activities under the programs of qualification tests and acceptance tests of the equipment is given in Table 5.2.1.

For each type of tests a test procedure is developed.

Table 5.2.1

Test/verification	Verified requirements (subparagraph # in Section 6)	Test type		Note
		Qual. test	AT	
1. Check for missing items	Requirements of design documentation for the scientific equipment	–	+	Checks delivery set for missing items and completeness of technical and operational documentation
2. Inspection of the external appearance	Requirements of design documentation for the scientific equipment	–	+	The external appearance of the equipment is checked against outline drawing, and it is checked whether logbooks and certificates are available and completely filled out
3. Dimensions check	Requirements of design documentation for the scientific equipment	–	+	To be checked are: outline dimensions of the hardware, center-to-center distances of mounting holes, mounting holes dimensions
4. Checking mass and position of the center of gravity	Requirements of design documentation for the scientific equipment	–	+	Mass and center of mass position are checked against the developed outline drawings

Test/verification	Verified requirements (subparagraph # in Section 6)	Test type		Note
		Qual. test	AT	
5. Packing check	Requirements of design documentation for the scientific equipment	–	+	
6. Safety review	6.3	+	+	Safety review includes safety assessment in general and specialized fields (strength, materials safety, toxicological and radiation safety, etc.), as well as an integrated assessment of the hardware safety, For Russian scientific equipment the reviews are conducted within the framework of qualification tests (per Program and Procedure of acceptance tests), for contractual scientific equipment within the framework of acceptance tests
7 Mechanical loads tests	6.1.3 for spacecraft 6.2.2 for ISS RS		**-{}-**	The tests are performed to check the strength of load-bearing elements of the hardware that has a mechanical interface (rigid attachment) with the spacecraft/module, as well as, if need be, to check the functional integrity of the hardware.
7.1. Vibration		+	+	
7.2. Shock loads		+	–	
7.3. Linear accelerations		A	–	

Test/verification	Verified requirements (subparagraph # in Section 6)	Test type		Note
		Qual. test	AT	
				The tests shall be performed in transportation and working configurations of the hardware under the types of loading which correspond to these configurations (for example, in a bag/package fastened in a way similar to the standard attachment to the spacecraft). If the hardware was tested at levels different from those currently established, the issue of extending the applicability of these results needs to be coordinated with RSC Energia.
8 Environmental tests				
8.1. Humidity	6.1.2.3 for spacecraft, 6.2.1.5 for ISS RS	+	–	The accuracy of humidity measurements is to be agreed with RSC Energia
8.2 Temperature when delivered to the processing facility	6.1.2.2	+	-	

Test/verification	Verified requirements (subparagraph # in Section 6)	Test type		Note
		Qual. test	AT	
8.3 Temperature in flight	6.1.2.2 for spacecraft 6.2.1.4 for ISS RS	+	+	The tests (for thermal stability) are conducted at lower/higher temperature
8.4 Thermal cycle	Requirements of specifications for the scientific equipment	+	–	Subjected to the tests is scientific equipment operating in unpressurized compartments under exposure to cyclically varying temperature
8.5 Acoustic noise	6.1.3.3 for spacecraft 6.2.3.3 for ISS RS	+	–	The tests are conducted if the equipment is considered critical with respect to acoustic noise exposure, as well as in the cases where the root-mean-square value of the acoustic pressure on the hardware in the locations where it is installed in the spacecraft/module exceeds 130 dB
8.6 High/low pressure tests	6.1.2.4 for spacecraft 6.2.1.3 for ISS RS	+	-	The tests are conducted in order to check operational integrity of the equipment under exposure to extreme pressure values

Test/verification	Verified requirements (subparagraph # in Section 6)	Test type		Note
		Qual. test	AT	
8.7 Pressure drop rate tests	6.1.2.4 for spacecraft	+	-	Subjected to the tests is scientific equipment built in the form of a pressurized unit or a vented container used inside the descent vehicle or orbital module of Soyuz spacecraft. Pressure drop rate is 100 mm Hg/s
9 Radiation stability tests	6.1.2.5 for spacecraft 6.2.6 for ISS RS	**A**	–	The test is run for the kinds of equipment that are radiation exposure critical
10 Leakage tests	Requirements of specifications for the scientific equipment	+	+	Subjected to the tests is the equipment that has a pressurized volume (an enclosure, a vessel containing gas, liquid, test tubes with biological samples, etc.). Before and after strength tests the equipment must be tested for leakage. Before filling, the flight unit must be tested for leakage.

Test/verification	Verified requirements (subparagraph # in Section 6)	Test type		Note
		Qual. test	AT	
11 Thermal vacuum test	6.1.2.2 for spacecraft 6.2.1.4 for ISS RS	+	–	Subjected to tests is the equipment that operates in open space in unpressurized compartments. It is recommended that the tests be combined with thermal stability tests (see paragraph 8.3)
12. A check of electric circuit	Requirements of specifications and design documentation for the scientific equipment	+	+	A check of electrical circuits continuity and isolation.
13 Insulation and insulation breakdown tests	6.1.4 for spacecraft, 6.2.4 for ISS RS	+	+	
14. Inrush current test		–	+	
15. Power consumption check		–	+	

Test/verification	Verified requirements (subparagraph # in Section 6)	Test type		Note
		Qual. test	AT	
16. Functional test	Requirements of specifications for the scientific equipment	+	+	Acceptance tests are performed at nominal supply voltage, while qualification tests are performed at those extreme voltages to which the scientific equipment is most sensitive under given conditions
17. EMC test	6.1.2.5 for spacecraft 6.2.6 for ISS RS	+	–	

Test/verification	Verified requirements (subparagraph # in Section 6)	Test type		Note
		Qual. test	AT	
18. Tests of self-contained power supplies and chargers				All flight units of self-contained power sources, except the ones of the “tablet” type are subject to tests. The tests include: visual inspection, recording physical characteristics, taking measurements of storage voltage and operating voltage, leakage test, cycling (charge/discharge). Tablet-type self-contained power sources are tested within operating equipment. Flight units of chargers are tested under normal operating conditions. **Self-contained power sources and chargers that have passed the tests within the equipment are not subjected to tests within this scope.**

Test/verification	Verified requirements (subparagraph # in Section 6)	Test type		Note
		Qual. test	AT	
19. Acoustic noise check	6.3.2.5.3	-	+	For scientific equipment containing motors, valves, moving fluids, sources of sound

Notes:

1) Symbols:

- "+" – this test must be conducted;
- "A" – these requirements can be verified through analysis;

"-" tests/checks are not conducted

2) It is acceptable, with the agreement of RSC Energia, not to conduct certain types of tests specified in the table. In that case, the equipment compliance with the requirements shall be verified through analysis.

6 Specifications for experimental equipment delivered to ISS

6.1 Specifications for equipment transported in Russian spacecraft Progress and Soyuz

6.1.1 General

These requirements are applicable to all the cargoes delivered to ISS in Progress and Soyuz spacecraft, to all the waste and cargoes removed from the station for disposal inside Progress cargo compartment or Soyuz orbital module, as well as to cargoes returned to Earth inside Soyuz descent vehicle. The document contains requirements for all the phases of transportation and for the spacecraft ground processing phase.

All the transported cargoes shall meet the requirements of the normal operating conditions described in this Section. In off-nominal situations, including depressurization, cargoes shall remain fire-and-explosion safe, nontoxic, leakproof (gases, liquids, biological samples) and preserve their mechanical integrity, meet safety requirements for crew and spacecraft equipment. There are no requirements to assure cargo functioning after an off-nominal situation.

In accordance with the conditions required onboard spacecraft for cargo delivery, all the cargoes are subdivided into:

- active cargoes, which require for their transportation connections to the spacecraft onboard systems (power supply system, thermal control system, telemetry, etc.);
- passive cargoes, which do not require for their transportation any connections to the spacecraft onboard systems.

6.1.2 Environmental conditions

6.1.2.1 Gas medium

Composition of the gas medium inside Cargo Compartment, Descent Vehicle and Orbital Module (in volume percentages) through all the phases of free flight up to the docking with the space station:

- oxygen – 21...40% (at partial pressure of 120...350 mm Hg);

- carbon dioxide – up to 3%;
- hydrogen – up to 2%;
- helium – up to 0.01%;
- nitrogen – the rest.

Gas media composition in the Cargo Compartment, the Descent Vehicle and the Orbital Module after docking with the space station and opening of the transfer hatches is the same as the composition of the atmosphere inside the space station pressurized cabin.

6.1.2.2 Temperature

Phase of operation	Temperature
In production and storage rooms	+5÷+30°C
Ground transportation	±50°C
Assembly and testing	0÷+40°C
On the launch pad (for cargoes)	0÷+40°C
Orbital flight	
- for cargoes, when the crew is not present	0÷+40°C
- for cargoes, when the crew is present	+18÷+25°C*)
- for cargoes outside pressurized compartments	from minus 150 to + 125°C
After descent vehicle landing (for cargoes)	±50°C

*) – Temperature is allowed to rise up to +30°C and drop down to +10° for no more than 3 hours a day.

6.1.2.3 Humidity

(at temperature +20°C)

Phase of operation	Relative humidity
In production and storage rooms	20...85%
Transportation	up to 90%
Assembly and testing	20...80%
On the launch pad (for cargoes)	20...85%
Orbital flight (for cargoes, when the crew is not present)	20...80%*)
Orbital flight (for cargoes, when the crew is present)	30...75%
After descent vehicle landing (for cargoes)	up to 98%

*) – A rise up to 90% for as long as 3 hours a day is possible.

6.1.2.4 Pressure

Absolute pressure of the gas medium inside pressurized compartments through all the phases of ground processing is the atmospheric pressure, and through all the mission phases it may vary within the range of 450...970 mm Hg.

The vacuum outside the spacecraft (in the cargo compartment of Progress spacecraft when conducting experiments requiring its depressurization, or when cargoes are located on the outer surface of the spacecraft) is at 10^{-3}...10^{-8} mm Hg.

In case of depressurization of the cargo compartment or the descent vehicle of Soyuz, the cargo may stay at a pressure as low as 10^{-6} mm Hg for as long as 10 hours. The maximum pressure drop rate is 100 mm Hg/s.

6.1.2.5 Radiation exposure

During its operation the scientific equipment is exposed to ionizing radiation of charged particles of the Natural Earth Radiation Belts (NERB), of

Galactic Cosmic Rays (GCR) and Solar Cosmic Rays (SCR). NERB are made up of electrons and protons captured by the Earth's magnetosphere, while GCR and SCR are streams of Heavy Charged Particles (HCP) — high-energy protons, nuclei and ions of chemical elements.

Considered as a space radiation causing a gradual (in the course of time) degradation of performance in electronic components and materials (dosage effects) are electrons and protons of the Earth radiation belts and SCR protons.

Degradation of functional assemblies, electronic components and materials of the equipment are determined by the absorbed dose of electron and proton radiation.

Doses outside and inside equipment units will depend on the mass thickness of the shielding provided by the spacecraft walls and other units, and inside a unit by structural elements of the unit itself. Mass thickness of the shielding (g/cm^2) is the product of linear thickness (cm) by material density (g/cm^3).

Annual absorbed dose inside the ISS modules does not exceed 300 rads. When determining the absorbed dose in the equipment operated outside cabin, one should take into account the effective thickness provided by the MLI and the housing of the scientific equipment unit.

Absorbed doses of space electrons and protons for materials and equipment of ISS RS per 1 year for various values of mass thickness of a spherical shielding under exposure to omnidirectional irradiation (solid angle 4π) are listed in tabular form in the requirements specification. If need be, the requirements specifications provide absorbed doses of space electrons and protons for materials installed outside ISS RS for various values of mass thickness of a flat layer of shielding under exposure to unidirectional irradiation (solid angle 2π), as well as integral energy spectra of electrons and protons in Earth radiation belts. Doses for shielding thicknesses that are different from values listed in the table are calculated through exponential approximation of dosage values between adjacent values of mass thickness per industrial standard OST 134-1044-2007. When the duration of the scientific equipment staying in flight changes, the absorbed doses are calculated proportionally to the annual absorbed doses listed in the tables.

Evaluation of resistance to electron and proton radiation by dose effects, and radiation-hardness tests shall be conducted in accordance with the industrial standard OST 134-1034-2012.

Dosage safety factor (with respect to the data listed in the requirements specification or data obtained through exponential interpolation of the tabular values) for any ISS equipment shall be no less than two. This is achieved through selection of equipment elements that are more resistant to absorbed dose, introduction, if need be, of additional shielding, and optimized layout of the hardware. The criterion for the need to conduct testing is the absence of a safety factor of three based on the results of radiation hardness analytical estimate.

When electronic equipment is exposed to individual heavy charged particles (HCP) and protons, single radiation effects occur in its integrated circuits (IC) and power field-effect transistors (PFET), which may result in the equipment malfunction and failure, if it does not use the necessary hardware- and software-based methods of upset recovery and protection of electronic equipment against failure.

Soft faults can be a serious hindrance to normal operation of the equipment, if it lacks special fault-tolerance measures.

Hard faults in the devices lacking special circuit-design-based protective measures may result in their catastrophic failures, and, accordingly, to the failure of radio and electronic equipment.

Considered as a space radiation causing soft and hard faults in electronic equipment under exposure to individual charged particles are protons of the Earth radiation belts (ERB), of solar cosmic rays (SCR), of galactic cosmic rays (GCR) and heavy ions (nuclei of elements from helium to uranium) in SCR and GCR. Proton and heavy ions are jointly referred to as heavy charged particles (HCP).

Characteristics of streams of heavy charged particles responsible for soft- and hard-faults (integral and differential spectra of HCP and linear energy transfer spectra), as well as absorbed doses vs. mass thickness of the shielding in their entirety are given in the requirements specifications.

Radiation hardness of the equipment for single events when exposed to HCP is achieved through selection of elements that are not susceptible to these effects or elements that have low soft-fault rates and probabilities of failure (that is, high LET thresholds for soft and hard faults and small cross-sections of these processes), which support the specified equipment service life and reliability level. In the cases where the used elements are integrated circuits (IC) and power field-effect transistors (PFET) that are susceptible to soft and hard faults, the immunity of the equipment to this factor is achieved through the use of algorithmic and circuit-design-based methods of protection, on both the device and cross-system levels.

Radiation hardness analysis based on single radiation effects is done in accordance with working documentation RD 134-0139-2005.

Radiation from the internal source inside the descent vehicle is a directed flux of gamma-ray photons with energies of up to 661 KeV. The dose rate does not exceed 0.1 rad/day at the distance of 0.5 meters from the source (the area under the couches).

The results of scientific equipment analysis for radiation hardness with respect to both dosages and single effects are documented in “Radiation Hardness Analysis”.

6.1.3 Mechanical loads

6.1.3.1 Coordinate systems

Ground transportation:

X_1 axis is parallel to the direction of transportation. Positive direction of the axis is against the transportation direction;

Y_1 axis is perpendicular to X_1 axis. The positive direction of the axis is up;

Z_1 axis is perpendicular to axes X_1, Y_1 and completes the right-handed coordinate system.

Orbital insertion and flight:

X axis is the longitudinal axis of the vehicle. Positive direction is towards maximum loads during ascent (Attachment 2);

Y axis is perpendicular to X axis;

Z axis is perpendicular to axes X, Y and completes the right-handed coordinate system.

The XYZ coordinate system is rotated about X axis through 135° with respect to X_1 Y_1 Z_1 coordinate system.

Descent vehicle reentry and landing:

X axis – The positive direction is towards maximum loads;

Y axis is perpendicular to X axis. The positive direction is towards maximum loads;

Z axis is perpendicular to axes X, Y and completes the right-handed coordinate system.

6.1.3.2 Types of mechanical loads

All types of loads can be grouped as follows:

- quasi-static linear and low-frequency dynamic loads;
- harmonic (sine) vibration;
- broad-band random vibration;
- shock pulse loads;
- acoustic loads.

Cargoes that are highly susceptible to shock and vibration loads shall be installed (if need be) onto shock absorbers by the developer.

6.1.3.3 Loads

6.1.3.3.1 When the spacecraft is transported within the processing facility

When the spacecraft is transported by rail within the processing facility, the operational loads are:

- $n_x1= \pm1.5$; $n_y1= -1 \pm0.25$; $n_{z1}= \pm 0.2$;

When lifted, carried and installed onto supports:

– in horizontal position:

$n_{x1}= \pm0.1$; $n_{y1}= -1\pm0.5$; $n_{z1}= \pm0.1$;

– in vertical position:

$n_{x1}= -1.5$; $n_{y1}= \pm0.1$; $n_{z1}= \pm0.1$.

6.1.3.3.2 During ascent to orbit

Operational values for linear loads for cargoes (without taking into account the low-frequency dynamic component) are:

- along X axis – +4.3;
- along Y,Z axes – ±1.5.

Operating values for quasi-static linear accelerations (taking into account the low-frequency dynamic component) for payloads secured in transportation position, which do not have (with the effects of transportation fixtures taken into account) any normal modes within the frequency range of up to 30 Hz, or have normal modes in the said frequency range, while having a Q-factor for the cargo-fasteners system of no more than 10, are 7.15 in any of the three mutually perpendicular directions occurring non-simultaneously. Time of exposure to the loads: up to 600 s.

Qualification levels of vibration loads for all phases of flight in three mutually perpendicular directions are expressed:

- on frequencies of up to 20 Hz by random vibration in Table 6.1.3.3.2.1;
- on frequencies ranging from 5 to 2000 Hz by equivalent sine vibration in Table 6.1.3.3.2.2;

Table 6.1.3.3.2.1

Mission phases	Spacecraft compartment	Frequency subranges, Hz						Exposure duration, s
		20-50	50-100	100-200	200-500	500-1000	1000-2000	
		Vibration acceleration spectral density, g^2/Hz						
Ascent to orbit	Orbital module, cargo compartment	0.02	0.02	0.02-0.05	0.05	0.05-0.025	0.025-0.013	120

Mission phases	Spacecraft compartment	Frequency subranges, Hz						Exposure duration, s
		20-50	50-100	100-200	200-500	500-1000	1000-2000	
		Vibration acceleration spectral density, g^2/Hz						
	Descent vehicle	0.02	0.02	0.02	0.02	0.02-0.01	0.01-0.005	120
	Orbital module, cargo compartment, descent vehicle	0.02	0.02	0.02	0.02-0.008	0.008-0.004	0.004-0.002	480
Orbital flight	Orbital module, cargo compartment	0.004	0.004	0.004	0.004	0.004	0.004-0.002	600
	Descent vehicle	0.004	0.004	0.004	0.004-0.01	0.01	0.01-0.005	600
Descent	Descent vehicle	0.004	0.004	0.004	0.004-0.01	0.01	0.01-0.005	600

Notes

1 Spectral density vary linearly with frequency within a sub-range when both axes use logarithmic scale.

2 On frequencies of 5 to 2000 Hz refer to Table 6.3.3.2.2.

Table 6.1.3.3.2.2

Mission phases	Frequency sub-range, Hz					Exposure duration, s
	5-25	25-200	200-800	800-1500	1500-2000	
	Vibration acceleration amplitude, g					
Ascent to orbit	1	1 - 3	3 - 5	5 - 8	8	300
Orbital flight	0.5	0.5 - 1	1 - 3	3 - 5	5 - 2	300
Descent	-	0.5 - 1	1 - 3	3	3 - 2	100

Note - Amplitude varies linearly with frequency within a sub-range.

Qualification levels of shock loads in three mutually perpendicular directions are listed in Table 6.1.3.3.2.3.

Table 6.1.3.3.2.3

Peak acceleration, g	Pulse duration, ms	Number of shocks
40	1 - 3	Two shocks in each direction and along each axis

Operational acoustic loads applied to the spacecraft during ascent are given in Table 6.1.3.3.2.4.

Table 6.1.3.3.2.4

Central frequencies of octave frequency bands, Hz								Total level, dB	Duration of exposure, s
31.5	63	125	250	500	1000	2000	4000		
RMS levels of acoustic pressure in octave frequency sub-ranges, dB									
On the surface of the spacecraft									
129	134	138.5	136	135	127	120	118	142.5	60
Inside cargo compartment or orbital module									
122	127	131	129	128	120	113	111	135	60

Inside the descent vehicle the total level of acoustic noise during ascent does not exceed 125 dB.

6.1.3.3.3 In orbital flight:

1) operating values for quasi-static loads (taking into account the low-frequency dynamic component) for payloads secured in transportation position, which do not have (with the effects of transportation fixtures taken into account) any normal modes within the frequency range of up to 30 Hz, or have normal modes in the said frequency range, while having a Q-factor for the cargo-fasteners system of no more than 10, are in longitudinal direction: nx=±0.3, in lateral direction: nx=±1.2, in transverse direction: nz=±1.2 (simultaneous exposure) for 12 minutes;

1) qualification vibration levels for all compartments of the spacecraft in three mutually perpendicular directions are given in Tables 6.1.3.3.2.1 and 6.1.3.3.2.2;

3) qualification levels of shock loads in orbital flight are given in Table 6.1.3.3.4.1;

Table 6.1.3.3.4.1

Peak acceleration, g	Pulse duration, ms	Number of shocks
40	1 - 3	5 shocks in each direction and along each axis

4) operational levels for dynamic loads during docking with ISS are given in Table 6.1.3.3.4.2.

Table 6.1.3.3.4.2

Loads in the X-axis direction			In two other mutually perpendicular directions		
Load	The number of loading cycles	Cycle duration, (ms)	Load	The number of loading cycles	Cycle duration, (ms)
±0.8	≤10	100÷1000	±1.0±0.2	≤10	100÷1000

6.1.3.3.5 During Soyuz descent and landing

1) operational values for linear accelerations:

a) normal descent of the descent vehicle (nominal conditions)

n_x= 0…+6, $n_{y,z}$= 0±1, duration of 600 s, including

n_x=+6, exposure duration is 20 s;

$n_{y,z}$= ±1, exposure duration is 20 s;

a) ballistic descent of the descent vehicle (off-nominal situation):

n_x= 0…+10, $n_{y,z}$= 0±1 for 600 s, including

n_x= +10, exposure duration is 20 s;

$n_{y,z}$= ±1, exposure duration is 20 s.

Variation of operating values of loads with time is approximated by a sine half-wave with half-period equal to the exposure duration;

c) during parachute system operation:

- during drogue chute operation

n= +10 (in any direction), exposure duration is 10 s;

- during main chute operation

n_x= +8, exposure duration is 15 s;

$n_{y,z}$= ±4, exposure duration is 15 s;

- during re-hooking

n= +5 (in any direction), exposure duration is 5 s;

d) touch-down with failed soft-landing thrusters (off-nominal situation):

at first impact n_x= +100 (a deviation of loading direction of ±15° is possible), $n_{y,z}$=50 (direction of loads in transverse plane is arbitrary).

Variation of loads with time is approximated by a sine half-wave with half-period τ=20-30 ms;

2) qualification levels of vibration (in three mutually perpendicular directions) of the descent vehicle during reentry are listed in Tables 6.1.3.3.2.1, 6.1.3.3.2.2:

3) qualification levels of shock loads are given in Table 6.1.3.3.5.1;

Table 6.1.3.3.5.1

Peak acceleration, g	Pulse duration, ms	Number of shocks
40	1 - 2	Two shocks in each direction and along each axis
20	3 - 5	7 shocks in each direction and along each axis

6.1.3.3.6 Autonomous transportation of equipment and hardware

For autonomous transportation of equipment and hardware by all types of transportation, the recommended accelerated test modes are given in Table 6.1.3.3.6.1

Table 6.1.3.3.6.1

Shock pulse acceleration, g	Transportation vehicle axes			Pulse duration, ms	Total number of shocks	The number of shocks per minute (no more than)
	X_1	Y_1	Z_1			
	Number of shocks					
± 9	750	2500	1750	5 to 10	5000	120
Note - If the orientation of the equipment with respect to the axes of the transportation vehicle is not clearly defined, the number of shocks shall be taken to be 2500 for all directions (the total number of shocks is 7500).						

6.1.3.4 Safety factors

Strength analysis of deliverable cargoes, including their fasteners, is done based on design overloads defined as the product of operating overloads and the safety factor f.

The same safety factors f are also taken into account during qualification tests.

Minimal safety factors for overloads are set in accordance with Table 6.1.3.4.1. When the structure is exposed to a combination of forces for the loads increasing the strength margin, the safety factor is set at f=1. Loads increasing the strength margin are determined during strength analysis.

Table 6.1.3.4.1

Loads per paragraphs	Value of safety factor f, no less than
6.1.3.3.1	1,5
6.1.3.3.2	1,4
6.1.3.3.3	1,3
6.1.3.3.4	2,0
6.1.3.3.5) a,b,c	1,5
6.1.3.3.5) d	not specified

In the course of strength analysis an additional coefficient K is introduced, which is a multiplier for the safety factor:

- for fasteners (for example: bolts, screws taking into account a pre-torque) К = 1.25;
- for critical fasteners having a complex geometric shape (for example: brackets, fittings), К=1.25;
- when using materials having a high spread in strength properties or a significant anisotropy (for example: engineering plastics), К=1.2;

6.1.3.5. Vibration and acoustic tests

6.1.3.5.1 Vibration and shock qualification tests are conducted at levels that are at least as high as those given in paragraph 6.1.3.3.

6.1.3.5.2 It is acceptable to replace random vibration tests with sine vibration tests.

6.1.3.5.3 Operational acoustic loads applied to the spacecraft during qualification tests are increased by no less than 3 dB, and the exposure duration by no less than a factor of 2.

6.1.3.5.4 G-load qualification tests are conducted taking into account safety factors per paragraph 6.1.3.4.

6.1.3.6 Microgravity

Active cargoes that operate continuously or in the microgravity mode shall meet the requirements for microgravity conditions specified in paragraph 6.2.3

6.1.4 Electrical conditions and requirements for electrical equipment

Electrical conditions and requirements are given for active cargoes which require connection to the spacecraft onboard power system.

Active cargoes are connected to the spacecraft onboard power system via four-pin connectors to outlets rated at 3A (Progress M1), 10A and 20A using a circuit breaker.

6.1.4.1 Onboard power system voltage

The spacecraft onboard power system provides DC power at 27^{+7}_{-4} V.

6.1.4.2 Bonding to protect against static electricity

In order to assure that all the conducting parts of the cargo and the spacecraft have the same electrical potential, all the electrically conductive structural elements need to be bonded, that is, have reliable electrical interconnections with contact resistance of no more than 2.5 mOhm.

6.1.4.3 Insulation resistance

Insulation resistance of electrical circuits in active cargoes shall be no less than 20 MOhm at relative air humidity of 45...80% within the temperature range of +15...+35°C, and no less than 1 MOhm at relative air humidity of 95% and +20°C temperature.

Insulation of primary current-carrying circuits from the device case and between any electrically isolated circuits shall be able to withstand a test voltage of 200 V (effective or DC voltage) for 1 s.

6.1.4.4 Design features

Design of high-voltage elements in active cargoes shall rule out any possibility of corona discharges and short-circuiting at low pressure inside compartments.

All current-carrying elements in active cargoes having non-insulated electric conductors located in the air flow shall be securely protected against contact with small objects using airtight covers.

6.1.4.5 Noise immunity and electromagnetic compatibility

Requirements for electrical and RF equipment to provide noise immunity and electromagnetic compatibility when exposed to inadvertent interference finding its way into the equipment in a typical noise environment are given in paragraph 6.2.4.2..

6.1.5 Cargo labeling requirements

The cargoes to be delivered or removed are to be labeled with onboard data sheets and barcode labels, as well as photographed and filmed on video.

Deliverable cargoes shall have onboard data sheets and barcodes to make them identifiable per requirements of paragraph 6.2.5.

Barcode labeling is done by affixing special labels carrying a barcode duplicated in alphanumeric format.

Barcode labels must not cover any existing inscriptions on the cargo.

The locations for onboard data sheets and labels are determined by the developer or a person in charge of the cargo and are specified in its dimensional installation drawing. If the cargo is not subject to barcode labeling, a “barcode is not to be installed” entry shall be made in the dimensional installation drawing.

Photographs of the delivered cargo are taken separately prior to installation on the spacecraft, as well as after its installation on the spacecraft.

Deliverable cargoes are loaded into the spacecraft and checked for labeling per design documentation requirements.

6.1.6 Requirements for cargo mechanical properties

Mechanical properties shall be consistent with the cargo delivery and disposal conditions. The cargo shall be able to go through the spacecraft hatches. The cargoes to be delivered are loaded into Progress spacecraft through the hatch in the docking assembly (inside diameter of 800 mm) and through three loading hatches (inside diameter of 470 mm) in the cargo compartment. Inside diameter of the boarding hatch in the orbital module of Soyuz is 660 mm, the diameter of the manhole hatch in the Soyuz descent vehicle is 620 mm. The dimensions of the cargoes are determined during approval of the dimensional installation drawings for these cargoes.

Cargoes to be delivered can be secured inside Progress and Soyuz by means of:

- flanges and bolts;
- bands and straps;
- putting cargoes inside containers.

Mass, dimensions, inertia properties of the cargoes to be delivered shall conform to the outline drawings approved by the Russian side.

6.1.7 Packing requirements

The packing used in flight shall preserve cargo integrity during transportation and storage within the transportation spacecraft.

The packaging material used in flight shall meet requirements for flammability, odor, toxic outgassing and microbiological resistance, which are available in the RSC Energia's list of materials allowed for use in the pressurized section of the ISS RS.

6.2 Specifications for the equipment stored and operated onboard ISS RS

6.2.1 Medical and technical requirements for habitable environment

6.2.1.1 Atmospheric composition

Maximum content of major components in the space station atmosphere in orbit (volume %):

- nitrogen: up to 78 % (no more than 600 mm Hg);
- oxygen: up to 24.8 %
- carbon dioxide: up to 3 %
- methane: up to 0.5 %
- hydrogen: up to 2.0 %
- helium: up to 0.01 %
- water vapor: up to 3 % (up to relative humidity of 90 %).

6.2.1.2. Harmful trace contaminants content

The maximum content of harmful trace contaminants shall comply with Table 6.2.1. Russian standards correspond to zero risk, US standards correspond to acceptable risk (the duration of a period within an expedition to orbit during which acceptable risk standards apply must be additionally defined).

Table 6.2.1 Maximum acceptable content of harmful trace contaminants in the space station atmosphere

Compound [1)]	Russian MAC values [2)] for 360 days in orbit mg/m^3	US SMAC values [3)] for 180 days in orbit mg/m^3
hydrogen	1600	340
methane	3300	380
pentane	10	590 (7 days)
hexane	5	180 (7 days)
heptane	10	200 (7 days)
formaldehyde	0.05	0.05
acetaldehyde	1	4
aliphatic aldehydes (benzaldehyde)	1	4 to 8
propionic aldehyde	0.02	0.03
methyl alcohol	0.2	9
ethyl alcohol	10.0	2000
2-propyl alcohol	1.5	150
1-butyl alcohol	0.8	40
acetone	2	50
2-butanone	0.25	30
benzole	0.2 (180 days)	0.2
toluene	8	60
xylene	5	220
sterol	0.25	43 (7 days)
isopropylbenzol	0.5	49 (7 days)
furan	0.05	0.025

Compound [1)]	Russian MAC values [2)] for 360 days in orbit mg/m^3	US SMAC values [3)] for 180 days in orbit mg/m^3
ammonia	1	7
ethyl acetate	4	-
carbon monoxide	5	10
polymethyl cyclosiloxane	0.2	9-15
dichloromethane	5	10
1,2-dichloroethane	0.5	1
Freon-218	150	85

[1)] compounds are grouped into structural classes

[2)] Russian Maximum Allowable Concentrations (MAC) are stated in the national standard GOST P 50804-95

[3)] US Maximum Allowable Concentrations (SMAC) are stated in the document "Maximum Allowable Concentrations for individual contaminants in spacecraft atmosphere" (JSC 20584)

6.2.1.3. Atmospheric pressure

The total nominal pressure onboard the space station is maintained within 734-770 mm Hg, the minimal pressure is no less than 700 mm Hg.

6.2.1.4. Atmospheric temperature

Atmospheric temperature:

- in the living area - 18-28 ^{o}C;
- in the instrumentation area - 10-40 ^{o}C (during manned missions) and 0-40 ^{o}C during unmanned missions.

Temperature outside pressurized compartments (in open space): -150 to + 125^{o}C

6.2.1.5. Humidity.

Relative humidity: 30-70%, up to 95% for short periods of time (up to 3 hours per day). Dew-point temperature: 4.4-15.6 ^{o}C.

6.2.1.6. Aerosol content.

Aerosol content in the atmosphere: no more than 0.15 mg/m^3 for particles ranging from 0.5 to 300 micron.

6.2.1.7. Medical and technical requirements for microbiological content.

Requirements for the allowable number of microorganisms are given in Table 6.2.2.

Table 6.2.2

Source	Sampling time	Number of bacteria (no more than)	Number of fungi (no more than)
Air (colony-forming units/m^3)	prior to flight	300	50
	in flight	100	100
Surfaces of the interior and equipment (colony-forming units/m^2)	prior to flight	5.0	0.1
	in flight	100	1.0

Furthermore, no pathogenic bacteria or fungi are allowed.

6.2.2 Mechanical loading conditions

Equipment loading and microgravity conditions and requirements given below apply to the loads occurring during storage and operation of the equipment in orbit within ISS RS. Requirements for other operational phases are defined separately in accordance with the documentation currently in effect. In particular, conditions and requirements for launching with the use of Soyuz transportation spacecraft and Progress logistics spacecraft, and for returning cargo using Soyuz are given in Section 6.1 of this document.

If the equipment meets the below requirements, it can be stored and operated (as far as mechanical loading conditions go) in any ISS RS module. If need be, mechanical loading modes for a specific piece of equipment can be updated to take into account its specific location on the ISS RS.

6.2.2.1 Vibration loading

Vibration modes are specified in terms of vibration acceleration amplitudes within the 5 to 20 Hz frequency range, and vibration acceleration spectral density values in the 20 to 2000 Hz frequency range. Vibration modes for the 5 to 20 Hz frequency range are listed in Table 6.2.3. Random vibration modes within the 20 to 2000 Hz frequency range are given in Table 6.2.2.1.2. The modes are specified for three mutually perpendicular directions. Modes listed in Tables 6.2.2.1.1 and 6.2.2.1.2 do not apply to the equipment located inside and outside propulsion compartments of spacecraft, SM and other modules, when propulsion systems located inside these compartments are operating. Mechanical loading modes for such equipment are specified separately in accordance with the documentation currently in effect.

Table 6.2.2.1.1 Sine-wave vibration modes

Frequency band, Hz	Vibration acceleration amplitude, g
5 -- 10	0.1 – 0.13
10 - 20	0.13

Notes

1 The Table lists the qualification (design) test levels.

2 Acceleration amplitudes vary linearly with frequency.

3 The tests are to be conducted by smoothly varying the frequency at the rate of no more than 0.5 octave per minute.

4 For one year of equipment operation onboard the ISS RS the time of testing in each octave frequency range shall be:

- 240 s (except for the equipment to be installed in the Pressurized Instrumentation Compartment 3 and the Pressurized Adapter of MLM);
- 2440 s (for the equipment to be installed in the Pressurized Instrumentation Compartment 3 and the Pressurized Adapter of MLM).

Table 6.2.2.1.2 Random vibration modes

Frequency, Hz						
20	50	100	200	500	1000	2000
Vibration acceleration spectral density, g^2/Hz						
0.0004	0.0004	0.0005	0.00045	0.0006	0.00044	0.00022

Notes

1 The Table lists the qualification (design) test levels.

2 The values for spectral densities between the above frequencies vary linearly with logarithmic scale for frequency and spectral density.

3 For one year of equipment operation onboard the ISS RS the time of exposure shall be:

- 600 s (except for the equipment to be installed in the Pressurized Instrumentation Compartment 3 and the Pressurized Adapter of MLM);
- 8600 s (for the equipment to be installed in the Pressurized Instrumentation Compartment 3 and the Pressurized Adapter of MLM).

If need be, the above vibration modes for an individual piece of equipment can be updated to take into account its specific location on the ISS RS.

6.2.2.2 Force loads acting on the equipment

The design of the equipment to be installed inside the ISS RS modules in the crew translation paths shall be capable of withstanding operational loads of 556 N, caused by inadvertent collisions with the crew. The force shall be applicable in any direction to any spot on the equipment accessible to the crew. The safety factor for this load is 1.5.

The design of the equipment to be installed on the outer surface of ISS RS in the vicinity of the crew translation paths shall be capable of withstanding operational loads of 490.5 N, caused by inadvertent collisions with the crew. The force shall be applicable in any direction to any spot on the equipment accessible to the crew. The safety factor for this load is 1.5.

A structure on the equipment which may serve as an attachment point for the hook of a crew tether shall be capable of withstanding the design load of 1962 N applied at the tether attachment point and acting in any direction accessible to the crew.

6.2.2.3 Plume impingement loads

The structure of the equipment installed on the ISS RS outer surface (with the exception of solar arrays and radiators), shall be capable of withstanding the following local operational pressures generated by the thruster jets:

- normal pressure of 16.7 kgf/m^2;
- tangential pressure of 3.91 kgf/m^2.

The surface area to which these pressures are applied: up to 0.25 m^2.

When equipment is installed on solar arrays and radiators, the values for operational pressures are to be additionally defined.

Safety factor for operational pressures generated by thruster jets is to be set equal to 2.0.

6.2.2.4 Dynamic cyclic loading of the equipment during in-orbit storage and operation within ISS RS

When flying as a part of the ISS RS, the equipment, at the point where it is attached to the structure, is subjected to variable cyclic loads at frequencies no higher than 5 Hz caused by forces acting on the ISS structure (contact forces from dockings and undockings of various spacecraft, forces generated by operation of control system effectors, as well as crew intravehicular and extravehicular activities).

The operational number of loading cycles for fifteen years of operation is assumed to be as per Table 6.2.2.4.1.

Таблица 6.2.2.4.1

Acceleration level, %	The number of cycles
100	115
90	155
80	550
70	4 100
60	5 700
50	7 200
40	25 000
30	80 000
20	800 000
15	5 500 000
10	20 000 000
5	56 000 000

Notes
1 For other operational lifetimes of the equipment the number of loading cycles is to be recalculated in proportion to the operational lifetime.
2 The safety factor for the number of loading cycles is 4.

The 100% loading level is assumed to be equal to operational values of amplitudes of accelerations altering in sign that are listed Table 6.2.2.4.2.

Table 6.2.2.4.2

Direction with respect to the axes of the ISS RS module	Operational value of amplitude of acceleration altering in sign, g
Logitudinal	0.12
Transverse	0.22

6.2.2.5 Acoustic loading of the equipment during in-orbit storage and operation within the ISS RS

The equipment placed inside the ISS RS modules shall remain operational under exposure to continuous acoustic noise and acoustic pulses.

RMS levels of acoustic pressure of the continuous acoustic noise in the RS modules do not exceed 85 dBA (with respect to 0.00002 Pa). The corresponding RMS levels of acoustic pressure in octave frequency sub-ranges are listed in Table 6.2.2.5.1.

Table 6.2.2.5.1

Center frequency of the octave frequency sub-range, Hz							
63	125	250	500	1000	2000	4000	8000
RMS level of acoustic pressure, dB							
69.2	75.5	79.3	80.8	81.7	78.3	69.2	56.5

Peak values of acoustic pulse levels do not exceed 125 dBA*I*.

6.2.3 Microgravity

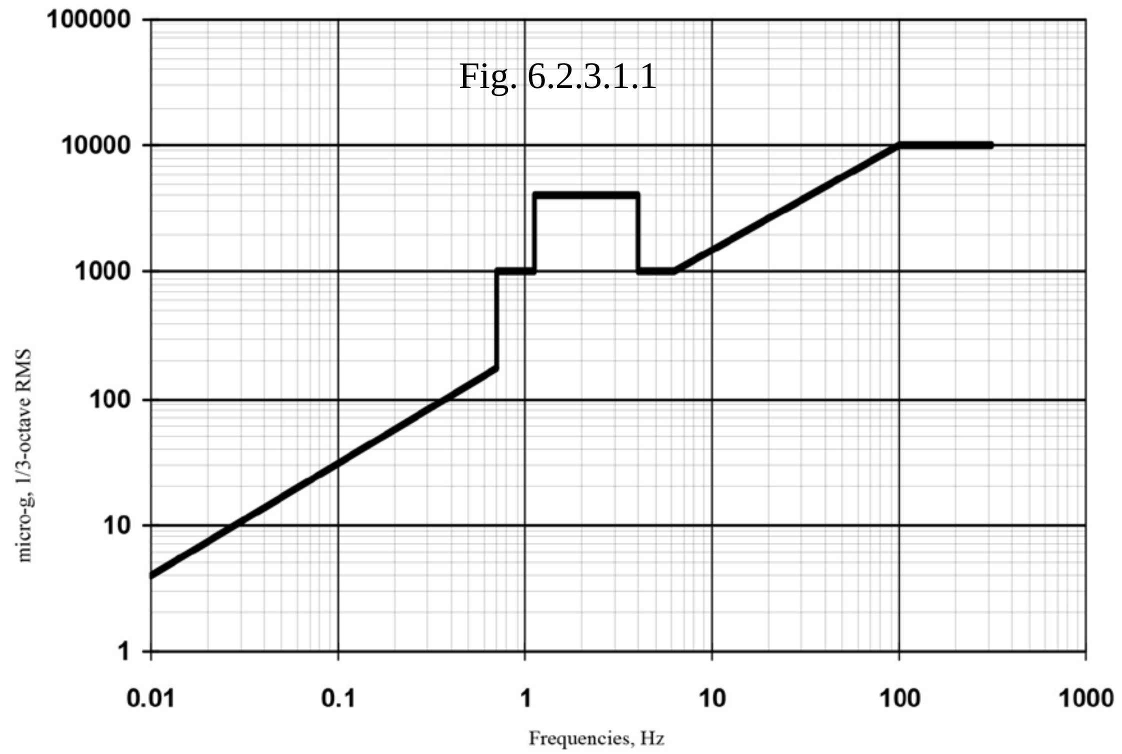
6.2.3.1 Microgravity environment in the RS modules

During the ISS microgravity flight modes, which are supposed to be maintained for 180 days per year in continuous 30-day intervals, RS modules provide the following microgravity environment:

- quasi-static accelerations (frequencies <0.01 Hz) of no more than 4 micro-g. Quasi-static acceleration in excess of NASA requirements is due to a disadvantageous position of the RS research modules with respect to the ISS center of gravity;
- root-mean-square (RMS) vibration acceleration levels in 1/3-octave frequency sub-ranges (averaged over time intervals of 100 s) do not exceed the levels shown in Fig. 6.2.3.1.1. Higher levels at frequencies ranging from 0.8 Hz to 5 Hz are due to the operation of solar array actuators and US segment radiators (SARJ, TRRJ), crew exercise on treadmill and stationary bicycle;
- maximum amplitudes of transient accelerations caused by individual sources do not exceed 10000 micro-g along each axis.

At frequencies of 10 Hz to 300 Hz requirements are met at distances of no less than 1 meter away from the most powerful sources of disturbance, which include, in particular, compressors (for example, in air-conditioning systems), electric pumps in the heating and cooling loops, toilet, control moment gyros.

Requirements may be updated for specific equipment locations.



6.2.3.2 Requirements for the equipment to maintain microgravity conditions

In order to comply with microgravity requirements for ISS RS and for ISS as a whole during microgravity modes of the ISS flight (180 days per year in periods stretching for 30 days each) every piece of equipment shall meet the following requirements:

– the equipment shall not produce quasi-stationary forces of more than 4 grams acting for long periods of time (exceeding 30 seconds);
– operation of the equipment shall not cause in the ISS RS modules any accelerations with frequencies of up to 10 Hz that are in excess of 10% of the levels shown in Fig. 6.2.3.1.1;

- operation of the equipment shall not cause accelerations with frequencies in the range of 10 Hz to 300 Hz that are in excess of 10% of the levels shown in Fig. 6.2.3.1.1 at the equipment attachment point;
- the operation of the equipment shall not cause non-stationary accelerations with amplitudes exceeding 1000 micro-g at the equipment attachment point.

6.2.3.3 Noise level limit requirements for the equipment

During its operation no piece of equipment shall generate noise in excess of 53 dBA at the distance of 1 m from the source.

6.2.4 Electrical requirements

6.2.4.1 Basic requirements

6.2.4.1.1 On-board power supply

Equipment is powered from a DC source of the Power Supply System (PSS) via the Onboard Equipment Control System of the module.

Steady-state supply voltage at the hardware input lies within the 23-29 V range.

The hardware shall operate normally when exposed to sudden changes in supply voltage by +/-4.5V with a frequency no higher than 1 Hz and duration of no less than 0.1 ms.

The on-board automatic equipment of the module provides bipolar switching of the primary power supplied to the hardware, as well as protection of power lines against possible overcurrent loads and short-circuits in the cabling and hardware.

To assure an optimal selection of elements for power switching, overload protection, and of power cabling parameters, the following inputs from the users are needed:

the number of power feeders and their purpose;

timelines for applying and removing power in each feeder under nominal and off-nominal situations;

characteristics of each power feeder, including:

the nature of the load (resistive, inductive, capacitive);

power consumption (watt, ampere) timelines for the equipment under all operational modes, taking into account possible input voltage variations within specified limits;

parameters of possible inrush currents in transient modes, including inrush current amplitudes and their durations.

Acceptable values for inrush currents and their durations are additionally specified in each individual case and are agreed during development of electrical schematics for the equipment interfaces with the module control system.

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In general, inrush currents must not exceed the maximum steady-state operating current multiplied by a factor of five. In that case the duration of the current pulses must not exceed 20 ms when input power voltage varies within 23-29V.

Primary power circuits of the equipment shall have conductive coupling with neither the case of the device, nor with the telemetry circuits.

The equipment must remain operational in case a primary power bus inadvertently comes into contact with the device case.

Loads (devices) having individual protected power feeders must not have any conductive coupling between themselves via the primary power plus buses (“+”).

As a rule, each device must be powered via a separate connector. Its type and pin assignment are additionally defined during development of electrical schematic for interfaces between the device and the onboard automatic equipment.

6.2.4.1.2 Electrical insulation resistance.

Resistance of electrical insulation between primary power supply circuits (both positive and negative) and equipment case shall be:

no less than 20 MOhm at relative humidity of (45…80) percent and ambient temperature of (+15…+35) deg.C.

no less than 1 MOhm at relative humidity of 95+/-3 percent and ambient temperature of 20+/-5 deg.C.

Insulation resistance measurements are taken at 30V DC.

6.2.4.1.3. Electric strength of the insulation.

Resistance of insulation between primary power circuits (both positive and negative) and the case of the equipment, as well as between any electrically isolated circuits, shall comply with requirements for electrical insulation resistance after application to these circuits of a 200V test voltage (effective or constant value).

The test voltage shall not exceed allowable test voltages for components used in the equipment.

6.2.4.1.4 Requirements for data interfaces with the ISS RS systems

The equipment, which has data interfaces with the ISS RS systems, shall be safe for the Russian hardware and control systems that are sharing the interfaces.

The equipment to be used onboard RS, shall be classified by the presence of the following interfaces:

- electrophysical interfaces, which determine parameters of interfacing with electrical circuits for data transmissions. Such an interface must be subjected to the following operations:

device connectors shall be mated to the actual on-board cabling to check their wiring;

electrical circuit parameters shall be measured in the actual onboard cabling and evaluated to make sure they lie within tolerances for data transmission lines (MIL STD1553B, ETHERNET, etc.)

performance tests shall be run via connected interfaces per user's manual for the device.

- information and logic interfaces determining protocols for data transmissions in the network to which the new user is connected, and clearly defining its functions.

To be checked are:

logic functions of the device as a user of a data network (controller or slave device);

the impossibility for the user to corrupt formats and data content in an interface unrelated to the user;

correctness of the user response to the set of commands contained in the interface.

- software interfaces between newly-added equipment and the user providing protection of RS systems against off-nominal situation.

To be checked in such an interface (belonging, for example, to a laptop computer) are hardware protection against false and invalid commands and operator's instructions.

The equipment shall be checked in real onboard environment in order to obtain actual measurement results from the flight model of the onboard cabling against the background of active operation mode of the onboard systems over applicable interfaces.

In verifying compliance with data security requirements, a special emphasis should be placed on standard interchangeable components and storage medium containing installation or autorun software (cartridges, hard drives, floppy disks, etc.)

The use of such elements onboard shall be tightly controlled and measures shall be in place to guard against their unauthorized use in the RS equipment.

To be checked is whether the protection is in place against:

unauthorized launch of software and its installation in RS computers;

corruption of basic software of the RS equipment supporting control system operation.

Protective/warning labeling must be made and applied to interchangeable components to limit the list of devices where these could be installed.

6.2.4.2. Electromagnetic compatibility

6.2.4.2.1 Electromagnetic interference generated by scientific equipment

6.2.4.2.1.1 Low-frequency noise

Peak voltage values for low-frequency noise (U_{peak}), generated by equipment in the ±28V power supply circuits of the ISS RS modules shall not exceed the values given in Fig. 6.2.4.2-1.

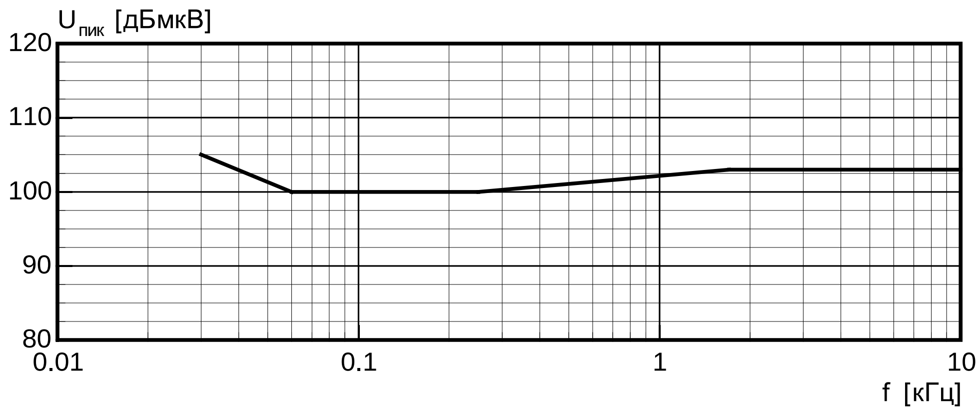


Fig. 6.2.4.2-1 – Low-frequency noise

Where: f is the frequency (kHz)

The width of the measurement band shall be at least:

10 Hz in the range of 30 Hz to 1 kHz;

100 Hz in the range of 1 to 10 kHz.

6.2.4.2.1.2 RF noise

Peak voltage values for RF noise shall not exceed values given in Fig.6.2.4.2-2.

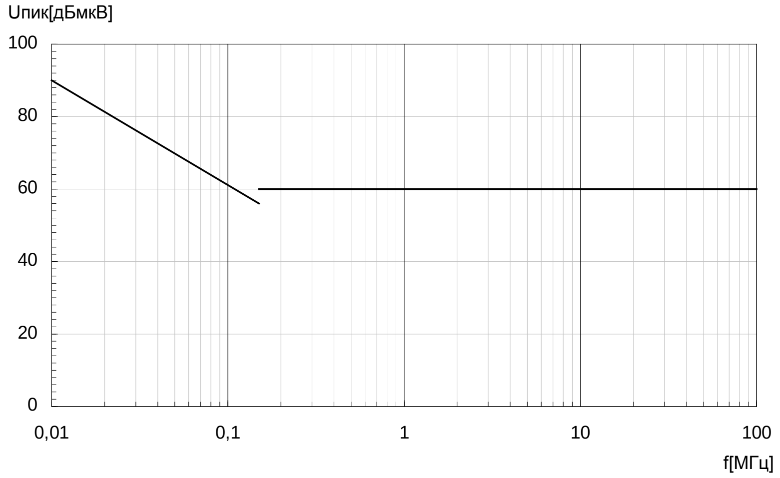


Fig. 6.2.4.2-2 – RF noise

The width of the measurement band shall be at least:

1 kHz in the range of 0.01 to 0.15 MHz;

10 kHz in the range of 0.15 to 30.0 MHz;

100 kHz in the range of 30 to 100 MHz.

6.2.4.2.1.3 Electric field strength of radiated RF noise.

Equipment installed onboard ISS RS shall not generate noise exceeding the limits specified in Fig. 6.2.4.2-3. Above 30 MHz, compliance with the limits shall be assured for both horizontally and vertically polarized waves.

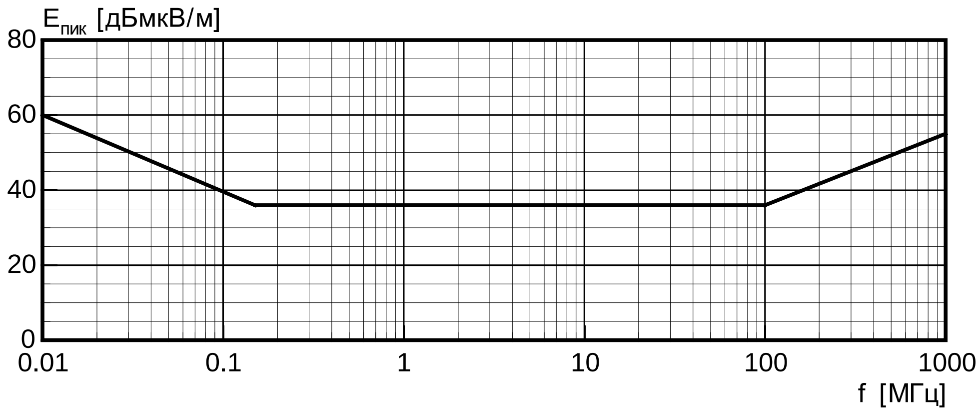


Fig. 6.2.4.2-3 – Electric field strength

The width of the measurement band shall be at least:

1 kHz in the range of 0.01 to 0.15 MHz;

10 kHz in the range of 0.15 to 30.0 MHz;

100 kHz in the range of 30 to 1000 MHz;

1 MHz above 1000 MHz.

These requirements do not apply to RF noise generated by emissions from radio transmitter outputs.

6.2.4.2.2. Immunity of equipment to electromagnetic noise

6.2.4.2.2.1 Low-frequency noise

Peak voltage values for low-frequency noise in the ±28V power supply circuits of the module are given in Fig. 6.2.4.2-4.

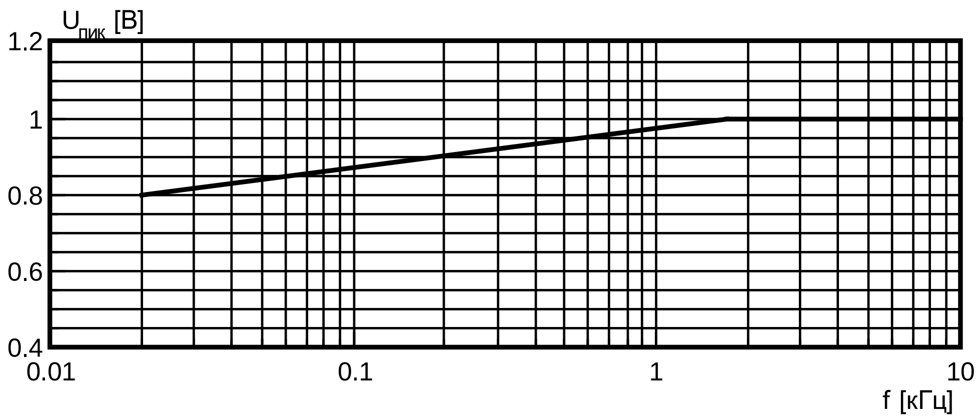


Fig. 6.2.4.2-4 – Low-frequency noise

6.2.4.2.2.2 Industrial RF noise

Peak voltage values for industrial RF noise in the ±28V power supply circuits of the ISS RS modules are given in Fig. 6.2.4.2-5.

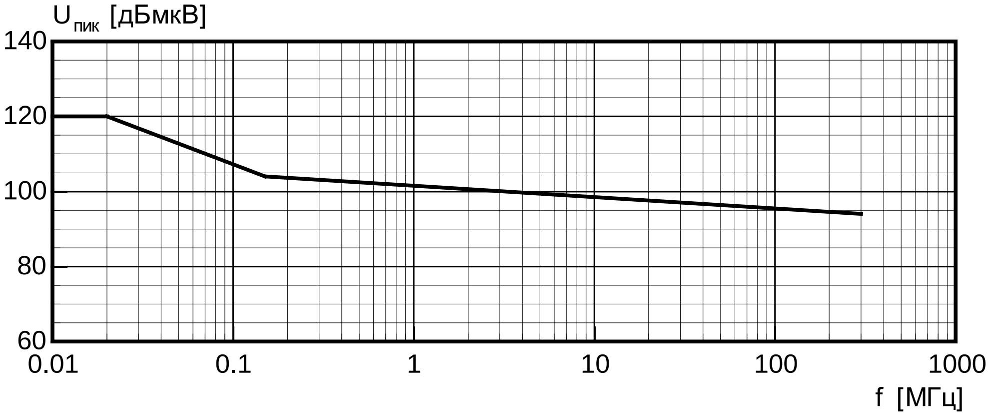


Fig. 6.2.4.2-5 – Industrial RF noise

6.2.4.2.2.3 Pulse noise

The effect of the pulse noise is characterized by the following parameters:

- amplitude and duration of a test pulse are given in Tables 6.2.4.2-1 and 6.2.4.2-2;
- pulse edge durations are no more than 5% of the pulse duration;
- pulse rate is 1 Hz for a period of 1 minute (or for a period of time needed to evaluate performance).

Table 6.2.4.2-1 Characteristics of pulse noise between power buses

Parameter	Value			
Pulse duration, microseconds	50	100	300	500
Pulse amplitude, V	+ 15 – 15	+ 15 – 15	+ 10 – 10	+ 10 – 10

Table 6.2.4.2-2 Characteristics of pulse noise between each of the power buses and the case

Parameter	Value			
Pulse duration, microseconds	50	100	200	300
Pulse amplitude, V	+ 35 – 35	+ 35 – 35	+ 10 – 10	+ 10 – 10

Peak values of electric field strength inside ISS RS modules are given in Fig. 6.2.4.2-6.

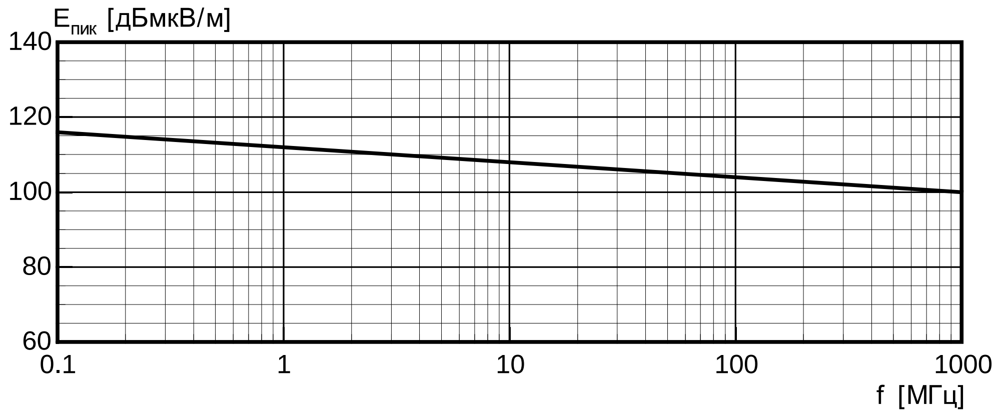


Fig. 6.2.4.2-6 – Electric field strength inside the module

6.2.4.2.2.4 Radiated RF noise outside ISS

Peak values of electric field strength outside ISS RS are given in Fig. 6.2.4.2-7.

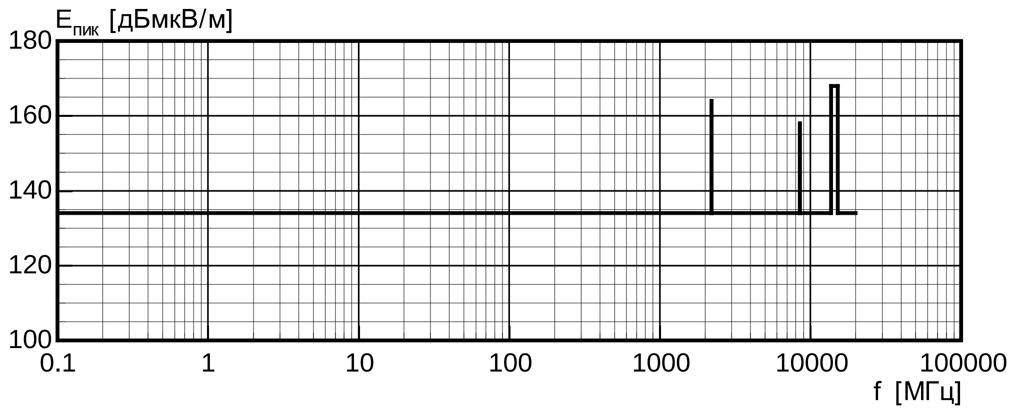


Fig. 6.2.4.2-7 – Electric field strength outside ISS RS

Field strength may vary from 134 dBmicroV/m to the specified value depending on the device location.

The radiated signal is modulated in amplitude with 1 kHz frequency and 50% depth of modulation.

6.2.4.2.3. Requirements for radio receivers, radio transmitters and AFD

Specifications of radio receivers, radio transmitters and antennas meet the requirements of Radio Regulations and recommendations of International Radio Consultative Committee (IRCC).

Specifications of radio receivers, radio transmitters and antennas are checked for compliance with the standards of Radio Regulations using procedures, which meet the requirements of IRCC Recommendations.

6.2.5. Labeling

6.2.5.1. Special labeling for ISS

In addition to the labeling usually used by the equipment developer or vendor, alphanumeric and barcode labels must be applied. Equipment delivered in a package shall have the proper labeling on the package.

6.2.5.2 Barcoding.

In order to set up inventory accounting of every piece of equipment and cargo, both delivered to ISS RS, and returned/disposed of from the space station, the ISS Cargo Traffic and Inventory is used. Each item included into block-by-block list and into cargo traffic shall have a description following a pre-defined data set, which is entered into and then stored in the information system ISS Cargo Traffic and Inventory. To automate the inventory keeping processes, barcoding is used; therefore, all the items intended for use onboard ISS shall have barcode labels of one of the sizes with different information content:

- barcode only, also duplicated in numerical format,
- name and barcode, duplicated in numerical format,
- system designation, name and barcode, duplicated in numerical format.

6.2.6. Requirements for materials

The below requirements apply to all materials listed in the full list of nonmetallic materials. The full list of nonmetallic materials, which are in contact with the pressurized cabin atmosphere, includes:

- structural materials used in fabrication of casings;
- fasteners, circuit boards, covers, sheathes, etc.;
- varnishes, paints, compounds, adhesives;
- insulating materials for wires, cables, harnesses.

The list has the official document status and must be signed by a responsible representative of the international partner.

6.2.6.1. Materials fire safety

Materials shall not be capable of spontaneous ignition.

Materials shall not be capable of maintaining combustion either on their own or when integrated into another product or system.

Fire-prevention measures

- all the circuit boards shall be covered on both sides with silicon or another approved material, if they are not completely enclosed in a metal container and if they are not otherwise accepted by the Russian side;
- all transformers or coils are fully enclosed in a metallic material or an approved potting compound. Exceptions from this rule must be specifically approved by the Russian side;
- all the wires are covered with Teflon, all wires and cables are protected or routed in such a way as to rule out any possibility of wire damage which may cause sparks or short-circuits;
- circuit protection shall be provided in order to avoid possible circuit overheating in off-nominal situations (for example, short circuit, as a result of an abrupt change or a delay);
- insulation of power cables shall be heat resistant; connectors that do not have such protection shall be shielded with housings made of nonflammable materials.

6.2.6.2. Materials toxicity

It is forbidden to use for the hardware structure any toxic or hazardous materials which may release gases detrimental to the crew in concentrations dangerous to the crew.

Materials of the equipment located on the outer surface of ISS shall meet the standards for outgassing in vacuum with respect to loss of mass (no more than 1%) and the amount of condensing substances (no more than 0.1%), determined per GOST P50109-92 or another standard similar to ASTME595.

6.2.6.3 Microbiological stability of the materials

Equipment destruction to a limit posing a threat to health and life is not allowed. Microbial resistance must be specified for each listed material.

Equipment and its container must be disinfected at the launch site, unless otherwise specified by the Russian side.

Usual methods of hardware disinfection include the use of liquid hydrogen peroxide and radiation. This usual processing applies to all external surfaces. This method can be revised if there is any danger of damaging the hardware. Disinfectant resistance shall be specified for each listed material.

6.2.6.4 Aging of materials

An estimate of the equipment susceptibility to ageing shall be made by means of non-metallic materials analysis. Assessed on a regular basis shall be devices intended for multiple use in flight, as well as items and materials, which are used as samples as defined by the Russian side. Periods of time during which the properties of the materials remain preserved shall be specified for each listed material.

6.2.7 Protection against static electricity

6.2.7.1 Protection of electronic equipment against static electricity during its installation and hookup to onboard cables shall be provided by taking the following measures:

- bonding the equipment, that is, providing a secure electrical connection between the cases of the devices and the body of the ISS RS modules;
- removing static electricity from the operator during electronic equipment installation using an antistatic wristband connected to grounding points available in the ISS RS modules.
- removing static electricity from onboard cables during their connection to electronic equipment by using a multipurpose device 17КС.300Ю9052-0.

6.2.7.2 Hardware bonding is provided by means of bonding straps, equipped with which must be casings of the devices to be installed inside pressurized compartments.

The bonding is established by connecting a bonding strap to the device casing and to the body of the pressurized compartment by means of a fastener (a screw), or by mating disconnectable bonding straps.

It is acceptable to bond devices via an electrical interface with the ISS RS onboard systems, where one of the electrical circuits which has galvanic coupling with the pressurized compartment body is assigned to serve as a bonding wire.

6.3 Safety requirements

6.3.1 General requirements

6.3.1.1 General requirements are applicable to SE design and development and are aimed at assuring the required level of SE safety both for the crew and for other hardware on the vehicle.

6.3.1.2 During its operation and storage the SE shall not crate dangerous situations or the risk of such situations occurring shall be minimized.

The dangerous situations, as applied to SE, are classified according to the hazard level as follows:

- Critical Hazard. The hazard which, if it occurs, may result in such damage to the vehicle equipment as does not preclude its further operation, or in a non-disabling injury to the crew, or in the need to use unplanned procedures, which affect the operation of onboard systems of the Russian spacecraft;
- Catastrophic Hazard. The hazard which, if it occurs, may result in the loss of the vehicle or in a disabling or fatal injury to the crew.

6.3.1.3 Development of SE and its utilization operations shall meet the following requirements in order to minimize the risk of occurrence of hazardous situations.

6.3.1.3.1 Tolerance to failures resulting in dangerous situations

SE shall be designed in such a way that:

- no combination of two failures or two operator errors, or one failure and one operator error can result in a catastrophic hazard;
- no single failure or single operator error can result in a critical hazard.

6.3.1.3.2 Design for Minimum Risk

This requirement consists in assuring/selecting the necessary safety factors, scope of developmental and verification tests to assure high strength properties, survivability, resistance to various kinds of loads. Safety factors and scopes of testing are determined by standards depending on the types of equipment and specifics of its use. Typical examples of the use of the design for minimum risk are selection of safety factors, of safety margins when analyzing the structural strength of the body of sealed pressurized vessels, of load-bearing structural elements.

6.3.1.3.3 Safety taking into account services provided by the vehicle/ISS

6.3.1.3.3 Safety without taking into account services provided by the vehicle/ISS
SE shall be capable of taking care of its safety by itself without any servicing on the part of the vehicle/ISS even in case of a contingency onboard the vehicle/ISS.

6.3.1.3.3.2 Safe With Vehicle Services
If requirements of safety without servicing (paragraphs 6.3.1.3.3.1 or 6.3.1.3.3.2) are difficult to implement for technical reasons, the requirement of safety with servicing on the part of the vehicle must be met.

In this case the overall safety of the SE together with the vehicle equipment that is being used shall meet the requirements of paragraph 6.3.1.3.1 or 6.3.1.3.2 of this document with respect to hazardous situations.

6.3.1.3.4 Hazardous functions control
6.3.1.3.4.1 A function, which, if inadvertently triggered, may result in a critical hazard, shall have two independent inhibits for the entire time while the likelihood of this hazard exists. In those cases where the loss of function may result in a critical hazard no single failure shall result in the loss of this function.

6.3.1.3.4.2 A function, which, if inadvertently triggered, may result in a catastrophic hazard, shall have at least three independent inhibits for the entire time while the likelihood of this hazard exists. There shall be a capability to monitor the status of at least two of the three required inhibits . In those cases where the loss of function may result in a catastrophic hazard no two failures shall result in the loss of this function.

6.3.1.3.5 Caution and warning devices

In those cases where the occurrence of a hazardous situation requires urgent action on the part of the crew (fire, depressurization, toxic release, etc.), devices shall be used for providing a timely warning to the crew about these hazardous situations and/or for switching off the SE (system hardware).

6.3.1.3.6 Special procedures

Procedures supporting the SE safety shall contain: Safety instructions for equipment handling, procedures to be followed in case of possible SE failures.

6.3.2 Design requirements

6.3.2.1 Materials

Materials used in SE structure, including packaging, shall meet the following safety requirements.

a) Toxicity

The materials in use that are in contact with the spacecraft environment shall not release into the environment any toxic and noxious chemical substances in concentrations constituting a threat to the life of the crew and spacecraft operation.

Care must be taken to avoid the use in the SE hardware of any chemical substances which do not come into direct contact with the environment, but may pose toxicity threat if they leak into the spacecraft atmosphere (for example, may cause crew skin or eye irritation or affect spacecraft equipment). If, nevertheless, they need to be used, requirements of paragraph 6.3.1.3 shall be met in accordance with the hazard level.

b) Fire safety

Materials used under normal operating conditions and in case of cabin depressurization:

shall not become a source of fire or explosion;

shall be heat-resistant and shall not sustain combustion neither by themselves, nor when used within hardware assemblies and systems;

shall not release flammable gases and form combustible or explosive mixtures.

c) Microbiological safety

The materials in use shall not be a source of microbiological contamination of the spacecraft atmosphere and structural elements, and shall not create a propitious environment for microorganism development, and shall be resistant to biodegradation.

d) Operation in vacuum

SE located outside the pressurized cabin of the spacecraft shall be resistant to exposure to heat and vacuum and shall not be a source of contamination of the space around and inside the module under normal environmental conditions.

Non-metallic materials, as well as coatings used for sealing and insulating electrical circuits shall be tested for mass loss and volatile matter content under exposure to heat and vacuum and have mass loss of no more than 1% and volatile matter content of no more than 0.1%.

Thermooptical properties of the surfaces of the SE located outside the pressurized cabin of the vehicle shall not affect the vehicle safety: exceed the allowable thermal conditions, as well as create glare or flood exposure of light-sensitive elements of the vehicle.

6.3.2.2 Structure

6.3.2.2.1 SE structure shall be designed taking into account actual loads and safety factors accepted for the vehicle.

6.3.2.2.2 Materials used for the SE structural elements, including fasteners, shall be reviewed for corrosion cracking under stress (fatigue strength). As far as possible, alloys with high resistance against stress corrosion cracking shall be used.

6.3.2.2.3 SE structure shall be designed for maximum differential pressure occurring during ascent, descent or activities involving emergency depressurization and subsequent re-pressurization of the vehicle/ISS. The vents in the vented compartments shall have such surface areas as to assure structural integrity while providing the maximum rate of change for the pressure.

6.3.2.2.4 Open surfaces on SE shall be smooth and have no burrs.

6.3.2.2.5 The structure of the SE and the packing used in flight shall have no breakable materials or shall preclude fragments of such materials spreading beyond casings or packing of the SE hardware in case of failures both under normal environmental conditions and in case of cabin depressurization.

6.3.2.3 Electrical safety

SE electrical circuits shall be protected against possible overloads and short-circuits (and potential ignition) by correct choice of wire gauge, wire insulation, circuit breakers, etc., etc.

There shall be no electrical contact between the vehicle body and electrical circuits of the SE.

SE hardware shall be designed in such a way as to protect the crew against an inadvertent contact with electrical circuits. In case the SE uses voltages above 30 V, measures shall be taken to protect the crew against electric shock per catastrophic hazard level.

Leak current during contact with the SE being serviced shall not exceed 0.07 mA DC for a normal contact with a human being.

No two electrically conductive surfaces within the reach of a member of the crew shall have a voltage difference exceeding 40 mV at frequencies of 1000 Hz or lower, measured across the resistance of 1000 Ohm.

6.3.2.4 Radiation safety

All the SE elements which produce ionizing radiation shall be identified and their use shall be the subject of a special discussion and agreement with RSC Energia.

6.3.2.5 Living space safety

6.3.2.5.1 SE shall not be the source of elements contaminating internal compartments of the vehicle. To assure the cleanliness of the living space inside the compartments, liquid, loose and paste-like substances shall be contained within a reliable sealed package.

6.3.2.5.2 The SE design shall guarantee that the amount of outgassing will not exceed maximum allowable concentrations, that is, the gas composition will not be disturbed. SE shall not be a source of strong smell.

6.3.2.5.3 SE shall not be the source of high-intensity acoustic noises and acoustic pulses.

For scientific equipment located in the habitable compartments of the RS modules and operating for a total of no more four hours a day, the average level of its acoustic emissions determined per standard GOST R ISO 3746-2013 on a hemispherical measuring surface with a radius r =1 m, shall not exceed 53 dBA (the upper limit).

Requirements for the levels of acoustic emissions from specific scientific equipment may be adjusted to raise the upper limit depending on the equipment location within the pressurized section of the RS module, on the equipment operational timeline and the duration of time the crew is supposed to work in the man-tended RS module. In particular, for the equipment which is not operated on a continuous basis, as well as for the equipment located in the RS man-tended modules, the upper limit for acoustic levels may be raised per Table 6.3.1.

Table 6.3.1

The maximum total time of operation per day, hours.	Increase in the upper limit for the level of acoustic emissions from the scientific equipment, dB
no more than 4.0	3
no more than 2.0	6
no more than 1.0	9
no more than 0.5	12

The peak level of acoustic pulses from operating scientific equipment shall not exceed 125 dBA*I*.

6.3.2.6 Non-ionizing radiation

The use of SE containing sources of laser radiation, as well as containing permanent magnets, shall be agreed with RSC Energia.

6.3.2.7 In-flight handling safety

6.3.2.7.1 SE shall have interlocks to prevent inadvertent operation or a change in configuration caused by crew actions during handling. For example, locking of switches can be achieved by means of protective covers.

If need be, onboard documentation (instructions) for the crew shall be prepared.

6.3.2.7.2 SE external structure and packaging shall have no sharp or protruding elements.

6.3.2.7.3 Touch temperature

Surfaces having temperature of 40 to 45°C, with which the crew may come into an inadvertent contact, shall have appropriate caution plates.

Surfaces with temperatures above 45°C shall have protective devices or insulation to prevent crew contact.

Surfaces with temperatures below 5°C, with which the crew may come into contact shall have protective devices or insulation to prevent such contact, as well as caution plates.

6.3.2.7.4 Spherical radii of outer corners and edges

The SE hardware shall have rounded corners and edges, or means of protecting the corners in accordance with Table 6.3.2.7.4

Table 6.3.2.7.4 Spherical radii of outer corners, planes and edges

Structural elements/fragments	Radius, mm		Note
	Outer	Inner	
Holes, panels, covers (corner radii in the panel plane)	6.4 3.0	3.0 1.5	Preferable Minimal
Open corners	13.0		Minimal
Open edges: (1) thickness of 2.0 mm and more (2) thickness of 0.5 to 2.0 mm (3) thickness of less than 0.5 mm	≥1.0 full radius; Smoothed out or rounded off		Minimal
Small pieces of hardware manipulated by hand wearing a spacesuit glove	1.0		Minimal

Note: Instead of a spherical radius, a chamfer 45^0 by 1.5 mm (minimum) with smoothly beveled edges is acceptable. The chamfer width shall be selected in accordance with approximate values for spherical radii described above.

6.3.2.7.5 Screws and bolts

Bolts and screws with threaded parts may protrude by 2-3 mm but by no more than 1 turn of the thread, and have means of protection, which do not interfere with installation or removal of the bolt or the screw. Fasteners shall be captive.

6.3.2.7.6 Moving parts

Moving parts (fans, belt-drives, turbine wheels, etc.), which may cause crew injury or damage to SE through inadvertent contact or capture, shall have guard rails or other protective devices.

6.3.2.7.7 Pitch or capture points

Controls, locks and other similar devices shall be designed and positioned in such a manner as to prevent them from pinching parts of the crew spacesuit. If need be, protective covers or enclosures shall be used.

SE hardware located outside habitable compartments, which during its operation may produce a gap of less than 3.5 mm between the hardware and adjacent structures shall be designed in such a manner as to prevent pinching or capture of parts of spacesuit of a crew member performing an EVA.

6.3.2.7.8 SE installation

Internal and external SE located along the crew translation paths and installed in the working areas shall be able to withstand loads caused by crew activities, including EVA.

6.3.2.8 Chemical power sources (batteries and storage batteries, electrochemical cells)

The structure, materials and electrolytes used in the chemical power sources shall meet requirements of paragraphs 6.3.1 and 6.3.2.1 of these requirements.

Chemical power sources and/or devices, which use them, shall have protection against charging/discharging overcurrents, excessive temperature and devices preventing release of electrolyte into the atmosphere of the vehicle.

The use of chemical power sources with more than 120 watt-hour capacity or having especially toxic electrolytes (such as theonylchloride lithium) is only allowed upon agreement with RSC Energia

6.4 A typical crew day plan during implementation of the standard mode

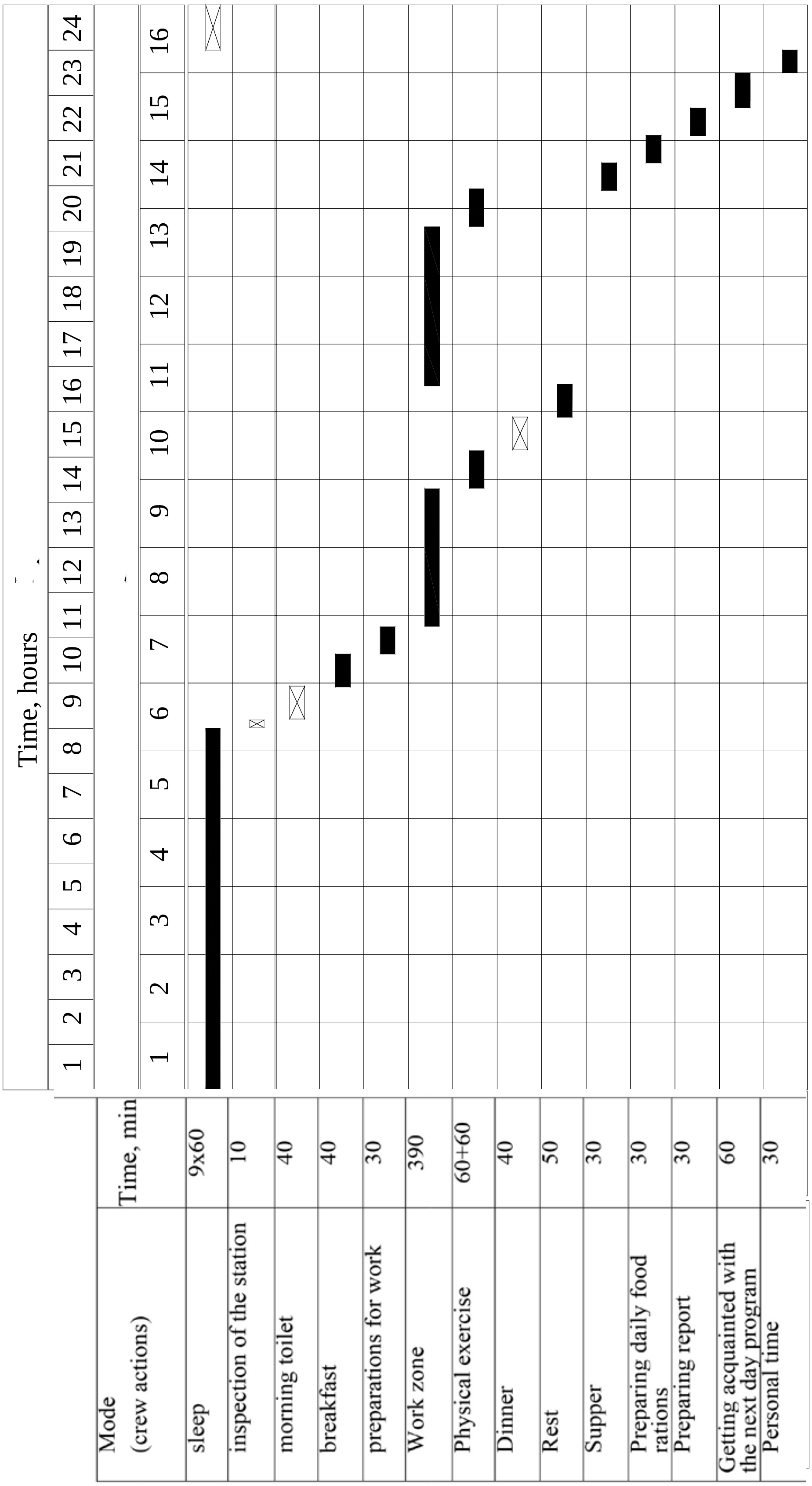


Fig. 6.4 – A typical ISS RS crew day plan

6.5 Cargo integration

6.5.1 General

Progress and *Soyuz* spacecraft deliver to the space station “dry” cargoes in pressurized compartments. In addition to this, *Progress* can deliver to the station liquids and gases. If need be, cargoes can be placed outside the pressurized compartment.

Cargoes transported by the vehicles shall meet requirements set fourth in this document.

Documentation shall be drawn up for all the cargoes (including the packing used in flight) to state that the cargoes are allowed to be stored and operated onboard the International Space Station and transported onboard the spacecraft, as well as to certify the flight safety of the cargo. The cargo accompanying documentation and technical manuals must be approved by RSC Energia.

In order for RSC Energia to perform work on integration of the cargo and to study the feasibility of its accommodation onboard the spacecraft, a documentation package is to be submitted, which contains:

6.5.1.1 For all cargoes:

- envelope and installation drawing;
- transportation safety data package;
- accompanying documentation.

6.5.1.2 For active cargoes, additional documentation is provided in accordance with agreements between RSC Energia and the cargo owner on its integration and delivery, including:

- electrical interface, including electrical consumption;
- heat release
- cargo operations timeline;
- special requirements (activation, telemetry, etc.)

Requirements for envelope and installation drawing are given in paragraph 6.7.1.

Requirements for transportation safety data package are given in paragraph 6.6.2.

Requirements for accompanying documentation are given in paragraph 6.6.3.

The cargo owner is responsible for validity of provided data and for cargo compliance with the specified requirements.

Cargo delivery, removal and return are only performed in case of positive results of RSC Energia's studies of cargo compliance with the requirements and feasibility of their accommodation and fastening. The studies are conducted on the basis of the documentation provided by the cargo owner/curator.

6.5.2 Project Management

Cargo integration project management consists of the following steps:

1) reviewing and approving the documentation package on the cargoes manifested for delivery on a specific spacecraft;

active cargoes require matching the interfaces;

2) engineering analysis – development of the configuration for cargo accommodation in the compartment meeting the requirements for mass, centering and inertial properties of the spacecraft and conditions for cargo delivery (fastening, in-flight attitude, etc.), and the conditions stipulating that the equipment in the compartments shall not interfere with the crew operating controls and using life support equipment;

3) physical integration – building up kits, accommodating and securing cargoes in the spacecraft compartment.

4)

6.5.3 Cargo accommodation

6.5.3.1 General

The cargos are arranged within the compartments in such a way as to meet the requirements and constraints of the vehicle and of the cargoes themselves, and this arrangement is covered in the vehicle design documentation.

Cargoes are installed onboard the spacecraft using RSC Energia drawings and design and operational documentation contingent upon availability of certificates for transportation and operation, and the installation is covered in the onboard documentation for the vehicle.

All the operations to service and process the deliverable cargoes at the processing facility are only conducted subject to availability of proper instructions agreed with RSC Energia and under the supervision of its responsible representatives.

6.5.3.2 Conditions for placing cargoes onboard Progress spacecraft

The owner/curator of the cargo shall keep in mind that after the cargo is stowed in the vehicle and until it is unstowed onboard the station, there will be no access to it. The duration of the above period depends on the conditions for stowing and installing cargoes onboard the vehicle.

Deliverable cargoes are stowed in containers designed for them and in free areas within the cargo compartment.

As a rule, cargoes with a mass of 8÷10 kg are stowed in the spacecraft containers (if there are no special transportation requirements), and cargoes with a higher mass are installed in special transportation racks, for which purpose the deliverable unit shall have mounting fixtures.

The need to develop special mounting fixtures and packaging (adapter racks, shock absorbers, thermal insulation, moisture-proofing, etc.) is stipulated when the contract is concluded.

6.5.3.3 Cargo accommodation onboard Soyuz spacecraft

Deliverable cargoes are stowed in the areas within the cargo compartment that are set aside for them.

As a rule, cargoes with a mass of up to 5 kg are stowed in the spacecraft containers (if there are no special transportation requirements), and cargoes with a higher mass are installed in special transportation racks, for which purpose the deliverable unit shall have mounting fixtures.

The need to develop special mounting fixtures and packaging (adapter racks, shock absorbers, thermal insulation, moisture-proofing, etc.) is stipulated when the contract is concluded.

The main place for accommodating payloads returning to Earth is the container under the middle seat. In the two-seater version of the spacecraft, returning payloads are also stowed in a special container installed into the right-hand seat.

Returning payloads shall be capable of being loaded through the payload container cover (dimensions 170x470 mm). The decision on the feasibility of returning a cargo to Earth is made based on the results of RSC Energia study.

6.5.4 Deliverable cargo integration timeline

6.5.4.1 Deliverable cargo integration into Progress spacecraft

The work to integrate cargoes into *Progress* spacecraft starts 6 months before the scheduled launch of the spacecraft and is based on the cargo delivery Manifest.

6 to 4 months before the spacecraft is launched, cargo outline and installation drawings are submitted to RSC Energia for approval.

Based on the results of the approval process for the cargo outline drawings, the feasibility of delivering cargo onboard the spacecraft is determined, and cargo delivery Manifest is updated (if necessary).

4 month before the spacecraft is launched, final outline and installation drawings of the deliverable cargos are to be submitted to the RSC Energia specialists on the spacecraft.

3 months before the launch, the specialists on the vehicle publish layout drawings for cargo accommodation inside the cargo compartment of the spacecraft, and perform a preliminary engineering analysis of mass, center of gravity, and inertial characteristics of the spacecraft.

Published 1.5 months before the launch of the spacecraft are engineering drawings and documentation on cargo installation, and the results of the analysis of cargo mass, inertial, and center of gravity properties of the spacecraft.

No later than 1 month before the launch, the cargo is to be delivered to the processing facility, where it will then be physically integrated into the vehicle.

Fig. 6.5.1 shows the process of deliverable cargo integration into *Progress* spacecraft.

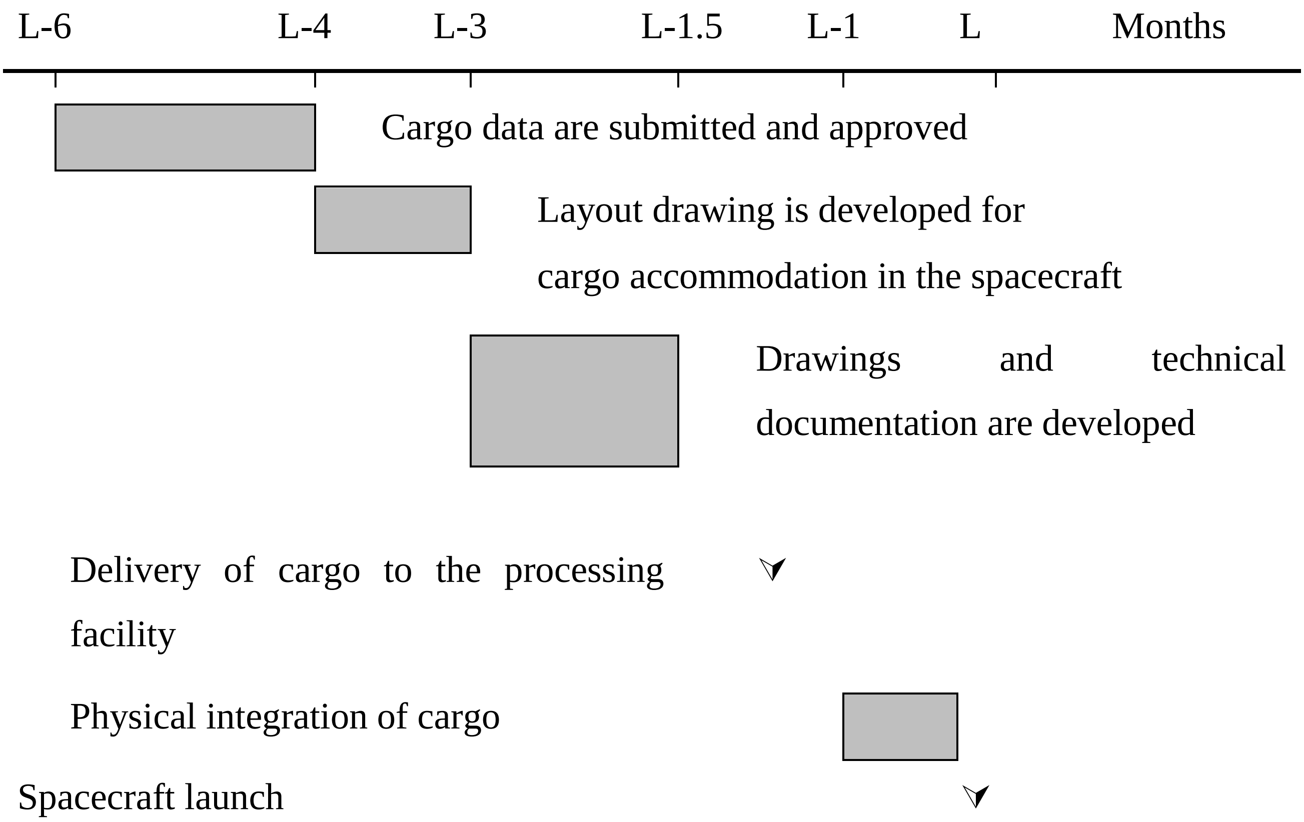


Fig. 6.5.1 The process of deliverable cargo integration into *Progress* spacecraft.

<u>Physical integration of deliverable cargos.</u>

The process of physical integration of cargoes is determined by the technical plan of spacecraft processing at the processing facility and the launch pad. Fig. 6.5.2 shows the process of physical integration of cargos into *Progress* spacecraft.

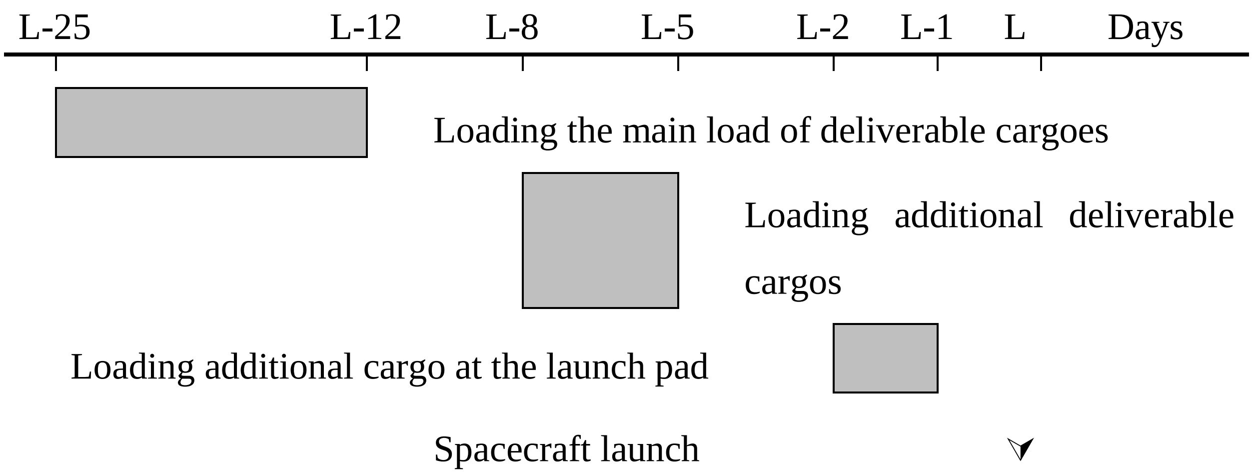


Fig. 6.5.2 The process of physical integration of cargo into *Progress* spacecraft.

The major portion of physical integration of deliverable cargo into the cargo compartment of the spacecraft is performed 25÷12 days before the launch of the spacecraft. Specific schedules for loading cargo within the specified interval of time and the number of days allocated for physical integration is determined by the technical plan for specific spacecraft processing.

Within the time period of 8÷5 days before the launch of the spacecraft, during final operations after the spacecraft has gone through the filling station and payload unit assembly, it is possible, by the decision of the technical management, to perform additional physical integration (additional loading) of deliverable cargoes of a limited mass and volume.

2÷1 days before the spacecraft launch, it is possible, by the decision of the RSC Energia General Designer, to load additional kits of a limited size through the side loading hatch on the spacecraft. The need to integrate cargo during that time period shall be stated when the cargo delivery request is submitted for inclusion in the Manifest.

6.5.4.2 Deliverable cargo integration into Soyuz spacecraft

The work to integrate cargoes into *Soyuz* spacecraft starts 4 months before the scheduled launch of the spacecraft and is based on the cargo delivery Manifest.

4 to 3.5 months before the spacecraft is launched, cargo outline and installation drawings are submitted to RSC Energia for approval.

Based on the results of the approval process for the cargo outline drawings, the feasibility of delivering cargo onboard the spacecraft is determined, and cargo delivery Manifest is updated (if necessary).

3 month before the spacecraft is launched, final outline and installation drawings of the deliverable cargos are to be submitted to the RSC Energia specialists on the spacecraft.

2.5 to 2 months before the launch, the specialists on the spacecraft publish layout drawings for cargo accommodation inside the cargo compartment of the spacecraft, and perform a preliminary engineering analysis of mass, center of gravity, and inertial characteristics of the spacecraft.

Published 1.5 months before the launch of the spacecraft by specialists on the spacecraft are engineering drawings and documentation on cargo installation, and the results of the analysis of cargo mass, inertial, and center of gravity properties of the spacecraft.

No later than 1 month before the launch, the cargo is to be delivered to the processing facility, where it will then be physically integrated into the vehicle.

Fig. 6.5.3 shows the process of deliverable cargo integration into *Soyuz* spacecraft.

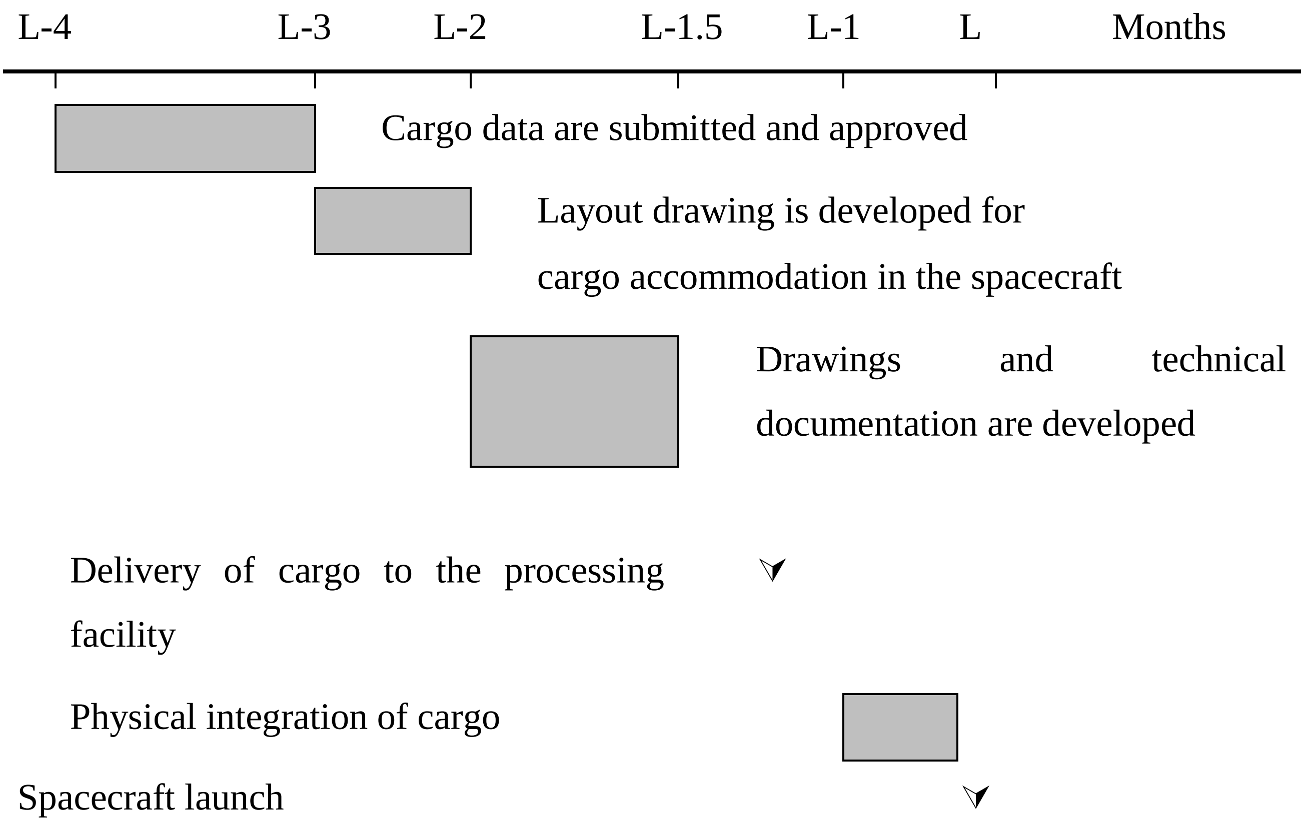


Fig. 6.5.3 The process of deliverable cargo integration into *Soyuz* spacecraft.

<u>Physical integration of cargoes into *Soyuz* spacecraft</u>

Fig. 6.5.4 shows the process of physical cargo integration into *Soyuz* spacecraft.

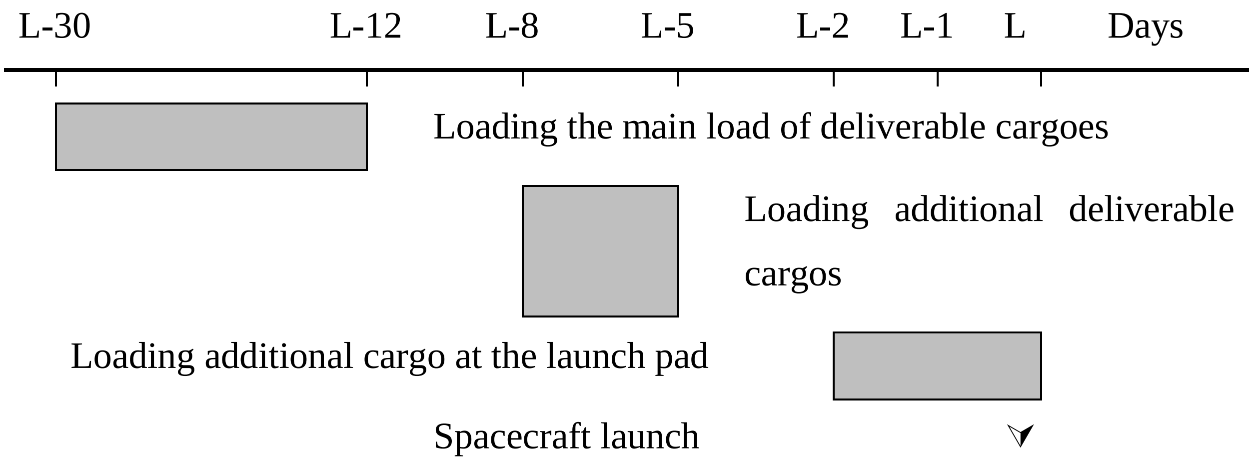


Fig. 6.5.4 The process of cargo integration into *Soyuz* spacecraft

The major portion of physical integration of deliverable cargo into the orbital module and the descent vehicle of the spacecraft is performed 30÷12 days before the launch of the spacecraft. Specific schedules for loading cargo within the specified interval of time and the number of days allocated for physical integration is determined by the technical plan for specific spacecraft processing.

Within the time period of 8÷5 days before the launch of the spacecraft, during final operations after the spacecraft has gone through the filling station and payload unit assembly, it is possible, by the decision of the technical management, to perform additional physical integration (additional loading) of deliverable cargoes of a limited mass and volume.

2÷1 days before the spacecraft launch, it is possible, by the decision of the RSC Energia General Designer, to load additional kits of a limited size through the side loading hatch on the spacecraft. The need to integrate cargo during that time period shall be stated when the cargo delivery request is submitted for inclusion in the Manifest.

6.5.4.3 Safety documentation submittal deadlines

Deadlines for submitting transportation safety data packages for review are:

–3 months before launch – for the first category cargoes (non-hazardous cargoes) and second category cargoes (the cargoes that are hazardous, but prevention measures are obvious);

–4 months before the launch – for the first and second category cargoes, which require developing special fixtures for securing them onboard the spacecraft.

- 6 months before the launch – for the cargoes of the third category (highly technical cargoes posing a great hazard during delivery, installation and operation), a transportation safety data package containing all the currently available information on potential hazards of the cargo must be submitted. The final complete transportation safety data package shall be submitted within the timeframe established for the first and second category cargoes.

Note: Deadlines for submitting transportation safety data package for review are different from deadlines for submitting inputs for assessments and analyses.

6.5.5 Integration timeline for cargoes that are to be disposed of

Considering the need to analyze and approve documentation packages for cargoes delivered to ISS onboard the transportation vehicles of the Partners, cargo documentation packages shall be submitted to RSC Energia from the cargo owners (curators):

– for approval – 1 month before spacecraft undocking from the space station;

– approved – 15 days before the undocking.

No documentation packages need to be submitted for the cargoes that were delivered to ISS onboard Russian vehicles.

6.5.6 Integration timeline for cargoes to be returned to Earth

Defined at 3 months before spacecraft undocks from the space station is: which cargoes to be returned to Earth are to be integrated into the descent vehicle of the spacecraft in orbit.

Defined at 2.5 to 2 months before spacecraft undocks from the space station is the configuration of the hardware to be returned in the order of priority. Submitted to RSC Energia shall be final documentation packages only for those cargoes, which were delivered to ISS onboard the transportation vehicles of the Partners.

1.5 to 1 month before the spacecraft undocking, RSC Energia specialists on the vehicle define the layout for cargoes to be returned to Earth. These materials are the basis for updating onboard documentation. The configuration and accommodation of the equipment to be returned can be updated using a radiogram from MCC after the *Soyuz* spacecraft has docked with the space station, but no later than 5 days before the scheduled landing of the descent vehicle (provided the cargo safety package is available) in consultation with RSC Energia.

Fig. 6.5.5 shows the process of integrating cargoes to be returned to Earth into *Soyuz* spacecraft.

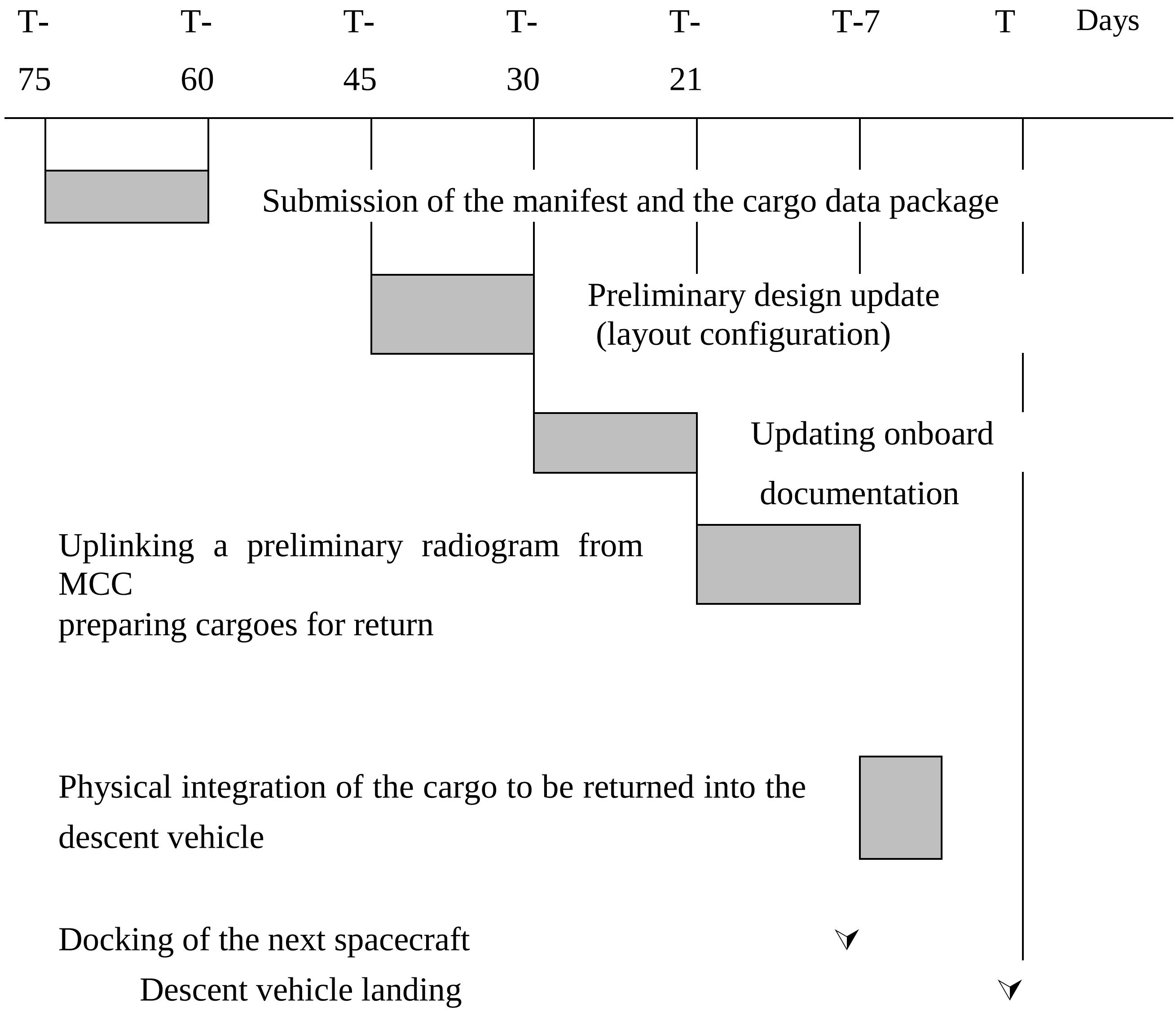


Fig. 6.5.5 The process of integration of cargo to be returned to Earth into *Soyuz* spacecraft

6.5.7 Documentation requirements

6.5.7.1 Requirements for the outline and installation drawing

The outline and installation drawing is a drawing of a cargo (a kit, a cable) in transportation position.

The outline and installation drawing shall cover the following data:

1) name;

2) drawing number;

3) mass;

4) coordinates of the center of mass (with tolerances);

5) moments of inertia (with tolerances);

6) unit drawing/configuration;

7) outline dimensions of the cargo, specifying dimensions of all protruding elements;

8) locations of connectors, monitoring or control panels, toggle switches;

9) coordinates of the unit attachment points and dimensions of fastener holes (for cargoes with a mass of more than 8÷10 kg.);

10) instructions for the unit orientation during transportation onboard spacecraft with respect to the flight/g-load direction, if there is such a constraint (subsection 0);

11) instructions concerning the feasibility of the unit delivery inside a spacecraft container or on-the-spot accommodation;

12) special requirements for transportation conditions onboard the spacecraft (if need be);

13) lifting points (for cargoes with a mass above 20 kg).

14) bar-code location

If, during transportation onboard the spacecraft, the cargo is staying inside its packaging or it has temporary protective elements (covers), the outline and installation drawing shall reflect the cargo in packaging and with its protective covers.

Outline and installation drawings of the cargoes shall be approved by specialists on the spacecraft (RSC Energia).

In case of repeated/multiple deliveries of a cargo that has already been delivered on the same type of spacecraft in the past, no additional approval of the outline and installation drawing is required.

6.5.7.2 Requirements for finite-element model

In order to simulate mechanical processes, Finite Element Models (FEM) shall be provided to RSC Energia for each unit of scientific equipment. FEM shall be provided in ANSYS or NASTRAN systems. FEM shall adequately represent dynamic properties (including damping parameters) of the equipment with standard fixtures for attachment to a rigid base. The integral mass and inertia properties of a FEM for a device (a unit) shall not diverge from its prototype by more than ±2% for mass, and ±10% for moments of inertia. Moreover, the modulus of the resultant position of the center of mass of the model from its actual position shall not exceed 10 mm. And the modulus of the resultant position of the center of mass of the model from its actual position shall not exceed 10 mm.

For equipment which changes its configuration (such as deployable antennas) models must be provided for each of its positions.

6.6.7.3 Requirements for the safety data package

In accordance with the documents agreed with the US side, cargo safety information shall be presented in the form of a safety data package.

In order to certify cargoes for compliance with the transportation environments and transportation safety requirements, the owners of these cargoes need to prepare a transportation safety data package to reflect compliance with requirements of Section 2.5.

Information about cargo hazards is considered complete, if each hazard in the transportation safety data package has:

- hazard description;
- measures to prevent the hazard;
- methods of safety verification and documentation with verification results.

Cargo ground processing safety is reviewed separately from transportation safety, therefore it shall not be covered in the transportation safety data package.

6.6.7.3 Requirements for accompanying documentation

Accompanying documentation is submitted to RSC Energia in Russian and in English.

Accompanying documentation contains:

- technical data sheet;
- cargo processing instructions (if need be);
- instructions for the crew (if need be).

The list of accompanying documentation for an active cargo is TBD (in consultation between RSC Energia and the country supplying the cargo).

The technical data sheet contains the name, the drawing number, the serial number, the useful life, as well as confirms that cargo has been fully processed and is operational (verification report), complies with specifications and is ready for flight operation within the ISS. The technical data sheet is published for each item on the deliverable cargo list, if several identical cargoes are delivered, one technical data sheet specifying their quantity is published.

Fig. 6.6.6 shows the reference coordinate system of the spacecraft.

Fig. 6.6.7 shows the cargo compartment of the *Progress* spacecraft.

Fig. 6.6.8 shows the arrangement of containers in the cargo compartment of the *Progress* spacecraft.

Fig. 6.6.9 shows dimensions of cargo containers on the *Progress* spacecraft.

Fig. 6.6.10 shows the container and locations for accommodating additional cargo inside the orbital module of *Soyuz-TMA* spacecraft.

Fig. 6.6.11 shows cargo container in the descent vehicle of the *Soyuz-TMA* spacecraft.

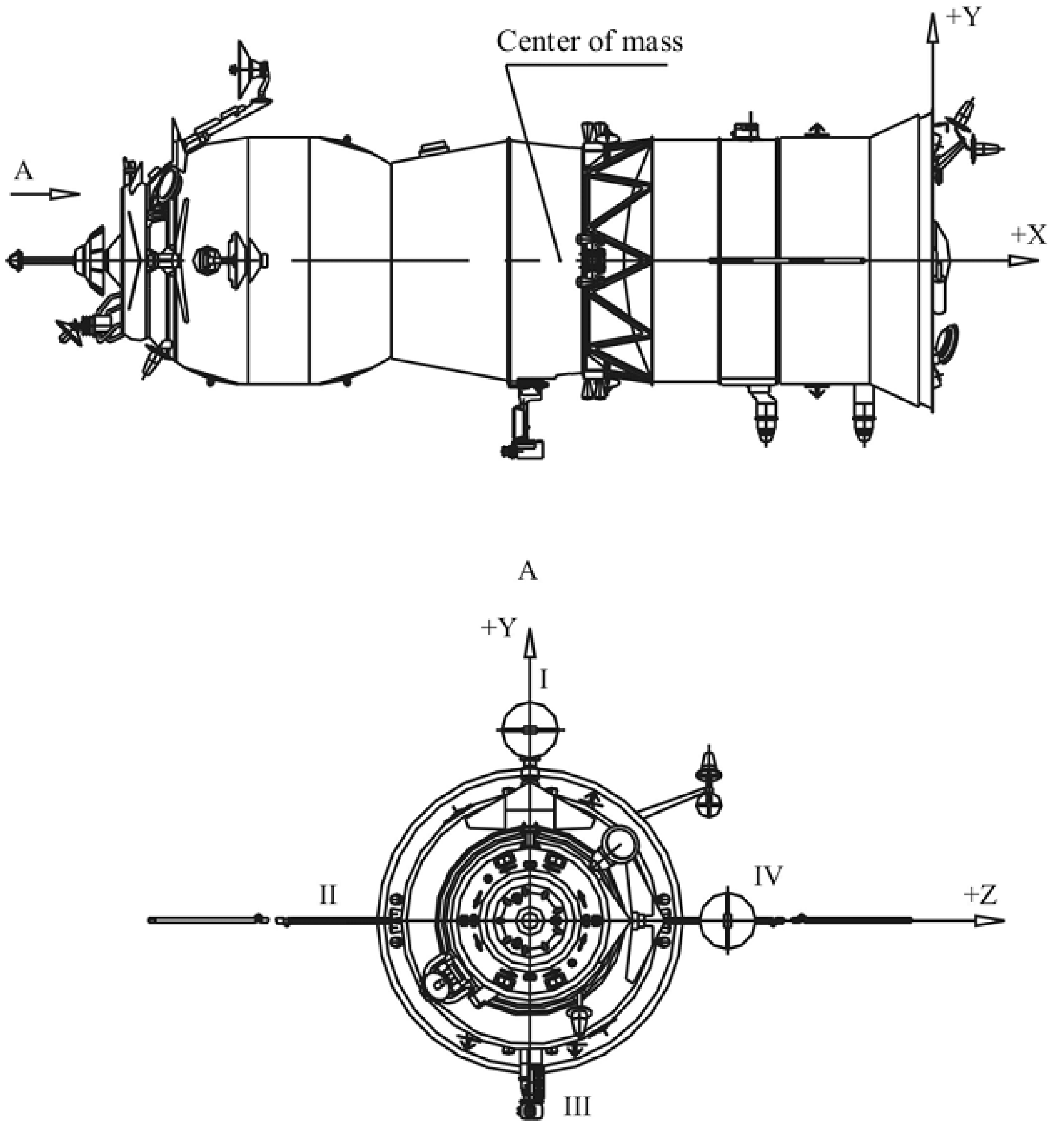


Fig. 6.6.6 Reference coordinate system of the spacecraft

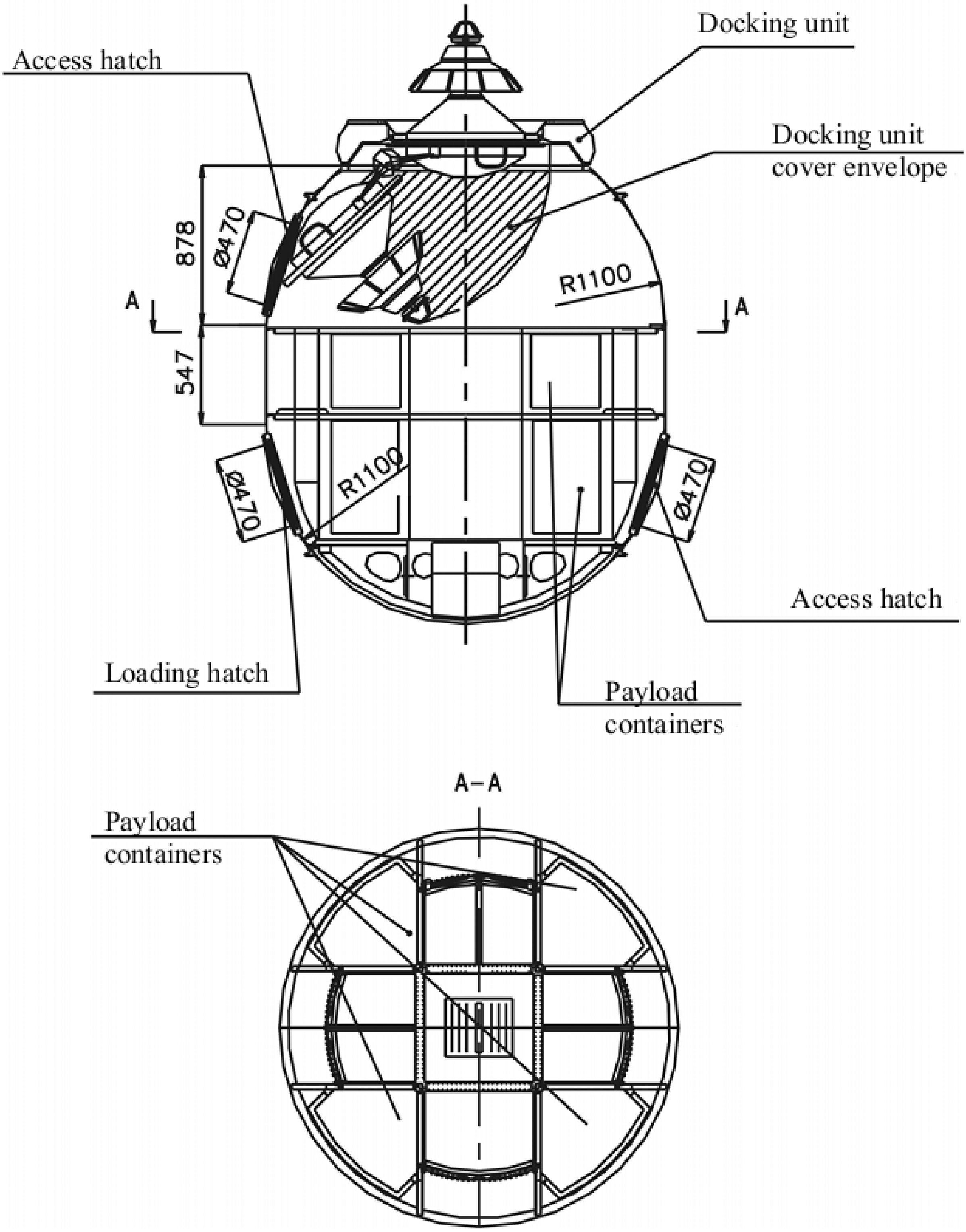


Fig. 6.6.7 Cargo compartment of the *Progress* spacecraft.

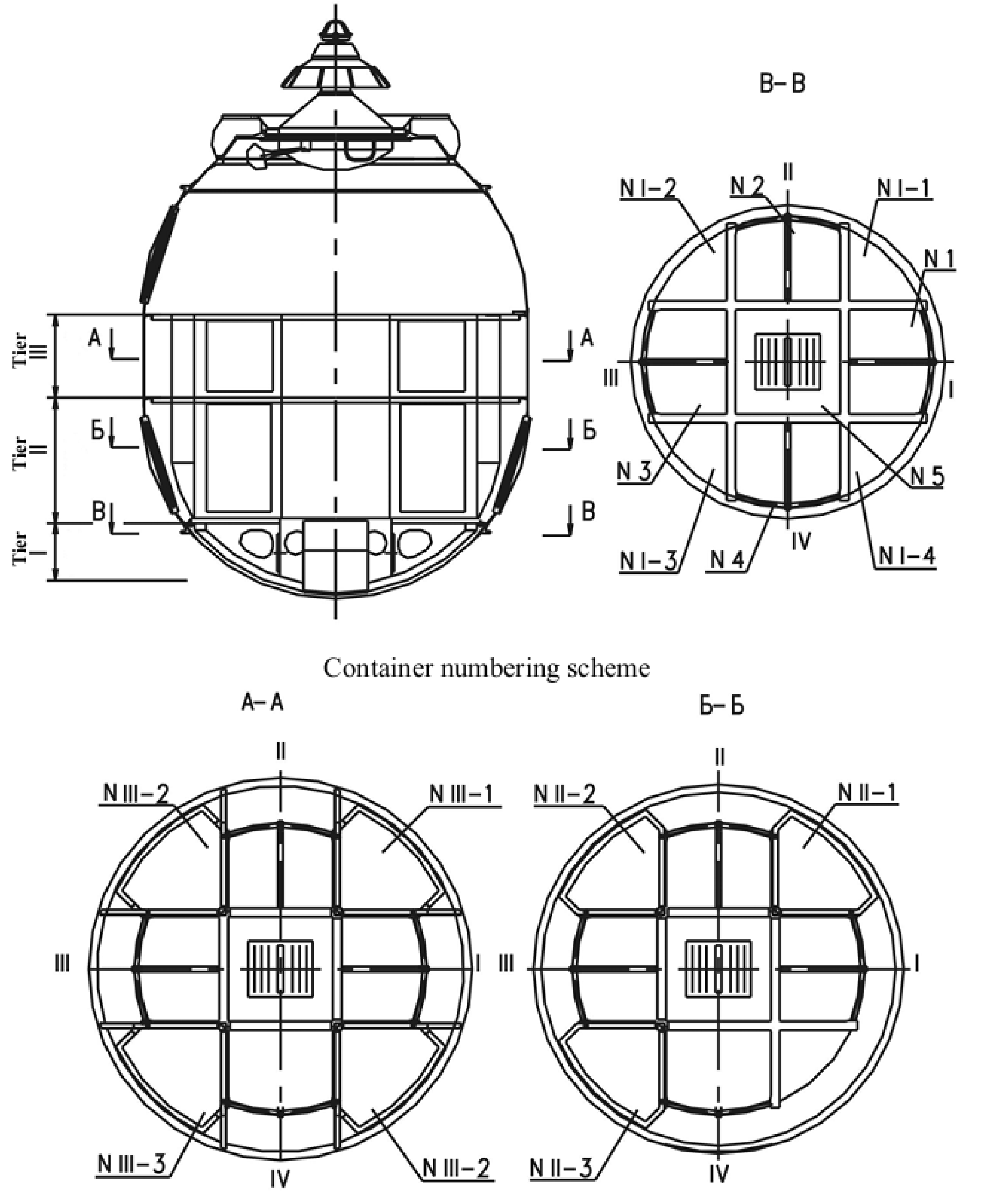


Fig. 6.6.8 The arrangement of containers in the cargo compartment of the *Progress* spacecraft.

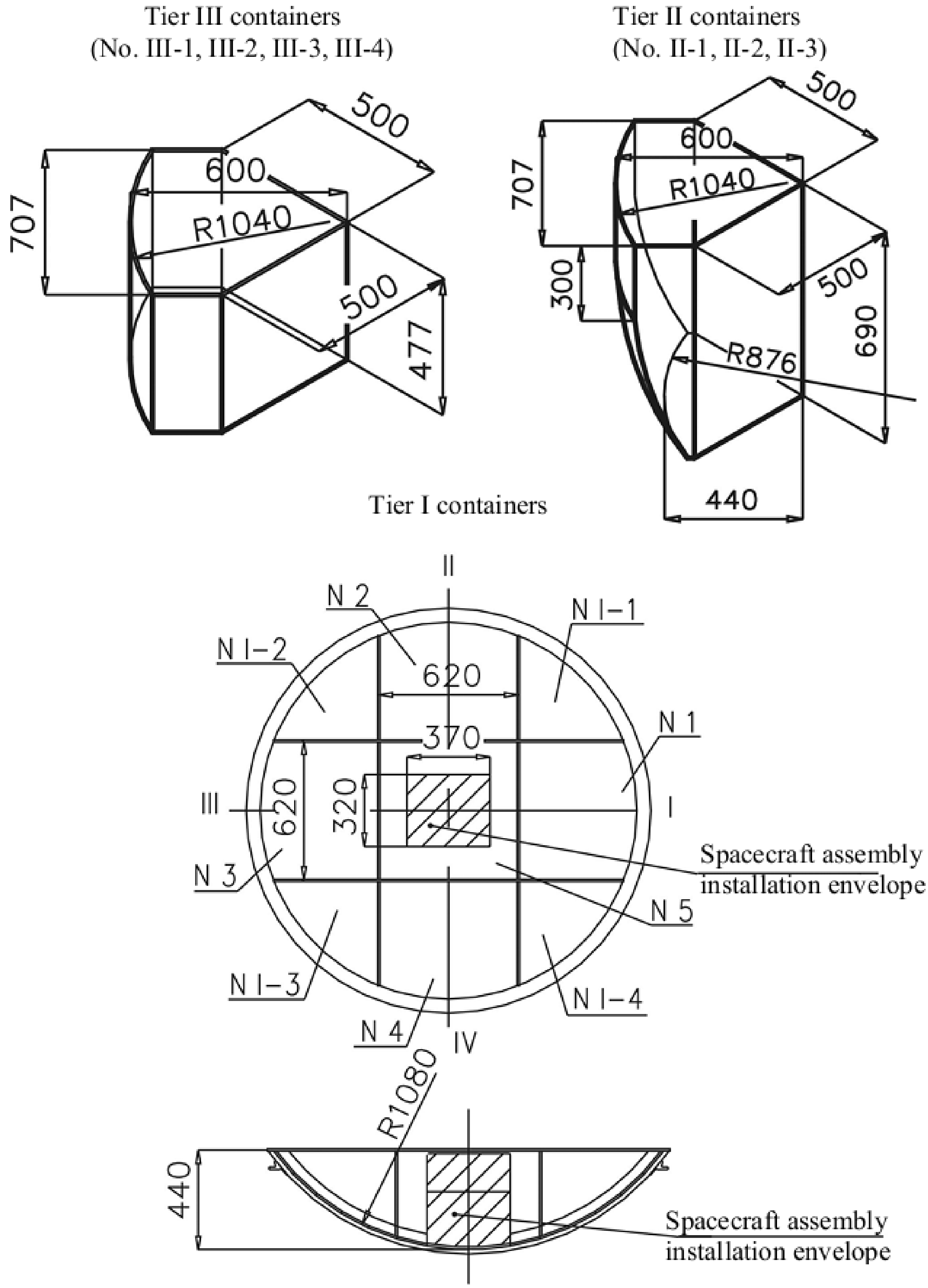
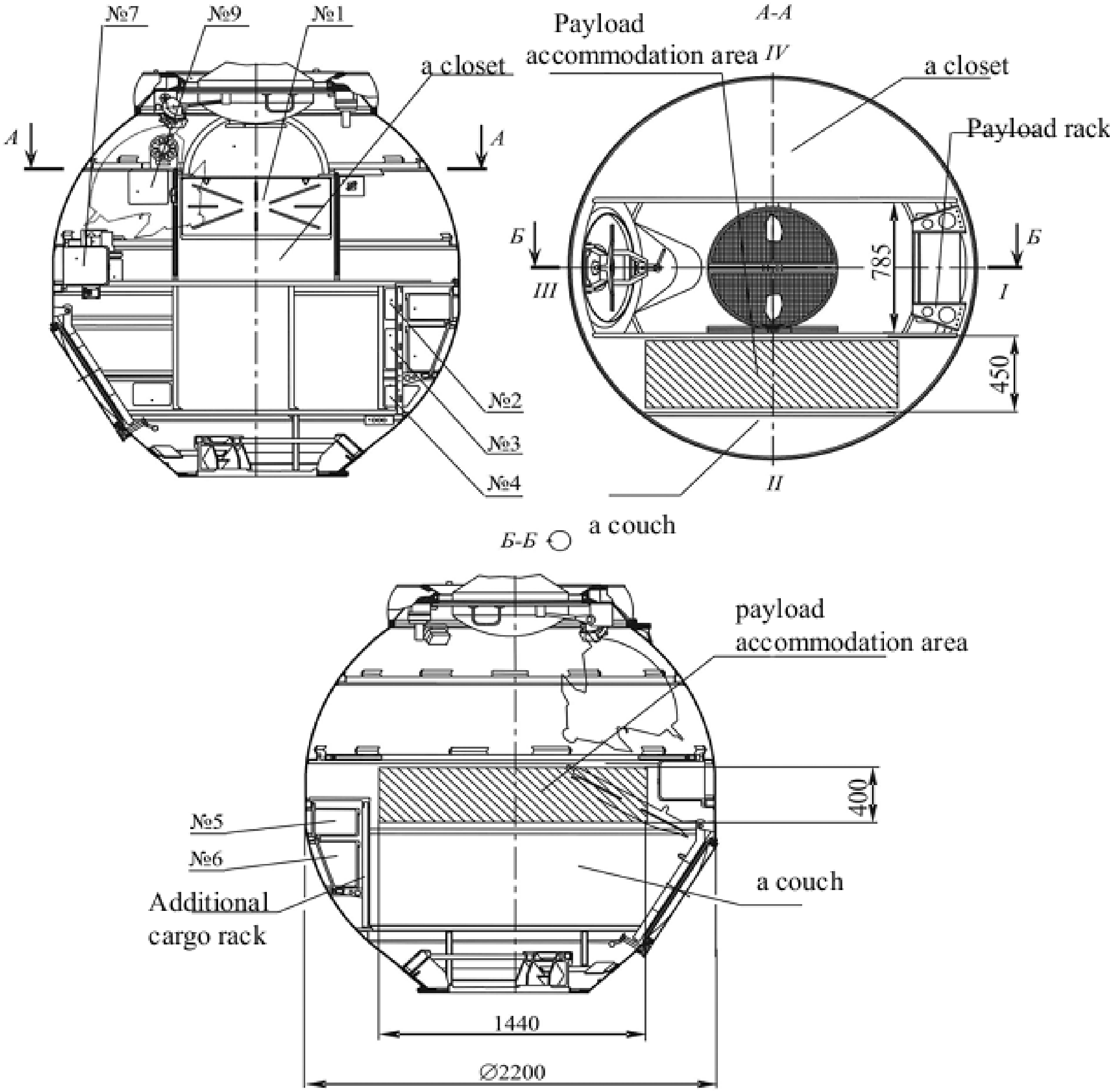


Fig. 6.6.9 Dimensions of cargo containers of the *Progress* spacecraft



Note:
1. In containers No. 1,5,7,9 the cargo to be delivered is placed in addition to the standard equipment.
2. The payload is only placed in container No.6, when a two-seater version of the of the spacecraft is used.

Fig. 6.6.10 The container and locations for accommodating additional cargo inside the orbital module of the *Soyuz-TMA* spacecraft

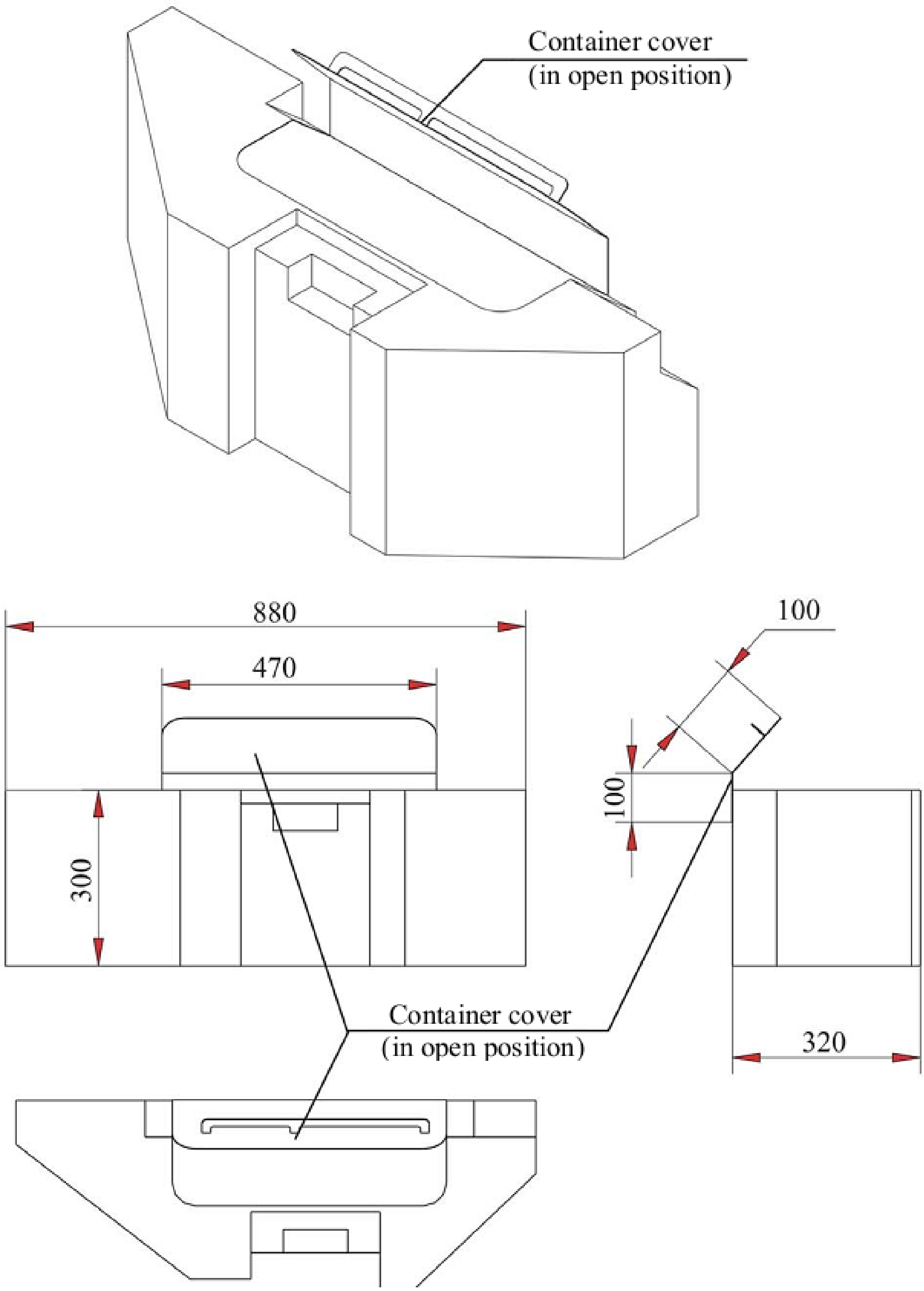


Fig. 6.6.11 Cargo container in the descent vehicle of the *Soyuz-TMA* spacecraft.

Attachment A
(obligatory)

List of Acronyms

АППГ	Агрегат перемещения полезного груза		Payload handling device
АФУ	Антенно-фидерное устройство	AFD	Antenna and Feeder Device
БИЛ	Бортовые информационные листки		Onboard information sheets
БИТС	Бортовая информационно-телеметрическая система	OI&TS	Onboard information and telemetry system
БКС	Бортовая кабельная сеть		Onboard cabling system
БНО	Баллистико-навигационное обеспечение		Trajectory and navigation support
БСР-ТМ	Блок сопряжения телеметрических массивов	TM IU	Telemetry array interface unit
БТА	Базовая точка активная		Active Basepoint
БТЛ	Базовая точка лабораторная		Lab basepoint
БТП	Базовая точка пассивная		Passive Basepoint
ВЗП-У	Платформа виброзащитная универсальная		Multipurpose vibration isolation platform
ВнеКД	Внекорабельная деятельность	EVA	Extravehiclular Activity
ВЧ	Высокая частота		High frequency
ГА	Гермоадаптер		Pressurized adapter
ГКЛ	Галактические космические лучи	GCR	Galactic cosmic rays
ГО	Головной обтекатель	PLF	Payload fairing
ГрО	Грузовой отсек		Cargo compartment

ДПП	Двухосная поворотная платформа		two-axial rotating platform
ИС	Информационная система		Information system
КП	Контакт подъема		Lift-off
КЭ	Космические эксперименты	SE	Space experiments
КЦН	Комплекс целевых нагрузок	MPF	Mission Payload Facility
ЛИ	Летные испытания		Flight tests
ЛПЭ	Линейная передача энергии	LET	Linear energy transfer
МБИТС	Малогабаритная бортовая информационно-телеметрическая система	SOI&TS	Small onboard information and telemetry system
МИМ2	Малый исследовательский модуль 2	MRM2	Mini Research Module 2
МИМ1	Малый исследовательский модуль 1	MRM1	Mini Research Module 1
МЛМ	Многофункциональный лабораторный модуль		Multi-purpose Laboratory Module
МЛМ-У	Многофункциональный лабораторный модуль с улучшенными эксплуатационными характеристиками	MLM-U	Multipurpose laboratory module with upgraded performance
МСС	Модуль сбора сообщений		Message collecting module
НА	Научная аппаратура	SE	Scientific Equipment
НИП	Наземный измерительный пункт		Ground tracking station
НШС	Нештатная ситуация	ONS	Off-nominal situation
ОСК	Орбитальная система координат	OCS	Orbital Coordinate System
ПДБ	Пакет данных по безопасности		Safety data packag
ПМО	Программно-математическое	SW	Software

	обеспечение		
ПН	Полезная нагрузка	PL	Payload
ПО	Программное обеспечение	SW	Software
ПЭИ	Программа экспериментальных испытаний		Test program
РО1	Рабочий отсек		Working compartment
РПЗ	Протоны радиационных поясов Земли		Earth radiation belt protons
РС МКС	Российской сегмент международной космической станции		International Space Station Russian Segment
РСУС	Радиотехническая система управления и связи		RF command and communications system
РЭА	Радиоэлектронная аппаратура		RF equipment
СА	Спускаемый аппарат		Descent vehicle
СБИ	Система бортовых измерений		Onboard measurement system
СККО	Средства крепления крупногабаритных объектов	LOAD	Large Objects Attachment Device
СМ	Служебный модуль	SM	Service Module
СО1	Стыковочный отсек	DC1	Docking Compartment
СОТР	Система обеспечения теплового режима	TCS	Thermal control system
СТТС	Система телефонно-телеграфной связи		Telephone and telegraph communications system
СЭП	Система энергопитания	PSS	Power supply system
ТБУ-В	Термостат биотехнологический универсальный высокотемпературный	MBHTT	Multipurpose Biotechnological High-Temperature Thermostat
ТБУ-Н	Термостат биотехнологический универсальный низкотемпературный	MBLTT	Multipurpose Biotechnological Low-Temperature Thermostat

ТВС	Телевизионная система		TV-system
ТЗЧ	Тяжелые заряженные частицы		Heavy charged particles
ТГК	Транспортный грузовой корабль		Re-supply spacecraft
УКВ	Ультракороткие волны	VHF	Very High Frequency
УМ	Узловой модуль	NM	Node Module
УРМ	Универсальное рабочее место	MPWS	Multi-Purpose Workstation
УСТТС	Устройство сопряжения с системой		System interface device
УФП	Устройство фиксации пассивное		Passive restraint
ФГБ	Функциональный грузовой блок	FGB	Functional Cargo Block
ЦА	Целевая аппаратура		Mission payload
ЦУП-М	Центр управления полетами Москвы	MCC-M	Mission Control Center – Moscow
ШК	Шлюзовая камера		Airlock
ERA	Европейский манипулятор	ERA	European robotic arm

REVISION LOG