

Multi-user Facilities and Support Equipment

Fig. 18. The Columbus Laboratory will provide a range of multi-user facilities.

This chapter describes ESA's significant contributions of multi-user facilities, Payload Support Equipment (PSE), Laboratory Support Equipment (LSE) and Standard Payload Outfitting Equipment (SPOE) to support the European Space Station users community. The known research facilities provided by the Partners are also summarised.

Table 11 provides an overview of those contributions and includes the currently planned Station laboratory location assignment for the pressurised payloads. The attachment site locations for the external payloads are under review. The contributions are then elaborated upon, with their utilisation characteristics.

The European pressurised multi-user facilities will allow laboratory multiple users or multiple experiments to employ specific capabilities in sequenced or simultaneous operations or in accessing the experiment/observation data transmitted to ground.

PSE and LSE for pressurised and external payloads comprises permanently on-orbit hardware that can be shared by payloads in support of their flight accommodation and operations.

SPOE for pressurised and external payloads covers qualified hardware items that may be payload-embedded to provide general operations and/or interface functions, and that pre-empt the need for users to undertake their own development.





Table 11. Range of European Facilities and Support Equipment Available to Users

	Facility	PSE/LSE	SPOE	
Pressurised Payloads Accommodated In	Columbus Laboratory	Biolab ¹	ESA-developed: European Stowage Rack (ESR)	ESA-developed: Avionics Air Assembly (AAA)
		European Drawer Rack (EDR) ¹		Remote Power Distribution Assembly (RPDA)
		European Physiology Modules (EPM) ¹		Standard Payload Computer (SPLC)
		Fluid Science Laboratory (FSL) ¹		Turbo Molecular Pump (TMP)
		Material Science Laboratory (MSL) ¹		
	US Laboratory	Protein Crystal Diagnostics Facility (PCDF, located in EDR)	US-developed: Mid-Deck Lockers (MDLs)	US-developed: Area Smoke Detector Assembly (ASDA)
			International Standard Payload Rack (ISPR)	Rack Main Switch Assembly (RMSA)
				Interface Connectors
			Japanese-developed: International Standard Payload Rack (ISPR)	
US Laboratory	Advanced Protein Crystallisation Facility (APCF) ²	ESA-developed: Cryosystem ²		
	Handgrip Dynamometer ²	Microgravity Science Glovebox (MSG) ²		
	Material Science Laboratory (MSL) ^{1,2}	Minus Eighty degree Lab Freezer for ISS (MELFI) ²		
	Modular Cultivation System (MCS) ²	US-developed: Express Racks (ERs)		
	Muscle Atrophy Research & Exercise System (MARES) ²	Active Rack Isolation System (ARIS)		
	Percutaneous Electrical Muscle Stimulator (PEMS) ²	Mid-Deck Lockers (MDLs)		
External Payloads	Atomic Clock Ensemble in Space (ACES) ⁴	ESA-developed: Coarse Pointing Device (CPD)	ESA-developed: External Payload Computer (XPLC)	
	Expose ⁴	Hexapod Pointing System ³	Power Distribution Unit (PDU)	
	Fire Detection Infrared Sensor System (FOCUS) ⁴	US-developed: Environmental Monitoring Package (EMP)	US-developed: Express Pallet Adapters (ExPAs)	
	Global Transmission System (GTS) ⁵			
	Matroshka ⁵			
	Solar Monitoring Observatory (SMD) ⁴			
	Sky Polarisation Observatory (Spot) ⁴			
	Technology Exposure Facility (TEF) ⁴			

Notes: 1 The facilities FSL, Biolab, MSL and EEM are also collectively known as the Microgravity Facilities for Columbus (MFC). 2 Europe supplies this equipment to NASA under a barter agreement. The US Lab responsibility rests with NASA and ESA has utilisation rights. Further introductory details may be obtained from the appropriate document. 3 Hexapod is being developed by ESA in support of the Stratospheric Aerosol and Gas Experiment (SAGE III) instrument from NASA/Langley Research Center. 4 These European facilities are externally mounted on Express Pallet Adapters as part of the US Express Pallet under NASA cooperative agreements. 5 Matroshka is located on a Russian element.

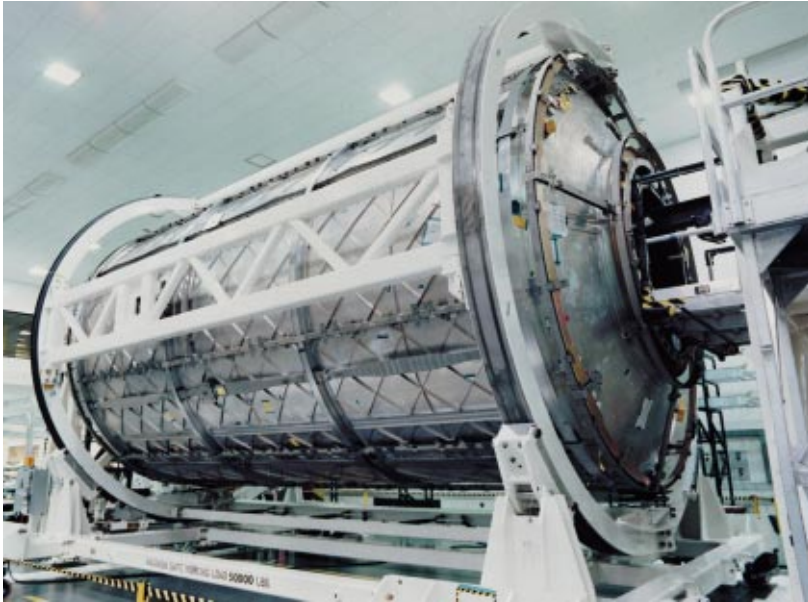


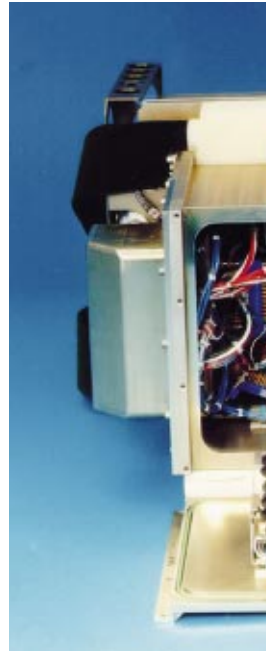
Fig. 19. The US Laboratory will provide a range of multi-user facilities. (NASA).

European Pressurised Multi-User Facilities in the US Laboratory

Advanced Protein Crystallisation Facility

The *Advanced Protein Crystallisation Facility* (APCF; Table 12; Fig. 20) offers a Mid-Deck Locker-size multi-experiment capability to perform protein screening experiments under reduced gravity and temperature-controlled conditions.

Fig. 20a. The Advanced Protein Crystallisation Facility will support protein screening experiments.



The APCF comprises a processing chamber and support systems. The processing chamber supports experiments contained in dedicated reactors that are activated and de-activated by software-driven electric motors. Multiple volume reactor sizes are available for users. The APCF support systems provide the interfaces with the MDL, as well as offering diagnostic capabilities.

Table 12. Advanced Protein Crystallisation Facility (APCF) Characteristics

Processing chamber	
Number of reactors	48
Reactor activation/deactivation	Selectable by groups of 12 reactors
Temperature	Selectable between 8°C and 30°C
Accuracy of temperature control	0.1°C
Temperature ramping	Selectable through software
Reactor types	
Free Interface Diffusion	20–470 L Extended Length Protein Chamber up to 1.3 mL
Dialysis	15–188 L
Vapour Diffusion	Drop volume 4–8 L or 35–80 L
Observation possibilities	
Direct observation	LED illumination through drive-mounted optical system
Wide Field of View (WFOV)	5 reactors on one side
Narrow Field of View (NFOV)	5 reactors on opposite side
Interferometry	Mach Zehnder capability
Field of View	8.5x6.3 mm; 5.0x3.7 mm
Camera (resolution)	B & W CCD (582 lines @ 500 pixels/line)
Grey levels	256
Storage capability	Up to 15 000 images, plus housekeeping

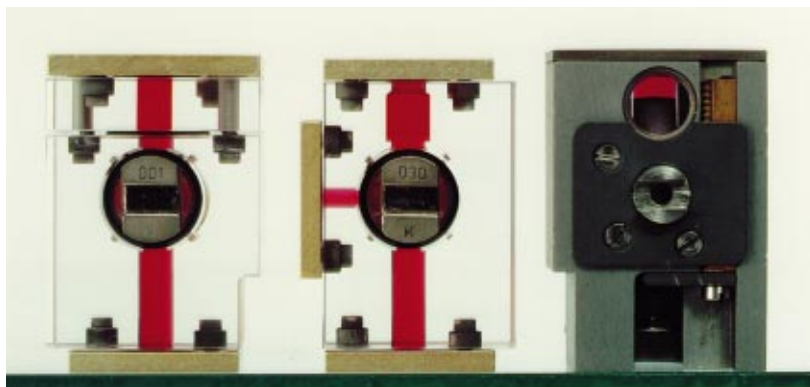
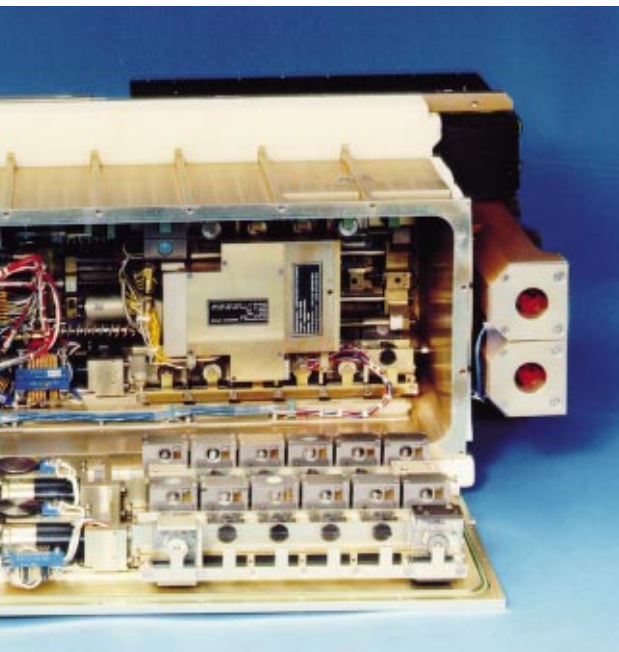


Fig. 20b. The three types of APCF reactors (from left): Dialysis; Free Interface Diffusion; Vapour Diffusion (Hanging drop).

Handgrip Dynamometer

The *Handgrip Dynamometer and Pitch Force Dynamometer* (Table 13; Fig. 21) is a hand-held capability used as a: measurement device for test-subject strength in connection with muscle-wasting under weightlessness; stressing device, particularly for stressing the autonomic nervous system; isometric exercise device for stressing the cardiovascular system.

The Handgrip Dynamometer is provided as part of the NASA Human Research Facility (HRF).



Fig. 21. The Handgrip Dynamometer and Pitch Force Dynamometer.

Table 13. Hand-Grip Dynamometer and Pitch Force Dynamometer Characteristics	
Hand-Grip Dynamometer	
Determines force applied by whole hand	
Force range	Up to 1000 N
Measurement accuracy	-7.5 N
Pitch Force Dynamometer	
Determines force applied between thumb and opposing fingers	
Force range	Up to 270 N
Measurement accuracy	-2 N

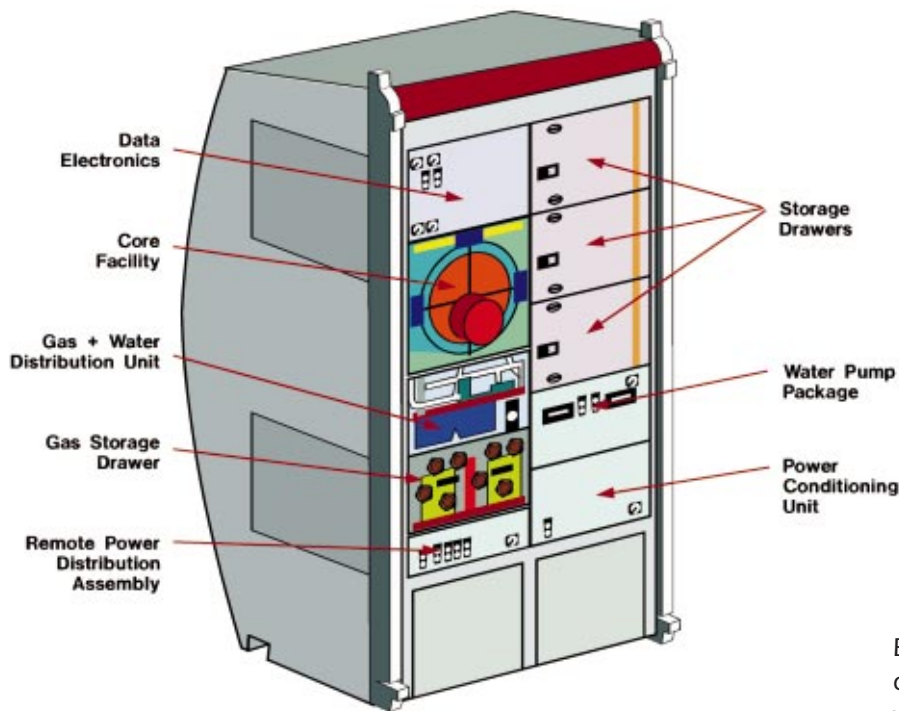


Fig. 22a. The Material Science Laboratory will investigate solidification physics, crystal growth with semi-conductors, thermophysical properties and the physics of liquid states.

Material Science Laboratory

The *Material Science Laboratory* (MSL; Table 14; Fig. 22) offers a multi-user capability to support scientific research in solidification physics, crystal growth with semi-conductors, measurement of thermophysical properties and the physics of liquid states. MSL occupies about half of an ISPR in the US Lab, and one ISPR in the Columbus Laboratory. The two MSL versions are identical except for minor rack interface differences.

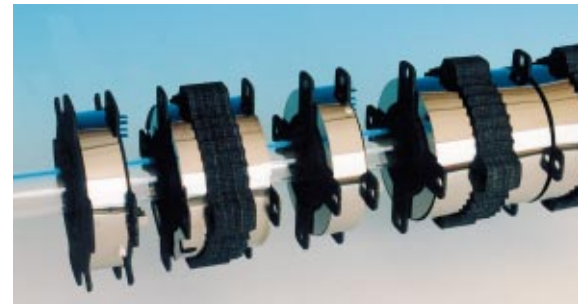


Fig. 22b. The Low Gradient Furnace (LGF) heater assembly for the Material Science Laboratory.

Each MSL comprises a core element consisting of a sealed process chamber in which interchangeable furnace inserts are hosted. These inserts process the samples. The sample cartridges are manually loaded into one of the furnaces. The furnace can be moved over the sample cartridge to displace the thermal gradients. Diagnostic systems provide scientific data on the facility and sample cartridge during operations. As the furnaces are modular, they can be upgraded or replaced according to utilisation needs. Additional MSL units complete the accommodation and operational interfaces to the laboratory.

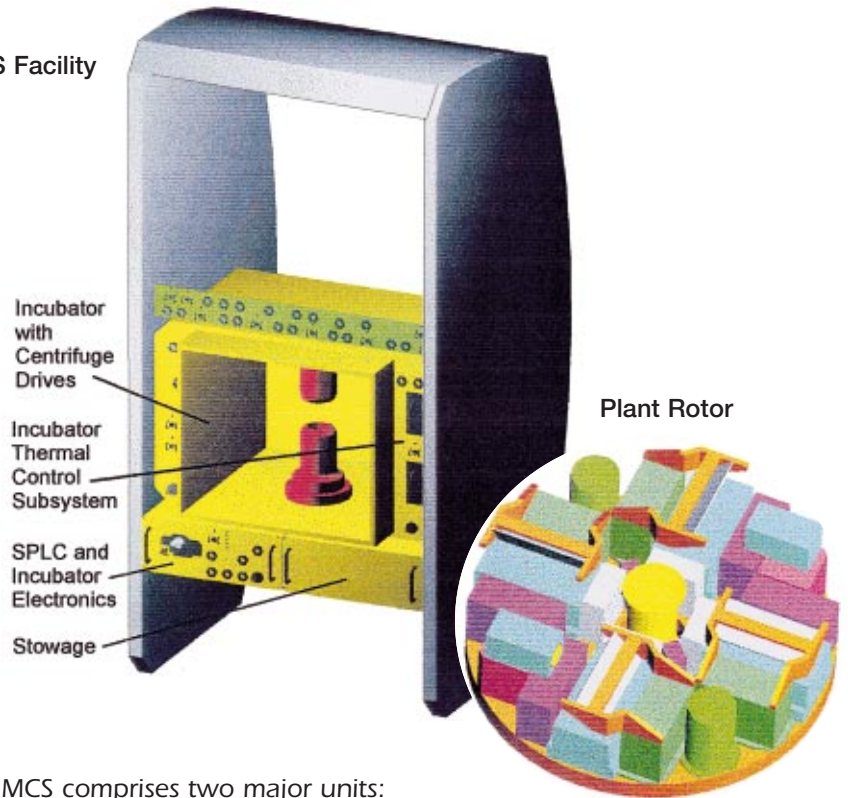
Table 14. Material Science Laboratory (MSL) Characteristics

	QMI*	DMI*	FMF*	LGF*	SQF*
Maximum furnace temperature (K)	1673	TBD	1773	1873	2073
Temperature stability (K)	-0.3	-	-0.02	-0.02	-0.2
Isothermality of plateau heaters (K)	-	1	-	-0.5	-
Maximum thermal gradient (K/cm)	TBD	100	5-25	50	150
Diameter of furnace bore (mm)	TBD	50 (TBC)	42	30	30
Length of hot cavity (mm)	TBD	TBD	250	200	250
Cartridge diameter (mm)	27	48	<39	<29	10-28
Length of adiabatic zone (mm)	TBD	TBD	-	50	50-100 var.
Length of cold cavity/cooling zone (mm)	TBD	TBD	-	120	variable
Diagnosis & stimuli					
Processing speed (mm/s)	10 ⁻⁵⁻²	-	10 ⁻⁵⁻²	10 ⁻⁵⁻²	10 ⁻⁵⁻²
Thermocouples	Up to 12 individually selectable				
Pulse Marking	Peltier				
Sample resistive measurement	yes				
Seebeck voltage measurement	yes				
Cartridge shear cell activation	yes				
Fast quenching speeds	Up to 100 mm/s selectable or 100 mm displacement within 1 s				
Differential thermal analysis	By thermocouple zoom				
Acoustic Interface monitoring	Upon request				
Rotating magnetic field	-	-	yes	yes	-
*QMI: Quench Module Insert. DMI: Diffusion Module Insert. FMF: Floating Zone Furnace with Rotating Magnetic Field. LGF: Low Gradient Furnace. SQF: Solidification and Quenching Furnace. The QMI and DMI furnaces are provided by NASA but can be used by European scientists within the framework of the ESA/NASA MSL Utilization Agreement.					



Experiment Container

MCS Facility



Modular Cultivation System

The *Modular Cultivation System* (MCS; Table 15; Fig. 23) is a multi-user capability for research into the early development events in plants; long-term growth stability; gravity influence during early development and growth; perception and signal transduction in plant tropism, as well as providing the possibility for research on insects, amphibia and radiation effects on cells and tissues.

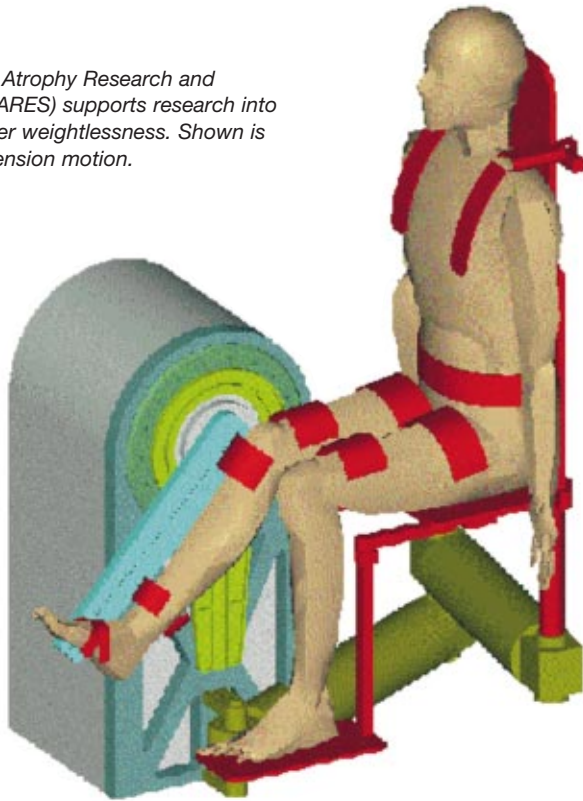
The scientific utilisation of MCS will be shared with NASA. MCS will be accommodated in a NASA Express Rack in the US Laboratory.

MCS comprises two major units: Experiment Containers and the multi-purpose cultivation unit. The Experiment Containers house the samples as well as all the experiment-specific hardware. Each Experiment Container is hosted on one of the multi-purpose cultivation unit rotors. A range of rotors with standard utility interfaces is available for users. The rotors provide the variable gravity environment. Additional MCS units complete the accommodation and operational interfaces to the laboratory.

Fig. 23. The Modular Cultivation System will be accommodated in the US Laboratory.

Table 15. Modular Cultivation System (MCS) Characteristics	
Experiment Containers	
Internal Volume	60x60x160 mm
O ₂ content	15-22%
C O ₂ content	0.03-0.5% but extendable from 1% to 5%
N ₂ content	Remainder
Ethylene removal	Provided
Temperature control	18-40°C
Humidity	50-95% relative humidity
Data interfaces	RS485. Command (digital I/O) and analog lines
Power lines	-12 Vdc, +5 Vdc
Plant Rotors	
Number of rotors	2
Experiment containers per rotor	4
Rotor speed	Selectable for 0 g and 0.001-2.0 g
Illumination:	
Day cycle	yes
Night cycle	Infrared
Video camera/signal	1 camera for 2 containers; 1 video signal per rotor Video frame-grabbing
Accommodation:	
Incubator, rotors and active containers	In 4 Mid-Deck Lockers
Electronics	1 Drawer

Fig. 24. The Muscle Atrophy Research and Exercise System (MARES) supports research into muscle atrophy under weightlessness. Shown is the knee flexion/extension motion.



Muscle Atrophy Research and Exercise System

The *Muscle Atrophy Research and Exercise System* (MARES; Table 16; Fig. 24) is a multi-user capability to support research in the area of muscle atrophy under weightlessness.

MARES comprises a custom-built motor system that includes torque and angular position/velocity sensors as well as a subject body restraint system consisting of a chair and limb adapters. These elements are controllable according to user-defined profile algorithms. The MARES Man-Machine Interface is accomplished on the Human Research Facility (HRF) laptop. This has two primary functions: to command the MARES-specific algorithms and to provide the operator/subject with feedback through displays.

MARES is provided by ESA as part of NASA's HRF.

Table 16. Muscle Atrophy Research and Exercise System (MARES) Characteristics

Movement possibilities	
Flexion/Extension	Ankle (dorsa/plantar), knee, hip, wrist, elbow, shoulder, trunk
Supination/Pronation & Radial/ulnar deviation	Wrist
Linear movement	Whole leg(s), whole arm(s)
Measurement modes	
Isometric	No movement/counteract subject forces
Isokinetic	Concentric/eccentric to maintain constant velocity during movement
Isotonic	Concentric/eccentric to maintain constant torque during movement
Position control	Based upon predefined complex position profiles
Velocity control	Based upon predefined complex velocity profiles
Torque/force control	Based upon predefined complex torque/force profiles
Power control	Constant power
Ideal elements	Simulate ideal spring, viscosity, inertia or some combination
Pseudo-gravitational	Simulate programmable mass and gravity vector
Quick-release	Sudden release of torque/force
Linear motions	
Force	±250 N
Velocity	±0.5 m/s
Length	±1 m
Angular motions	
Torque	< 450 Nm continuous < 900 Nm peak up to 200 ms
Velocity	< 515 _r /s
Angle	Unlimited number of turns
Power	Maximum 2700 W

Percutaneous Electrical Muscle Stimulator

The *Percutaneous Electrical Muscle Stimulator* (PEMS; Table 17; Fig. 25) is a research capability that provides stimulation of specific muscle groups in a test subject to study muscle atrophy occurring under weightlessness. It is provided by ESA as part of the NASA Human Research Facility.

PEMS will be used in conjunction with MARES for support in the measurement of the intensity of involuntary muscle contractions. Other features include:

- programmable trains of pulses (pulse width, amplitude, time between pulses);
- the possibility for adding a randomised delay before the first pulse.



Table 17. Percutaneous Electrical Muscle Stimulator (PEMS) Characteristics	
Stimulation form	Positive-going charge pulse followed by negative after-pulse as muscle is passively discharged
Pulse widths (width of positive-going pulse)	50 s and 250 s
Maximum charge per pulse	40 C
Muscle groups stimuli	1 Triceps surae (ankle) 2 Quadriceps (knee) 3 Triceps brachii/biceps brachii (2 groups for elbow) 4 Flexor/extensor carpi ulnaris/radialis (2 groups for wrist) 5 Adductor pollicis (thumb)

Fig. 25. The Percutaneous Electrical Muscle Stimulator will study muscle atrophy in weightlessness.

Fig. 26b. The Biolab mockup (right) in the Columbus simulator of the Space Station User Information Centre at ESTEC.

European Pressurised Multi-User Facilities in the Columbus Laboratory

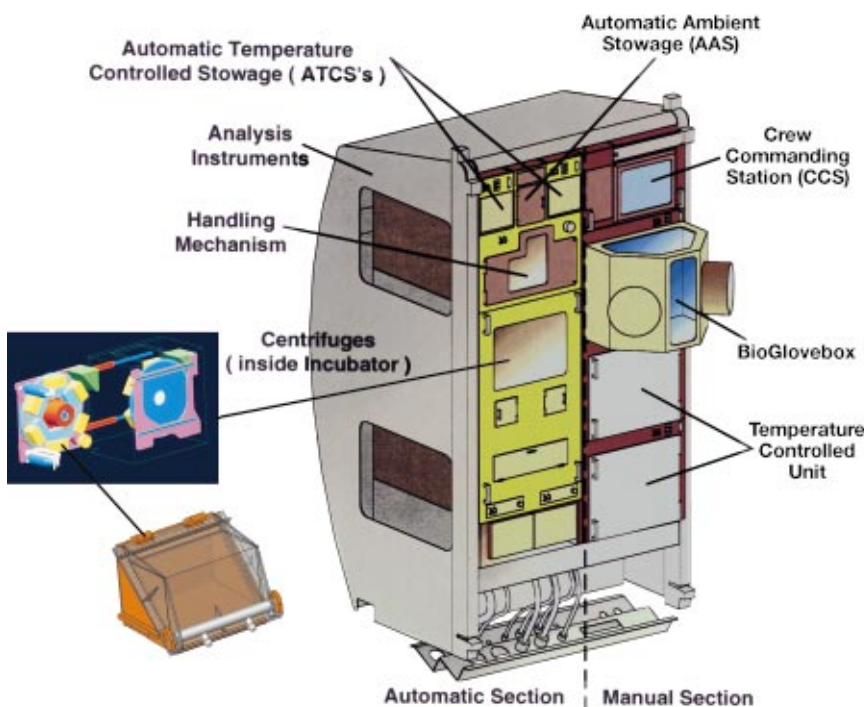
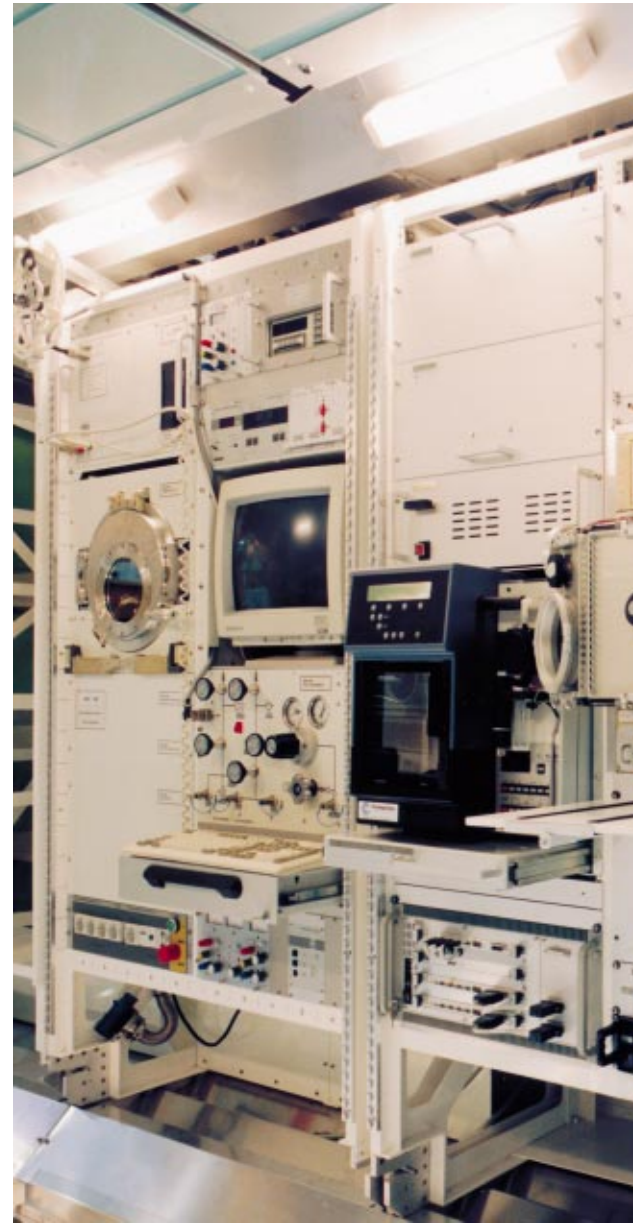
Biolab

Biolab is a multi-user facility (Table 18; Fig. 26) designed to support biological experiments on microorganisms, animal cells, tissue cultures, small plants and small invertebrates. Biolab occupies one ISPR.

The facility features an incubator equipped with centrifuges offering controlled levels of accelerations.

Experiment samples are contained in two versions of Experiment Containers placed on the centrifuges. The Experiment

Fig. 26a. Biolab will support biological research. (ESA/D. Ducros)



Containers can be handled automatically by the Biolab Handling Mechanism. Independent analysis instruments are available for supporting experiment sample test analyses. A capability for the visualisation of images is at hand. The atmospheric environment of the Experiment Container may be adjusted during centrifuge operations. Automatic temperature-controlled and ambient temperature stowage units are available for storing Experiment Container samples.

A Biolab glovebox provides a clean, controlled and enclosed environment for manual operations on Experiment Container samples. The glovebox, working under negative pressure, pre-empts any possible contamination to the laboratory atmosphere.

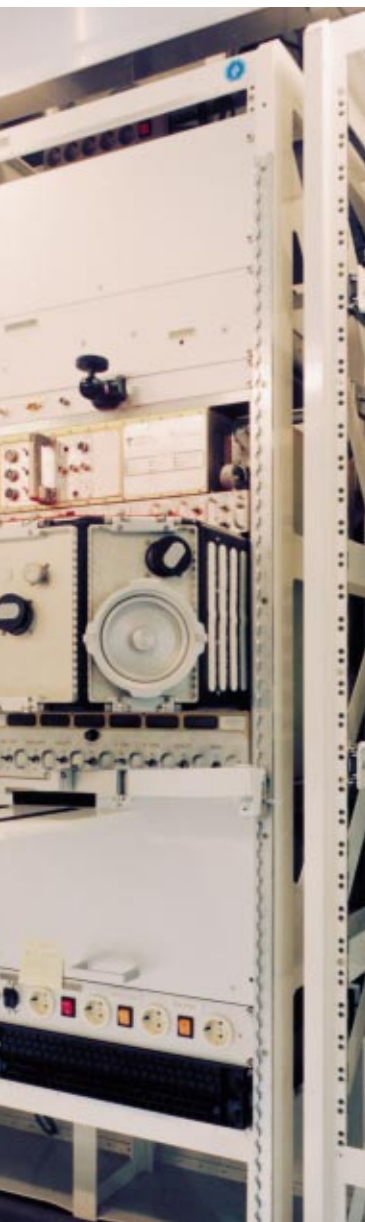


Table 18. Biolab Characteristics

Experiment Container (EC)	
Available volume (Basic EC)	60x60x100 mm
Available volume (Advanced EC)	2.5 litre
Filter system	Particle filters with pore size <0.2 μ m
Power interfaces	-12 Vdc 5 W maximum +5 Vdc 10 W maximum
Data interfaces	RS-485 (serial) 5 analog channels 3 digital inputs/outputs
Video (Advanced EC only)	NTSC
Incubators	
Temperature range	Selectable 18°C to 40°C
Centrifuges	2
Centrifuge g-level control	Selectable 10 ⁻³ g to 2g
Number of containers	6 per centrifuge
Observation resolution	0.2 mm on a 40x40 mm FOV
Life Support System	
Relative humidity	Adjustable 60-90%
Atmospheric concentration	Adjustable CO ₂ , O ₂ and N ₂
Ethylene removal	yes
Automatic Temperature Controlled Stowage	
Temperature controlled stowage capability	89 vials; 2 ml/vial
Temperature range	Adjustable -20°C to +10°C
Ambient Stowage	
Ambient stowage capability	Up to 3 litre
Analysis Instruments	
Microscope	
Low resolution	5 m /1.5 mm diameter FOV
High resolution	0.5 m/0.15 mm diameter FOV
Mode	Single step or scan
Features	Phase contrast, Bright field, Dark field
Spectrophotometer	
Range	220-900 nm
Resolution	10 nm
Light sources	Deuterium lamp (UV); Tungsten lamp (VIS to NIR)
Handling Mechanism	
Piston speed	0.1-30 mm/s
Push/pull force	20 N
Rotation	4-120 rpm with 5 rpm steps
Torque	0.1 Nm
Piston movement	45 mm
Bioglovebox	
Workspace volume	355x300x280 mm (width x height x depth)
Operation mode	Closed loop
Disinfection mode	Ozone generator
Accessories	Light source; Video camera; Restraint tools
Temperature Controlled Unit	
Units available	2
Storage capacity	12 ECs or 10 ATCS inserts
Usable volume	about 20 litre
Temperature range	-20°C to +10°C
Temperature accuracy	-1°C

Fig. 27. The European Drawer Rack (EDR) provides a modular capability for sub-rack payloads. AAA: Avionics Air Assembly. BPU: Branching Protection Unit (power branching with fuses). FASP: Fire Annunciation Suppression Panel. MDL: Mid-Deck Locker. RPDA: Remote Power Distribution Assembly. SDA: Smoke Detector Assembly. SED: Standard Experiment Drawer. SPLC: Standard Payload Computer.

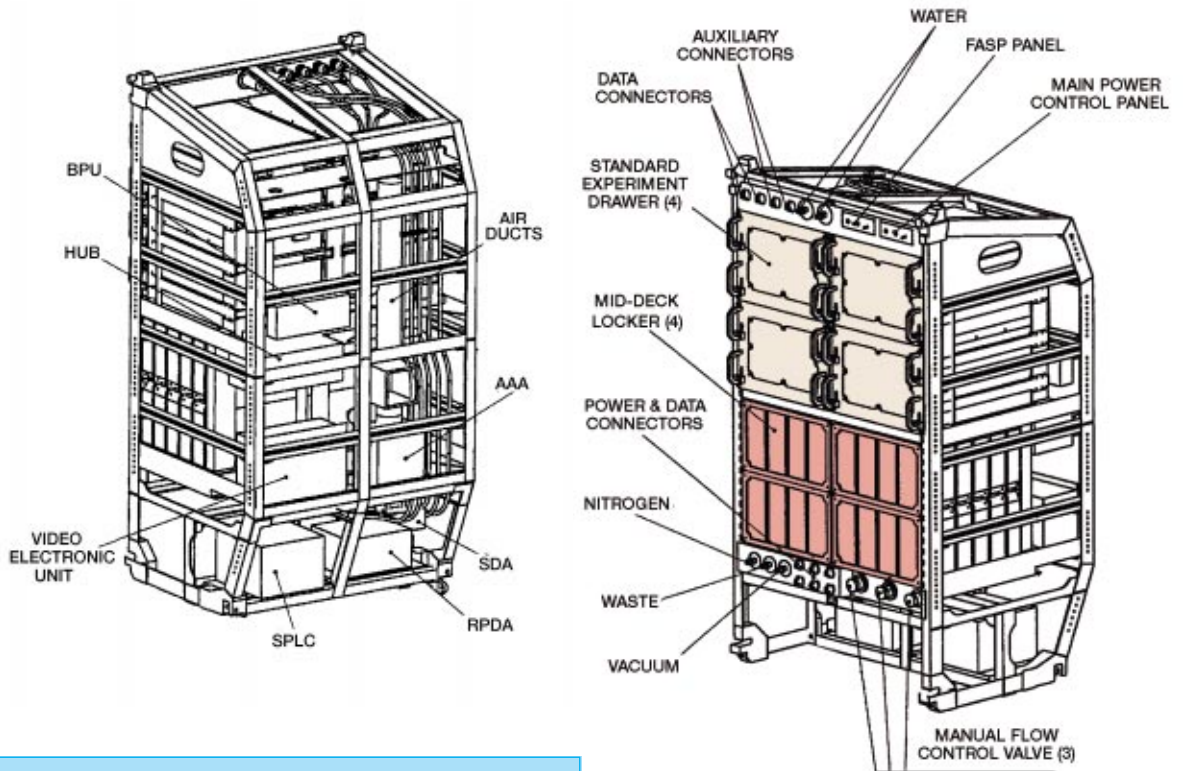


Table 19. European Drawer Rack (EDR) Characteristics

	SED	MDL
Number in baseline	4*	4*
Volume available to payload	72 litre	57 litre
Mass available to payload	38 kg	20 kg
Heat rejection capability (air cooling) ¹	300W	300W
Heat rejection capability (water cooling) ¹	500W	500W
Resources available to user	Via rear connector	Via UDP cable/s to MDL front
Main power 28 Vdc (5 A & 10 A)	1 per SED ²	1 per MDL
Main power 120 Vdc (3 A)	1 per SED ²	N/A
Auxiliary power 120 Vdc (3 A)	For selected SEDs only	For selected MDLs only
Analog video NTSC RS 170A	1 per SED	1 per MDL
Digital video or high-rate data ³	1 per SED	1 per MDL
RS422	1 per SED	1 per MDL
Data IEEE 802.3 (Ethernet)	1 per SED	1 per MDL
Discrete Input	2 per SED	2 per MDL
Discrete Output	2 per SED	2 per MDL
Analog Input	2 per SED	2 per MDL
Common resources		
Water cooling ⁴	Via UDP	Via UDP
Gaseous Nitrogen ⁴	Via UDP	Via UDP
Vacuum (venting) ⁴	Via UDP	Via UDP

*the initial launch configuration for the EDR includes 4 SEDs and 4 MDLs.
 1. The maximum rack cooling capability for air cooling is up to 1200 W and for water cooling up to 2000 W. A combination of both types of cooling is possible provided that the individual cooling capacity is not exceeded and the overall capacity of 2000 W is not exceeded. 2 SEDs will be configurable either for 28 Vdc or for 120 Vdc. 3 This connection is a high-rate data connection to be used by payloads that perform their own video processing. ESA's Protein Crystallisation Diagnostics Facility is an example. 4 The fluid utilities are routed through the Utility Distribution Panels (UDPs). The interfaces may be shared among the different payloads.
 These characteristics represent the baseline version. However, the modular configuration permits adaptations to be accommodated.

European Drawer Rack

The European Drawer Rack (EDR; Table 19; Fig. 27) provides a modular capability for sub-rack payloads contained in standard experiment drawers (SEDs) and Mid-Deck Lockers (MDLs) accommodated in an ISPR.

The EDR supports the independent operation of the multiple sub-rack payload hardware as well as the provision of a standardised interface to laboratory resources. It supports payload exchange at SED or MDL level.

A fundamental goal of the EDR is to support the development of smaller sub-rack payloads through the provision of accommodation and flight opportunities where quick turnaround mission objectives are required.

Fig. 28. The European Physiology Modules (EPM) will support physiological research. (ESA/D. Ducros)



European Physiology Modules

The *European Physiology Modules* (EPM; Table 20; Fig. 28) constitute a multi-user facility supporting physiological experiments in respiratory/cardiovascular conditions, hormonal/body fluid shift, bone demineralisation and neuroscience. EPM incorporates physiological instruments (Science Modules) provided by the ESA microgravity programme and the national programmes of ESA member states. The EPM will be accommodated in one ISPR.

EPM comprises a number of diverse Science Modules to support typical physiological experiments having duration times ranging from hours to a few months.

Table 20. European Physiology Modules (EPM) Characteristics	
Bone Analysis Module (BAM)	
Determines changes in bone properties via measurement of changes in the ultrasound transmission properties of a subject's heel bone (Calcaneus)	
Respiratory Monitoring Module (RMM)	
Gas components analysed	Freon-22, O ₂ , CO ₂ , CO, SF ₆ , CH ₄
Gas analysis response time	~150 ms
Flow meter type	Fleisch, turbine, ultrasonic
Mouthpiece pressure	Relative pressure -100 mbar & accuracy -0.2 mbar
Additional instrumentation:	
ECG	3-lead
Blood pressure	Portapres (continuous BP registration from the finger)
Respiratory Inductance Plethysmograph	Lung volume changes
Ambient conditions	Temperature, pressure, relative humidity
Multi-Electrode Electroencephalogram Mapping Module (MEEEMM)	
Supports EEG and EMG, or a combination of both	
Number of channels	128
Physiological Pressure Measurement Instrument (PPMI)	Danish module
Provides a pressure-sensitive catheter that can be used, for example, for central venous pressure or esophageal pressure determination	
Xenon Skin Blood Flow Measurement Instrument (XSMI)	Danish module
Measures skin blood flow by determining wash-out of injected bolus of radioactive Xe-133	
Cardiolab	CNES/DLR module
To measure arterial blood pressure and heart rate & fluid volume regulation. Comprises a set of sensor modules, a set of stressor modules and a data management central unit	
Elite-S2	ASI module
Tracks postural movements in 3D. Uses IR video techniques using four cameras. Body markers located on subject reflect IR flashes from flash-guns mounted close to cameras. Cameras record reflections from the markers. System calculates 3D coordinates of markers in real time	
Samples Collection and Waste Management Drawer	
Provides accommodation for clinical and medical laboratory equipment necessary for in-flight samples of blood, saliva and urine, and the processing of solid and/or liquid waste produced during EPM usage.	

Fig. 29. The Fluid Science Laboratory will study fluid behaviour in the absence of gravitational effects. (ESA/D. Ducros)



Fluid Science Laboratory

The Fluid Science Laboratory (FSL; Table 21; Figs. 29/30) is a multi-user research capability to study dynamic phenomena of fluid media in the absence of gravitational forces. FSL occupies one ISPR.

For facility users, the most significant FSL element is the Facility Core Element that houses the central experiment module, the optical diagnostics module and the standardised Experiment Containers (ECs). The central experiment module is divided into two parts:

1. contains the suspension structure for the ECs, including all the functional interfaces and optical equipment, and

2. contains all the diagnostic and illumination equipment and its control electronics to command and monitor the electro- and opto-mechanical components.

Fig. 30. Principal features of the Fluid Science Laboratory.

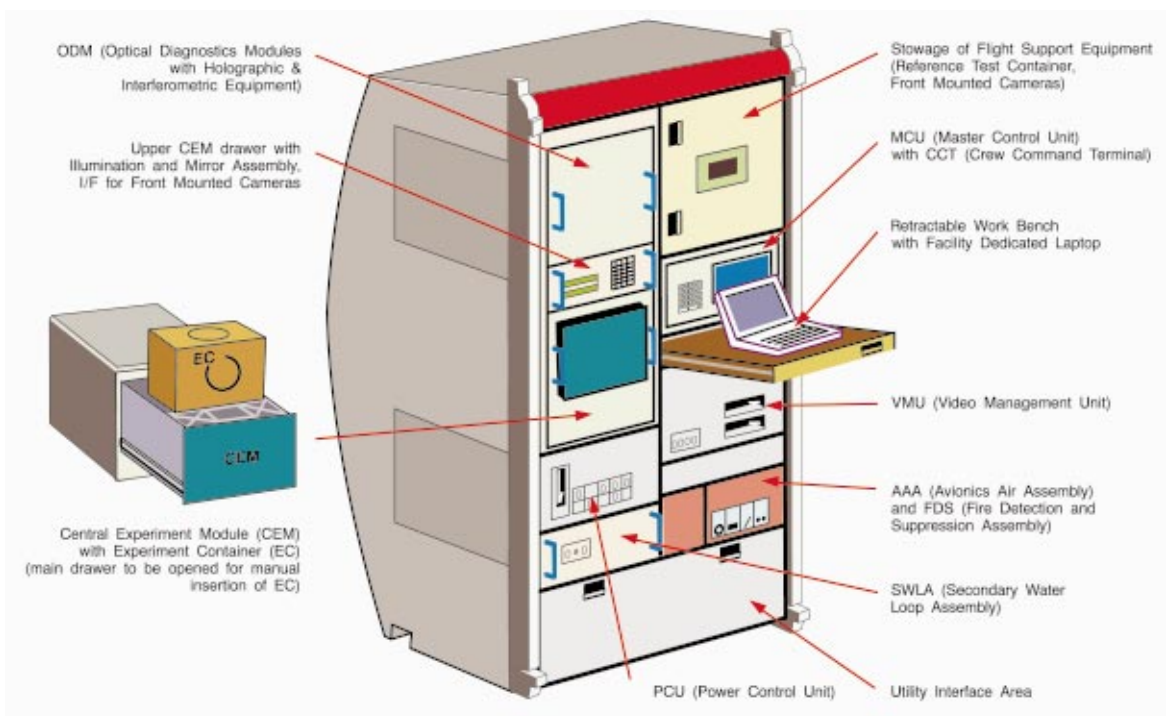


Table 21. Fluid Science Laboratory (FSL) Characteristics	
Experiment Container	
Power available	+28, +15, -15, +12, +5, -5 Vdc
High-voltage supply	Future upgrade
Mass	<40 kg
Dimensions	400x270x280 mm
Fluid volume	1-1000 cm ³
Measurement channels	e.g. 16 analog/ 8 digital
Experiment Container housing	
Containment	Double/triple type
Sealed	yes
Pressurised	yes
Toxic Fluids	yes
Diagnostic/Analysis tools	
Integrated cameras	Integrated CCD or CMOS imagers
Front-mounted cameras	Still, high-speed, high-resolution, IR as required
Parameter setting & diagnostic calibration	Optical reference targets
Standard facility diagnostic capabilities	
White light background	yes
White light and monochromatic light sheet	Variable 0.1-30 m m
Infrared	yes
Visual spectral range	yes
Electronic Speckle Pattern Interferometer	In reflection/transmission modes
Wollaston interferometer	yes
Schlieren interferometer	yes
Holographic interferometer	yes
Complementary Experiment Container diagnosis possibilities	
Special interferometers	yes
Light scattering diagnosis	yes
Laser Doppler anemometer	yes
3-D photogrammetry	yes
Microscopes, endoscopes	yes
Special laser sources	Selectable wavelengths
High-rate non-optical diagnosis	Pressure/temperature sensors
Microgravity reduction capability	
Use of Canadian Space Agency Microgravity Vibration Isolation Mount (MIM) under investigation	

The optical diagnostics module houses the equipment for visual and interferometric observation, their related control electronics and the attachment points and interfaces for front-mounted cameras. The ECs provide the exchangeable receptacle to host the experiment fluid cells as well as any process stimuli and specific user diagnostics, and their supporting container electronics.

The FSL can be operated in fully automatic or semi-automatic modes by the flight crew, or in a remote-control mode from the ground (telescience).

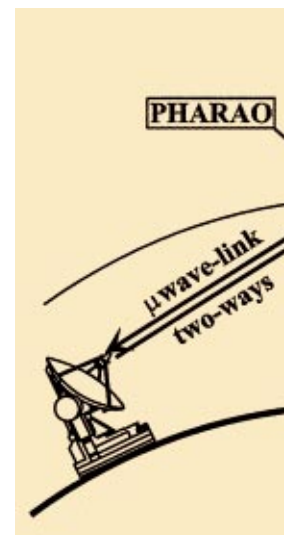


Table 22. Protein Crystallisation Diagnostic Facility (PCDF) Characteristics	
Process Unit	
Process chamber temperature	Selectable 14–30°C
Process chamber capacity	4 Experiments Boxes including reactor temperature control system
Experiment Boxes	
Reactor temperature	Selectable 4–40°C
Solution injection	yes
Stirrer capability	yes
Individual process control for temperature and concentration	yes
Reactor types	
Dialysis	Volumes 300, 130, 100 and 50 L
Extended length dialysis	1.1 mL
Batch	3 mL to 6 mL final
Manufacturing material	Quartz glass
Temperature sensors	yes
Diagnostic capabilities	
Specific diagnostic capabilities on central carousel in process chamber location:	
B & W digital video camera	yes
Dynamic light scattering system	Back Scattering (170..)
Specific diagnostic capabilities in experiment box location:	
90° dynamic light scattering system	yes
Mach-Zehnder interferometer	yes
General diagnostic capabilities	
High-resolution video camera	Wide-field/Microscope modes
Housing:	Mid-Deck Locker
Ascent/descent power	yes
Electronic Unit	
Process controller	Pre-programmed sequences
Telemetry/telecommanding	Interface to host EDR
Housing	European drawer

Protein Crystallisation Diagnostic Facility

The *Protein Crystallisation Diagnostic Facility* (PCDF; Table 22) offers a multi-user research facility to enable an in-depth knowledge and understanding of protein crystal growth processes under microgravity conditions without convection and sedimentation effects. The PCDF will be accommodated in the European Drawer Rack.

The PCDF comprises a process unit and an electronics unit. The process unit includes a process chamber housing experiment boxes containing the reactors in which experiment solutions are hosted as well as the reactor control electronics. The experiment boxes include drive systems for the individual injection of solutions into the reactors, complemented by a stirrer for experiment solution distribution. Diagnostics are provided within the process chamber or can be installed directly in the experiment boxes. The electronics unit accommodates all the controls for performing experiments as well as the interfaces to the European Drawer Rack.

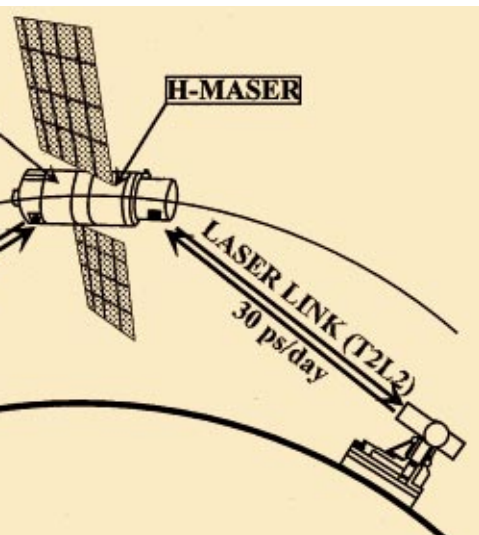


Fig. 31. The ACES concept. Pharaoh is the laser-cooled atomic clock.

European External Facilities on US Express Pallets

Under a barter agreement, ESA has access to five Express Pallet Adapters on US Express Pallets. For these opportunities, ESA made an Announcement of Opportunity in 1997 and selected the following external facilities.

Atomic Clock Ensemble in Space

The *Atomic Clock Ensemble in Space* (ACES) is a programme to test the performance of a new type of clock that exploits and depends upon microgravity conditions. It consists of four key elements: a laser-cooled atomic clock; a hydrogen maser; a laser link for optical transfer of time and frequency; a microwave link for transfer of time and frequency.

The aims of ACES are to:

- validate the performance of this new generation of clocks in space;
- provide an ultra-high performance global time scale;

- support fundamental physics tests such as relativity, once ACES is established.

ACES occupies one Express Pallet Adapter.

Expose

Expose (Table 23; Fig. 32) is a multi-user external facility to support long-term in-situ studies of microbes in artificial meteorites as well as microbial communities from special ecological niches such as endolithic and endoevaporitic ecosystems. Investigations include the study of photobiological processes in simulated planetary radiation climates (e.g. early Earth, early and present Mars, and the role of the ozone layer in protecting the biosphere from harmful UV radiation).

Expose is mounted on the Coarse Pointing Device. Together, they occupy about half of an Express Pallet Adapter. *Expose* is equipped with experiment containers that are individually covered by entrance optics. A subset of the containers is covered by lids that allow controlled Sun exposure times.

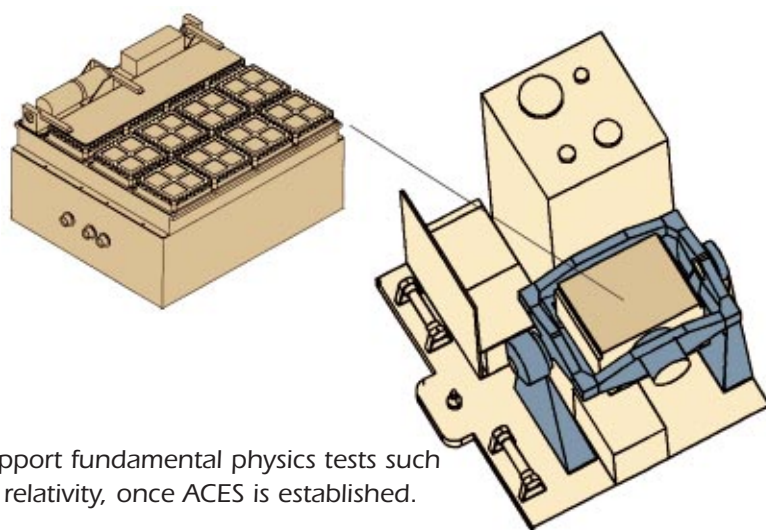
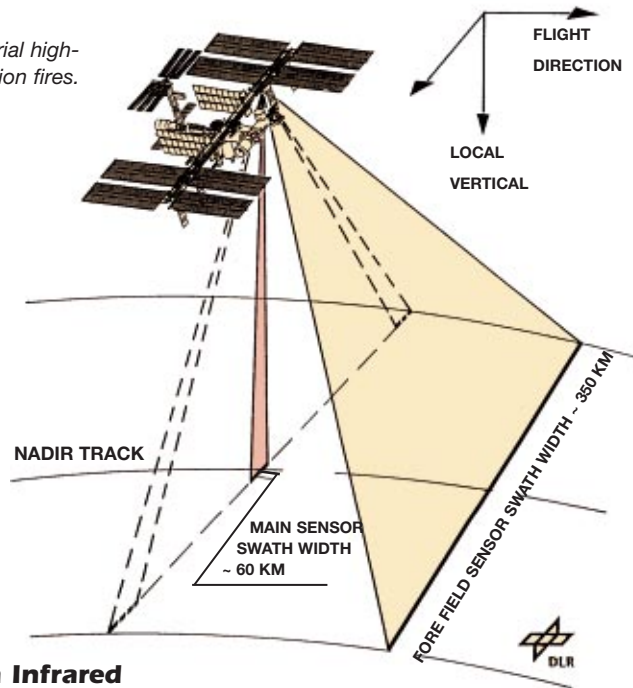


Fig. 32. The *Expose* unit (mounted on the Coarse Pointing Device) will expose biological specimens to the space environment.

Table 23. *Expose* Characteristics

Pointing requirements	<i>Expose</i> requires zenith orientation and solar pointing
Pointing	Coarse Pointing Device
Sample exposure variable control	Motorised lids/shutters
Expose features:	
Sample containers	12
Selectable open/close lids	8
Permanently open	4
Atmosphere	Vacuum or inert gas
Temperature control	Heating (only)
Sensors	U V, radiation, temperature and pressure
Active signals	Real time telemetry

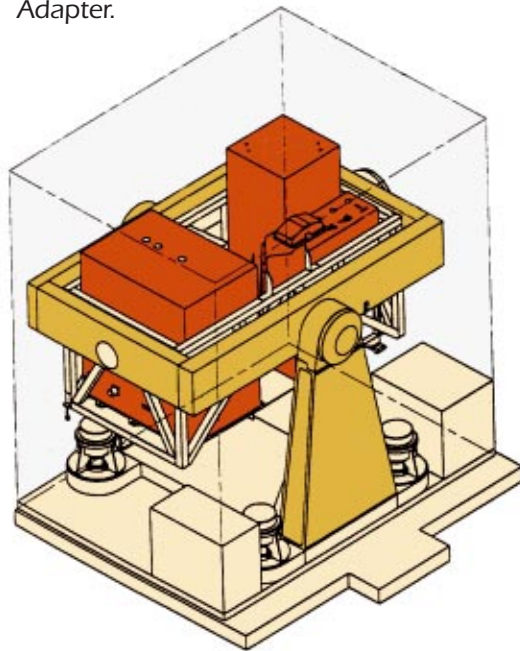
Fig. 33. Focus will detect terrestrial high-temperature events such as vegetation fires.



Intelligent Fire Detection Infrared Sensor System (Focus)

The *Intelligent Fire Detection Infrared Sensor System* (Focus; Table 24; Fig. 33) aims towards the autonomous detection and analysis from space of high-temperature events such as vegetation fires and volcanic eruptions. It is a forerunner for a spaceborne high-temperature environment disaster recognition system. Focus occupies one Express Pallet Adapter.

Fig. 34. The Solar Monitoring Observatory will measure the Sun's total and spectral irradiance.



Solar Monitoring Observatory

The *Solar Monitoring Observatory* (SMO; Fig. 34) carries three instruments to measure the solar total and spectral irradiance. It is mounted on a Coarse Pointing Device (CPD) in order to orient the instruments towards the Sun. SMO occupies one Express Pallet Adapter.

SMO measures the solar flux across almost the whole spectrum: 17-3000 nm, which carries 99% of the Sun's energy emission. The three instruments are:

- SOVIM: solar variable and irradiance monitor;
- SOLSPEC: solar spectral and irradiance measurements;
- SOL-ACES: auto-calibrating extreme ultraviolet and ultraviolet spectrophotometers

Sky Polarisation Observatory

The *Sky Polarisation Observatory* (Sport; Fig. 35) surveys the polarisation of diffuse cosmic background radiation in the range 20-70 GHz. The Galaxy's synchrotron radiation is the strongest source of polarisation emission in this range.

Sport occupies half of an Express Pallet Adapter.

Table 24. Intelligent Fire Detection Infrared Sensor System (Focus) Characteristics

Viewing direction	Local vertical
Fore field sensor swath width	~350 km
Main sensor swath width	~60 km
Pixel size resolution	30-150 m
Spectrometer footprint (diameter)	10 km
Mass	227 kg

SPORT Microwave Receiver with 4 Horns

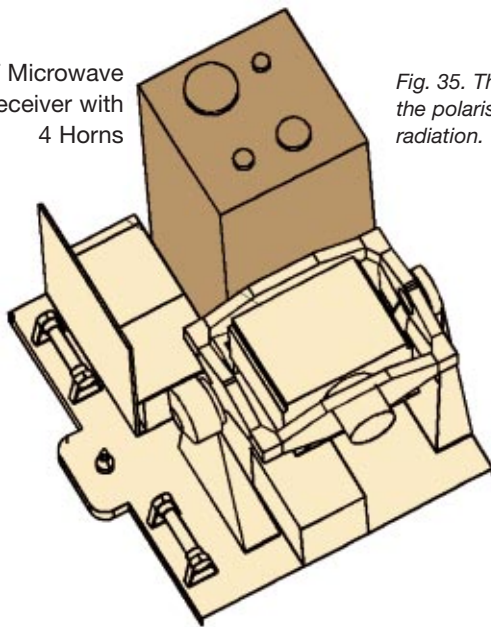


Fig. 35. The Sky Polarisation Observatory will survey the polarisation of the diffuse cosmic background radiation.

Technology Exposure Facility

The *Technology Exposure Facility* (TEF; Table 25; Fig. 36) is an externally-mounted multi-user capability that provides a physical and operational infrastructure for a wide range of on-orbit investigations and experiments in technology research and development. Experiments can be mounted in modules that provide standard services. TEF occupies one Express Pallet Adapter.

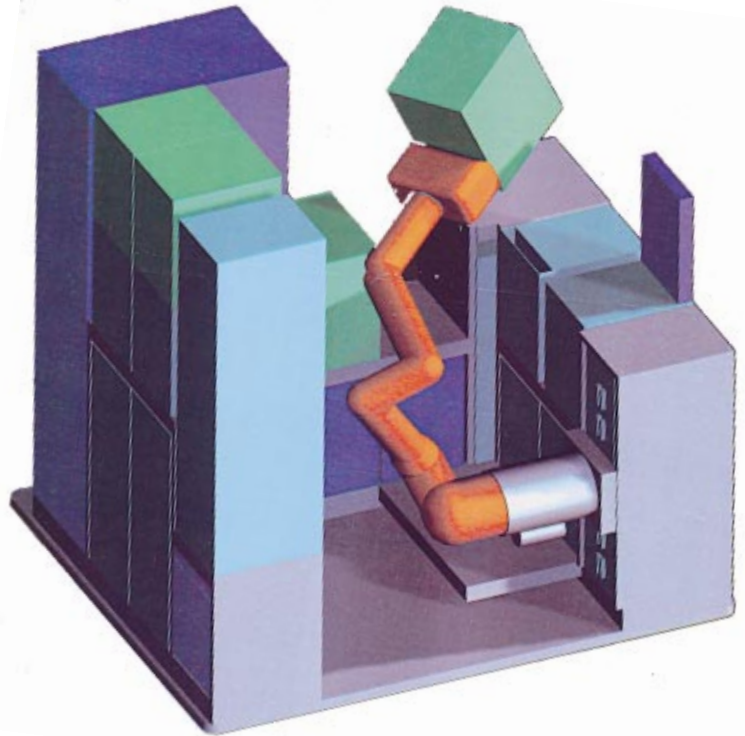
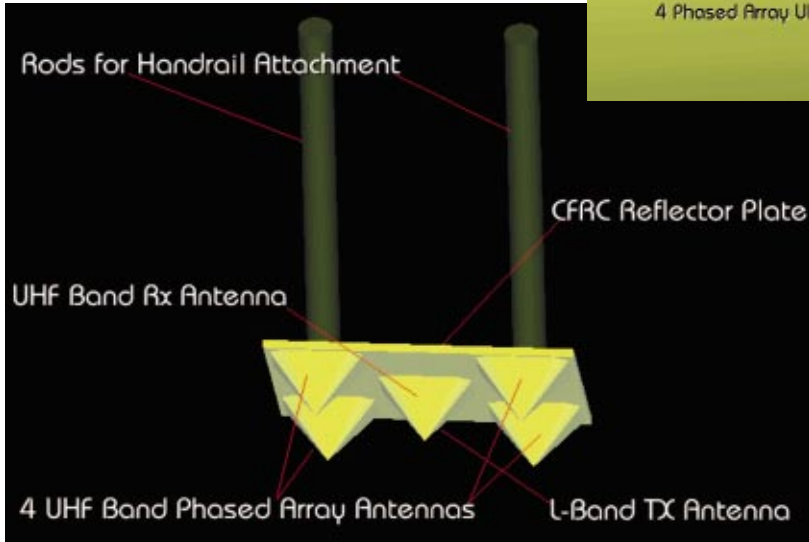
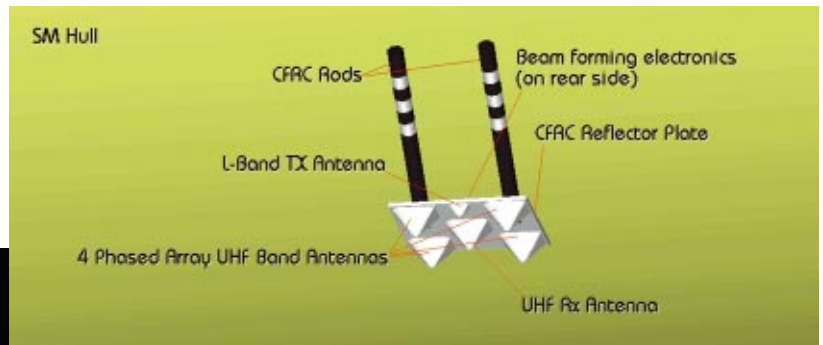


Fig. 36. The Technology Exposure Facility (TEF) supports space technology research and development.

Table 25. Technology Exposure Facility (TEF) Characteristics

Number of Payload Modules (PMs)	Maximum 15
PM Dimensions	200x250x600 mm or double sized
Retrieval opportunities	After 1.5 years or within 3 years
Robotic manipulation opportunities	Pointing, re-locating, inspection and measurement
Power availability	For the full platform: 600 W peak, 400 W average
Mass capability	225 kg
Data transfer capability	yes
General accommodation possibilities	
Ram-facing surface area	yes
Surface area not receiving ram effects	yes
Maximal inherent isolation from microgravity disturbances	yes
Zenith-facing area with wide field of view	yes
Out-of-plane-facing area	yes
Nadir-facing area	yes
Volumetric exposure of known geometry	yes
Solar flux exposure (cyclical & sustained)	yes
Inertial stabilisation	yes
Local pointing	yes
General facility capabilities	
Centralised environment radiation measurement data unit	yes
Test article translation	Inside and outside the facility
Support pointing & controlled acceleration	yes
Material properties laboratory	yes

Fig. 37. The Global Transmission System provides high-accuracy time and data signals to ground users.



European External Facilities on Russian Elements

Global Transmission System

The Global Transmission System (GTS; Table 26; Fig. 37) provides a capability for transmitting highly accurate time and data signals via a Space Station external antenna to ground-based users. The data signals can be coded according to the specific user requirements and can include such information as the Station orbital position.

GTS' main objectives are to:

- verify the performance and accuracy of a time signal transmitted to Earth from Low Earth Orbit;
- assess the ground-received signal quality and data rates;
- measure disturbing effects, including Doppler shifts, multipath reflections, shadowing and elevation impacts.

The GTS uses a transmitter operating at two dedicated frequencies and mounted externally on the Russian Service Module. The GTS signals are available to ground receivers for periods of 5-12 min several times a day.

Although GTS primarily provides a service to ground users, identical services are available to Russian-element users onboard the Station.

Table 26. Global Transmission System (GIS) Characteristics		
	400 MHz Transmitter	1.4 GHz Transmitter
Operating frequency	400.10 MHz	1428 MHz or 1430 MHz, depending on final allocation
Bandwidth	50 kHz	1.5 MHz
Transmitter power	1.0 W	0.5 W
Antenna type and number	4-element phased array	crossed dipole
Antenna transmission cone	140 degrees	140 degrees
Antenna polarisation	Left-Hand Circular	Right-Hand Circular
Expected max. communications range	1200 km	1200 km
Scientific data rates	1000 bit/s	1000 bit/s
Data format	NRZ-L	NRZ-L
Modulation type	QPSK	BPSK

Matroshka

Matroshka (Table 27; Figs. 38/39) is a multi-user external human 'phantom' facility representing the upper part of the human body. The goal is to support studies into the depth dose distribution of different orbital radiation field components during Extra Vehicular Activities on different sides of human organs.

Matroshka is equipped with user-provided passive and/or active detectors for ionising radiation placed at different locations within the facility. Matroshka will be mounted on the outside of the Russian Service Module.

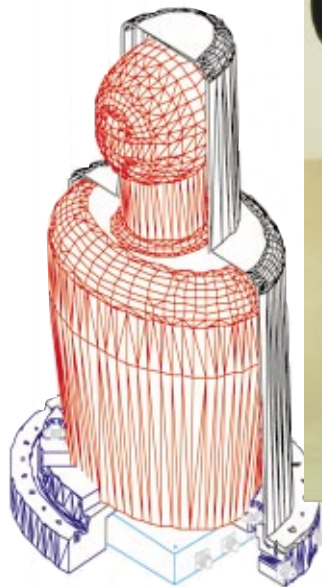
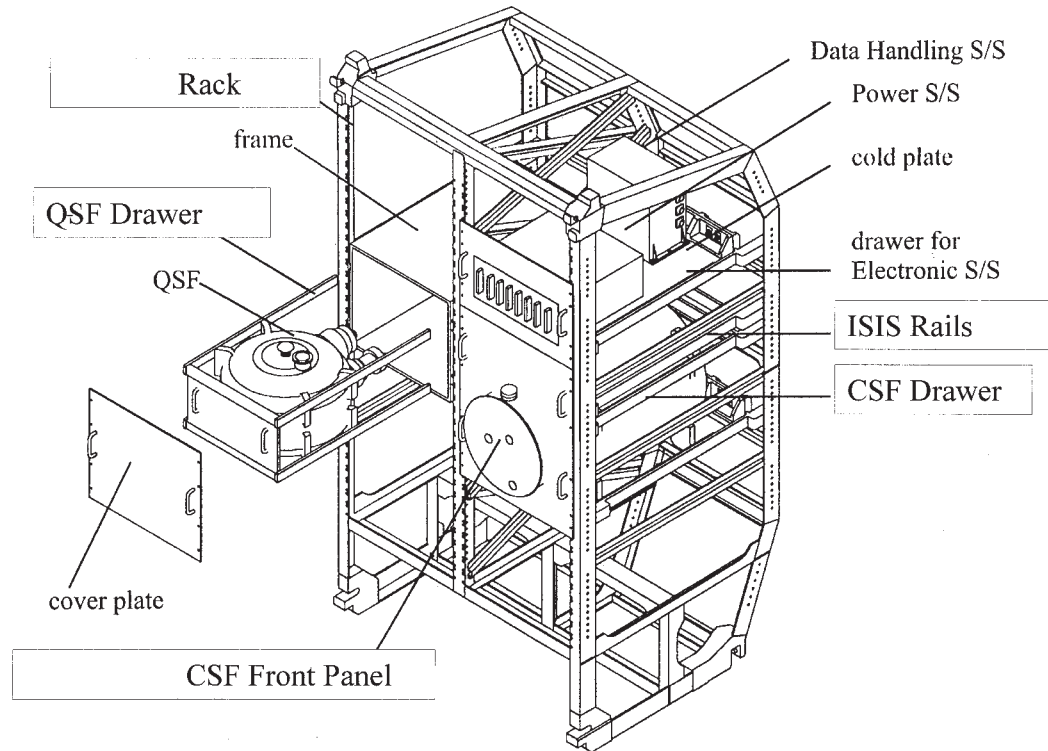


Fig. 38. Matroshka will be mounted on the outside of the Russian Service Module.

Fig. 39. Cutaway of the Matroshka human 'phantom'.

Table 27. Matroshka Characteristics	
Composition	Multi individual slices of tissue/bone/organ equivalent materials
User diagnostic capabilities	Active & passive radiation experiment packages embedded into individual slices
Active signals	Real time radiation telemetry

Fig. 40. The Cryosystem stores biological specimens down to -180°C .



Support Systems for Pressurised Facilities

Cryosystem

Cryosystem is a combined set of facilities built by ESA under an ESA/NASA cooperative agreement for the Life Sciences user community in support of optimal preparation, preservation and storage of biological samples and protein crystals down to -180°C .

The major elements of Cryosystem consist of the Cryogenic Storage Freezer (CSF), the Quick/Snap Freezer (OSF), the On-Orbit Preservation Assembly Rack (OPAR) and the Transportation Rack (Track). In addition, Orbital Support Equipment (OSE) consisting of tools and accessories as needed during on-orbit operations.

The CSF provides for the storage and preservation of already-frozen biological samples and supplies. The OSF provides the means for the ultra-rapid cooling of

samples as well as the temporary holding of cryogenic samples during CSF maintenance. The OPAR, housed in one ISPR rack, is outfitted with a liner and the subsystems to accommodate and support the CSF and OSF operations, and is intended to be integrated into the Centrifuge Accommodation Module (CAM). The Track is functionally similar to the OPAR but is used for the transportation and operations of the CSF and passive payloads in the Mini Pressurised Logistics Module.

Table 28. Cryosystem Characteristics

Cryogenic Storage Freezer (CSF)		
Type of samples stowed		Animal (organisms, cells, enzymes); Vegetable (cells); Harvested protein crystals
Storage temperature		Mode 1: Tissues, blood and other fluids: <-160.C Mode 2: Harvested protein crystals: -180-5.C
Modular stowage volume		Single cold volume (dewar) with multiple cavities, each containing a storage tube for ten 2 m L or five 5 m L containers
Stowage capacity		1. 2000 2 m L containers, or 2. 1000 5 m L containers, or 3 a combination not exceeding the volume of either 1 or 2
Power-off survival		Temperatures maintained for 8 h without electrical power
Power supply		Main and auxiliary bus automatic switching provided on ISS (not in MPLM during transportation)
Frequency of up/down load		CSF may be up/downloaded on every MPLM flight (every 3 months)
Monitoring		1. Continuous during nominal operations. 2. Temperature Data Recorder provided for power-off conditions
Location in ISS		1. Transportation to/from ground in MPLM. 2. Installed in Cryosystem Orbital Rack (OPAR) in CAM
Quick/Snap Freezer (QSF)		
Type of samples:	Quick freezing	Animal (organisms, cells, enzymes); Vegetable (cells)
	Snap freezing	Animal internal organs, muscles, tendons, ligaments, tissues; Vegetal tissues
Sample dimensions:	Quick freezing	2 m L and/or 5 m L containers
	Snap freezing	Specimen surface area equivalent to a circle of 6-mm radius. Sweet zone (no cellular damage) extends over at least 10% of the surface area described above
Temporary stowage volume		Cavities for ten 5 m L container and twenty 2 m L containers
Operation capability:	Quick freezing	6 samples in 2 h
	Snap freezing	4 samples in 2 h
Frequency of operations		3 cycles of 2 h each, with interval of 1 h between successive cycles followed by a minimum recovery time of 16 h
Frequency of samples transfer to CSF		Every 8 h or three operation cycles of 2 h
Monitoring		1. Continuous during nominal operations. 2. Temperature Data Recorder provided for power-off conditions and transfer conditions
Power-off survival		Temperature maintained for 1 h (min) without electrical power
Interfaces		ISIS sub-rack payload interfaces
Location in ISS		1. quick/snap freezing operations performed while attached at the Life Science Glovebox (LSG) rack 2. transfer of samples to/from CSF and stand-by operations performed while attached at the Cryosystem Orbital Rack (OPAR) located in CAM 3. reception of harvested and frozen protein crystals containers at the X-Ray Crystallography Facility (TFD)
Monitoring		1. Continuous during nominal operations. 2. Temperature Data Recorder provided for power-off conditions
Orbital Rack (OPAR)		
Volume taken by Cryosystem elements		1 CSF Drawer (24 FU); 1 QSF drawer (12 FU); 1 Utilities drawer (8 FU); 1 Cryosystem Stowage drawer (4 FU)
Volume available to other payloads		6 Drawers (4 FU each)
Mass available to other payloads		180 kg (30 kg per drawer)
Heat rejection capability for Cryosystem elements		600 W
Heat rejection capability for other payloads		None
Resources for other payloads		None
Location in ISS		CAM
Transportation Rack (Track)		
Volume taken by Cryosystem elements		1 CSF Drawer (24 FU); 1 Utilities drawer (8 FU)
Volume available to other payloads		10 Drawers (4 FU each)
Mass available to other payloads		300 kg (30 kg per drawer)
Heat rejection capability for Cryosystem elements		300 W
Heat rejection capability for other payloads		None
Resources for other payloads		None
Location in ISS		MPLM

Fig. 41. The European Stowage Rack (left) provides storage for samples and equipment.



Fig. 42. The Microgravity Science Glovebox (right) provides a confined environment to handle primarily material science payloads.



European Stowage Rack

The *European Stowage Rack* (ESR; Table 29; Fig. 41) provides a modular capability for the stowage of payload equipment and samples contained in Standard Experiment Drawers (SEDs) and Mid-Deck Lockers (MDLs), which require no power, data and thermal control resources.

Once the ESR is on-orbit, standard equipment drawers and Mid-Deck Lockers will be regularly exchanged using the (upmass/downmass) logistics flights.

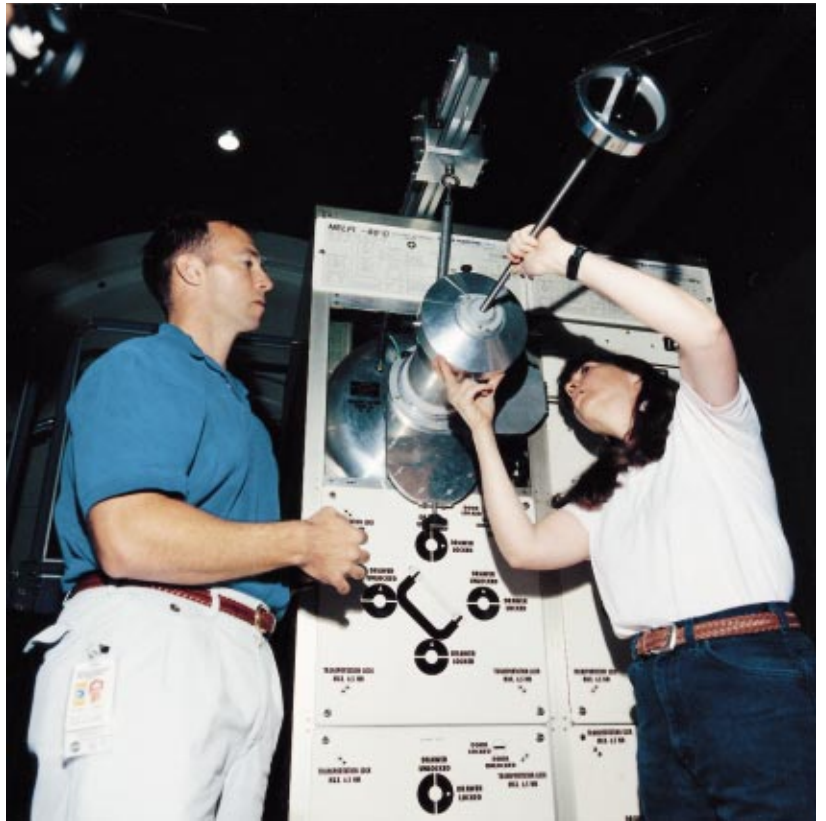
Microgravity Science Glovebox

The *Microgravity Science Glovebox* (MSG; Table 30; Fig. 42) is built by ESA under an ESA/NASA cooperative agreement and provides a large-volume glovebox for small- to medium-size payloads, primarily in material science.

	SED	MDL
Number in baseline	8	*
Volume available to payload	72 litre	57 litre
Mass available to payload	38 kg	26 kg
*the launch configuration for the ESR includes 8 SEDs, although on-orbit it is also possible to accommodate MDLs in place of drawers.		

Work volume for experiments	255 litre
Largest access dimension	40 cm diameter
Pressure environment with respect to cabin	Negative pressure with air circulation and filtration
Airlock module capability for transfer of payloads and equipment	Maximum 40 litre
Resources available to glovebox users:	
Power	+120, +28, -12, +5 Vdc
Video link (analog)	yes
Video cameras	4
Video recorder	3 + 1 hard disc
Gaseous Nitrogen	yes
Vacuum and venting	yes
Cooling	Up to 200 W by air, up to 800 W by cold plate

Fig. 43. The Minus Eighty Degree Laboratory Freezer for the ISS (MELFI) stores and preserves biological specimens.

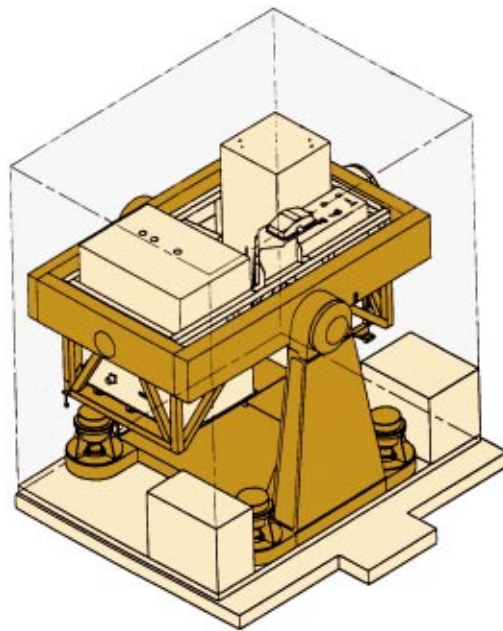


Minus Eighty Degree Laboratory Freezer for the ISS

The *Minus Eighty Degree Laboratory Freezer for the ISS* (MELFI; Table 31; Fig. 43) is built by ESA under an ESA/NASA cooperative agreement and provides for stowage and retrieval of cold biological specimens.

Table 31. Minus Eighty Degree Laboratory Freezer for the ISS (MELFI) Characteristics	
Modular stowage volume	4 independent compartments (dewars) of 75 litre each. Total refrigerated stowage volume of 300 litre
Minimum active configuration	At least 1 dewar at -80°C
Multiple mission configuration	One to three -80°C dewars active plus a +4°C or a -26°C dewar active Two -80°C dewars active plus a +4°C and a -26°C dewar active Two -80°C dewars active plus two -26°C dewars active
Controlled temperatures	-80°C mode: samples maintained below -68°C -26°C mode: samples maintained at -37°C to -23°C +4°C mode: samples maintained at +0.5°C to +6°C
Standard dewar outfitting	4 sliding trays of 575 mm length 2 type A box modules of half-tray length 12 type B box modules of quarter-tray length 18 vial bags 12 vial cards
Types of samples stowed	Cell culture of 1-10 mL size Fluid samples (blood, media, etc) of 1-500 mL size Specimens/dissection tissues of 2-10 mL size Specimens (whole) of 10-500 mL size
Power of f survival	Temperature conditions maintained for 8 h without electrical power
Contingency survival	Cooler replaceable in-orbit in less than 8 h Cooler and support equipment needed for replacement available in the rack Electronic box containing computer replaceable in-orbit in less than 8 h Replacement for the electronic box available in the rack
Power supply	Main and auxiliary bus automatic switching provided
Power consumption	Ranging from 600 W to 900 W, depending on the active configuration

Fig. 44. The Coarse Pointing Device provides pointing for external payloads.

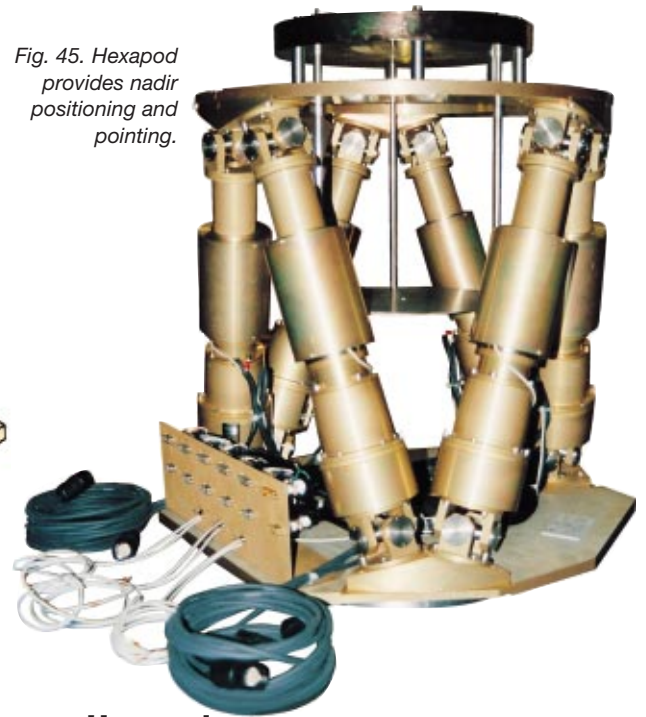


Support Equipment for External Payloads

Coarse Pointing Device

The *Coarse Pointing Device* (CPD; Table 32; Fig. 44) provides a 2-axis pointing capability for external payloads to achieve a pointing accuracy in the order of 1° to compensate for Station orbital motions and seasonal Sun apparent motion. Two versions of the CPD are under development for supporting the SMO and Expose facilities.

Fig. 45. Hexapod provides nadir positioning and pointing.



Hexapod

Hexapod (Table 33; Fig. 45) is built by ESA under an ESA/NASA cooperative agreement and provides nadir positioning and pointing for the NASA Stratospheric Aerosol and Gas Experiment (SAGE III) external payload. It could provide, however, pointing in any direction for other payloads with appropriate adaptations and modifications.

Table 32. Coarse Pointing Device (CPD) Characteristics

Pointing accuracy	-1_i
Pointing stability	0.1_i over 10 s
Number of rotational axes	2
User load capability	Max 75 kg
CPD envelope stowed (including Payloads)	W within ExPA envelope
Payload mounting plate footprint	Adaptable to payload requirements. Two versions under development, for: half and full pallet adapters
CPD Power	150 W _{max}
Data interface for payloads	RS422
Power supplies to payloads	28 Vdc
CPD controller	Based on ESA SPLC
CPD operations modes	Of f, standby, tracking

Table 33. Hexapod Characteristics

Degrees of freedom	6
Pointing range	$-8..$
Pointing accuracy	-90 arcsec
Pointing stability	9 arcsec/s
SAGE III sensor assembly mass	35 kg
SAGE III approximate envelope size	340x340x740 m m

Standard Payload Outfitting Equipment

Standard Payload Outfitting Equipment (SPOE; Fig. 46) covers pressurised and external standardised space-qualified hardware items that can be procured and embedded into payloads to support more general payload functions and/or Station interface functions and so pre-empt the need for users to undertake any specific development.

The use of SPOE within the framework of Columbus Laboratory payload facilities and the ground test equipment is shown in Fig. 46.

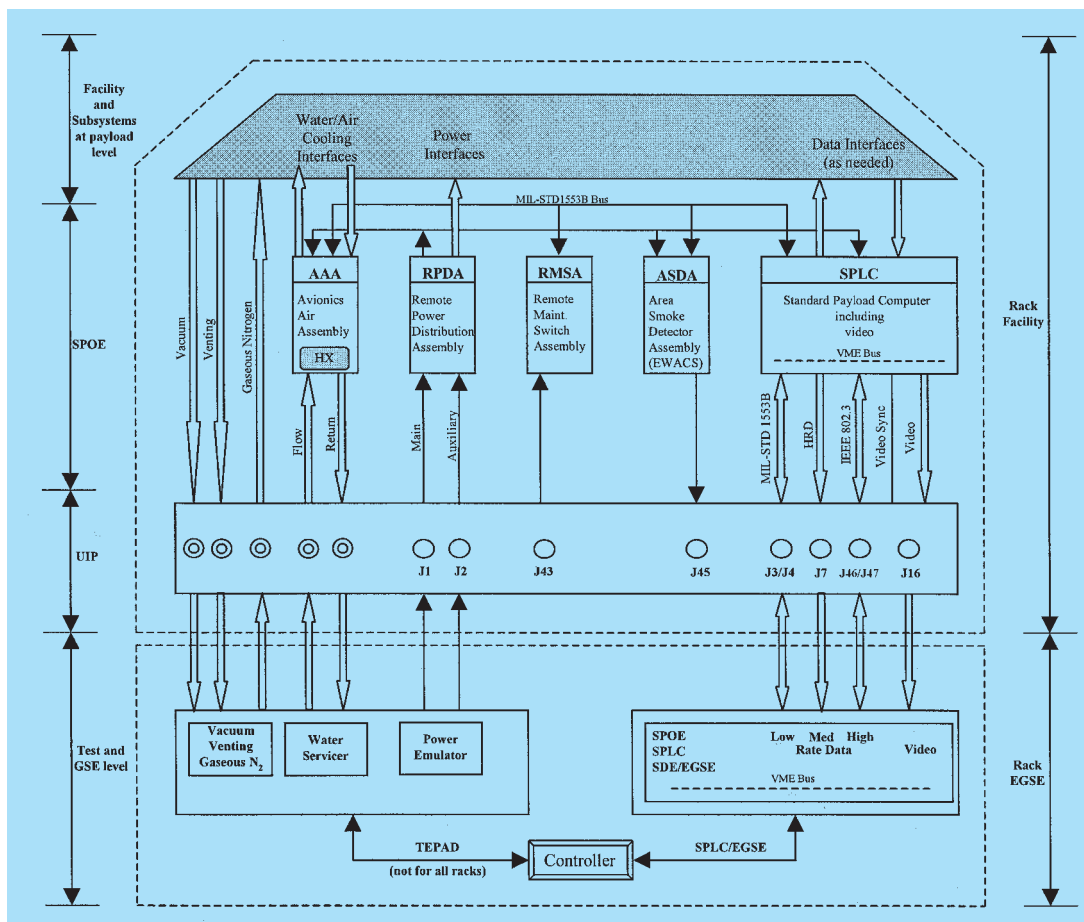


Fig. 46. Standard Payload Outfitting Equipment within Rack Facility/EGSE.

Fig. 47. The Standard Payload Computer with ISS interfaces.

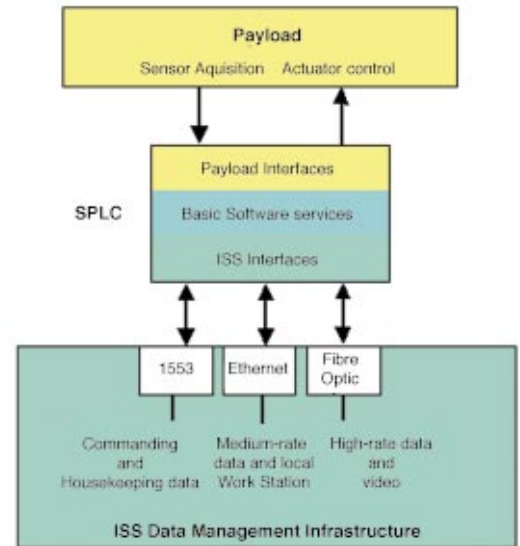


Avionics Air Assembly

The *Avionics Air Assembly (AAA)* provides ISPR payloads with an air cooling capability for up to 1200 W and employs a water-to-air exchanger with selectable speed fan. The AAA uses the moderate temperature cooling loop available at the rack interface.

External Payload Computer

The *External Payload Computer (XPLC)* provides data management interfaces between the payloads on an Express Pallet Adapter and the Express Pallet or the Columbus EPF. The XPLC is based upon the Standard Payload Computer (see SPLC) as modified for the external Station environment and specific



adaptations for the Express Pallet Adapter payloads.

Power Distribution Unit

The *Power Distribution Unit (PDU;* Table 34) provides power conversion, switching and protection functions for payloads on an ExPA.

Remote Power Distribution Assembly

The *Remote Power Distribution Assembly (RPDA;* Table 35) provides power distribution, power control, power status monitoring, overcurrent protection and power conversion from 120 Vdc to 28 Vdc with rack exchangeable modules to facilitate on-orbit reconfiguration and/or replacement.

Standard Payload Computer

The *Standard Payload Computer (SPLC;* Table 36; Fig. 47) provides a modular and configurable data-handling system based on an industrial-standard VME Bus and a self-standing processor with interfaces connected via a standardised local bus.

The processor board is equipped with a minimum set of interfaces and includes a local bus to allow the addition of mezzanine interface boards. For complex payloads, a VME extension board can provide the same local bus as that of the processor board and is able to support additional mezzanine interface boards. Specialised VME boards for performing complex functions can be added because of the open VME bus architecture.

Table 34. Power Distribution Unit (PDU) Characteristics

Input voltage	120 Vdc
Output voltage	28 Vdc
Nominal mode:	
Output current capability	5 A
Output stage protection trip line	5 ms < t < 10 ms with 1.5 x current _{max}
Output control per output stage	Programmable at activation
Stay Alive mode:	
Output voltage	28 Vdc
Stay-alive current capability	1 A
Output control per output stage	None

Table 35. Remote Power Distribution Assembly (RPDA) Characteristics

Input voltage	120 Vdc
Output voltage	120 Vdc, 28 Vdc
Output current protection ratings:	
120 Vdc	1, 3, 5 & 10 A
28 Vdc	5 & 10 A

Table 36. Standard Payload Computer (SPLC) Characteristics

CPU Module	
Power interface	5 V/10 W without mezzanine boards
Data interfaces	Master VME bus, A32/D32 mode, 6 serial interfaces, 2 x local mezzanine interfaces
CPU	ERC32
Memory	8 MB SRAM, 4 MB EEPROM
Software	Basic software package and VxWorks kernel in ROM
Temperature range	-55°C to +125°C
Mass	700 g
Mass Memory Module	
Power interface	5 V/<5 W
Host CPU data interfaces	Slave VME Bus
Memory	Disk or DRAM
Storage capacity	50 MB
Mass	600 g
Extension Module	
Power interface	5 V/200 mA (without mezzanine boards)
Host CPU data interfaces	Slave VME Bus and mezzanine I/O local Bus (x 4)
Mass	500 g
MIL 1553B Mezzanine Board	
Power interface	5 V/250 mA, 12 V/300 mA
Host CPU data interfaces	Mezzanine I/O local Bus
MIL Bus	MIL STD-1553B
Mass	120 g
Ethernet I/F Mezzanine Board	
Power interface	5 V/1 W
Host CPU data interfaces	Mezzanine I/O local Bus
LAN Data interface	AUI
Mass	80 g
Serial I/F Mezzanine Board	
Power interface	5 V/200 mA
Host CPU data interfaces	Mezzanine I/O local Bus
Data interface	2 Asynchronous RS 422/RS 485
Mass	100 g
Analog Input I/F Mezzanine Board	
Power interface	5 V/<1 W, -12 V/<1.2 W
Host CPU data interfaces	Mezzanine I/O local Bus
Performance	12 bit resolution, max. 100 samples/s, 8 differential input channels
Mass	100 g
Digital I/F Mezzanine Board	
Power interface	5 V/<1 W
Host CPU data interfaces	Mezzanine I/O local Bus
Performance	12 Opto-isolated input/output lines, max. 100 samples/s
Mass	100 g
SPLC Housing	
Mass	3.4 kg including power supply, backplane and harness
Housing size	160x295x260 mm
Number of VME slots	5
Construction	Coated aluminium
Power supply	120 Vdc or 28 Vdc input
SPLC EGSE	
Development environment	Unix and VxWorks
Test system	PACTS
Hardware platform	VME

Turbo Molecular Pumps

The *Turbo Molecular Pumps* (TMPs; Table 37) provide a higher vacuum capability than is available with the Columbus Laboratory central vacuum system. Two sizes of TMP are available.

Partner Research Facilities

The research facilities provided by ESA's Partners are summarised in Table 38.

Partner Payload/Laboratory Support Equipment

The *Environmental Monitoring Package* (EMP) measures a number of contamination environment parameters (radiation, plasma, mass deposition of contaminants) external to the Station as a service to the attached payloads community, which requires characterisation of operational conditions.

The *Express Rack* (ER) provides accommodation for payloads that do not require the entire volume of an ISPR and provides physical interfaces for payloads contained in International Subrack Interface Standard (ISIS) drawers, Mid-Deck Lockers (MDLs) or their equivalents.

The *International Standard Payload Rack* (ISPR) provides standardised payload accommodation that is interchangeable on-orbit between the pressurised modules of NASA, NASDA and ESA (See the chapter 'Accommodation and Utilisation Resources Capabilities for Payloads').

The *Mid-Deck Locker* (MDL) provides standard Space Shuttle locker accommodation with limited capabilities (power, air-cooling) for mid-size payloads.

A number of further Partner payload and laboratory support equipment is under

Table 37. Turbo Molecular Pump (TMP) Characteristics

	TPH 180 HM	TMH 065
Volume flow rate N ₂	170 litre/s	56 litre/s
Volume flow rate He	170 litre/s	48 litre/s
Compression ratio N ₂	>10 ¹²	>10 ¹⁰
Compression ratio He	>10 ⁸	10 ⁷
Ultimate pressure N ₂	2x10 ⁻⁹ mbar	<4x10 ⁻⁹ mbar
Nominal rotation speed	50 000/min	90 000/min
Maximum backing pressure N ₂	20 mbar	20 mbar
Maximum gas throughput N ₂	6 mbar.litre/s	0.6 mbar.litre/s
Cooling type	Natural convection or cold plate	Natural convection or cold plate
Input power: Back pressure 1 mbar run-up	59 W	57 W
Input power: Back pressure 1 mbar nominal	40 W	13 W
Run-down time until stop: Back pressure 1 mbar	~12 min	~12 min
Mass with ISO-K flange	9.38 kg	2.51 kg

Table 38. The Research Facilities to be Provided by ESA's Partners

Initial outfitting in US Laboratory	Initial outfitting in JEM
<p>PRESSURISED :</p> <p>Avian Development Facility Biomass Production Facility Gravitational Biology Facility Human Research Facility 1 & 2 Crew Health Care System* Biotechnology Facility Material Science Research Facility Fluids & Combustion Research Facility X-ray Crystallography Facility Window Operational Research Facility Facilities for engineering and commercial research</p> <p>EXTERNAL :</p> <p>Stratospheric Aerosol & Gas Experiment (SAGE III) Alpha Magnetic Spectrometer (AMS) Environmental Monitoring Package (EMP) Low Temperature Microgravity Physics Facility</p> <p>In preparation:</p> <p>Advanced Cosmic Ray Experiment for ISS (ACCESS) Extremely Heavy Cosmic Ray Composition Observer (ECCO)</p>	<p>PRESSURISED :</p> <p>Cell Biology Experiment Facility & Clean Bench Fluid Physics Experiment Facility Zone Melting Furnace with X-ray radiography Gradient Heating Furnace Solution/Protein Crystal Growth Facility Isothermal Furnace Electrostatic Levitation Furnace Aquatic Animal Experiment Facility Advanced Furnace for Microgravity Experiment with X-ray Radiography Image Processing Unit</p> <p>EXTERNAL :</p> <p>Laser Communication Submillimetre-Wave Limb Emission Sounder X-ray monitoring Space Environmental Data Acquisition</p>
Canada	
Aquatic Research Facility Insect Habitat Levitation Furnace Microgravity Isolation Mount (MIM)	
<p>*The Crew Health Care System is not a research facility although elements of it will be used by the Human Research Facility (HRF) to support HRF research.</p>	

development, and descriptions are given in Partner documentation.

Partner Standard Payload Outfitting Equipment

The *Active Rack Isolation System* (ARIS) can be installed in the US-developed ISPR. It attenuates vibration disturbances to support specific requirements for a microgravity environment.

The *Area Smoke Detector Assembly* (ASDA) provides the capability for detecting smoke within a fire protection zone and initiates an alarm to the Columbus Laboratory Vital Monitoring System.

The *Express Pallet Adapter* (ExPA) provides an external payload accommodation and interface capability that can be exchanged on-orbit using the Space Station Remote Manipulator System (see the chapter 'Accommodation and Utilisation Resources Capabilities for Payloads').

Interface Connectors provide for quick connect/quick disconnect between payload racks and the utility interfaces provided in the pressurised modules.

The *Rack Main Switch Assembly* (RMSA) provides the capability for the crew to shut down power to a payload rack for maintenance and exchange activities.