Operations and Utilisation

Accommodation and Transport

The MELFI system has been designed for an operational life of 10 years, and it has been qualified for 15 launches flying active in the MPLM. MELFI will be the first payload to fly active in the MPLM and it basically has been designed for installation in the US Lab module Destiny of the ISS. Activities are ongoing for extending this capability to interface the Japanese Experiment Module.

Operational Concept

MELFI can be controlled in two ways: in remote mode through the US Lab 1553B payload bus from either the ground or the ISS laptop, or in manual local mode from the CPI (Control Panel Interface). The MELFI software provides overall control and monitoring of the MELFI subsystems. In particular, it implements the algorithms that control the speed of the machine and cold power to each dewar. The algorithms minimise the power consumption for a selected configuration (dewar mode and temperature set point).

Utilisation Scenario

The utilisation scenario will provide late access (within hours or few days) to MELFI while MELFI is in the Shuttle launch pad. Also, after the landing of the Space Shuttle, there will be the possibility to have early access to retrieve the samples. MELFI provides the necessary ground support equipment to support these operations. On orbit, the transfer of samples between the ISS and the MPLM can be done at MELFI level (i.e. exchange of the complete rack) or at tray level, by using the MELFI provided On-Orbit Transfer Bag.

Many different utilisation scenarios are possible. MELFI provides the required heat lift to each of the dewars. The basic accommodation hardware provided by MELFI is the tray. Each dewar includes four trays that can be extracted without disturbing the samples in the other three. In addition to the trays, MELFI provides standard accommodation hardware for the insertion of samples of different sizes and shapes.

Schedule

MELFI has been developed by ESA under different Barter Agreements that ESA formalised with NASA and JAXA. Under those agreements ESA will deliver three MELFI flight units to NASA and one flight unit to JAXA. The first MELFI freezer will be launched inside a Multi Purpose Logistics Module (MPLM) on the Space Shuttle in 2006.

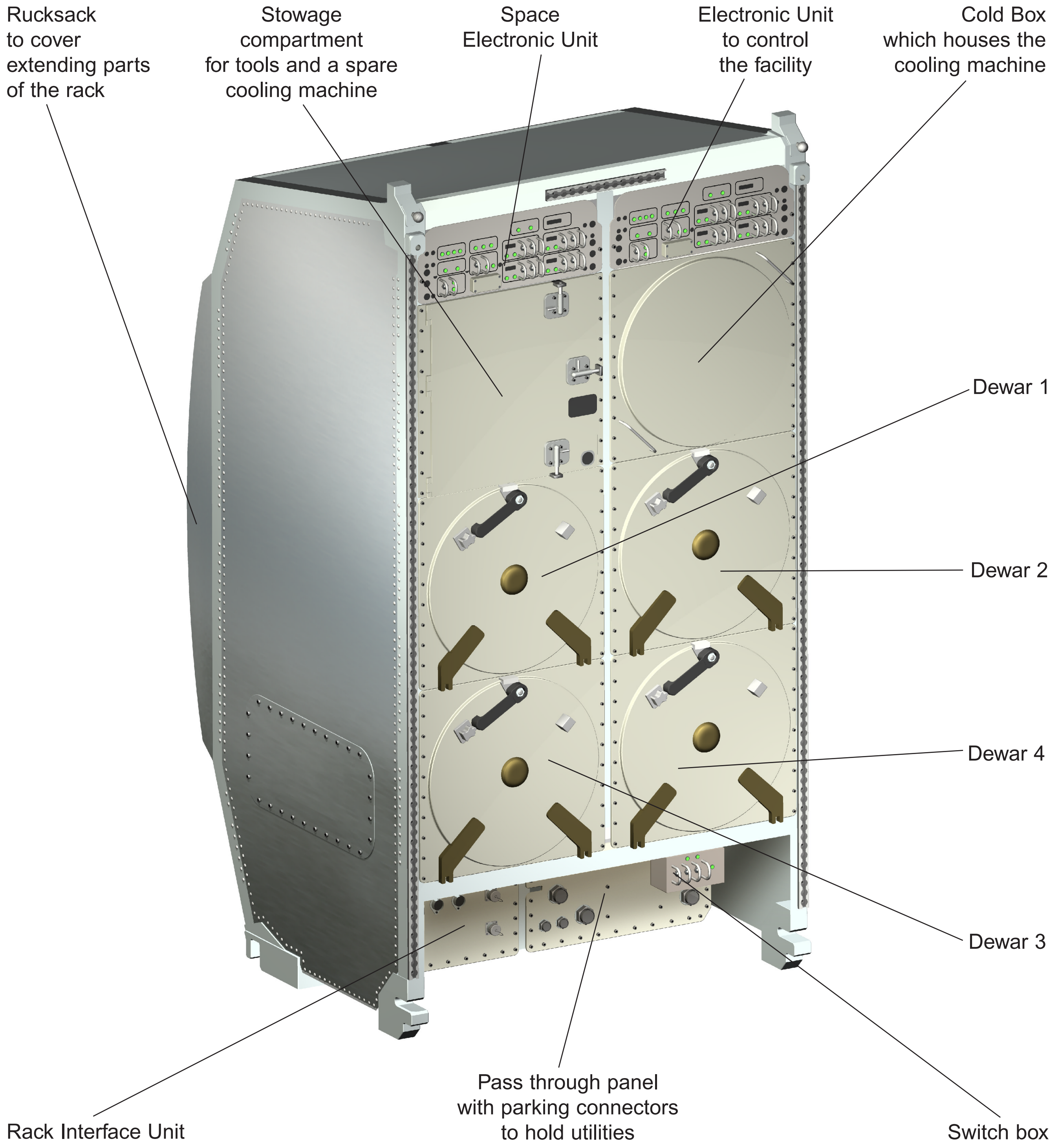
In addition, ESA has agreed to deliver to NASA certain ground units and to provide the necessary spares and sustaining engineering to maintain the NASA MELFI units for up to 10 years of MELFI operations.

Illustrations: ESA/D. Ducros

Minus Eighty Laboratory Freezer for ISS (MELFI)

Laboratory freezer for the International Space Station

The Minus Eighty (Degrees Celsius) Laboratory Freezer for ISS (MELFI) will provide the Space Station with refrigerated volume for storage and fast-freezing of life science and biological samples. MELFI will also ensure transportation of conditioned specimens to/from the ISS by flying in fully-powered mode inside the Multi Purpose Logistics Module (MPLM). It is foreseen to have mission durations of up to 24 months for each MELFI unit.



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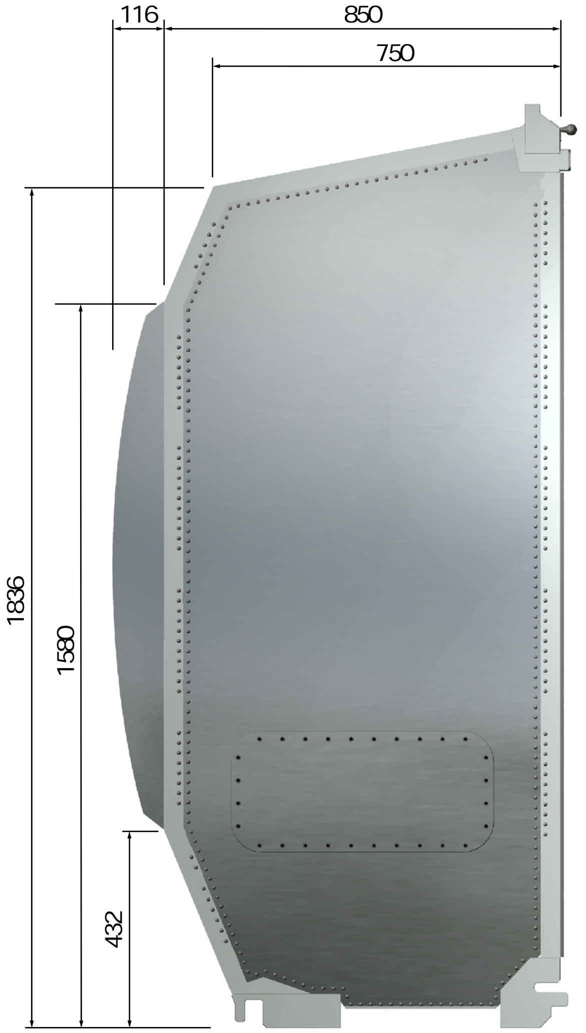

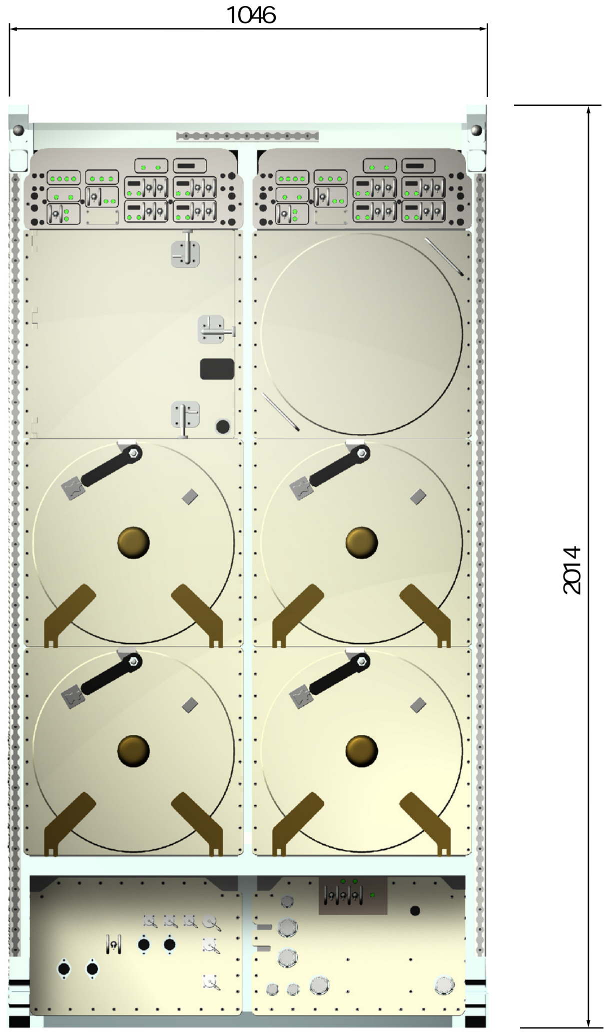

Facility Description

The Dewar System includes the cold volume, made by four separate compartments (dewars), and a nitrogen distributing system, consisting of piping and control valves. Each dewar is a cylindrical vacuum insulated container with a total capacity of about 75 litres. Its internal volume is divided in four parts by a cross structure, having two functions: the support function for the specimen containers and the heat transport function, from the heat exchanger to the specimen.

The cooling system of MELFI is based on the Brayton thermodynamic cycle, using nitrogen as a working fluid. The cooling engine is a turbo-machine or Brayton Machine (BM) that provides the flow of cold nitrogen. The Brayton Machine is cooled by water running through the Motor Heat Exchanger that surrounds the cartridge.
The BM motor, of which the magnet is integrated on a single shaft together with the turbo-expander and the compressor can rotate at speeds up to 90,000 rpm depending on the cooling requirements and uses gas bearings for support and a brush-less and sensor-less technology. Brushes are not suitable for the high speed and the long life requirements and because they generate pollution. The sensor-less technology was selected because it is robust in the cold environment and allows very fast accelerations of the rotor.
The heat exchangers needed to implement the Brayton thermodynamic cycle are integrated in a closed container called the Cold Box. The Brayton Machine is inserted into the Cold Box, forming an integrated assembly called the Brayton Subsystem. A set of tubes distributes the cold nitrogen to four independent cold cavities (the dewars). The supply and return nitrogen flows are concentric in the tubes. The nitrogen tubing provides the cold power to the dewars in a closed loop (i.e. the nitrogen is not in direct contact with the samples in the dewars), at the so called “cold fingers” that house the load heat exchangers. A valve at the tip of each cold finger regulates the nitrogen flow. In this way, the temperature in the dewars can be controlled independently at three operating modes (-80, -26 and +4°C). Control of - 26ºC and + 4ºC is achieved with good overall efficiency when at least one dewar is working at - 80º C. The upper temperature limit for the - 80º C mode is fixed at - 68º C. This gives a 12º C safety margin, which complies with the power-off phases during transportation in the MPLM and during the ground operations. The temperature is continously monitored and recorded even in power-off phases and during transportation. Notification of out-of-limit conditions will be performed.

The dewars are designed to improve the thermal coupling between the samples and the cold fingers.
The external surfaces and internal volumes where the nitrogen flows at different temperatures require a very efficient thermal insulation to reduce the thermal leaks. To achieve this the double walls are covered with MLI sheets and pumped out to very high vacuum levels. The very low leakage requirement requires a “Getter pump” that keeps the vacuum by molecular pumping at the desired level.
The Cold Box design features an axi-symmetric configuration with all the components integrated around the housing of the Brayton Machine. Because of mass effectiveness, all the Cold Box metallic parts are assembled by hundreds of welded joints.
The electrical subsystem provides the overall control of the MELFI system and supplies electrical power to the BM motor and control electronics. It is integrated in two main boxes: the Electronic Unit and the Rack Interface Unit. The Electronic Unit includes the Power Supply Unit, the Control and Data Handling Unit (built around the commercial Intel 386 processor and includes the I/O boards and the VME boards), the Motor Drive Electronics and the Control Panel Interface. The Rack Interface Unit interfaces directly to the ISS power supply. It provides electrical protection, electrical filtering and the automatic switching between the ISS Main and Auxiliary power supplies. It also selects automatically the active bus. A battery driven Temperature Data Recorder records the temperature in the dewars when MELFI is not powered.

MELFI uses International Standard Payload Rack interfaces such as:
- 120 V Electrical Power from the Main and Auxiliary buses (no Auxiliary bus in MPLM);
- Cold Water Loop (nominally 3.3 to 7.2ºC) for cooling the EU and the BM, and removing heat from the Brayton cycle;
- the US Lab Payload 1553B bus for controlling MELFI (MPLM 1553B bus when flying in MPLM).

Being a freezer, the continuous availability of MELFI is a key parameter for the success of the mission. Therefore, several key components of MELFI are designed as Orbital Replaceable Units.

In addition to the flight units, the MELFI project includes the following ground units:
- Laboratory Ground Model
- MELFI Training Unit
- MELFI Engineering Unit.

Specifications

Facility size and mass:	Double size International Standard Payload Rack. Maximum mass about 800 kg, including spares and up to 100 kg cold payload.
Modular Stowage Volume:	Total stowage volume of 300 litres, in four independently controlled dewars
Minimum Active Configuration:	at least 1 dewar at - 80º C
Multiple Mission Configurations:	Combinations of dewars at three different temperature modes (- 80, - 26 and + 4º C) Nominally, no more than one dewar at - 26º C and/or + 4º C are allowed at any given time.
Controlled Temperatures:	- 80º C Mode: samples maintained below - 68º C - 26º C Mode: samples maintained in - 37º C to - 23º C range + 4º C Mode: samples maintained in the + 0.5º C to + 6º C range
Type of Samples Stowed	
Cell Culture:	of 1 to 10 ml size
Fluid Samples (blood, media, etc.):	of 1 to 500 ml size
Specimens/Dissection Tissues:	of 2 to 10 ml size
Specimens (whole):	of 10 to 500 ml
Loading capabilities:	Sample mass equivalent to 100 ml saline solution each 45 minutes, up to 2 kg of samples per day from ambient temperature to - 80º C.
Typical Specimen Cooling Time	(from + 23º to - 68º C) in 0-g conditions:
Samples of 2 ml:	18 to 25 minutes
Samples of 5 ml:	29 to 41 minutes
Samples of 10 ml:	44 to 56 minutes
Samples of 100 ml:	165 minutes
Samples of 500 ml:	460 minutes maximum
Power-Off Survival:	Temperature conditions maintained for at least 8 hours without electrical power
Power Supply:	Main and Auxiliary bus automatic switching provided
Power Consumption:	Ranging from 550 W to 900 W depending on the active configuration
Heat Rejection:	Water cooled
Facility Control:	From ground or from the ISS Laptop through the payload MIL Bus 1553B, and manually from the control panel