

# Cold Stowage Flight Systems

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The International Space Station (ISS) provides a test bed for researchers to perform science experiments in a variety of fields, including human research, life sciences, and space medicine. Many of the experiments being conducted today require science samples to be stored and transported in a temperature controlled environment. NASA provides several systems which aid researchers in preserving their science. On orbit systems provided by NASA include the Minus Eighty Laboratory freezer for ISS (MELFI), Microgravity Experiment Research Locker Incubator (MERLIN), and Glacier. These freezers use different technologies to provide rapid cooling and cold stowage at different temperature levels on board ISS. Systems available to researchers during transportation to and from ISS are MERLIN, Glacier, and Coldbag. Coldbag is a passive cold stowage system that uses phase change materials to maintain temperature. Details of these current technologies are provided along with operational experience gained to date. This paper discusses the capability of the current cold stowage hardware and how it may continue to support NASA's mission on ISS and in future exploration missions.

## I. Introduction

With Shuttle retirement looming, NASA has protected the capability to provide a temperature controlled environment during transportation to and from the ISS. The furthered use of the Minus Eighty Laboratory freezer for ISS (MELFI), Microgravity Experiment Research Locker Incubator (MERLIN), Glacier, Ice Bricks and Coldbags will allow this mission to continue. Most of the cold stowage hardware either is or is planned to be certified to fly on future vehicles such as SpaceX Dragon, and Orbital's Cygnus Vehicles.

## II. Hardware and Capabilities

The CS Group supports the needs of the International Space Station (ISS) Program with both powered (MELFI, MERLIN and Glacier) and unpowered hardware (Coldbag and Ice Bricks).

### A. MELFI

The Minus Eighty Laboratory Freezer for ISS (MELFI) is a European Space Agency (ESA)-provided rack. Each MELFI has four identical dewars which can be controlled independently at certain set points when Dewar 2 is set at -95°C. The three set points for dewar temperatures are -95°C, -35°C, and +2°C. One MELFI can hold 175 liters; each dewar holds approximately 44 liters and is divided into four quadrants, each of which holds a tray. Each tray contains two ½ box modules which hold individual science samples. Although MELFI is designed for storage and cooling of samples, it does not provide any containment for samples. Sample containment is the responsibility of the Payload Developer (PD).

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There are three MELFI Flight Units on ISS. Currently Flight Unit 1 and 3 are in the Japanese Experiment Module (JEM) and Flight Unit 2 is in the US Lab. There is also one Training Unit, one Laboratory Ground Model (LGM), and one Engineering Qualification Unit (EQM) all located at Johnson Space Center (JSC).



**Figure 1. MELFI**



**Figure 2. MELFI Tray Insertion**

## B. MERLIN

MERLIN is a single-middeck-locker sized, powered unit that will both cool and incubate science. It can be used on-orbit as well as for stowage transportation to and from orbit. It can maintain approximately +4°C to +48.5°C in air cooling mode (rear breathing) and temperatures as low as -20°C in water cooling mode on ISS. The MERLIN's maximum heating rate is 15°C/min to +48.5°C.

MERLIN supports a maximum payload size of 7.62 cm x 17.53 cm x 31.24 cm (4.17 liters), with 1" of foam on the inside walls of the MERLIN internal pouch.

There are seven Flight Units and a Qualification/Trainer unit owned by University of Alabama at Birmingham (UAB) Center for Biophysical Science and Engineering (CBSE). After shuttle retirement, a minimum of 3 MERLIN units will remain onboard ISS.

MERLIN is compatible with Shuttle Middeck, MPLM, ISS, Progress, ATV and HTV. In the future it can be certified for future vehicles such as SpaceX Dragon and Orbital's Cygnus Vehicles.



**Figure 3. MERLIN with pouch**

## C. Glacier

Glacier is a double-middeck locker sized, powered refrigerator freezer. It can be used on-orbit as well as for cold transportation to and from orbit. Glacier can cool using air (rear breathing) or water (front panel QD's) and supports a selectable temperature range of +4°C to -95°C on air or -130°C on water. Glacier can accommodate approximately 11.35 liters of payload in two tray configurations: the 4 tray configuration, as shown in Figure 4, or a two double sized tray configuration that is currently being developed.

Glacier is compatible with Shuttle Middeck, MPLM, and ISS, as well as future vehicles such as SpaceX Dragon, and Orbital's Cygnus Vehicles. There are Six Glacier Flight Units with two additional Flight Units to be built to support extension of ISS (2012).

Two Glaciers are planned to remain on ISS after Shuttle retirement.



**Figure 4. Glacier with door open showing regular size trays**

#### **D. Ice Brick**

Ice Bricks are solid-liquid phase change material in a hard plastic rectangular container compatible with the cold storage systems.

The Ice Bricks are designed to be conditioned on-orbit in active freezers (e.g. MELFI, Glacier, MERLIN) and are available in specific melting temperatures: +4°C, -26°C, -32°C. Other phase change materials with melting temperatures such as +23°C and +37°C are under investigation.

#### **E. Coldbag**

Coldbag is a passive, low temperature science storage resource for transportation to and from orbit. The Coldbag complement consists of 14 Double Coldbags and various Ice Bricks to provide cold conditioning for Coldbag contents. Temperature hold times depend on the Ice Brick type and quantity, and the environment.

With a standard compliment of Ice Bricks, a Coldbag can support a sample size up to 10.16 cm x 33.3 cm x 28.5 cm (9.6 liter) in size within a cavity formed by 12 Ice Bricks.

The Coldbag is compatible with Shuttle Middeck, MPLM, ISS, Progress, ATV, HTV as well as future vehicles such as SpaceX Dragon, and Orbital's Cygnus Vehicles.

During ascent or descent, Coldbags need to be stowed in early retrieval locations due to their limited hold times. Coldbags can be stowed in a locker or soft stowed, but if soft stowed, heavy items must not be stowed on top of Coldbags.



**Figure 5. Coldbag with Ice Bricks**

## **F. Operations**

Due to their nature, launch/landing ops with passive cooling hardware should have late load and early destow requirements. On average, the Coldbag can keep a payload frozen (below  $-20^{\circ}\text{C}$ ) for appx 130 hours. Loading the Coldbag onto the vehicle as late as possible (for launch or return) gives the maximum hold time for the payload.

The Cold Stowage (CS) group provides engineering oversight for hardware development and operations. It also delivers CS hardware to KSC for flight and performs off-line operations during both launch and landing. The CS group also supports on orbit operation involving cold stowage assets. A Remote Operations Center is located at the CS Team's facilities to allow for real time support and collaboration.

At JSC the CS Group has the ability to conduct thermal cycle testing (i.e. acceptance thermal cycle, cryo-cycle, etc.) in the range of  $+93^{\circ}\text{C}$  to  $-191^{\circ}\text{C}$ . It can also conduct thermal performance tests (e.g. determine how long samples will stay cold in Double Coldbag or MELFI during a power off) and end-to-end Science Verification testing duplicating planned on-orbit scenarios with CS Fleet.

The group also supports Crew Training on the entire CS fleet.

## **G. Lessons Learned**

The experience gained while supporting the launch, landing and on-orbit operations of the Space Program has given the Cold Stowage group insight into how best to successfully perform stowage and transfer of temperature critical payloads.

Lessons learned include:

1. The use of secondary containment, such as plastic bags, can greatly increase the volume a sample takes up in the CS hardware. Care must be taken to use as small a plastic bag as possible and to remove as much air as possible.
2. On-orbit Packing procedures need to be as simple as possible.
3. Packing samples in microgravity is much more difficult than ground based tests and training demonstrate..

## **H. Post Shuttle Future**

Post Shuttle, the CS Group will continue to support the cold stowage needs of the Space Program by utilizing current launch vehicles including ATV, HTV, Progress and Soyuz, and future vehicles including SpaceX and Orbital.