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International Space Station Permanent Multi-purpose Module (PMM) Life Extension

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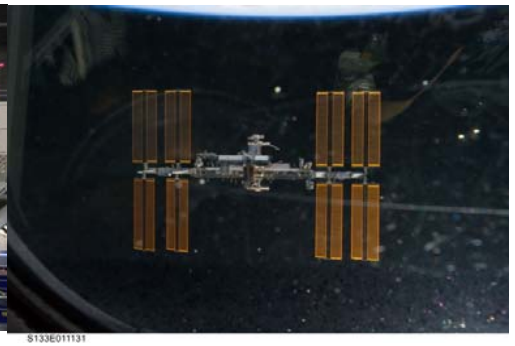
ISS Pressurized Logistics Resupply and Return Element: The Multipurpose Logistics Module (MPLM)

- The International Space Station first United States element launch was the Unity Node (Node 1) in December 1998 (STS88) which docked to the Russian built Zarya (FGB) element.
- All U.S. pressurized modules, truss segments, solar arrays, radiators, etc., as well as the European and Japanese pressurized modules have been launched within the Space Shuttle Orbiter's cargo bay and assembled/integrated on orbit.
- The International Space Station has been continuously occupied for over ten years (since November 2000).
- Three Multipurpose Logistics Module (MPLM) were designed and built by the Italian Space Agency and delivered to NASA in 1998-1999 to deliver and return pressurized cargo to and from the station via the Shuttle Orbiter.
- The MPLM Flight Module #1, was named "Leonardo" after the famous Italian artist Leonardo DaVinci. Leonardo has been an integral part of the International Space Station since its first resupply flight in March 2001 on STS102.

ISS after STS102/5A.1 mission

Leonardo in Module Rotation Stand at KSC



ISS after STS133/ULF5 mission

Photo source: http://io.jsc.nasa.gov

Leonardo Module Flight History

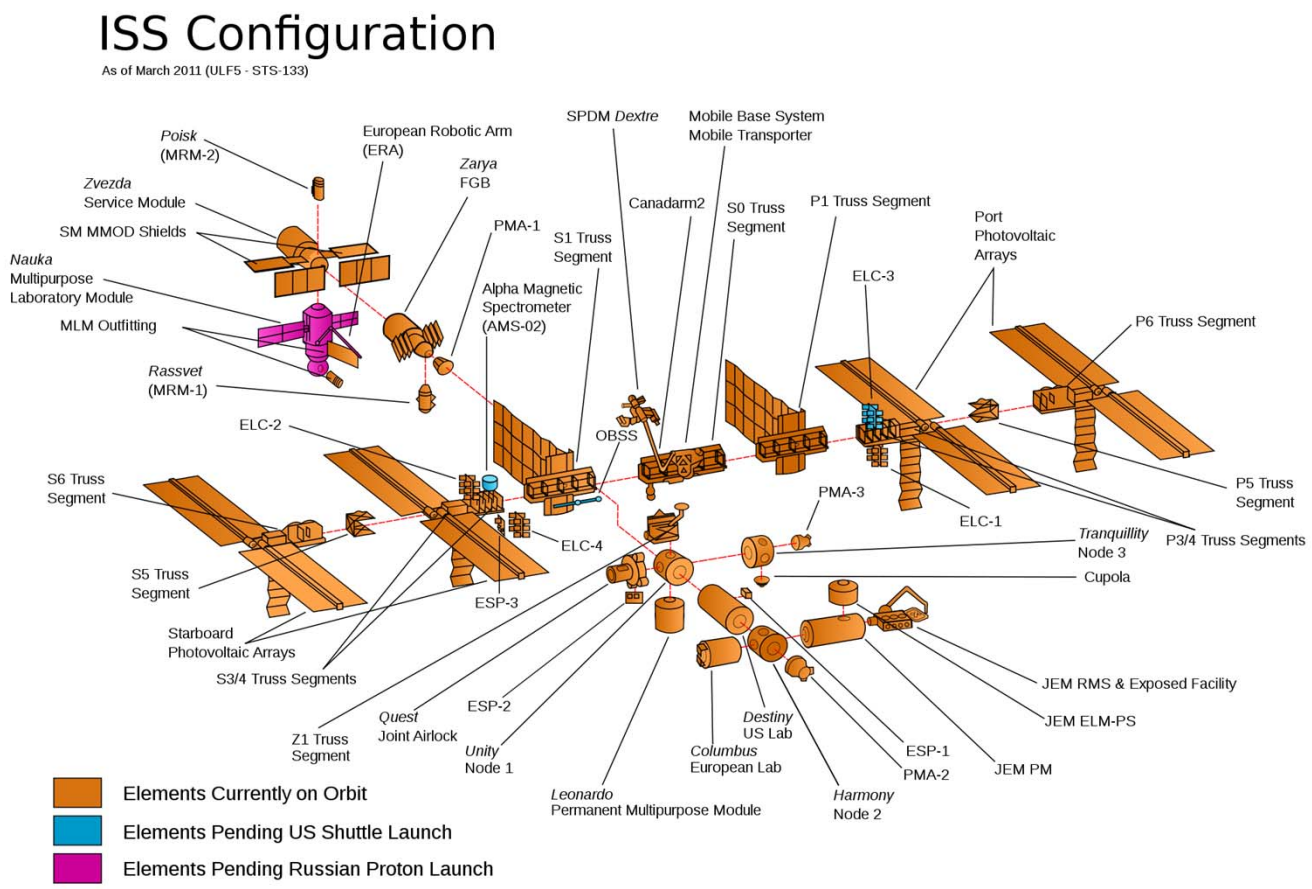
- To date, there have been 10 MPLM missions. Seven of these were using the Leonardo Flight Module #1 (FM1) and three using the Raffaello Flight Module #2 (FM2).
- After 10 years and 7 MPLM missions the Leonardo Module was re-certified to serve as the ISS Permanent Multipurpose Module which will provide a significant increase in on-orbit pressurized storage accommodations, serving as a key part of a long term, integrated stowage solution for the ISS.
- Leonardo's legacy continues as the Permanent Multi-Purpose Module (PMM) when it was launched for the eighth time aboard STS133.

Shuttle flight Designation	ISS Flight Designation	Shuttle	Module Designation	Shuttle Mission dates
STS-102	5A.1	Discovery	MPLM-FM1	3/8-3/21/2001
STS-105	7A.1	Discovery	MPLM-FM1	8/10-8/22/2001
STS-111	UF2	Endeavor	MPLM-FM1	6/5-6/19/2002
STS-121	ULF1.1	Discovery	MPLM-FM1	7/4-7/17/2006
STS-126	ULF2	Endeavor	MPLM-FM1	11/14-11/30/2008
STS-128	17A	Discovery	MPLM-FM1	8/28-9/11/2009
STS-131	19A	Discovery	MPLM-FM1	4/5-4/20/2010
STS-133	ULF5	Discovery	PMM	2/24-3/9/2011 *

* The PMM continues to operate on the ISS at the Node 1 nadir port

Photo source: http://io.jsc.nasa.gov
Flight History Information: Shawn Reagan, MPLM Project Manager,

ISS Configuration
Components and Elements



Sources: http://en.wikipedia.org/wiki/File:ISS_configuration_2011-02_en.svg
and http://www.nasa.gov/images/content/166624main_iss_config_012007.jpg

How big is the ISS??

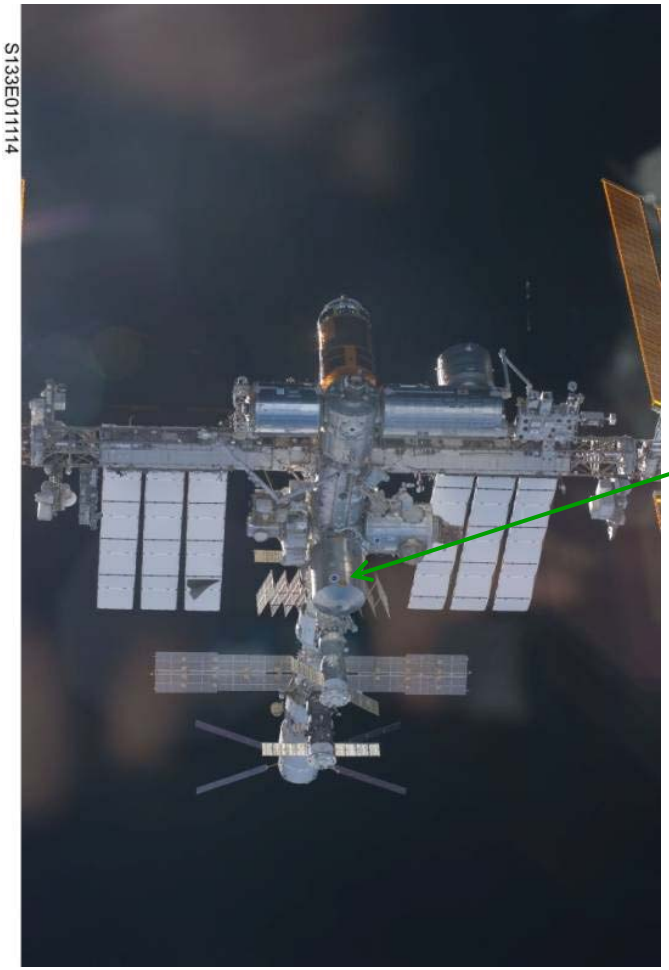
International Space Station Size & Mass

Pressurized Volume Length: 167.3 feet (51 meters)
Truss Length: 357.5 feet (109 meters)
Solar Array Length: 239.4 feet (73 meters)
Mass: 816,349 lb (370,290 kilograms)
Habitable Volume: 12,705 cubic feet (360 cubic meters)
Pressurized Volume: 29,561 cubic feet (837 cubic meters)
Power Generation: 8 solar arrays = 84 kilowatts

Source:
http://www.nasa.gov/mission_pages/station/main/onthestation/facts_and_figures.html

PMM Location at Node 1 Nadir

S133E007807

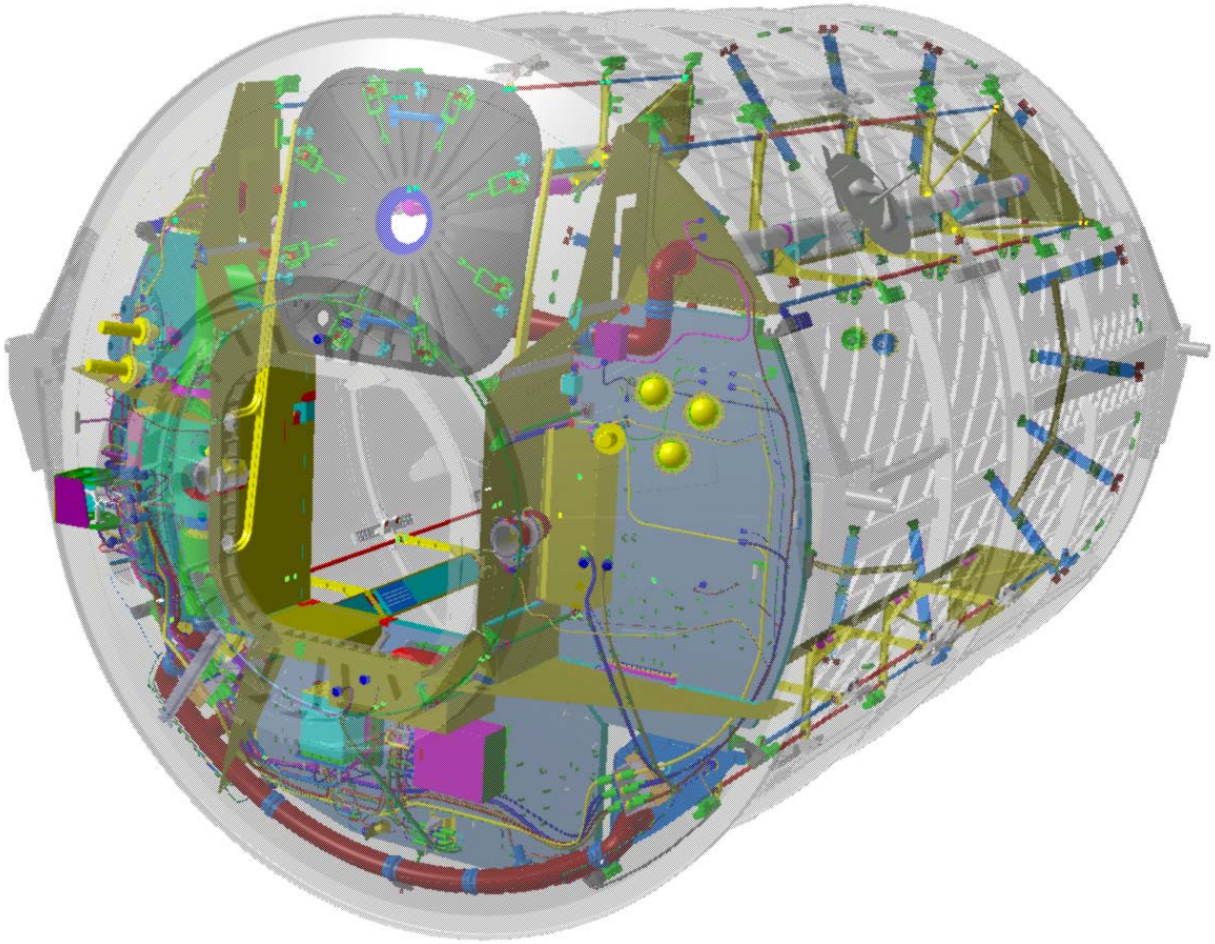


S133E011114

PMM docked to Node 1 Nadir

Photo source: http://io.jsc.nasa.gov

PMM Internal Configuration



Source: ASI/TASI chart in the PMM Acceptance Review Data Package

Examples of Differences between the MPLM and the PMM

- Mission Duration
  - MPLM designed for 25 Shuttle launch/landing cycles with a 10 year static/operational life. Shuttle missions are typically around 14 days long.
  - PMM has a 10 year on-ISS operational life starting after activation on STS133.
- Environments (short-term vs long-term)
  - Exposure to radiation, micrometeoroid/orbital debris, uv/atomic oxygen
  - Contributions to ISS external contamination environment (e.g., the addition of Nextel-Kevlar blankets)
  - Exposure to more extreme ISS thermal environments including during visiting vehicles approach/departure.
- Maintenance
  - MPLM designed to be maintained on-ground by KSC team
  - PMM will be maintained on-orbit by ISS crew
- Structural Loads
  - MPLM was designed for 25 Shuttle launch/landing cycles with short duration exposure to ISS loads at the Node Common Berthing Mechanism (CBM) nadir port.
  - PMM will experience 10 years of ISS loading at the Node 1 nadir CBM port which would include ISS reboost.

PMM Risk Management Approach

- A risk-based assessment was conducted to confirm that the 10 year old Leonardo module's life could reasonably be extended for an additional 10 years of on-orbit operational life.
- Key assumption for certification of Leonardo as a permanent element: Failure tolerance for Leonardo is unchanged for conversion from MPLM to the PMM. For example: If power is lost and cannot be recovered, the ultimate response would be to close the hatch (to isolate the module).
- A review of the following was conducted as a part of the PMM re-certification:

1. MPLM requirements and verifications with those required for a permanent ISS element.
2. MPLM Materials Usage Agreements (MUAs) for continued applicability
3. ISS Problem Reporting and Corrective Action (PRACA), approved waivers/exceptions, and Electromagnetic Effects (EME) Tailoring Interpretation Agreements (TIAs) for PMM applicability
4. Leonardo systems and components to identify hardware which had already or would soon reach their specified MPLM operational life and/or static age life limit.
5. Accessibility of critical components/ORUs to ensure that on-orbit maintenance was feasible.
6. Routine MPLM mission processing and system testing to identify necessary changes.

PMM Verification Approach

- The PMM Prime Item Development Specification (PIDS) was developed and used for verification.
  - A critical initial task was to identify and mutually agree upon the “still valid” MPLM requirements and verifications.
  - The MPLM requirements which were unchanged used the original verifications closures. No new assessment was required.
  - New or modified requirements were verified using new analyses and test data that was augmented with original MPLM data as necessary.
  - The PMM team spent considerable time discussing the additional information which was needed to accept PMM modified hardware and to close the modified requirements.
  - Updated analyses (e.g., thermal, structural, external contamination, radiation, etc.) were conducted by the Thales Alenia Space Italy (TASI).
  - The TASI/KSC leakage testing of the module and feed-through seals provided the verification data for closing the new PMM leakage requirement.

PMM ORU list
(ref: TASI-PMM-ORP-0012)

- Based upon extensive review of TASI logistics analysis and the outputs of the Logistics Support Analysis Records (LSAR) Database, a list of Orbital Replacement (ORU) candidates was identified and jointly agreed upon by NASA and TASI.

- For each individual ORU, step-by-step on-orbit maintenance procedures are developed.

In the following pages the list of the PMM LSA candidates items is included:

Part Number	Assigned LCN	Location	Nomenclature	Installed Qty	ISS Common HW
8266726-903	SQDAS0	Zenith Cone, Stbd Side	MDM	1	Y
658470	SQDBS0	Zenith Cone, Stbd Side	PDB	1	N
02-HCU-00.000	SQGBA0	Zenith Cone, Aft Side	HCU	1	N
SV819591-4	SQGCA0	Zenith Cone, Aft Side	Cabin Fan Assembly	1	Y
2119814-3-1	SQIAF0	Zenith Cone, Fwd Side	Duct Smoke Detector	1	Y
B40482-3	SQGAA0, SQGAF0	Zenith Cone, Aft/Fwd Side	IMV Shut-Off valve	2	N
219006-1	SQPAF0	Zenith Cone, Fwd Side	Remote Control Assembly	1	Y
SV822093-1	SQKAA0, SQKBA0, SQKCA0	Zenith Cone, Aft Side	Total Pressure Sensor	3	Y
1260066	SQKAS0	Zenith Cone, Stbd Side	Air Temperature Sensor	1	N

Table 1: PMM LSA Candidate Item List - Internal Equipment Hardware

PMM hardware activities supporting life extension

- Physical hardware inspections for potential materials degradation
- Replacement of large diameter seals in the Aft Access Closure (AAC) and Passive Common Berthing Mechanism (PCBM), and ECLSS valves feed-through plate in the +Y Fwd Cone.
- Testing of all seals except the hatch window seal.
- Augmentation of Micro-Meteoroid Orbital Debris (MMOD) shielding and blankets to meet more stringent MMOD requirement as a permanent ISS element.
- Modification of access panels and cabling to allow tilting for on-orbit access for maintenance.

Example of PMM Seal Life Assessment Spreadsheet (reference TASI-PMM-ORP-0007)

	On-Station Path to:		Seal:							
PMM Feedthrough	Node 1 Vestibule	Space Vacuum	Part Number	Material	Certificate Date	TAS-I Recommendation for Remove&Replace	Disturbed since MPLM Delivery to NASA (N4)	Remove&Replace Impact Assessment (if done)	Potential Risks to Flight Hardware (if done)	TAS-I Recommendation for Leak Check
Bulkhead										
Hatch	X		683-13095-1	Metallic/Silicone	Expires in 2017	No	No	High (N5)	High (N5)	Yes / done by KSC
Hatch Sampling Port	X		2-010 S383-70 2-014 S383-70	Silicone	Expires in 2017	No	No	Low	Low	Yes / done by KSC
MPEV	X		TBD (N7)	Silicone	Expires in 2017	No	No	High (N5)	High (N5)	Yes / done by KSC
J03 Electrical	X		TBD (N6)	Silicone	Expires in 2017	No	No	Low	Low	Yes / done by TAS-I
Fwd Cone										
PCBM to Module		X	683-13530-21 683-13530-17	Silicone	Expires in 2017	No	No	Very High	Very High	Yes / done by KSC
ECLSS Valves +Y Feedthrough Plate		X	968288	Metallic/Silicone	20 years (new seal)	Yes (N3)	No	Low	Low	Yes / done by TAS-I
PPRA3		X	TBD (N7)	Silicone	Expires in 2017 (N1)	No	Yes	Medium	Low	Yes / done by TAS-I
NPRV1		X	TBD (N7)	Silicone	Expires in 2017 (N1)	No	No	Medium	Low	Yes / done by TAS-I
Aft Cone										
AAC to Module		X	968287	Metallic/Silicone	20 years	Yes (N3)	No	Medium	Low	Yes / done by KSC

ISS Permanent Multipurpose Module (PMM)
Part Of An Integrated Logistics/Stowage Solution for ISS.






PMM Launch date: February 24, 2011
Aboard STS-133/ULF5

Photo source: http://io.jsc.nasa.gov

PMM Before, During and After

Source: chart from a presentation made by Hubert Brasseux (NASA-JSC);
photos from http://io.jsc.nasa.gov/app/collections.cfm?cid=9994

PMM Project Management
NASA Organization

- PMM Project Manager: Rafael Garcia, NASA-JSC
- MPLM Project Manager: Shawn Reagan, NASA-MSFC
- KSC Launch Package Manager: Scott Higginbotham, NASA-KSC
- JSC Chief Engineer: Larry Moon, NASA-JSC
- MSFC Chief Engineer: Dallas Clark, NASA-MSFC
- SE&I Lead: Kathy Jones, NASA-MSFC
- Verification Lead: Jerry Owens, NASA-MSFC
- Operations Lead: Hubert Brasseux, NASA-JSC
- Configuration Management and Data Management Lead: Kathy Moorhead, MSFC-Colsa Corp
- Administrative Assistant Wendy Reiter, JSC-Boeing