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National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

Assessment of Transporting the Portable Fire Extinguisher (PFE) onboard the Multi Purpose Logistics Module (MPLM) for the Flight 7A.1 Mission

PHASE III

SAFETY DATA PACKAGE

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PREFACE

This document contains the assessment for transporting the Portable Fire Extinguisher onboard the Multi Purpose Logistics Module (MPLM) for the Flight 7A.1 mission. This data has been assessed in accordance with the requirements of SSP 50021, "Safety Requirements Document". The data is presented in the format for Phase III as outlined in SSP 30599, "Safety Review Process".

This document was prepared by the Marshall Space Flight Center Space Cargo Assurance Department (QS22) in response to Technical Task Agreement XXXX. The information contained herein represents the MPLM and PFE hardware design as of July 2001. Any changes to the hardware design or its anticipated use will be evaluated to determine its impact to safety and changes to this document will be made accordingly.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS

AAC	Aft Access Closure
ACBM	Active Common Berthing Mechanism
ACE	Advanced Carrier Equipment
ACON	Aft end cone
ACS	Atmosphere Control and Supply
ACYL	Aft cyclinder
AFD	Aft Flight Deck
AKA	Active Keel Assembly
APCF	Advanced Protein Crystal Facility
APCU	Auxilairy Power Converter Unit
ARS	Atmosphere Revitalization System
ASE	Airborne Support Equipment
ASI	(Italian Space Agengency)
ATCS	Active Thermal Control Subsystem
ATLAS	Atmospheric Laboratory for Applications and Science
AVS	Avionics System
BCSS	Biotechnology Cell Science Stowage
BSTC	Biotechnology Specimen Temperature Controller
BTR	Biotechnology Refrigerator
BULK	Bulkhead
CBM	Common Berthing Mechanism
CDR	Comander
CE	Cargo Element
CFA	Cabin Fan Assembly
CG	Center of Gravity
CHeCS	Crew Health Care System
CI	Cargo Item
CWC	Continegency Water Container
D&C	Displays and Control
DA	Depressurization Assembly
DAK	Double Aluminized Kapton
DC	Direct Current
DCPCG	Dynamically Controlled Protein Crystall Growth
DDCU	DC to DC Converter Unit
DDCU-E	DC/DC Converter Unit – External
DFRC	Dryden Flight Research Center
DOC	Document
DP	Delta Pressure (Delta Pressure Sensor)
EAS	External Ammonia Servicer
ECLSS	Environmental Control and Life Support System
ECS	Environmental Control System
EEL	Emergency Egress Lighting
EGSE	Electrical Ground Support Equipment
ELH	Electrical Harness
ELPS	Emergency Lighting Power Supply
ELS	Emergency Lighting System
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMU	Extravehicular Mobility Unit
ERS	Element Rotation Stand
ERS	Element Rotating Stand
ESD	Electrostatic Discharge
EURECA	European Retrievable Carrier
EVA	Extravehicular Activity
EXPRESS	Expedit the Processing of Experiments to Space Station
F/T	Feed Through
FCON	Forward end cone
FCYL	Forward Cyclinder

FDI	Fault Detection and Isolation
FEU	Flight Equivalent Unit
FM1	Flight Module 1 (Leonardo)
FM2	Flight Module 2 (Rafaello)
FM3	Flight Module 3 (Donatello)
FMEA	Failure Mode and Effects Analysis
FRGF	Flight Releasable Grapple Fixture
FSE	Flight Support Equipment
FSW	Flight Software
FWD	Forward
GAS	Get Away Special
GLA	General Luminaire Assemblies
GN_2	GASEOUS NITROGEN
GO_2	GASEOUS OXYGEN
GRAP	Grapple Fixture
HCU	Heater Control Unit
HDBK	Handbook
HEAT	Hitchhiker Experiments Advancing Technology
HR	Hazard Report
HRF	Human Research Facility
IBSS	Infrared Background Signature Survey
ICC	Integrated Cargo Carrier
ID	Inside Diameter
IMV	Intermodule Ventilation
ISPR	International Standard Payload Racks
ISS	International Space Station
ITCS	Internal Thermal Control System
IV	Intravehicular
JEM	Japanese Experiment Module
JSC	Johnson Space Center
KEELFIT	Keel fitting
KHB	KSC Handbook
KSC	Kennedy Space Center
LAB	Laboratory
LB	Pound
LCC	Launch Commit Criteria
LIDAR	Light Detection and Ranging
LITE	LIDAR in Space Technology Experiment
LSU IPT	Launch Support Integrated Product Team
MAINFIT	Main Fitting
MBE	Metal Bellows Expander
MDM	Multiplexer/Demultiplexer
MDPS	Meteoroid and Debris Protection System
MLI	Multi-Layer Insulation
MLP	Mobile Launch Platform
MMSE	Multi Misson Support Equipment
MPLM	Multi Purpose Logistics Module (formerly Mini Pressurized Logistics Module)
MS1	Mission Specialist 1
MS2	Mission Specialist 2
MSFC	Marshall Space Flight Center
MSS	MOBILE SERVICING SYSTEM
NASA	National Aeronautics and Space Administration
NCR	Non-Compliance Report
NDE	Nondestructive Evaluation
NHB	NASA Handbook
NPRA	Negative Pressure Relief Assembly
NPRV	Negative Pressure Relief Valve
NSTS	National Space Transportation System
OD	Outside Diameter
ODA	Orbiter Disconnect Assembly
ODM	Orbiter Deployment Mechanism

ODS	Orbiter Docking System
OPIRS	Orbiter/Payload Interface Requirements Summary
ORU	Orbital Replacement Unit
OSVS	On orbit Space Vision System
PBA	Portable Breathing Apparatus
PCA	Pressure Control Assembly
PCBM	Passive Common Berthing Mechanism
PCMMU	Pulse Code Modulation Master Unit
PDA	Payload Disconnect Assembly
PDB	Power Distribution Box
PDR	Preliminary Design Review
PFE	Portable Fire Extinguisher
PHA	Prelimianry Hazard Analysis
PLB	Payload Bay
PMA	Pressurized Mating Adapter
PPRA	Positive Pressure Relief Assembly
PPRV	Positive Pressure Relief Valve
PRS	Payload Retention System
PSI	Pounds Per Square Inch
PTCS	Passive Thermal Control Subsystem
QD	Quick Disconnect
R/F	Radio Frequency
RAB	Rack Attachment Blocks
RCA	Remote Control Assembly
ROAP	Removable Overhead Access Platform
RPCM	Remote Power Controller Module
RSP	Resupply Stowage Rack
RSR	Resupply/Return Stowage Rack
RTV	Room Temperature Vulcanizing
S&MA	Safety and Mission Assurance
S0	Starboard O Truss Element
SAFER	Simplified Aid for EVA Rescue
SAR	Safety Analysis Report
SDP	Safety Data Package
SEE	Standard End Effector
SEM	Student Experiment Module
SFOC	Shuttle Flight Operations Contract
SIP	Standard Interface Panel
SL	Spacelab
SLP	Spacelab Logistics Pallet
SMWLL	Super Middle Weight Longeron Latch
SPEC	Specification
SRMS	Shuttle Remote Manipulator System
SSP	Space Shuttle Program
SSP	Standard Switch Panel
SSRMS	Space Station Remote Manipulator System
STABFIT	Stabilizer fitting
STD	Standard
STS	Space Transportation System
TBE	Teledyne Brown Engineering
TCC	Thermal Control Coating
TCID	Test Configuration Identifier Build
TCS	Thermal Control System
UARS	Upper Atmosphere Research Satellite
UF-1	Utilization Flight 1
UF-2	Utilization Flight 2
UF-3	Utilization Flight 3
UNTS	USOS/NSTS Thermal Simulator
USA	United Space Alliance
W&CG EE	Weight and Center of Gravity End Effector
WMV	Water Modulation Valve

WOV	Water ON/OFF Valve
WPP	Water Pump Package
WSK	Water Servicer Kit

APPLICABLE DOCUMENTS LIST

THE APPLICABLE DOCUMENTS LISTED REPRESENT THE LATEST REVISIONS AVAILABLE AT THE TIME THIS DOCUMENT WAS PRINTED. ANY REVISIONS MADE AFTER THIS DOCUMENT WAS PRINTED ARE NOT CONSIDERED APPLICABLE.

ICD 2-19001	Shuttle Orbiter/Cargo Standard Interfaces
MSFC-HDBK-505	Structural Strength Program Requirements
MSFC-HDBK-527 F	Materials Selection List for Space Hardware Systems
MSFC-SPEC-522 B	Design Criteria for Controlling Stress Corrosion Cracking
MSFC-HDBK-1453	Fracture Control Program Requirements
MSFC-SPEC-250 A	General Specification for Protective Finishes for Space Vehicle Structures and Associated Flight Equipment
MSFC-STD-1249	Standard NDE Guidelines and Requirements for Fracture Control Programs
MSFC-STD-2594	MSFC Fastener Management and Control Practices
MSFC-STD-486	Torque Limits For Threaded Fasteners
MSFC-STD-561	Threaded Fasteners, Securing of Flight Hardware used on Shuttle Payloads and Experiments
NASA-STD-5003	Fracture Control Requirements for Payloads using the Space Shuttle
NHB 8071.1	Fracture Control Requirements for Payloads Using the National Space Transportation System
NSTS 1700.7 B	Safety Policy and Requirements for Payloads using the Space Transportation System
NSTS 07700, Volume XIV, Appendix 7	Space Shuttle System Payload Accommodations - Extravehicular Activities
NSTS 07700, Volume XIV, Appendix 4	System Description and Design Data – Structures and Mechanics
NSTS 18798 B	Interpretations of NSTS/ISS Payload Safety Requirements
NSTS 21000 IDD STD	Interface Definition Document for Standard Payload Accommodations
SSP 30233 E	Space Station Requirements for Materials and Processes
SSP 30245 C	Space Station Electrical Bonding Requirements
SSP 30558 B	Fracture Control Requirements for Space Station
SSP 30559 B	Structural Design and Verification Requirements
SSP 30599	Safety Review Process
SSP 41164	Italian Mini-Pressurized Logistics Segment
SSP 50005 B	International Space Station Flight Crew Integration Standard
SSP 50021	International Space Station Safety Requirements Document

REFERENCED DOCUMENTS LIST

	7A.1/STS-105 Quick Reference Summary
ISS-ECLSS-404-5A	Boeing Prime Hazard Report "Fire Event On-Board ISS"
MLM-RP-AI-0055	System Hazard Analysis for Flight OP's
SFOC-FL0884	Shuttle Crew Operations Manual OI-27
QA 10024D	System Safety Analysis Report for PFE, CO_2

1.0 INTRODUCTION

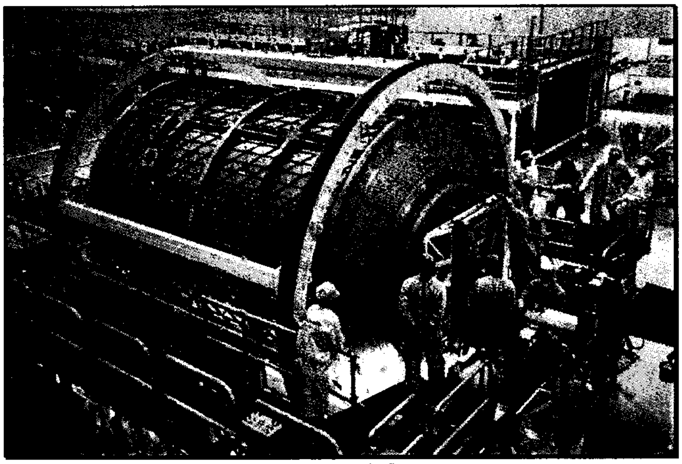


FIGURE 1. THE ITALIAN SPACE AGENCY'S LEONARDO LOGISTICS MODULE AS FINAL TESTING AND LAUNCH PREPARATIONS BEGIN AT THE KENNEDY SPACE CENTER, FLORIDA.

The Italian Space Agency (ASI)-built Leonardo Multi Purpose Logistics Module (MPLM) is the first of three pressurized modules that will serve as the International Space Station's "moving vans," carrying laboratory racks filled with equipment, experiments and supplies to and from the station aboard the Space Shuttle.

The unpiloted, reusable logistics modules function as both a cargo carrier and a space station module when they are flown. Mounted in the Space Shuttle's cargo bay for launch and landing, they are berthed to the station using the Shuttle's robotic arm after the Shuttle has docked. While berthed to the station, racks of equipment are transferred from the module to the station and are then replaced with racks and equipment from the station to be returned to earth. The logistics module is then detached from the station and positioned back into the Shuttle's cargo bay for the trip home. While in the cargo bay, the MPLM is independent of the Shuttle cabin, with no passageway for Shuttle crewmembers to travel from the Shuttle cabin to the module.

In order to function as an attached station module as well as a cargo transport, the logistics modules also include components that provide some life support, fire detection and suppression, electrical distribution and computer functions. Eventually, the modules will also carry refrigerator freezers for transporting experiment samples and food to and from the station. Although built in Italy, the logistics modules are owned by the U.S. and provided in exchange for Italian access to U.S. research time on the station.

The Leonardo module is the first of three such modules and was launched on Shuttle mission STS-102 in February 2001. On that flight, Leonardo was filled with equipment and supplies to outfit the U.S. laboratory module. The US Laboratory was launched on STS-98 in January 2001. The Rafaello module is the second MPLM module and was luanched on Shuttle mission STS-100. On its flight, Rafaello was used to continue outfitting the US Laboratory and to resupply the International Space Station.

Construction of ASI's Leonardo module began in April 1996 at the Alenia Aerospazio factory in Turin, Italy. Leonardo was delivered to Kennedy in August 1998 by a special Beluga cargo aircraft. The cylindrical module is approximately 21 feet long and 15 feet in diameter, weighing almost 4.5 (english) tons. It can carry up to 10 (english) tons of cargo packed into 16 standard space station equipment racks. Of the 16 racks the module can carry, five can be furnished with power, data and fluid to support a refrigerator freezer. The second module, named Rafaello, was delievered to KSC in 1999. The third module, named Donatello, was delivered to KSC in 2000.

1.1 SCOPE

This doucment was written to provide a safety assessment of transporting the Portable Fire Extinguisher aboard the Multi Purpose Logistics Module (MPLM). The information contained in this document was taken directly from othervdocuments including ISS-MPLM-DOC-002 "Multi Purpose Logistics Module (MPLM)/Orbiter Integrated Phase III Safety Data Package" and QA 10024D "System Safety Analysis Report for PFE, CO2".

TABLE 1. HARDWARE HAZARD REPORTS.

Hardware	Doc. No.	Title	Organization
MPLM	MLM-RP-AI00055	System Hazard Analysis for Flight OP's	Alenia
PFE	QA 10024	System Safety Analysis Report for PFE, CO2	Boeing/ARDE
MPLM/Orbiter	ISS-MPLM-DOC-002	Multi Purpose Logistics Module (MPLM)/Orbiter Integrated Phase III Safety Data Package	MSFC

In writing this hazard analysis, the causes, controls, and verifications used in Appendix A were taken directly from an existing hazard analysis where possible. New controls and verifications were only written in cases where an existing hazard report could not be used. Hazard controls dealing with the PFE are based on the ARDE PFE Hazard Analysis. This hazard report was presented to the SRP sometime in the past. Hazard controls for the MPLM side of the MPLM/PFE interface were written based on information from Alenia's MPLM Hazard Analysis for the MPLM and infromation provided by the MPLM Cargo Element Integator at JSC. Additional information was taken from previous Boeing-Prime Hazard Reports for several Boeing built elements.

Hardware	Manufacturer	Responsible Organization	
MPLM	Alenia	MSFC	Station Hardware
PFE	ARDE/Boeing	JSC(Boeing)	Station Hardware

2.0 MISSION OVERVIEW

Flight 7A.1 is scheduled to fly on STS-105 (Discovery) in the July to August timeframe of 2001. The primary objective of this flight is crew rotation with the Expedition 3 crew replacing the Expedition 2 crew on the International Space Station at the conclusion of this flight. Subsequent objectives include the transfer of logistics and utilization payloads for Station Increment 3. Table 2 shows the Flight 7A.1/STS-105 crewmembers.

TABLE 2. FLIGHT 7A.1/STS-105 CREWMEMBERS.

Flight 7A.1/STS-105 Crewmembers					
ISS 7A.1 Crew		Expedition 3 Crew		Expedition 2 Crew	
CDR	Scott J. Horowitz	ISS3-1	Frank Culbertson (CDR)	ISS2-1	Yuri Usachev (CDR)
Pilot	Frederick W. Sturkow	ISS3-2	Vladamir Dezhurov	ISS2-2	James Voss
MS1	Patrick G. Forrester EV1	ISS3-3	Mikhail Turin	ISS2-3	Susan Helms
MS2	Daniel T. Barry EV2				
Note: Flight 7A.1 is currently planned as a crew rotation mission.					

For Flight 7A.1, Discovery has been outfitted with the Orbiter Docking System (ODS) and the following payload carriers: the Integrated Cargo Carrier (ICC), the Multi Purpose Logistics Module (MPLM) Leonardo, and Hitchhiker Experiments Advancing Technology (HEAT). The ICC is an unpressurized carrier used to secure Orbital Replacement Units (ORUs) during the launch and on orbit phases of the mission until they can be installed during mission EVAs. The Flight 7A.1 ICC is used to carry the S0 truss cables, the External Ammonia Servicer, and MISSE experiments. Current plans are to install these payloads on the station during the two scheduled EVAs. The MPLM is used primarily to carry logistics equipment related to Station Increment 3 and is described in greater detail below. The current mission profile calls for the Orbiter to dock to PMA 2 of the ISS on Flight Day 3. Station Crew handover and middeck equipment transfers are expected to begin immediately upon ingress. Shuttle middeck equipment consists primarily of equipment for crew rotation, MPLM activation, and the HRF and Dreamtime projects. The MPLM will be installed on the ISS and activated on Flight Day 4. This will give the STS-105 crew four full days to complete all rack and soft stowage transfers. The HEAT payload is actually a collection of Get Away Special (GAS) canisters under the direction of Goddard Space Flight Center. Heat consists of the following experiements: the Advanced Carrier Equipment (ACE) avionics system, Simplesat, the Student Experiment Module (SEM), G-774, and G-780.

The MPLM is a pressurized carrier that supports the ISS logistics scenario by providing the capability for cargo uploading and downloading without the need for Extravehicular Activity (EVA). The MPLM can be set up in one of two different configurations. These are the active configuration and the passive configuration. In the passive configuration, the MPLM is attached to the orbiter at its structural interfaces and receives power through the ROEU in order to operate the shell heaters and monitor the MPLM systems. These heaters are only powered while the MPLM is on orbit. During the launch and landing phases of the mission, the MPLM is unpowered. The active configuration is identical to the passive configuration except for the addition of the refrigerator/freezer system. This system allows the MPLM to carry payloads that have to be maintained at low temperatures and requires the use of the ROFU. The ROFU is an umbilical used to establish a fluid connection between the MPLM and the Orbiter heat exchanger system. An MPLM in the active configuration is also unpowered during the launch and landing phases of the mission. The MPLM is currently planned to operate in the passive mode until Flight UF-3.

On Flight 7A.1, the MPLM will carry twelve integrated racks. Two of these are experiment racks that will be transferred to the US Laboratory once on orbit (EXPRESS rack 4 and 5). The remaining ten racks are used for logistics and consit of six Resupply Stowage Racks (RSRs), and four Resupply Stowage Platforms (RSPs). All of these racks and platforms will be passive on Flight 5A.1 and no power is provided to the rack locations. The MPLM is composed of a cylindrical shell terminated on one side by a forward cone that includes hatch and berthing mechanism to allow on-orbit transfer of crew and utilities, and on the other side, by a large access door for cargo installation and removal on the ground.

The MPLM will not be powered during the ascent phase of Flight 5A.1. MPLM on-orbit activities begin after the payload bay doors have been opened. The MPLM is powered during this phase and is unpowered prior to docking. Once the Orbiter rendezvous and docks to the ISS, the MPLM is removed from the Payload Bay (PLB) and attached to the ISS. The racks and RSP stowage bags are transferred between the MPLM and the ISS. The Boeing Prime Hazard Analysis will address the hazards that could occur during rack and stowage transfer. The MPLM is detached from the ISS and secured in the Orbiter PLB. The hazards that are associated with the MPLM transfer to and from the ISS are addressed by the Boeing Prime Hazard Analysis. The Orbiter undocks, de-orbits, and lands.

Post flight the MPLM is inspected in the airlock area for any immediate damage, installed in the Element Rotating Stand where it is opened and the racks are removed and returned to the rack processing area. The maintenance activities are then performed including a possible reconfiguration from passive to active and a leak check. A MPLM storage period may be necessary.

The following tables provide additional on the Flight 7A.1 mission. Table 3shows the primary tasks set for the Flight 7A.1 mission. Those items in bold are tasks that involve the MPLM.

Table 4shows the US and Russian hardware to be transferred on this flight. Items in bold are items that are manifested in the MPLM.

TABLE 3. KEY MISSION OBJECTIVES.

Key Mission Objectives or Flight 7A.1/STS-105	
1	Water Transfer from Shuttle to ISS (10 CWC's)
2	Rotate Expedition 2 crew with Expedition 3 (includes mandatory crew equipment transfer and mandatory crew handover
3	**Berth MPLM to Node 1 nadir port, activate and checkout MPLM**
4	**Transfer to ISS from MPLM and middeck: critical systems, maintenance, and crew related cargo**
5	**Return MPLM to cargo bay**
6	EVA: Transfer and install the EAS, connect associated umbilicals, and apply heater power
7	EVA: Transfer and S0 LTA ORU heater power cables
8	Generic crew handover
9	**Transfer and stow EXPRESS racks in US lab**
10	Transfer active payloads from Shuttle middeck to US Lab, install in Rack #1, apply power. Transfer on-orbit payloads from US Lab to middeck for return.
11	**Transfer and stow critical return hardware from ISS to MPLM and middeck**
12	**Transfer and stow remaining hardware from MPLM and middeck to ISS**
13	**Transfer and stow remaining hardware from ISS to MPLM and middeck**
14	Flight specific crew handover
15	EVA: Transfer, install, and deploy MISSEPECs on joint airlock crew lock and high pressure gas tank #2
16	Perform Human Research Facility (HRF) Hoffman Reflex (H-Reflex) experiment data collection.
17	Perform Dreamtime payload activities
18	EVA: Install S0 LTA ORU heater power cables
19	EVA: Remove/relocate 2 handrails from the US Lab in preparation for Flight 8A.
Note: Activities related to the MPLM are in bold.	

TABLE 4. US AND RUSSIAN HARDWARE.

US and Russian Hardware manifested on Flight 7A.1/STS-105	
US Hardware	Russian Hardware

• CHeCS, crew provisions, and housekeeping pantry
• Temporary Sleep Station (TESS)
• Radiation Protection Bricks
• Utilization
  • **EXPRESS Racks 4 and 5**
  • Advanced Protein Crystal Facility (APCF)
  • Biotechnology Refrigerator (BTR)
  • Dynamically Controlled Protein Crystall Growth (DCPCG)
  • Dreamtime
  • Human Research Facility (HRF)
  • Biotechnology Cell Science Stowage (BCSS)
  • Biotechnology Specimen Temperature Controller (BSTC)
  • (2) MISSE Passive Experiment Carriers (PECs) (External)
• DC/DC Converter Unit – External (DDCU-E)
• Remote Power Controller Module (RPCM)
• S0 LTA ORU heater power cables and EVA handrails
• SAFER and EVA tools
• **Portable Fire Extinguisher (PFE)**
• ISS Ham
• 10 CWC's
	800 A Battery
	(50) Food Containers
	PTAB

Note: Items manifested on the MPLM are in bold.	

TABLE 5. PROJECTED UPCOMING MPLM MISSIONS.

Projected MPLM Missions					
Flight	Date	STS	MPLM	MPLM Manifest	MPLM/Orbiter Interfaces
5A.1	**Mar 2001**	**102**	**Leonardo**	**6 System Racks, RSRs, RSPs**	**PRLAs, AKA, ROEU**
6A	**Apr 2001**	**100**	**Rafaello**	**RSPs, RSRs, ISPRs**	**PRLAs, AKA, ROEU**
7A.1	Aug 2001	105	Leonardo	RSRs, RSPs, ISPRs,	PRLAs, AKA, ROEU
UF-1	Nov 2001	106	Rafaello	ISPRs, RSRs, RSP-2s	PRLAs, AKA, ROEU
UF-2	Apr 2002	109	Leonardo	ISPRs, 3 RSRs, 1 RSPs, 1 RSP-2s, MELFI	PRLAs, AKA, ROEU
ULF1	Aug 2002	113	Rafaello	RSRs, RSPs, ISPRs,	PRLAs, AKA, ROEU
UF-3	Jan 2005	129	Donatello	ISPRs, 1 JEM rack, 1 RSP, 1 RSP-2	PRLAs, AKA, ROEU, ROFU
UF-5	Sep 2005	133	Leonardo	ISPRs, 1 RSP, 1 RSP-2,	PRLAs, AKA, ROEU, ROFU
17A	Dec 2005	139	Rafaello	1 Lab system rack, 4 Node system rack, 3 CHeCS, 2 RSP-2s, ISPRs	PRLAs, AKA, ROEU, ROFU
UF-6	Jan 2006	135	Donatello	3 RSP-2s, 1 RSP, ISPRs	PRLAs, AKA, ROEU, ROFU
19A	Feb 2006	141	Leonardo	5 RSP-2s, RSR, ISPRs, 4 Crew Quarters	PRLAs, AKA, ROEU, ROFU
Note: Flight UF-3 may be the first flight of an MPLM in the active configuration, which means that the ROFU will be flown as well. Missions subsequent to Flight UF-3 may also be flown in the active configuration. Missions in bold have already flown.					

MPLM ECLSS

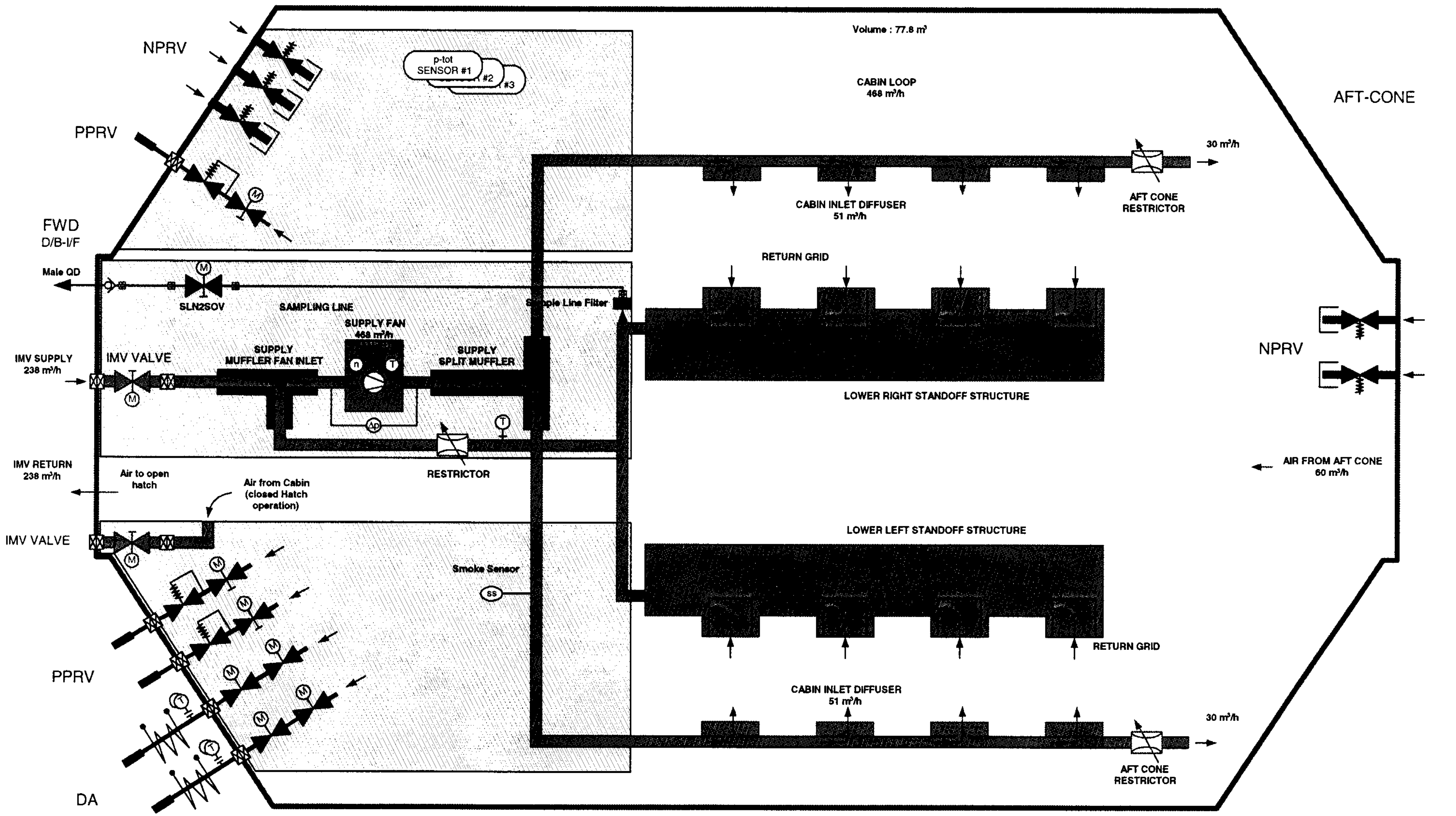


FIGURE 2. MPLM ECLSS SCHEMATIC.

4.0 HARDWARE DESCRIPTION

4.1 MPLM

The MPLM is a pressurized logistic system that is used in the International Space Station program for the two-way transport of supplies and materials (up to 9,000 kg), including user experiments, between Earth and orbit using the Shuttle. The MPLM is also designed to work attached to the International Space Station (ISS) to support active and passive storage and to provide a habitable environment for two people when in orbit. The configurations studied by Alenia Aerospazio allow transportation of passive cargo only, or a combination of passive and active cargoes utilizing cold cargo functions accommodated in refrigerator/freezer (R/F) racks.

The MPLM provides two major functions. It operates first, as a carrier that can be flown on multiple missions, and second, as a habitable module operating on orbit. To meet these two design goals, the MPLM was built with a complex robust system capable of operating for 25 missions over a period of 10 years. The MPLM is the first space station module designed as an active module in the Shuttle payload bay.

The MPLM is a pressurized cylindrical module measuring 4.6 m in diameter. Including the forward and aft cones, it measures 6.5 m with a total mass of 4,685 kg. The total payload carrying capability is 9,000 kg. The payloads are accommodated in sixteen tiltable and removable racks called International Standard Payload Racks or ISPRs. Five of these racks can be powered to allowed the transportation of payloads that require conditioning. The habitable volume remaining for the crew after the ISPR installation amounts to 31 m^3 (881 ft^3). The MPLM is designed to carry payloads that require a pressurized environment to and from the ISS. The MPLM is capable of transporting passive racks as well as racks requiring refrigerator or freezer interface services. For the passive missions, the MPLM is capable of carrying 16 racks. For active flights, the MPLM can carry 11 passive racks and 5 Refrigerator/Freezer Racks.

The MPLM external configuration consists of an Aluminum cylindrical shell that is closed at the ends with a forward cone and an aft cone. An external view is shown in Figure 3. The forward cone includes the common berthing mechanism for berthing the MPLM, the hatch, the vent valves, and the NSTS Orbiter umbilical connectors. The forward cone also contains equipment necessary to provide a comfortable working environment once attached to the station. The aft cone is terminated by an 8 foot diameter closure that can be removed during ground operations to facilitate integration activities.

The module is equipped with two grapple fixtures used to transfer the MPLM between the Orbiter and the ISS via remote manipulator system arms. The primary shell is covered with a Micrometeoroid Debris Protection System (MDPS) and is thermally isolated using a set of Multilayer Insulation Blankets (MLI). Once attached to the station, the MPLM is designed to function as part of the station for up to 16 days before it is returned to the Orbiter payload bay.

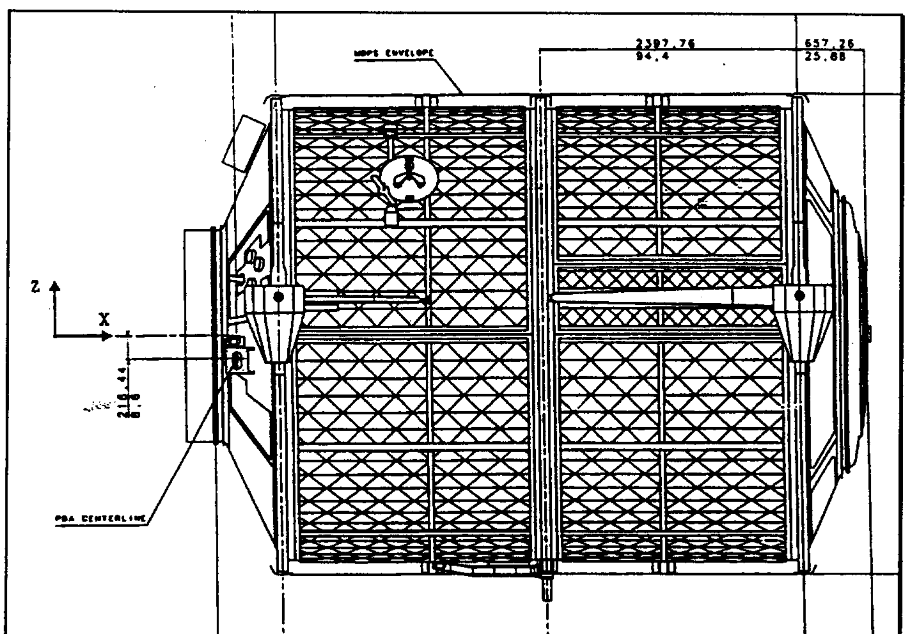


FIGURE 3. MPLM EXTERNAL CONFIGURATION (PORT SIDE VIEW).

4.1.1 STRUCTURE AND MECHANISM.

The MPLM Flight System consists of the primary structure, the secondary structure, and the mechanisms.

4.1.1.1 PRIMARY STRUCTURE.

The MPLM Flight System primary structure is designed to transport a maximum of 20,000 lbs (9,072 kg) of cargo and equipment. The main components of the primary structure are:

- The cylindrical shell, which consists of two sections interfacing through a central ring:
- Three (3) forged rings (two external rings and one central ring) and two (2) machined rings
- (Intermediate rings);
- Sixteen (16) box-shaped longeron assemblies;
- The Forward (FWD) cone shell, which consists of Aluminum alloy waffle panels welded together,
- Plus one Feed-through (F/T) plate;
- The Bulkhead, which includes the penetrations for the utility lines to/from the ISS;
- The Hatch;
- The aft cone shell, formed by waffle panels welded together and one forged ring;
- The Aft Access Closure AAC);
- The flight fittings (two main fittings, two stabilizing fittings and one keel fitting);
- The Rack Attachment Blocks (RAB's), which provide the mechanical interface between the racks and the cylindrical shell longerons.

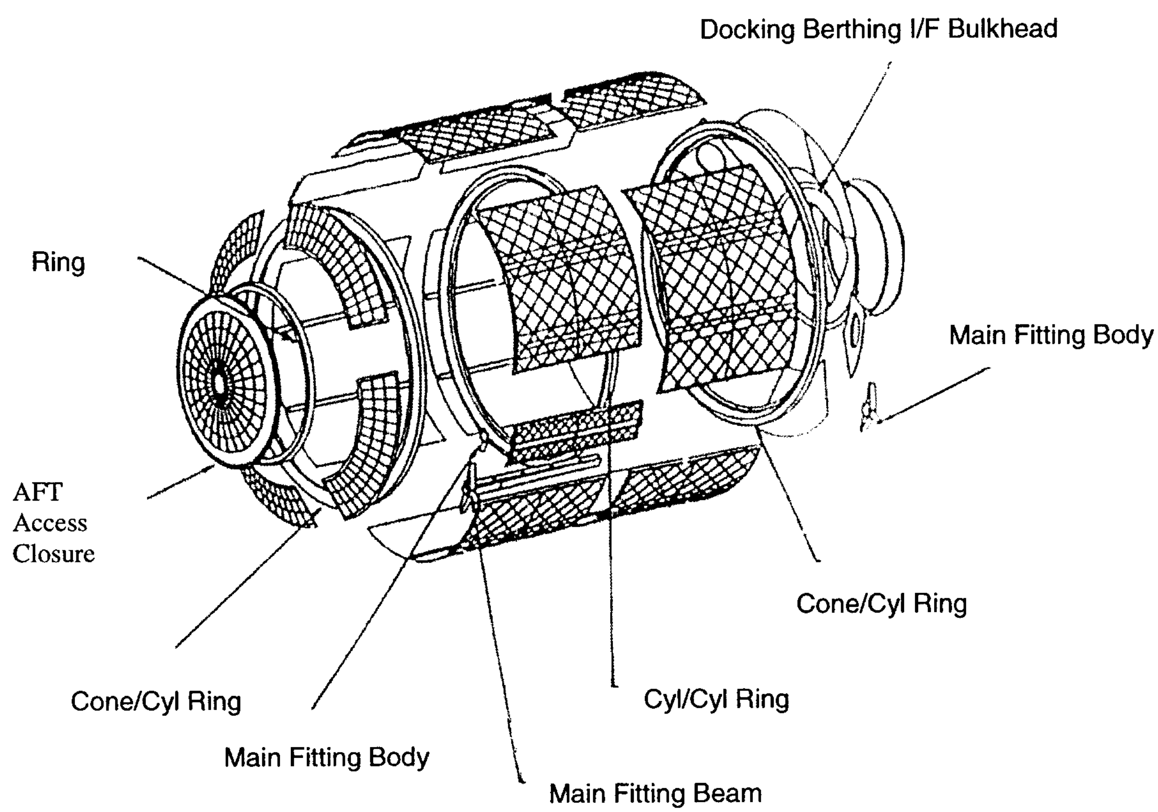


FIGURE 4. MPLM PRIMARY STRUCTURE.

4.1.1.2 SECONDARY STRUCTURE.

The MPLM Flight System secondary structure includes:

- The Meteoroid and Debris Protection System (MDPS), which consists of a single bumper shield, provided with openings in proximity of the Grapple Fixtures, the atmosphere control valves and other hardware arranged externally on the module shell;
- The FWD cone support structure, which includes three independent honeycomb panels connected to the primary structure, used to support most of the MPLM Flight System equipment:
- Four stand-offs, which mainly provide support for diffusers, grids, lights, ducting, piping and electrical harness; the stand-offs also allow rack on-orbit tilting by insertion of dedicated hinge mechanisms; the upper stand-offs are open, while the lower ones are closed by means of light-weight panels for ventilation purposes.
- Close-out panels, to meet Human Factor Engineering requirements, and light-weight panels for fire suppressant containment;
- Bracketry.

4.1.1.2.1 MPLM METEOROID AND DEBRIS PROTECTION SYSTEM (MDPS) DESCRIPTION

The MPLM is protected from the meteoroid and debris environment by means of a single bumper shield 0.031 in (0.8 mm) thick, made of aluminum alloy. The distance between the shell internal surface and the MDPS external surface is 5 in (127.6 mm). The MPLM covering consists of 48 panels on the cylindrical shell, 6 panels on the FWD cone, 6 panels on the aft cone, and 6 panels on the AAC. Openings in the coverings are provided for the attachment of the two FRGFs and in the center of the AAC for the installation of two NPRVs. The exterior surface of the MDPS is chemically treated for passive thermal control.

4.1.1.3 MECHANISMS.

The MPLM Flight System include the following external mechanisms:

- The Passive Common Berthing Mechanism (PCBM), to interface with the Active Common Berthing Mechanism (ACBM) installed on the ISS Node 1 and Node 2 nadir ports;
- Two (2) Flight Releasable Grapple Fixtures (FRGF's), to allow the on-orbit deployment and berthing to the ISS, and the retrieval and the re-insertion into the Orbiter cargo-bay;
- The Remotely Operated Electrical Umbilical (ROEU) and the Remotely Operated Fluid Umbilical (ROFU) Payload Disconnect Assemblies (PDA's).

4.1.1.4 FLIGHT FITTINGS

The flight fittings provide the mechanical interface between the MPLM and the Orbiter. The MPLM flight fittings consist of two primary trunnions reacting to X and Y loads, two stabilizing trunnions reacting to Z loads, and one keel pin that reacts to Y loads. The primary fittings are fixed to the aft external ring along the Y direction. The stabilizing fittings are fixed to the forward external ring along the Y direction. Each primary and secondary fitting consists of:

- A titanium alloy body attached by bolts to the external ring;
- A titanium alloy longitudinal beam fixed to the aft external ring and to the cylindrical shell with hi-lock fasteners;
- An inconel trunnion externally plated with chromium and housed in a dedicated seat drawn into the body;
- An aluminum alloy scuff plate that protects the trunnion from impacts against the orbiter payload bay.
- The keel fitting is fixed to the central ring along the Z direction. Each keel fitting consists of:
- A titanium alloy body attached by bolts to the external ring;
- An inconel trunnion externally plated with chromium and housed in a dedicated seat drawn into the body;
- A beam reacting to the friction induced loads.
- The distance between the trunnion centerlines of the primary and stabilizing fittings is 192.73 in (5895.3 mm). The distance between the keel pin and the primary trunnions is 94.4 in (2397.8 mm) centerline to centerline.

4.1.2 MPLM INTERNAL CONFIGURATION

The MPLM internal structural configuration consists of Rack Attachment Blocks (RAB's), the Forward Cone Structure, and Rack Standoffs, Close out and Light Panels, and support brackets.

The RAB's transfer the loads that are induced by the launch and landing accelerations from the payload racks to the MPLM longeron assembly. The RAB's are Titanium alloy brackets that interface between the cylindrical shell, and both the standoffs, and rack knee brace or lower rack assemblies.

The rack standoffs are constructed from five aluminum frames that are connected together by an L-shaped beam. The MPLM has two upper and two lower standoffs that are designed to allow the unobstructed routing of wire harnesses, air ducting and water piping. These standoffs allow for on-orbit rack tilting with the hinge orbital support equipment.

The Forward Cone Structure consists of three independent honeycomb panels, connected to the primary structure through five points. To reduce the risk of crew injury and to avoid loose hardware concerns, close out panels are provided in the Forward Cone Structure. Light panels are provided for fire suppression containment purposes. These panels are constructed of beta cloth.

During launch, landing and on orbit pre-MPLM operational phases, the racks are connected to the MPLM by four attach points. Two upper attach points interface with the rack knee brace assembly. The two lower rear attach points connect to a dedicated MPLM bracket. The upper and lower attach points contain restraint pins that prevent the attach rods from backing out under a launch load environment. Two pivot point attachments are used on orbit to transfer the loads associated with the rack transfer operations to the MPLM Standoffs.

4.1.3 MPLM AVIONICS SYSTEM (AVS)

The MPLM Avionics System provides the electrical power distribution and conditioning, module illumination, and data management functions for the MPLM. The electrical power distribution and conditioning subsystem takes 120 VDC externally supplied power and distributes an internal power supply of 120 VDC and 28 VDC inside the MPLM. The module illumination subsystem provides both general and emergency egress lighting from the MPLM. The Data Management subsystem provides the capabilities to monitor and control the MPLM equipment and the Refrigerator/Freezer Racks (if configured for an active mission). The data management function is performed by one Multiplexer/Demultiplexer that can interface with the Orbiter Interface Unit, the ISS MDM INT ½, and the KSC EGSE. Table 6shows the component average power usage based on the Flight 5A.1 mission. Subsequent missions will show a similar table.

The Avionic System (AVS) performs electrical power distribution and conditioning, module illumination, data management and processing. The electrical power distribution equipment includes:

- One (1) Power Distribution Box (PDB), which distributes electrical power to all subsystem equipment (except for the shell heaters) depending on the user interface characteristics;
- One (1) Heater Control Unit (HCU), which distributes electrical power to the shell heaters;
- One (1) Battery, which supplies the ROFU PDA heaters during the transfer phases (when the MPLM is manifested with active cargo).

The module general illumination is accomplished by means of eight (8) General Luminare Assemblies (GLA's), switched on/off by one (1) Remote Control Assembly (RCA). The emergency illumination, which ensures lighting for an emergency egress in the event of loss of power, is provided by the Emergency Egress Lighting (EEL) System, which consists of one (1) Emergency Lighting Strip and one (1) Emergency Lighting Power Supply (ELPS). The ELPS is re-charged on-ground during each turn-around.

The data management and processing provides the capability to monitor and control the MPLM Flight System equipment and the active cargo (when included in the flight manifest). The hardware dedicated to this function is the Multiplexer/Demultiplexer (MDM). Electrical harness (cabling, connectors, backshells, MIL-STD-1553B components) is provided to support power distribution and data transfer.

TABLE 6. MPLM COMPONENT AVERAGE POWER USAGE (BASED ON FLIGHT 5A.1 MISSION).

Subsystem/Equipment	Estimated Power	Margin	Continuous Power
ECLSS			
Depress Assembly #1	0	0	0
Depress Assembly #1 Heater	0	0	0
Depress Assembly #2	0	0	0
Depress Assembly #2 Heater	0	0	0
Positive Pressure Relief Assy #1	0	0	0
Positive Pressure Relief Assy #2	0	0	0
Positive Pressure Relief Assy #3	0	0	0
Pressure Transducer #1	0	0	0
Pressure Transducer #2	0	0	0
Pressure Transducer #3	0	0	0
Sampling Line Shut-Off Valve (SSOV)	0	0	0
Duct Smoke Detector	0.8	0	0.8
Air Temperature Sensor	0	0	0
IMV Shut-Off Valve #1	0	0	0
IMV Shut-Off Valve #2	0	0	0
Cabin Fan Assembly	94	0	94
ECLSS Total Power	*95*	*0*	*95*
TCS			
Water Pump Package	N/A		N/A
Water On/Off Valve	N/A		N/A
Water Modulating Valve	N/A		N/A
TCS Total Power	*0*		*0*
AVIONICS			
Power Distribution Box	23	0	23
General Luminarie Assembly #1	30	0	30
General Luminarie Assembly #2	30	0	30
General Luminarie Assembly #3	30	0	30
General Luminarie Assembly #4	30	0	30
General Luminarie Assembly #5	30	0	30
General Luminarie Assembly #6	30	0	30
General Luminarie Assembly #7	30	0	30
General Luminarie Assembly #8	30	0	30
Emergency Lighting Power Supply	5	0	5
Heater Control Unit	15.5	0	15.5
MDM	56	0	56
Avionics Total Power	*340*	*0*	*340*

4.1.4 SOFTWARE.

The Flight Operational Software of the MPLM Flight System, running on the MDM computer, provides the following functions:

- Monitoring and commanding of the active cargo (when included in the flight manifest);
- Monitoring and commanding of the ECS powered equipment and the electrical power distribution equipment;
- Detection and isolation of predefined equipment failures, to prevent catastrophic hazardous events and failure propagation;
- Function status data assessment;
- Detection of potential fire events, by processing monitored data.

4.1.5 DRAG-ON EQUIPMENT.

The equipment accommodated into the MPLM Flight System after berthing to the ISS and removed before re-entry on ground (except in an emergency) is called drag-on equipment. The drag-on equipment includes:

- One (1) Portable Fire Extinguisher (PFE), used as the manual fire suppression system;
- One (1) Portable Breathing Apparatus (PBA), which provides respirable atmosphere for one (1) crew member in the event of a hazardous atmosphere condition;
- Intra-vehicular Activity Restraints and Mobility Aids, used to assist crew operations and work activities.

4.1.6 ACTIVE-TO-PASSIVE RECONFIGURATION.

The MPLM Flight System external active-to-passive reconfiguration is done by removing the ROFU PDA. The battery is also removed (note that the battery is typically removed for charging anyway). Both the ROFU PDA support bracket and the Battery support structure are maintained in the passive configuration. As a consequence of the Battery removal, the MDPS and the MLI are locally reconfigured.

The MPLM Flight System internal active-to-passive reconfiguration is performed by removing the R/F Kit, which includes:

- The Water Pump Package (WPP);
- The On/Off Valve;
- The On/Off Valve Electronics:
- Some ATCS loop hard and flex lines;
- Some Electrical Harness (ELH).

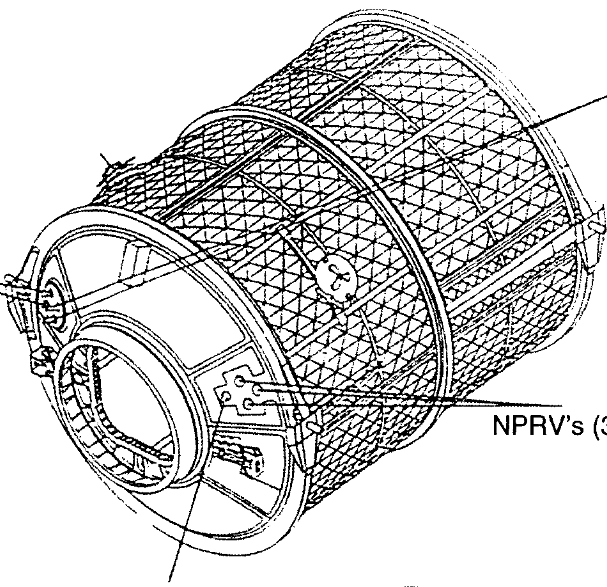
4.1.7 ENVIRONMENTAL CONTROL SYSTEM (ECS)

The ECS includes the Environmental Control and Life Support Subsystem (ECLSS) and the Thermal control Subsystem (TCS). The ECLSS includes the following functions: temperature and humidity control, fire detection and suppression, atmosphere control and supply, and atmosphere revitalization.

4.1.7.1 ENVIRONMENTAL CONTROL AND LIFESUPPORT SUBSYSTEM

Temperature and Humidity Control: a ventilation system including one Cabin Fan, ducting, diffusers, grids and one temperature sensor, ensures the air circulation inside the MPLM Flight System cabin; Inter-module Ventilation (IMV) Lines, each with a dedicated IMV Shut-Off Valve, are provided to supply the module with revitalized air from the ISS and to return heat loaded air to the ISS.

When the MPLM is berthed to the ISS, the temperature, humidity and air circulation is controlled by the ISS ECLSS. When the hatch is opened, circulated air and MPLM generated heat loads are transferred though the hatch opening. During the closed hatch operations, the MPLM Inter-module ventilation will be used for air circulation and MPLM heat rejection. Atmospheric circulation inside the MPLM is accomplished by a cabin air fan and diffuser/ducting system.



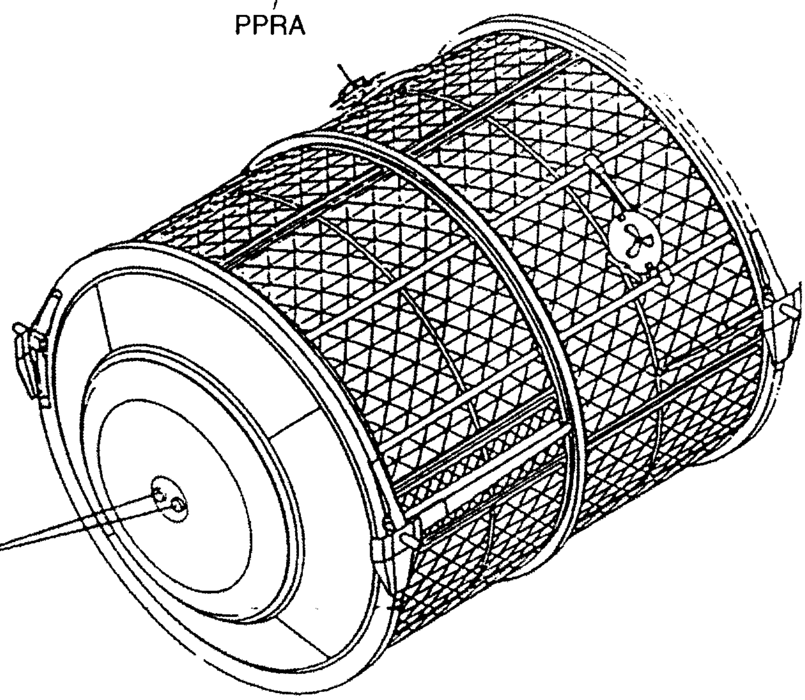


FIGURE 5. ACS EQUIPMENT (PPRA'S, DA'S, NPRA'S) LOCATION - EXTERNAL VIEW.

4.1.7.1.1 FIRE DETECTION AND SUPPRESSION

MPLM smoke detection is limited to the monitoring of the cabin recirculated air. The smoke detector is installed in the air duct downstream of the cabin air fan and is physically located in the Forward Cone port area. The smoke detector is monitored and commanded by the MPLM MDM. Fire suppression is provided by Portable Fire Extinguisher that is brought on the MPLM from the ISS and is removed prior to latch closing.

Fire Detection and Suppression: the implementation of the Fault Detection and Isolation (FDI) criteria allows to limit the fire detection to the cabin recirculated air only, by means of one (1) Duct Smoke Detector; the MPLM Flight System zones containing a credible fire risk are subdivided in three non-hermetically sealed compartments, by means of beta cloth panels: Fire Suppression Ports allow the crew members to discharge the fire suppressant contained in a Portable Fire Extinguisher (PFE) into the compartment affected by the fire event.

4.1.7.1.2 ATMOSPHERE CONTROL AND SUPPLY (ACS)

The ACS provides to the MPLM Depressurization, Positive and Negative Pressure Relief, and ISS/MPLM Equalization functions. Depressurization is used to purge the MPLM in the event a severe contamination is sensed or as secondary method of fire suppression. The depressurization function is performed two depressurization valve assemblies. Each assembly consists of two motorized valves installed in series. The Positive Pressure Relief function is accomplished by three independent Positive Pressure Relief Assemblies (PPRA). Each PPRA is composed of one self-actuating relief valve and one motor operated valve. The Negative Pressure Relief function permits repressurization in the event the MPLM depressurizes during descent. This function is provided by five, independent, self-actuating relief valves. The ISS/MPLM Pressurization Equalization is provided by a manual valve that is located in the lower starboard area of the MPLM latch.

Atmosphere Control and Supply: the hardware dedicated to this function consists of two Depressurization Assemblies (depressurization in the event of internal environment contamination or fire), three Positive Pressure Relief Assemblies (relief in the event of isolated module internal over-pressure), five Negative Pressure Relief Valves (automatic relief in the event of a depressurized module return to ground) and three Total Pressure Sensors (module internal pressure monitoring).

4.1.7.1.3 ATMOSPHERIC REVITALIZATION SYSTEM (ARS)

The ARS provides the sampling capability of the internal MPLM atmosphere from the ISS. Atmosphere Revitalization System: a Sampling Line provided with Sampling Line Filter and Sampling Line Shut-Off Valve routes the air sampled inside the MPLM Flight System to the ISS allowing for composition analyses and contaminant substance presence detection.

4.1.7.2 THERMAL CONTROL SUBSYSTEM (TCS).

The Thermal Control Subsystem (TCS) includes the Active Thermal Control Subsystem (ATCS) and the Passive Control Subsystem (PTCS). The TCS provides active and passive thermal control for the MPLM. The TCS ensures suitable environmental conditions. For active flights, the TCS collects the rejected heat from the refrigerator freezer racks when the MPLM is in the Orbiter cargo bay and while docked to the ISS.

The ATCS collects the heat loads rejected by the active cargo (when included in the flight manifest) and transfers them to the Orbiter or to the ISS. This function is performed by means of a water loop, which includes one Water Pump Package, one On/Off Valve (that permit manual pressure drop regulation on the ground), one Modulating Valve, one Differential Pressure Sensor, hard and flex lines and Quick Disconnects.

The PTCS protects the MPLM Flight System from the external environment influences, minimizes the heat leakage/gains and prevents condensation inside the MPLM Flight System. The Passive Thermal Control System (PTCS) protects the MPLM from the external environment and prevents condensation inside the MPLM. The PTCS consists of the Thermal Control Coating (TCC), the Multi-Layer Insulation (MLI), anti-condensation insulations and heaters. Anti-condensation insulators will not be discussed since they are only applicable to the active mission.

The TCC is a Chromic Acid Aluminum Anodizing process that was applied to the external surfaces of the Meteoroid and Debris Protection System (MPDS). This coating assures suitable thermo-optical properties that minimize MPLM heat gains and temperature excursions.

The MPLM shell, passive Cargo Berthing Mechanism (PCBM) and the external side of the hatch are covered with MLI. The MLI is composed of 220 blankets that are installed between the shell and the MDPS by Torlon fasteners stuck directly to the shell external surface. Each MLI Blanket is formed of 19 layers of Double Aluminized Kapton (DAK) foils, alternated with spacers of Dacron Net. Each blanket is completed, on both the external and internal sides by a layer of Nomex reinforced DAK. For the MLI blankets located in areas not covered by the MPDS, the external layer of Nomex is replaced by a layer of Beta cloth and the internal layer is Single Aluminized Kapton.

Seventy-six thermofoil heaters are arranged on the module shell external surface to prevent shell internal surface condensation and water loop freezing during active missions. Each heater is provided with two electrical tracks, independently at different voltages, 28 Vdc and 120 Vdc, to respectively support the Orbiter and ISS heating power requirements. The heaters are connected in 22 independent electrical circuits. Each circuit contains no more than six heaters in parallel. Each heater circuit is controlled by one thermostat.

The PTCS equipment includes:

- The Thermal Control Coating (MDPS external surface finish);
- The Multi-Layer Insulation, composed by blankets which cover all the MPLM Flight System shell, including the Hatch and PCBM external/internal surfaces;
- Insulation material, which covers the ATCS equipment;
- Items which reduce (washers) or increase (fillers) the thermal conductivity at the interface level;
- Heaters arranged on the shell external surface, to prevent internal condensation and ATCS loop water freezing;
- Heaters arranged externally on each Depressurization Assembly, to prevent icing inside the Non-Propulsive vent during the depressurization;
- Heaters arranged on the ROFU PDA, to prevent water freezing inside the jumpers.

4.2 PORTABLE FIRE EXTINGUISHER

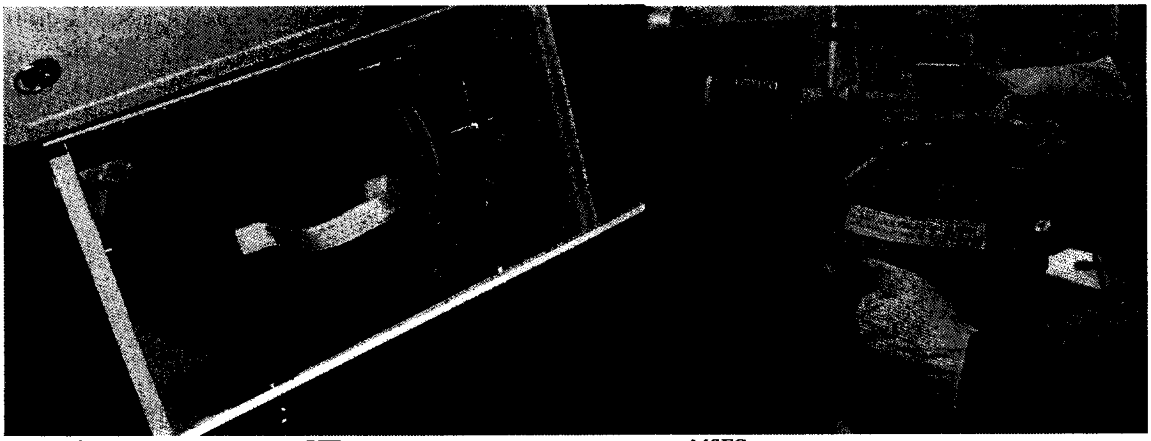


FIGURE 6. PHOTOGRAPH OF THE PFE IN ITS LOCKER AND DURING TESTING AT MSFC.

4.2.1 FUNCTIONAL DESCRIPTION

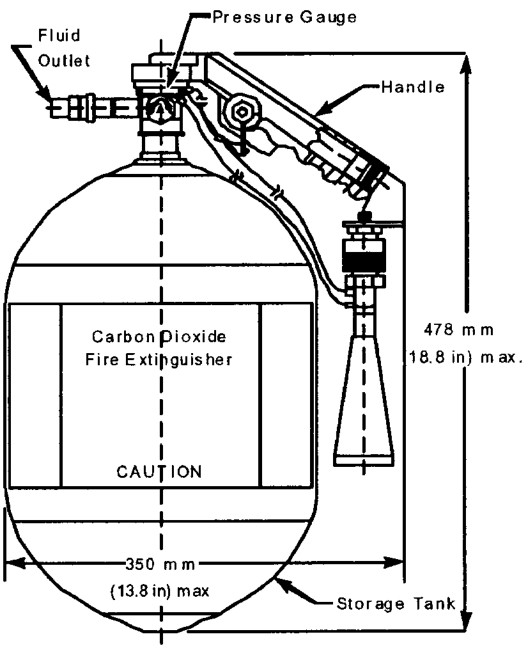


FIGURE 7. PORTABLE FIRE EXTINQUISHER.

The US Portable Fire Extinguisher (PFE) contains 6 lbs of gaseous CO_2 (850 psi at 70 degrees F). The CO_2 quantity is sufficient to reduce oxygen concentration below 10.5% in an enclosed volume of 60 ft3. This oxygen reduction occurs for a total cabin pressure between 13.9 and 15.2 psia and an oxygen partial pressure between 2.83 and 3.35 psia. The bottle can exhaust its contents to ambient pressure within one minute after initiating discharge.

The PFE consists of a pressure vessel, a valve and handle assembly equipped with a pressure gauge and burst disk, and two discharge nozzles. The open area nozzle is used to extinguish fires in the open cabin. The enclosed volume interconnect nozzle allows discharge of CO_2 via a fireport, into enclosed volumes (racks, standoffs, endcones, etc…), without requiring crew to open access panels. Both nozzles minimize propulsive effects by discharging highpressure CO_2 radially. The open area nozzle provides a cone to redirect the low pressure CO_2 exhaust in the desired direction. Crewmembers using the PFE can restrain themselves by using the crew restraint and mobility aids. Each PFE weighs 9 lbs dry and 15 pounds full. The PFE is certified to operate in the following environmental ranges.

The PFE tank exceeds the lower touch temperature limit requirement near the bottom of the tank when discharged and has received a waiver of this requirement. The PFE has been discharged many times during development and qualification testing and this cold temperature of the tank does not pose a health threat to a trained crewman. The tip of the nozzle also gets very cold when discharged, and should not be touched as a matter of course in handling the PFE during a fire response. More operational discussions are included in Section 5 of this document. A series of development testing done form 1991 through 1996 substantiates the proper sizing of the Portable Fire Extinguisher for a typical sixty cubic foot rack volume. (See T683-85274-1 POST Avionics Air/Fire Detection and Suppression Rack Test Report; and T683-16001-1 USC Fire Suppression Development Test Report.)

TABLE 7. PORTABLE FIRE EXTINGUISHER OPERATING ENVIRONMENT RANGES.

Portable Fire Extinguisher Opeating Ranges	
Cabin Pressure	$5x10^4$ torr - 796 torr (15.4 psia)
Cabin Temperature	40 °F – 109 °F (2 °C-49 °C)
Cabin Humidity	0%-75%

TABLE 8. PORTABLE FIRE EXTINGUISHER CHARACTERISTICS.

Portable Fire Extinguisher Characteristics	
Vendor Part Number	ARDE, Inc. P/N E4482
Boeing Part Number	683-10050-1
Specification Number	ARDE, Inc.: PM 10011, Boeing: 683-10050
Empty Weight	9.04 lbm
Full Weight	15.10 lbm
Amount of CO_2 Suppressant Weight	6.07 lbm
Operating Pressure (MDP)	1050 psia
Operating Temperature Range	40 °F to 109 °F
Mass of Suppressant Discharged in 10 sec.	3.32 lbm
Mass of Suppressant Discharged in 45 sec.	5.65 lbm
Maximum Average Thrust of Discharge	2.0 lbf
Maximum Impulse Thrust of Discharge	24.0 lbf/sec

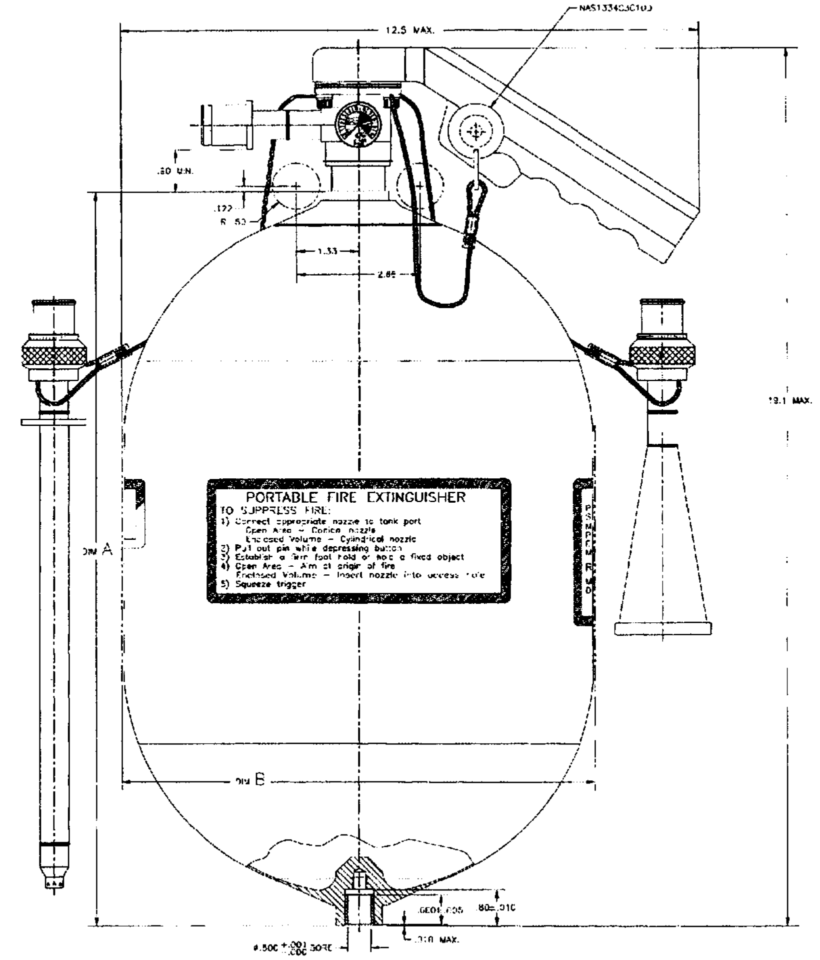


FIGURE 8. PORTABLE FIRE EXTINGUISHER 2.

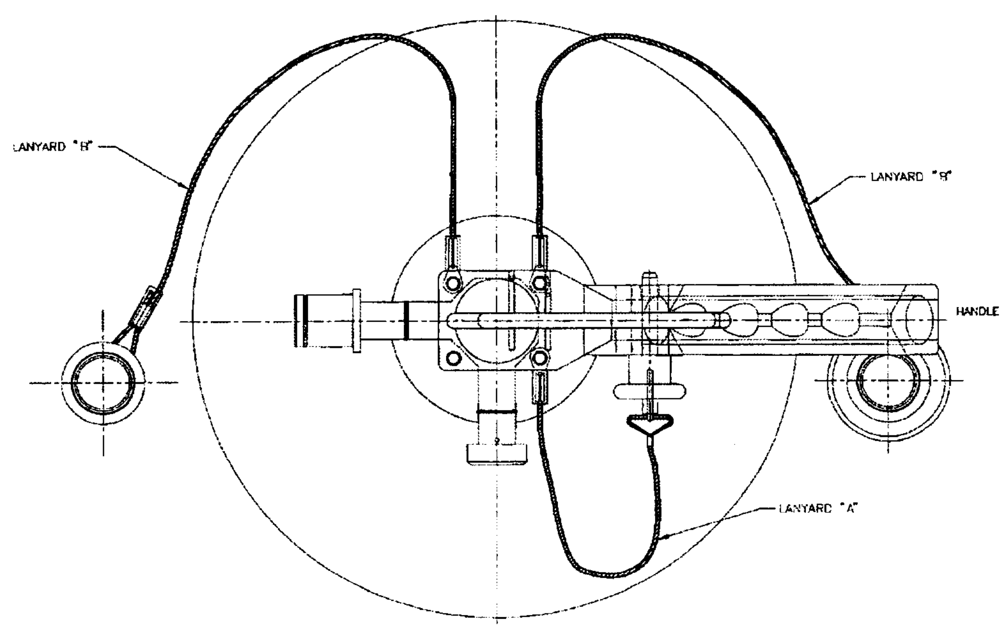


FIGURE 9. POTABLE FIRE EXTINGUISHER (TOP VIEW).

4.2.2 PHYSICAL DESCRIPTION

4.2.2.1 PRESSURE VESSEL

The pressure vessel is a cylinder roughly 11 inches in diameter and 15 inches tall, with a volume of approximately 881 in3. It consists of one cylinder and two endcaps of 301 cryoformed stainless steel, with an additional boss on each end for valve and bottom launch restraint attachments. Tank strength requirements are defined in Table 9.

TABLE 9. PORTABLE FIRE EXTINGUISHER PRESSURE RATINGS.

Portable Fire Extinguisher Pressure Ratings	
Operating Pressure	65 psia – 1050 psia
Relief Pressure	1170 psia – 1320 psia
Proof Pressure	1575 psia
Burst Pressure	2100 psia (2850 psia tested)

The extinguisher becomes very cold when discharged. The pressure vessel reaches 0 °F and nozzle reaches –30 °F. The handle maintains an allowable touch temperature. The ISS Safety Review Panel has approved the waiver for the bottle and nozzle.

4.2.2.2 MANUAL VALVE AND PRESSURE GAUGE

The manual poppet valve shares a similar design with earthbound extinguishers. The valve is normally closed via a spring load, with a manual trigger, requiring less than 4 lbs pressure to open it. The trigger permits throttling of the CO_2 discharge, and a soft seat within the valve permits resealing after a partial discharge. A lock pin, located above the trigger, prevents inadvertent operation and is tethered to the valve body. The pin is removed by depressing the end button and removing (very similar to lock pins on commercial fitness equipment).

A male quick disconnect fitting on the valve permits attachment of either of two nozzles provided with the PFE.

The pressure gauge is a 1 in dial bourdon tube assembly threaded into the side of the valve assembly. The gauge has a range of 0 psia to 2000 psia, wit tic marks every 50 psia and an accuracy of ±25 psia. A description of the gauge is provided in the following table.

TABLE 10. PORTABLE FIRE EXTINGUISHER GAUGE COLOR SCHEME.

Color Scheme	
Background Color	White
Character Color	Black
0-B psia	Red
B-C psia	Yellow
C-D psia	Green
D-E psia	Yellow
E-2000 psia	Red

4.2.2.3 PFE NOZZLES

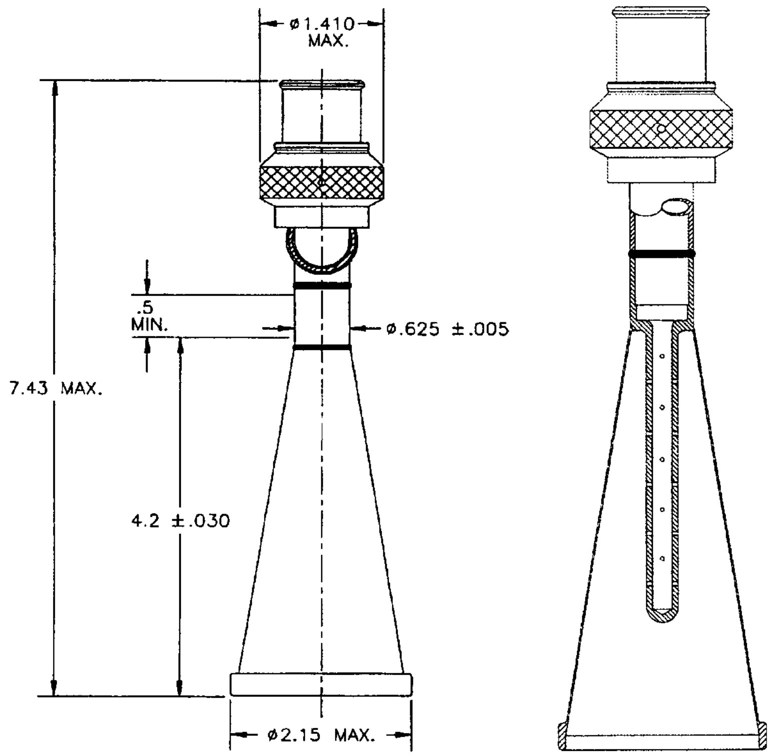


FIGURE 10. PORTABLE FIRE EXTINGUISHER NOZZLE.

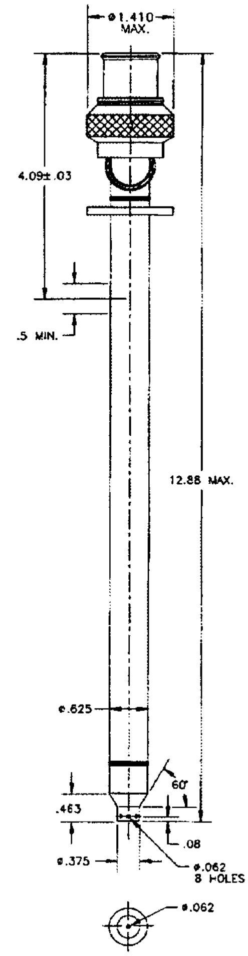


FIGURE 11. PORTABLE FIRE EXTINGUISHER WAND.

Each PFE is equipped with two nozzles – one to direct CO_2 at a fire event in the open cabin and a second for discharging CO_2 behind the closeout panels of an enclosed volume.

Both nozzles are equipped with a female quick disconnect for quick installation and removal. The QD exposes a white ring on the nozzle side when the nozzle is properly installed, and a red ring on the valve side when incorrectly installed. Each nozzle is separately tethered to its bottle, with no restraint provided on the bottle – each nozzle will dangle from the PFE when free of the storage locker. Each locker provides a dedicated clamp for storing each nozzle.

The open area nozzle consists of a 2.15 in diameter piccolo tube with holes positioned at regular intervals. When discharged, high pressure CO_2 exhausts through these radial holes. A conical shroud surrounding the tube redirects the now low pressure CO_2 exhaust in the desired direction. This design feature reduces the thrust without severe flow restrictions.

The enclosed volume interconnect nozzle consists of TBD in diameter tube that narrows at the tip. Radial discharge hoses are positioned around this tip, with an additional hole on the end. When discharged, CO_2 exhausts primarily through the radial holes, thereby reducing thrust and impingement force on equipment, wire harnesses, etc., within the enclosed volume.

4.2.2.4 INTERFACES

The PFE assembly is an ORU which has mechanical and fluid interfaces. The mechanical interface is with the module's tertiary structure. The PFE is mounted in the endcones of each element. The fluid interfaces of the PFE assembly are with the open cabin when it is used to suppress an open area fire, and with a fireport when used to suppress a fire in an enclosed volume. The fireport provides the crew with the capability to manually release suppressant into the zone via the PFE.

4.2.2.5 MASS PROPERTIES

Each PFE weighs 9 pounds dry and 15 pounds full.

4.2.2.6 MECHANICAL INSTALLATION

Each PFE is stored in a locker providing separate restraints for the extinguisher and each nozzle. The locker comes equipped with two restraints for the bottle and one for each nozzle. The bottom boss of each PFE provides a hole, into which a pin on the bottom launch restraint fits. The neck of the valve body rests inside a clip. Once on orbit, the bottom launch restraint can be removed from the locker to ease PFE removal in an emergency. Each Nozzle is provided a dedicated locker clamp.

4.2.2.7 MATERIALS AND CONSTRUCTION

The PFE supplier is ARDE Inc., of Northwood, New Jersey, under contract with Boeing-Huntsville. The PFE is constructed primarily from various classes of stainless steel. The pressure vessel is welded from several pieces of 301 CRES, then plastically deformed at 320 F and subsequently annealed to produce high strength with light weight.

4.2.3 ENVIRONMENTS

4.2.3.1 THERMAL

The PFE operates after being exposed to surface temperatures of 36 F to 150 F. While on orbit, the PFE operates while being exposed to surface temperatures ranging from 40F to 109 F.

4.2.3.2 PRESSURE

The on orbit ambient operating pressure for the PFE is 1.9 x 10-7 to 15.4 psia. The PFE is able to return to normal operation after depressurization to 1.9 x 10-7 psia. The depressurization rate cannot exceed 27.0 psid/min. The repressurization rate cannot exceed 60.0 psid/min.

4.2.3.3 AMBIENT HUMIDITY

The PFE operates in an ambient humidity environment ranging from 0.0 to 75% relative humidity.

4.2.3.4 CREW LOADS

The PFE operates after exposure to the crew loads shown in the table below.

TABLE 11. ON-ORBIT CREW INDUCED LOADING.

	On-Orbit Crew Induced Loading		
Crew Systems or Structure	Type of Load	Load	Direction of Load
Levers, Handles, Operating Wheels	Push or Pull concentrated on most extreme tip or edge	50 lb. Limit 75 lb. ultimate	Any direction
Small Knobs	Twist (Torsion)	11 ft-lb. Limit 17 ft-lb. ultimate	Any direction

4.2.3.5 FLUIDS

Fire suppression gaseous CO_2 inlet source is from the PFE; outlet release is to anywhere aimed. The PFE fluid characteristics are shown in the table below.

TABLE 12. FLUID INTERFACES.

	Fluid Interfaces			
	Pressure (psia)	Fluid Temp (F)	Mass Rate (lbm.sec)	Flow Rate at Max. Pressure (lbm/sec)
Gaseous CO_2	65 - 1050	-50 - 120	0.25 – 1.0	3.0

4.2.4 PERFORMANCE

The PFE is designed to exhaust its contents within one minute. Both nozzles provide identical pressure and flow rate curves, as depicted in Figure 12. Note that 50% of the bottle's contents (3 lbs) is discharged within 8 seconds, and that 90% is discharged within 30 seconds. A valve open duration of 45 seconds ensures approximately 98% of available CO_2 is exhausted. This time was used by Boeing Huntsville in its suppression effectiveness tests conducted in 1996.

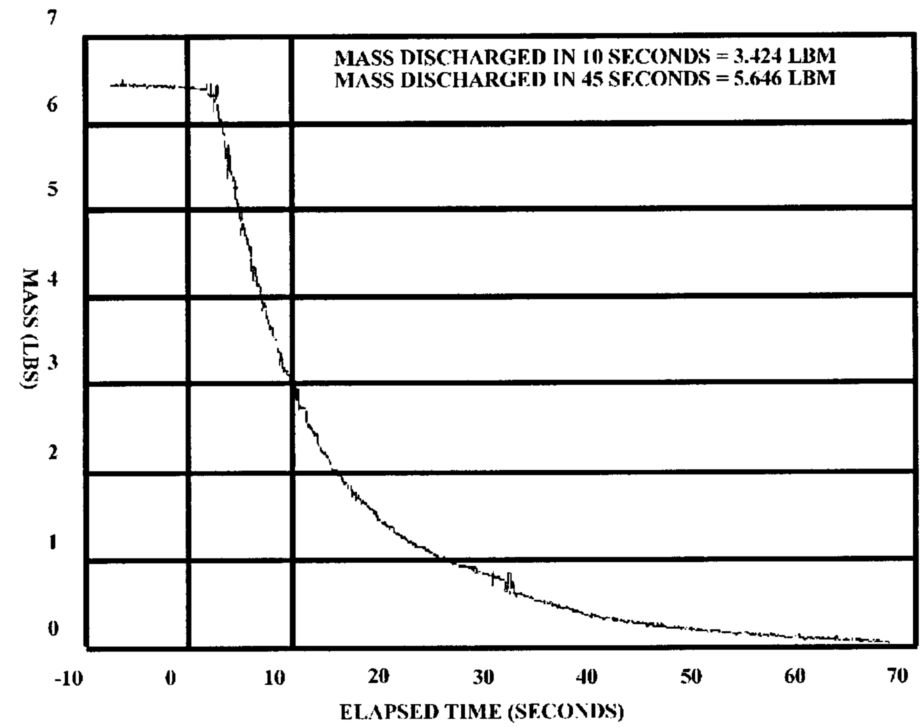


FIGURE 12. FIRE DISCHARGE PERFORMANCE WITH CLOSED VOLUME NOZZLE.

Thrust tests performed by the vendor suggest a thrust of less than 2 lbs is produced by either nozzle during use. The operator will need to secure himself in some manner prior to discharge by using a hand hold or an available crew restraint.

Discharge is quite loud (107 dB peak). This noise level is not considered threatening given the PFEs infrequent use. Noise level drops as the bottle discharges.

The PFE is qualified for 180 pressure cycles, thus permitting recharging on the ground and subsequent reuse aboard the ISS.

Bottle leakage can be detected by regular inspection of the pressure gauge. Detection of rising CO_2 by the Major Constituent Analyzer would require discharge into a small volume, such as an airlock during a campout.

Inspection of the CO_2 extinguishers are performed at approximately 30 day intervals to comply with the National Fire Protection Association standards (NFPA-10). Inspections are performed on the bottle and both nozzles (cabin and rack nozzle). Inspections are performed looking for and at possible obstructions, seals, and tamper indicators, physical damage, corrosion, leakage, clogged nozzle, and pressure gauge reading.

4.2.5 OPERATIONS DATA

4.2.5.1 OPERATIONAL CONSTRAINTS AND PHILOSOPHIES

The PFE is considered a highly reliable device, with few moving parts, no electrical components, and 10-year service life. A PFE is considered ineffective if its pressure drops below TBD psia, as this suggests insufficient CO_2 for suppressing fire events in enclosed volumes. A PFE considered lost will be clearly marked as such to prevent attempts to use it during a fire response.

If more than one PFE is considered lost, the ground crew will review placement of remaining PFEs to ensure that the crew has quick access to one or more for a fire event anywhere in the non-Russian segments.

4.2.5.2 OPERATIONS AND CONTROLS

Each PFE provides decals on the pressure vessel sides that define the operating steps. The presence of the decal negates the need for operating procedures in the Operations Data File. A short procedure resides in the ODF for inspection and is modeled after Code NFPA-10 of the National Fire Protection Association. Such inspection requires the crewmember to observe the PFE in its locker and permits its removal. It is not necessary to test fire the bottle, pull the lock pin, or attach/detach the nozzles as part of this procedure. The crew will record pass/fail on a card to be kept within the locker and notify the ground if any off nominal conditions are found. At this time there are no plans for returning bottles that pass such and inspection for detailed examination on the ground.

The PFE is designed to operate identically to 1-g extinguishers, with the operator pulling the pin, aiming the nozzle, and depressing the trigger.

Crew discretion will determine how much CO_2 should be discharged for a given fire event. It is recommended that an enclosed volume receive a full 45 second discharge. This does not have to be precisely timed, as the discharge is complete once the exhaust sound ceases. Obviously, discharge can be discontinued if the crew observes that the fire is extinguished. Once a bottle has been partially or completely used it will be clearly labeled to prevent any further attempts to use it for subsequent events.

A discharged or failed PFE is returned to earth via shuttle, recharged and/or repaired at ground facilities, and returned to service on a subsequent delivery to the ISS.

5.0 ON-ORBIT OPERATIONS

Flight 7A.1 is scheduled to be an eleven-day shuttle mission to the International Space Station. Rendezvous with the ISS is scheduled to occur at 210 nautical miles on flight day 3. Flight 7A.1 is the first reflight of the Leonardo (FM1) MPLM module and the third flight of the MPLM system. This particular mission will not have the refrigerator/freezer installed in the MPLM so it is considered a passive mission. Flight UF-3 and subsequent missions are expected to use the refrigerator/freezer racks and will be considered active missions. Table 13 shows a summary of the mission activities for Flight 7A.1. Operations involving the MPLM are bolded. Please note that this list contains activity highlights based on preliminary flight timelines and does not represent the final approved flight time line.

TABLE 13. MISSION SUMMARY.

FLIGHT DAY	ACTIVITY
Flight Day 1	Launch Standard FD1 activities **APCU 2 is activated to support MPLM Environment Checks.** **Activate MPLM Shell Heaters** Crew sleep is seven hours after luanch in preparation for docking on FD3.
Flight Day 2	SRMS Checkout Cargo Visual Inspection with SRMS Setup for Water Transfer to ISS Fill 2 CWCs with Orbiter fuel cell water Activate/Checkout OSVS Setup/Activate PCS Machine Activate/Checkout OIU 1 **Check Status of MPLM Environment (partial activation to confirm internal temperature and pressure integrity)** ODS Ring Extension Centerline Camera Installation/Checkout

Flight Day 3	**MPLM Environment Check**
	Rendezvous with ISS
	Dock Orbiter to PMA2 on LAB (Fwd port)
	Pressurize and checkout PMA2
	ODS Ingress Preparation
	Ingress Station
	Transfer Activities
	    EVA equipment transfer
	    Transfer 3 CWC's

Flight Day 4	Checkout Port and Nadir CBMs
	Power up SRMS
	Install MPLM on Node nadir CBM
	    Maneuver SRMS to MPLM pre-grapple position
	    Grapple MPLM with SRMS
	    Prep MPLM for unberthing from PLB
	        Deactivate shell heaters
	        Disconnect ROEU
	        Release PRLAs and AKA
	    Unberth MPLM with SRMS
	    Install MPLM on Node
	Configure MPLM for ISS Ops
	    Pressurize Node-to-MPLM Vestibule
	    Ingress Node-to-MPLM Vestibule
	    Node-to-MPLM Vestibule Prep for Activation
	    Activate MPLM
	Ungrapple MPLM and maneuver SRMS clear
	Power down SRMS
	Prep IELK for transfer to ISS.
	Begin transfer Middeck Items (APCF, CGBA, DCPCG-V, and CPCG-H)

Flight Day 5	Prep for rack transfers
	MPLM Ingress
	    Transfer logistics from 4 Resupply Stowage Platforms (RSPs)
	    Transfer logistics from 6 Resupply Stowage Racks (RSRs)

Flight Day 6	Assemble EMU from parts on ISS EMU Checkout ISS Airlock preperation for EVA 1 **Transfer MPLM Express Rack 4** **Transfer MPLM Express Rack 5** **Continue MPLM logistics transfers** EVA 1 Preparation
Flight Day 7	EVA 1 **Continue MPLM logistics transfers**

FLIGHT DAY	ACTIVITY
Flight Day 8	EVA 2 preparation **Continue MPLM logistics transfers** Prep CBM for MPLM uninstall
Flight Day 9	EVA 2 **Egress MPLM** **Deactivate MPLM** **Node-to-MPLM vestibule Prep for Unberthing** **Depressurize Node-to-MPLM Vestibule** Activate/Checkout Node nadir CBM Power up SRMS/OSVS **Demate MPLM from Node nadir CBM and return to PLB** **Maneuver SRMS to MPLM pre-grapple position** **Grapple MPLM with SRMS** **Demate MPLM from Node nadir CBM and unberth using SRMS** **Maneuver MPLM to low hover position** **Berth MPLM into PLB** **Secure MPLM in PLB** **Latch PRLAs and AKA** **Connect ROEU** **Activate MPLM Shell Heaters** **Ungrapple MPLM and maneuver SRMS clear** Power down SRMS/OSVSTransfer Activities **Deactivate MPLM Shell Heaters**
Flight Day 10	Close station hatch ODS leak check Undock Fly around **MPLM environment check**
Flight Day 11	Deploy Simplesat Cabin Stow activities
Flight Day 12	Deorbit Preparation Landing

6.0 HAZARD SAFETY ASSESSMENT

MSFC S&MA was requested to evaluate the hazard associated with transporting a PFE to the International Space Station in a Resupply Stowage Rack (RSR) integrated into the MPLM. This assessment addresses the impacts to the MPLM structure/systems and not other integrated cargo.

The hazard associated with stowing a PFE in the MPLM for ascent is exceeding 15.2 psia in the event of PFE leakage/rupture. The control philosophy to prevent the pressure from exceeding 15.2 psia due to PFE leakage or rupture is to design for minimum risk. Controls for leakage/rupture of the PFE are:

- The PFE design provides an O-ring seal between the tank and valve to prevent leakage.
- The PFE tank and valve are classified as fracture critical. The design of the PFE tank incorporates a leak before burst design and incoporates the Proof/burst factors of safety listed in SSP 30559 at the MDP of 1050 psia as defined in SSP 30559.

Based on the MPLM Phase III Safety Data Package, MLM-RP-AI-0055, when the PFE is stowed, the PFE discharge valve is provided with a pin to prevent inadvertent operation. Structural failures of the PFE tank or valve assembly are controlled by design to minimum risk and thus are considered non-credible failures. The only credibile failures that could result in a significant PFE flow would be a seal failure in the PFE valve assembly or a leak through the pressure gauge bourdon tube. These failures are highly unlikely because seal leaks are not instantaneous failures. The PFE pressure gauge is examined upon installation to determine that the valve seal or pressure gauges are not degraded. Therefore, other than a seal failure in the valve or pressure gauge that can be detected by inspection, there are no other credible failures that can lead to an inadvertent discharge.

In the event of a seal failure, Alenia's MPLM Phase III Safety Data Package, MLM-RP-AI-0055 (20 Mar 98) – Hazard Cause 3, assumed a worst case leak rate of 1000 times the PFE specificaton rate of 6.86×10^{-7}. ~~Since a failure of the PFE is considered a catastrophic hazard~~, three inhibits must be in place to control the hazard. The first control is through the incorporation of an O-ring. The second control is the use of the Positive Pressure Relief Assemblies (PPRA) incorporated into the MPLM design. A failure of one of the PPRAs will still control the hazard. Using the assumed worst case leak rate mentioned above, Boeing-Huntsville conducted an analytical assessment and verified that two PPRAs could keep the internal MPLM pressure below 15.2 psia.

{Since exceeding MDP of MPLM due to leak or discharge of PFE is considered a catastrophic hazard}

MP

APPENDIX A – MPLM TO ORBITER REFLIGHT ASSESSMENT

MPLM TO ORBITER INTERFACE HAZARDS
International Space Station
MPLM-PFE-1

1. HAZARD TITLE:
Overpressurization of the MPLM structure due to leakage/rupture of the Portable Fire Extinguisher leads to MPLM structural failure

a. Review Level: Phase III
b. Revision Date: July 2001
c. Scope: Flight 7A.1
d. Hazard Report Focal: Gordon DeRamus, (256) 544-0624

2. HAZARD CONDITION DESCRIPTION:
Leakage and/or rupture of the Portable Fire Extinquisher (PFE) could lead to a situation where the amount and rate of CO_2 released exceeds the capability of the Positive Pressure Relief Valves (PPRVs) to vent the excess pressure. This could cause the MPLM to exceed its Maximum Design Pressure (MDP).

3. CAUSE SUMMARY:

CAUSE 1: Rupture of the Portable Fire Extinguisher
SEVERITY: **CATASTROPHIC** LIKELIHOOD: **IMPROBABLE**

CAUSE 2: Depressurization of the Portable Fire Extinguisher due to discharge or valve failure
SEVERITY: **CATASTROPHIC** LIKELIHOOD: **IMPROBABLE**

CAUSE 3: Leakage of the Portable Fire Extinguisher due to seal failure
SEVERITY: **CATASTROPHIC** LIKELIHOOD: **IMPROBABLE**

4. PROGRAM STAGE(S):

	FLIGHT 7A.1
CAUSE 1	X
CAUSE 2	X
CAUSE 3	X

5. INTERFACES:

MPLM internal atmosphere
Portable Fire Extinguisher (PFE)

6. STATUS OF OPEN WORK:

	PFE	MPLM
CAUSE 1:	CLOSED	CLOSED
CAUSE 2:	CLOSED	NA
CAUSE 3:	CLOSED	NA

7. REMARKS:
The controls and verifications conatined in this Hazard Report have been copied from other previous hazard reports. Those controls and verifications dealing with the PFE were taken from QA 10024D "System Safety Analysis Report for PFE, CO2" which is the baseline hazard analysis performed by ARDE for Boeing-Huntsville for the PFE. This document has been attached for reference purposes in Appendix B.

8. SUBMITTAL CONCURRENCE:

Gordon DeRamus, III — 7/16/01
Gordon DeRamus
HEI Payload Safety Engineer
Date

Carl Ise — 7/16/01
Carl Ise/QS 22
MPLM S&MA Lead Engineer
Space Cargo Assurance Department
Date

Randy K McClendon — 7/16/01
Randy McClendon
MPLM Program Manager FD 23
Date

7/16/01
Allen Shariett
MPLM Lead Systems Engineer FD 23
Date

9. APPROVAL: (Safety Review Panel)

Gregg J Baumer — 7/20/01
SRP Co-Chairman
Date

SRP Co-Chairman
Date

MPLM-PFE-1
CAUSE 1

1. HAZARD CAUSE DESCRIPTION:

Rupture of the Portable Fire Extinguisher

SEVERITY: **CATASTROPHIC** LIKELIHOOD: **IMPROBABLE**

2. CONTROLS:

PFE (subcauses) **ARDE 02-004 Cause 1 - Overpressure beyond burst pressure because of overfill.**
ARDE 02-004 Cause 2 - Overpressure beyond burst because of overtemperature caused by exposure to a heat source.
ARDE 02-004 Cause 3 - Impact during handling, shipping, or servicing results in a substantial loss of tank strength.

CONTROL 1: (PFE only) **(ARDE 02-004, Rev. 1 Cause 1,2 Control 1)**

Tanks are designed to leak before burst.

CONTROL 2: (PFE only) **(ARDE 02-004, Rev. 1 Cause 1,2 Control 2)**

The pressure gauge will provide an indication fo any overpressure conditions. Note: The Burst Disk and Relief Valve (Controls) were deleted from the oringial design after evaluation by Boeing Safety. This makes proper "Mass Filling" a Critical Safety concern.

CONTROL 3: (PFE only) **(ARDE 02-004, Rev. 1 Cause 1,2 Control 3)**

ARDE developed procedures and cautions for safe handling, filling, and pressure testing will be referenced in the applicable test plans and documentation to include guidelines for mass filling.

Controls continued on the following page

3. METHOD FOR VERIFICATION OF CONTROLS:

VERIFICATION FOR CONTROL 1:

1.1.1 Analysis – EG 10002, Fracture and Stress Analysis Report of Tank Carbon Dioxide, PFE P/N 4406 and EG 10031 Stress Analysis Report Manual Control Valve CO_2 Portable Fire Extinguisher initial version presented at the CDR.

1.1.2 Test – Proof Pressure Testing and Acceptance Testing for Valve and Tank per ATP's QA 10009, QA 10014 Acceptance Test Plan Procedure Tank CO_2 Cylinder ARDE P/N E4406 and QA 10060 Qualification Test Procedure for E4482, CO_2 PFE provides validation of the ARDE process; equipment and procedures.

STATUS OF VERIFICATION FOR CONTROL 1:

1.1.1 CLOSED. **(See ARDE 02-004 Cause 1,2,3, Safety Verification Status 1)**
Data: **ANALYSIS** EG 10002, Fracture and Stress Analysis Report of Tank Carbon Dioxide, PFE P/N 4406 and EG 10031 Stress Analysis Report Manual Control Valve CO_2 Portable Fire Extinguisher initial version presented at the CDR.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

1.1.2 CLOSED. **(See ARDE 02-004 Cause 1,2,3, Safety Verification Status 7)**
Data: **TEST** Proof Pressure Testing and Acceptance Testing for Valve and Tank per ATP's QA 10009, QA 10014 Acceptance Test Plan Procedure Tank CO_2 Cylinder ARDE P/N E4406 and QA 10060 Qualification Test Procedure for E4482, CO2 PFE provides validation of the ARDE process; equipment and procedures.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

VERIFICATION FOR CONTROL 2:

1.2.1 Analysis – Reference Pressure Gauge design presented at the CDR.

STATUS OF VERIFICATION FOR CONTROL 2:

1.2.1 CLOSED. **(See ARDE 02-004 Cause 1,2,3, Safety Verification Status 2)**
Data: **ANALYSIS** Reference Pressure Gauge design presented at the CDR.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

VERIFICATION FOR CONTROL 3:

1.3.1 Audit – Internal and Boeing audits to verify effectiveness of ARDE procedures.

STATUS OF VERIFICATION FOR CONTROL 3:

1.3.1 CLOSED. **(See ARDE 02-004 Cause 1,2,3, Safety Verification Status 3)**
Data: **ANALYSIS** Internal and Boeing audits to verify effectiveness of ARDE procedures.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

Verifications continued on the following page

2. CONTROLS: (CONT'D)

CONTROL 4: (PFE only) **(ARDE 02-004, Rev. 1 Cause 1,2 Control 4)**

Boeing is responsible for developing procedures for proper Ground Station mass filling.

CONTROL 5: (PFE only) **(ARDE 02-004, Rev. 1 Cause 2,3 Control 5)**

Boeing is responsible for providing a compartment and mounting which will protect the PFE from exposure to heat sources and damage from accidental contact.

CONTROL 6: (PFE only) **(ARDE 02-004, Rev. 1 Cause 2,3 Control 5)**

Handling of the Tank sets internally at ARDE will be in accordance with the procedures and using handling techniques outlined in the Process Sheets. Shipping container sketches will be provided to Boeing, to be used as a guide in developing crew and ground handling procedures and equipment. Boeing is responsible to provide handling procedures for the other phases of the program.

MPLM Cargo Element Integration

CONTROL 7: (MPLM only) **(MPLM CEI level)**

For Flight 7A.1, the PFE will be transported in a drawer inside a Resupply Stowage Rack. The inside of the drawer is fully padded to support the PFE and prevent any movement of the PFE during launch. The RSR is also designed such that it provides positive margins of safety for carrying the PFE (in addition to other payloads) during launch, landing, and on-orbit operations.

3. METHOD FOR VERIFICATION OF CONTROLS: (CONT'D)

VERIFICATION FOR CONTROL 4:
1.4.1 Boeing responsibility

STATUS OF VERIFICATION FOR CONTROL 4:
1.4.1 CLOSED. **(See ARDE 02-004 Cause 1,2,3, Safety Verification Status 4)**
Data: Boeing responsibility.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

VERIFICATION FOR CONTROL 5:
1.5.1 Boeing responsibility

STATUS OF VERIFICATION FOR CONTROL 5:
1.5.1 CLOSED. **(See ARDE 02-004 Cause 1,2,3, Safety Verification Status 5)**
Data: Boeing responsibility.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

VERIFICATION FOR CONTROL 6:
1.6.1 Audit – Internal and Boeing audits to verify effectiveness of ARDE procedures.

STATUS OF VERIFICATION FOR CONTROL 6:
1.6.1 CLOSED. **(See ARDE 02-004 Cause 1,2,3, Safety Verification Status 6)**
Data: **AUDIT** Internal and Boeing audits to verify effectiveness of ARDE procedures.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

VERIFICATION FOR CONTROL 7:
1.7.1 Review of drawings and CEI documentation to ensure that the PFE will be transported to and from station in a padded drawer inside an RSR and that the mass of the PFE falls well within the load capabilities of the RSR.

STATUS OF VERIFICATION FOR CONTROL 7:
1.7.1 CLOSED.
The MSFC MPLM program has received assurances from the MPLM CEI at JSC that the PFE has been loaded into one of the drawers of the RSRs inside the MPLM and that the PFE has been padded in such a way as to prevent any movement of the PFE during any of the mission phases. The MSFC MPLM program has also been assurred that the load of the PFE is well within the capaiblities of the RSR.

4. SAFETY REQUIREMENTS:

PFE

DOCUMENT: SSP 30559
TITLE: Structural Design and Verification Requirements

Paragraph:		
	3.1.11.2.4.1	Storage Containers
	3.2.1	683-10050H (Leak Before Burst)
	3.2.1.2.4.8	Proof Pressure
	3.2.1.2.4.10	Fail Safe
	3.1.2.2.7	Fatigue
	3.2.1.3.2.4	Fracture Control
	3.3.6.3	683-10050H Failure Tolerance Requirements related to Safety

DOCUMENT: MSFC-HDBK-1453
TITLE: Fracture Control Program Requirements

Paragraph:		
	3.2.1.2.1	Safe Life/Fail Safe Design
	3.3.10.2	683-10050H Factors of Safety

DOCUMENT: SSP 30558
TITLE: Fracture Control Mechanics for Space Station

Paragraph:		
	3.3.10.1	683-10050H Safe-Life Fail-Safe
	3.2.1.2.4.9	Safe Life

DOCUMENT: MSFC-HDBK-527
TITLE:

Paragraph:		
	3.2.1.3.2.4	Materials Selection List for Space Hardwar Programs

DOCUMENT: SSP 30233
TITLE: Space Station Requirements for Materials and Processes
Paragraph:

DOCUMENT: MSFC-STD-1249
TITLE: Guidelines and Controls for Fracture Control Programs
Paragraph:

5. MISSION PHASES:

O	Launch Processing
X	Launch
X	Rendezvous/Docking
X	Deployment
O	Orbital Assembly & Checkout
O	On-Orbit Operations
O	On-Orbit Maintenance
X	Return/Decommissioning

6. PROGRAM STAGE(S):

Flight 7A.1

7. DETECTION AND WARNING METHOD(S):

PFE

(ARDE 02-004, Rev. 1 Rupture of Pressurized PFE Tank)

- The Pressure Gauge on the PFE will provide an indication of any overpressure conditions. There are no warinings of impending failures by other causes except physical inspection for impact damage.

8. CAUSE REMARKS:

PFE

(ARDE 02-004, Rev. 1)

The probability of this failure mode is remote because:

- Given the leak before burst design
- Both the tank and valve have been classified as "Fracture Critical"
- Meeting the Safe Life requirements of SSP 30558
- Being subject to Proof Pressure tests at 1.5 Maximum Operating Pressure (MOP), as well as, subjected to cryoforming pressures in excess of the Burst Pressure requirements.

A mass monitored fill is the control for preventing a potential hazard induced as a result of warming to ambient conditon from developing. For in house CO_2 fills ARDE will provide procedures and equipment for mass fill and pressure relief in the fill and test setups. Boeing hs the responsibility for providing the controls and procedures for the Ground Fill Stations. Fill weights should not exceed 6.1 lbm maximum including allowances for instrumentaiton error.

9. CIL REFERENCE(S):

10. POINT OF CONTACT:

Gordon DeRamus	HEI Payload Safety Engineer	(256) 544-0624

MPLM-PFE-1
CAUSE 2

1. HAZARD CAUSE DESCRIPTION:

Depressurization of the Portable Fire Extinguisher due to discharge or valve failure.

SEVERITY: **CATASTROPHIC** LIKELIHOOD: **IMPROBABLE**

2. CONTROLS:

PFE (ref. causes) **ARDE 02-006 Cause 1 – Depletion of the stored CO2 gas because of tank or valve leak for any of the causes given for the leak external failure mode or from an internal valve leak past the valve seals.**
ARDE 02-006 Cause 2 – Improper Gauge Reading, reads empty when the Tank is full or vice versa resulting in the discarding fo a usable PFE or attempting to use an empty PFE.
ARDE 02-006 Cause 3 – Internal valve failure, inability to remove retention pin, jammed or broken lever results in valve stuck closed.
ARDE 02-006 Cause 4 – Inability to attach nozzle to Pressure Coupling because of handling or accidental damage to nozzle or pressure coupling connections.

CONTROL 1: (PFE only) **(ARDE 02-006, Rev. 1 Cause 2,4 Control 3)**

Problems with the Pressure Gauge, Pressure Coupling, Retention Pins or Valve operation will be picked up during filling or during recommended monthly checks.

CONTROL 2: (PFE only) **(ARDE 02-006, Rev. 1 Cause 1,3 Control 4)**

The Valve Stress Analysis and qualification testingt provides functional validation of the design and moving fits and the Valve acceptance tests will provide build process validation. Inspection of the Tank, Valve and valve components will include NDE to meet SSP 30558 as specified on the individual drawing, and the applicable Inspection and Process Sheets for the various parts and assemblies. This includes Penetrant Inspection for the Tank, Valve, and Valve components, Ultrasonic for the Tank and Xray for the Valve body and welds.

CONTROL 3: (PFE only) **(ARDE 02-006, Rev. 1 Cause 1,3 Control 5)**

Materials and parts selected have a minimum service life of 10 years.

Controls continued on the following page

3. METHOD FOR VERIFICATION OF CONTROLS:

VERIFICATION FOR CONTROL 1:
2.1.1 Boeing responsibility

STATUS OF VERIFICATION FOR CONTROL 1:
2.1.1 CLOSED. **(See ARDE 02-006 Cause 2,4, Safety Verification Status 4)**
Data: Boeing responsibility.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

VERIFICATION FOR CONTROL 2:
2.2.1 Analysis – Reference EG 10031 Stress Analysis Report Manual Control Valve CO2 Portable Fire Extinguisher and EG 10002 Fracture and Stress Analysis Report of Tank Carbon Dioxide, PFE P/N 4406.

STATUS OF VERIFICATION FOR CONTROL 2:
2.2.1 CLOSED. **(See ARDE 02-006 Cause 2,4, Safety Verification Status 5)**
Data: **ANALYSIS** Reference EG 10031 Stress Analysis Report Manual Control Valve CO2 Portable Fire Extinguisher and EG 10002 Fracture and Stress Analysis Report of Tank Carbon Dioxide, PFE P/N 4406.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

VERIFICATION FOR CONTROL 3:
2.3.1 Analysis – Reference applicable MUAs listed in the MIUL.

STATUS OF VERIFICATION FOR CONTROL 3:
2.3.1 CLOSED. **(See ARDE 02-006 Cause 2,4, Safety Verification Status 6)**
Data: **ANALYSIS** Reference applicable MUAs listed in the MIUL.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

Verifications continued on the following page

2. CONTROLS: (CONT'D)

CONTROL 4: (PFE only) **(ARDE 02-006, Rev. 1 Cause 3,4 Control 6)**

Procedures and cautions for safe handling of valve and valve component parts will be referenced in the applicable process and inspecton sheets.

MPLM Cargo Element Integration

CONTROL 5: (MPLM only) **(MPLM CEI level)**

For Flight 7A.1, the PFE will be transported in a drawer inside a Resupply Stowage Rack. The inside of the drawer is fully padded to support the PFE and prevent any movement of the PFE during launch. The RSR is also designed such that it provides positive margins of safety for carrying the PFE (in addition to other payloads) during launch, landing, and on-orbit operations. This will prevent any damage from occuring to the PFE valve due to movement of the PFE during transport. Padding will also prevent an inadvertent pin release and subsequent valve activation due to PFE vibration or movement during transport.

3. METHOD FOR VERIFICATION OF CONTROLS: (CONT'D)

VERIFICATION FOR CONTROL 4:

2.4.1 Audit – Internal and Boeing audits to verify the effectiveness of the ARDE procedures.

STATUS OF VERIFICATION FOR CONTROL 4:

2.4.1 CLOSED. **(See ARDE 02-006 Cause 2,4, Safety Verification Status 7)**
Data: **ANALYSIS** Reference applicable MUAs listed in the MIUL.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

VERIFICATION FOR CONTROL 5:

1.5.1 Review of drawings and CEI documentation to ensure that the PFE will be transported to and from station in a padded drawer inside an RSR and that the mass of the PFE falls well within the load capabilities of the RSR.

STATUS OF VERIFICATION FOR CONTROL 5:

1.5.1 CLOSED.
The MSFC MPLM program has received assurances from the MPLM CEI at JSC that the PFE has been loaded into one of the drawers of the RSRs inside the MPLM and that the PFE has been padded in such a way as to prevent any movement of the PFE during any of the mission phases. The MSFC MPLM program has also been assurred that the load of the PFE is well within the capaiblities of the RSR.

4. SAFETY REQUIREMENTS:

PFE

DOCUMENT: SSP 30559
TITLE: Structural Design and Verification Requirements

Paragraph:	3.1.11.2.4.1	Storage Containers
	3.2.1	683-10050H (Leak Before Burst)
	3.2.1.2.4.8	Proof Pressure
	3.2.1.2.4.10	Fail Safe
	3.1.2.2.7	Fatigue
	3.2.1.3.2.4	Fracture Control
	3.3.6.3	683-10050H Failure Tolerance Requirements related to Safety

DOCUMENT: MSFC-HDBK-1453
TITLE: Fracture Control Program Requirements

Paragraph:	3.2.1.2.1	Safe Life/Fail Safe Design
	3.3.10.2	683-10050H Factors of Safety

DOCUMENT: SSP 30558
TITLE: Fracture Control Mechanics for Space Station

Paragraph:	3.3.10.1	683-10050H Safe-Life Fail-Safe
	3.2.1.2.4.9	Safe Life

DOCUMENT: MSFC-HDBK-527
TITLE:

Paragraph:	3.2.1.3.2.4	Materials Selection List for Space Hardwar Programs

DOCUMENT: SSP 30233
TITLE: Space Station Requirements for Materials and Processes
Paragraph:

DOCUMENT: MSFC-STD-1249
TITLE: Guidelines and Controls for Fracture Control Programs
Paragraph:

5. MISSION PHASES:

O	Launch Processing
X	Launch
X	Rendezvous/Docking
X	Deployment
O	Orbital Assembly & Checkout
O	On-Orbit Operations
O	On-Orbit Maintenance
X	Return/Decommissioning

6. PROGRAM STAGE(S):

Flight 7A.1

7. DETECTION AND WARNING METHOD(S):

PFE

(ARDE 02-006, Rev. 1)

- The pressure gauge on the PFE will provide an indication of any leak, loss of gas conditions which can be discovered during the recommended monthly checks. The fits of the retention pin and nozzle coupling attachment can also be verified during the checks.

8. CAUSE REMARKS:

PFE

(ARDE 02-006, Rev. 1)

- This is a minor hazard considering the monthly maintenance checks will pick up most of the types of failures listed as causes and will allow sufficient time to replace defective PFE's before they are needed for fire fighting. Problems with the Pressure Gauge, retention pins, and nozzle and pressure coupling attachments can be detected by adding the required checks to the recommended monthly checks. The probablity of these failure modes developing between filling and use cycles is remote given the genrally static nature of the conditions to which the tank and valve and valve components are subject to when not in use and the beign nature of CO_2, the storage media. Moreover the probability of needing to use the PFE at the same time this failure mode developed undetected between maintenance checks is extremely remote, to the point that this is not a credible condition.

9. CIL REFERENCE(S):

10. POINT OF CONTACT:

Gordon DeRamus HEI Payload Safety Engineer (256) 544-0624

MPLM-PFE-1
CAUSE 3

1. HAZARD CAUSE DESCRIPTION:

Leakage of the Portable Fire Extinguisher due to seal failure.

SEVERITY: **CATASTROPHIC** LIKELIHOOD: **IMPROBABLE**

2. CONTROLS:

PFE (ref. causes) **ARDE 02-005 Cause 1 – Overpressure beyond MOP because of overfill and or overtemperture**
ARDE 02-005 Cause 2 – Impact during handling, shipping, or servicing results in a loss of tank or valve strength.
ARDE 02-005 Cause 3 – Overuse beyond specified limits of pressure and temperature cycles results in fatigue or fracture of tank or valve.
ARDE 02-005 Cause 4 – Corrosion due to improper environmental exposure.

CONTROL 1: (PFE only) **(ARDE 02-005, Rev. 1 Cause 1,2 Control 1)**

The pressure gauge will provide an indication fo any overpressure conditions. Note: The Burst Disk and Relief Valve (Controls) were deleted from the oringial design after evaluation by Boeing Safety. This makes proper "Mass Filling" a Critical Safety concern.

CONTROL 2: (PFE only) **(ARDE 02-005, Rev. 1 Cause 1,2 Control 2)**

ARDE developed procedures and cautions for safe handling, filling, and pressure testing will be referenced in the applicable test plans and documentation to include guidelines for mass filling.

CONTROL 3: (PFE only) **(ARDE 02-005, Rev. 1 Cause 1,2 Control 3)**

Boeing is responsible for developing procedures for proper Ground Station mass filling.

Controls continued on the following page

3. METHOD FOR VERIFICATION OF CONTROLS:

VERIFICATION FOR CONTROL 1:

3.1.1 Analysis – Reference Pressure Gauge design presented at the CDR.

STATUS OF VERIFICATION FOR CONTROL 1:

3.1.1 CLOSED. **(See ARDE 02-005 Cause 1,2, Safety Verification Status 1)**
Data: **ANALYSIS** Reference Pressure Gauge design presented at the CDR.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

VERIFICATION FOR CONTROL 2:

3.2.1 Audit – Internal and Boeing audits to verify the effectiveness of the ARDE procedures.

STATUS OF VERIFICATION FOR CONTROL 2:

3.2.1 CLOSED. **(See ARDE 02-005 Cause 1,2, Safety Verification Status 1)**
Data: **AUDIT** Internal and Boeing audits to verify the effectiveness of the ARDE procedures.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

VERIFICATION FOR CONTROL 3:

3.3.1 Boeing Responsibility.

STATUS OF VERIFICATION FOR CONTROL 3:

3.3.1 CLOSED. **(See ARDE 02-005 Cause 1,2, Safety Verification Status 1)**
Data: Boeing Resonsibility.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

Verifications continued on the following page

2. CONTROLS: (CONT'D)

CONTROL 4: (PFE only) **(ARDE 02-004, Rev. 1 Cause 2,3 Control 5)**

Boeing is responsible for providing a compartment and mounting which will protect the PFE from exposure to heat sources and damage from accidental contact.

CONTROL 5: (PFE only) **(ARDE 02-004, Rev. 1 Cause 3 Control 5)**

Handling of the Tank sets internally at ARDE will be in accordance with the procedures and using handling techniques outlined in the Process Sheets. Shipping container sketches will be provided to Boeing, to be used as a guide in developing crew and ground handling procedures and equipment. Boeing is responsible to provide handling procedures for the other phases of the program.

CONTROL 6: (PFE only) **(ARDE 02-004, Rev. 1 Cause 4 Control 6)**

To preclude any potential hazards as a result of corrosion there should be no unauthorized labels/attachments/straps in contact with the vessel membrane which could provide entrapment of moisture and salts.

Controls continued on the following page

3. METHOD FOR VERIFICATION OF CONTROLS: (CONT'D)

VERIFICATION FOR CONTROL 4:
3.4.1 Boeing responsibility

STATUS OF VERIFICATION FOR CONTROL 4:
3.4.1 CLOSED. **(See ARDE 02-004 Cause 2,3, Safety Verification Status 5)**
Data: Boeing responsibility.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

VERIFICATION FOR CONTROL 5:
3.5.1 Audit – Internal and Boeing audits to verify effectiveness of ARDE procedures.
3.5.2 Test – Proof Pressure Testing and Acceptance Testing for Valve and Tank per ATP's QA 10009, QA 10014 Acceptance Test Plan Procedure Tank CO2 Cylinder ARDE P/N E4406 and QA 10060 Qualification Test Procedure for E4482, CO2 PFE provides validation of the ARDE process; equipment and procedures.

STATUS OF VERIFICATION FOR CONTROL 5:
3.5.1 CLOSED. **(See ARDE 02-004 Cause 3, Safety Verification Status 5)**
Data: **AUDIT** Internal and Boeing audits to verify effectiveness of ARDE procedures.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.
3.5.2 CLOSED. **(See ARDE 02-004 Cause 3, Safety Verification Status 6**
Data: **TEST** Proof Pressure Testing and Acceptance Testing for Valve and Tank per ATP's QA 10009, QA 10014 Acceptance Test Plan Procedure Tank CO2 Cylinder ARDE P/N E4406 and QA 10060 Qualification Test Procedure for E4482, CO2 PFE provides validation of the ARDE process; equipment and procedures.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

VERIFICATION FOR CONTROL 6:
3.6.1 Analysis – Stress and Fracture Analysis Reports: EG 10031 – Stress Analysis Report of the Manual Control Valve Co2 Portable Fire Extinguisher; EG 10002 – Fracture and Stress Analysis of Tank Carbon Dioxide, PFE P/N 4406; and Fracture Control Plan PM 10005 submitted at CDR.

STATUS OF VERIFICATION FOR CONTROL 6:
3.6.1 CLOSED. **(See ARDE 02-004 Cause 3, Safety Verification Status 5)**
Data: **ANALYSIS** Stress and Fracture Analysis Reports: EG 10031 – Stress Analysis Report of the Manual Control Valve Co2 Portable Fire Extinguisher; EG 10002 – Fracture and Stress Analysis of Tank Carbon Dioxide, PFE P/N 4406; and Fracture Control Plan PM 10005 submitted at CDR.
Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.

Verifications continued on the following page

2. CONTROLS: (CONT'D)

MPLM

CONTROL 7: (MPLM only)

The MPLM system is designed to prevent exceeding its 15.2 Maximum Design Pressure through the use of three Positive Pressure Relief Valves. For the Flight 7A.1 configuration, the MPLM can handle the worst credible depressurization rate of the PFE using just two out of the three PPRVs. (First failure being the loss of the PFE seal and the second failure being the loss of one of the three PPRVs)

3. METHOD FOR VERIFICATION OF CONTROLS: (CONT'D)

VERIFICATION FOR CONTROL 7:

3.7.1 Analysis of the worst case credible depressurization rate of the PFE compaired to the cability of two of the three PPRVs on the MPLM shows that the depressurization rate of the PFE falls within the capability of the MPLM.

STATUS OF VERIFICATION FOR CONTROL 7:

3.7.1 CLOSED.

Data: **ANALYSIS** Depressurizaion analysis of the PFE done by Boeing-Huntsville shows that the worst case credible depressurization rate of the PFE falls within the capabilities of the MPLM using two of three PPRVs. This analysis considered several scenarios including the worst case credible scenario mentioned in Control 7 above. A copy of this analysis has been provided in Appendix C. A short discussion of the scenario's considered is contained in the remarks section. According to the analysis, the specification leakage rate of 6.84×10^{-10} Kg/s would have to be increased by several orders of magnitude before the pressure would increase enough to cause a single PPRV would activate. The specification leakage rate would also have to increase about 3,500,000 times per PPRV in order to reach the MPLM MDP.

4. SAFETY REQUIREMENTS:

PFE

DOCUMENT: SSP 30559
TITLE: Structural Design and Verification Requirements

Paragraph:		
	3.1.11.2.4.1	Storage Containers
	3.2.1	683-10050H (Leak Before Burst)
	3.2.1.2.4.8	Proof Pressure
	3.2.1.2.4.10	Fail Safe
	3.1.2.2.7	Fatigue
	3.2.1.3.2.4	Fracture Control
	3.3.6.3	683-10050H Failure Tolerance Requirements related to Safety

DOCUMENT: MSFC-HDBK-1453
TITLE: Fracture Control Program Requirements

Paragraph:		
	3.2.1.2.1	Safe Life/Fail Safe Design
	3.3.10.2	683-10050H Factors of Safety

DOCUMENT: SSP 30558
TITLE: Fracture Control Mechanics for Space Station

Paragraph:		
	3.3.10.1	683-10050H Safe-Life Fail-Safe
	3.2.1.2.4.9	Safe Life

DOCUMENT: MSFC-HDBK-527
TITLE:

Paragraph:		
	3.2.1.3.2.4	Materials Selection List for Space Hardwar Programs

DOCUMENT: SSP 30233
TITLE: Space Station Requirements for Materials and Processes
Paragraph:

DOCUMENT: MSFC-STD-1249
TITLE: Guidelines and Controls for Fracture Control Programs
Paragraph:

5. MISSION PHASES:

O	Launch Processing
X	Launch
X	Rendezvous/Docking
X	Deployment
O	Orbital Assembly & Checkout
O	On-Orbit Operations
O	On-Orbit Maintenance
X	Return/Decommissioning

6. PROGRAM STAGE(S):

Flight 7A.1

7. DETECTION AND WARNING METHOD(S):

PFE

(ARDE 02-005, Rev. 1)

- The pressure gauge on the PFE will provide an indication of any overpressure conditions. There are no warnings of impending failures by other causes expect physical inspection for impact damage.

8. CAUSE REMARKS:

PFE

(ARDE 02-005, Rev. 1)

The probability of this failure mode is remote because:

- Given the leak before burst design
- Both the tank and valve have been classified as "Fracture Critical"
- Meeting the Safe Life requirements of SSP 30558
- Being subject to Proof Pressure tests at 1.5 Maximum Operating Pressure (MOP), as well as, subjected to cryoforming pressures in excess of the Burst Pressure requirements.

MPLM

MPLM background.
- Maximum Design Pressure (MDP) is 15.2 psia
- The MPLM Qualification unit in Alenia was proof tested to 2 X MDP (30.4 psia)
- Each MPLM Flight Module was acceptanced tested at 1.5 X MDP (22.8 psia)

Scenairo 1 (credible).
- PFE seal leaks at its specification leak rate (6.86 x 10^{-10} Kg/s or 1.35 scc/hr)
- Effect on the MPLM would not be noticiable and would be unlikely to produce enough pressure to activate a single PPRV between launch and MPLM hatch opening on station. (0 failures) (according to the analysis in Appendix C, if the PFE was leaking at this rate at MPLM closeout, the resultant pressure rise would be less than 0.001psia inside the MPLM.)

Scenairo 2 (worst case credible).
- PFE seal leaks about 1000 times its specification leak rate (6.86 x 10^{-10} Kg/s)
- Resultant pressure would be well within the capability of two out of three PPRVs. (two failures) (according to the analysis in Appendix C, if the PFE was leaking at this rate at MPLM closeout, the resultant pressure increase would be 0.24 psia. It is worth noting that this increase would impact the nominal MPLM mission timeline (heater activation) and may result in PPRA activation following lift-off.

Scenairo 3 (non credible).
- PFE seal leaks at a rate greater than 1000 times the specification leak rate (6.86 x 10^{-10} Kg/s).
- Resultant pressure would be well within the capability of two out of three PPRVs. (two failures) (according to the analysis in Appendix C, if the PFE was leaking at this rate at MPLM closeout, the resultant pressure increase would be greater than 0.24 psia. It is worth noting that this increase would impact the nominal MPLM mission timeline (heater activation) and may result in PPRA activation following lift-off.
- The actual leakage rate of the PFE would have to increase by seveal orders of magnitude over the specification leakage rate before the resultant pressure increase would be enough to cause any of the PPRVs to activate.
- The actual leakage rate of the PFE would have to increase by 3,500,000 times the specification leakage rate per PPRV (2.4 x 10^{-3} per valve) before the resultant pressure increase would be enough to reach the MPLM MDP.

Scenairo 4 (non credible).
- PFE completely discharges at full flow rate
- Based on the configuration of the inside of the MPLM for the Flight7A.1 mission and an initial pressure of 14.95 psid, the MPLM would exceed its MDP even if all three valves operated. The resulting pressure would be about 15.23 psid which is 0.03 psid over the MPLM MDP. This pressure exceedance would be momemtary with the MPLM internal pressure dropping back below the MDP as the PFE completely discharges and the operating PPRVs are allowed to catch up. (1 failure)

Scenairo 5 (non credible).
- PFE completely discharges at full flow rate
- Based on the configuration of the inside of the MPLM for the Flight7A.1 mission and an initial pressure of 14.95 psid, the MPLM would exceed its MDP even if two out of three valves operated. The resulting pressure would be about 15.25 psid which is 0.05 psid over the MPLM MDP. This pressure exceedance would be momemtary with the MPLM internal pressure dropping back below the MDP as the PFE completely discharges and the operating PPRVs are allowed to catch up. (2 failures)

Scenairo 6 (non credible).
- PFE completely discharges at full flow rate
- Based on the configuration of the inside of the MPLM for the Flight7A.1 mission and an initial pressure of 14.95 psid, the MPLM would exceed its MDP even if one out of three valves operated. The resulting pressure would be about 15.27 psid which is 0.07 psid over the MPLM MDP. This pressure exceedance would be momemtary with the MPLM internal pressure dropping back below the MDP as the PFE completely discharges and the operating PPRVs are allowed to catch up. (2 failures)

Scenairo 7 (non credible).
- PFE completely discharges at full flow rate
- Based on the configuration of the inside of the MPLM for the Flight7A.1 mission and an initial pressure of 14.95 psid, the MPLM would exceed its MDP if ~~all~~ None of the three valves operated. The resulting pressure would be about 15.3 psid which is 0.1 psid over the MPLM MDP. (4 failures)

9. CIL REFERENCE(S):
N/A

10. POINT OF CONTACT:

Gordon DeRamus HEI Payload Safety Engineer (256) 544-0624

APPENDIX B – QA 10024D SYSTEM SAFETY ANALYSIS REPORT FOR PFE, CO_2.

DATA TRANSMITTAL AND INFORMATION SHEET

TO: IPT #26	ORGN	M/S	REFERENCE NUMBER ARDE 206A
ATTENTION: D. MIELE	ORGN	M/S JS-11	DATE 16-JUL-1996

CC:
D. BOWDEN JR-17 H. DOMINGO JR-26 (DTI)
M. BERHE JR-26

TYPE OF DATA ENCLOSED (DESCRIPTION)

SDS SA-107	DOCUMENT NUMBER QA 10024D	REV
SDRL	TITLE SYSTEM SAFETY ANALYSIS REPORT FOR PFE, C02	

Ref Supplier Letter Number — Dated:
Ref Boeing Letter Number DMB-4740-96 — Dated: 16-JUN-96
Supplier Letter Number KH02012 — Dated: 12-JUL-96

SUPPLIER NAME
ARDE PFE

SUPPLIER PART NUMBER	BOEING PART NUMBER

PART DESCRIPTION

PROGRAM SSP	PURCHASE CONTRACT NUMBER HS1390/10000

THIS FORM SUPPLEMENTS DATA TRANSMITTAL AND INFORMATION FORM NO. ________ DATED ________
THE ABOVE DATA OR INFORMATION WAS REQUESTED BY:

REVIEWERS: PROVIDE COMMENTS OR APPROVAL TO D. MIELE BY 19-JUL-96 — [X] COMMENTS REQUIRED

D. MIELE PROVIDE RESOLUTION BY 19-JUL-96 — [ ] FOR INFORMATION ONLY

FOR ADDITIONAL INFORMATION CONTACT	ORGN	M/S	PHONE NUMBER
D BOWDEN	2-4450	JR-17	461-2253

REPLY: USE SPACE BELOW FOR REPLY, IF ADDITIONAL SPACE IS REQUIRED, USE ATTACHMENTS.

COMMENTS OR EXPLANATION:

RESOLUTION:

[ ] APPROVED [ ] APPROVED W/COMMENTS [ ] DISAPPROVED [ ] N/A OR REVIEW NOT REQUIRED

REVIEWER SIGNATURE	ORGN	MAILSTOP	PHONE	EVAL DATE
EQUIP MGR SIGNATURE	ORGN	MAILSTOP	PHONE	EVAL DATE

BOEING OUTGOING LETTER DATED

DATA TRANSMITTAL AND INFORMATION

TO: Data Management	ORGN.	MAIL STOP: JR-18	REFERENCE NUMBER: ARD-206
ATTENTION: Martha Stone	ORGN	MAIL STOP	DATE: July 16, 1996

CC
1. D. Bowden, JR-17 (Original)
2.
4.

TYPE OF DATA ENCLOSED (DESCRIPTION)
SDRL SS-CM-230D, SS-SA-107C, SS-LS-173C, ARDE Letter kh02012 dated 7/12/96

SUPPLIER'S NAME
ARDE INC

SUPPLIER PART NUMBER | BOEING PART NUMBER

PART DESCRIPTION
PFE

PROGRAM OR AIRPLANE MODEL(S): INTERNATIONAL SPACE STATION | PURCHASE CONTRACT NUMBER: HS1390

THIS FORM SUPPLEMENTS DATA TRANSMITTAL AND INFORMATION FORM NO. ________ DATED ________

THE ABOVE DATA OR INFORMATION WAS REQUESTED BY:

☐ REVIEW AND APPROVE

☐ YOU ARE REQUESTED TO: Distribute -.

REPLY DUE: 7/19/96	APPROVED BY			DATE
FOR ADDITIONAL INFORMATION CONTACT: D. Bowden	ORGN. 2-4450	MAIL STOP: JR-17	PHONE NUMBER: 461-2253	

REPLY: USE SPACE BELOW FOR REPLY; IF ADDITIONAL SPACE IS REQUIRED, USE ATTACHMENTS.

TO	ORGN.	MAIL STOP	DATE

COMMENTS OR EXPLANATION

PREPARED BY	ORGANIZATION	MAIL STOP	PHONE NUMBER	DATE
APPROVED BY	ORGANIZATION	MAIL STOP	PHONE NUMBER	DATE

D1-4133-7000 REV 10/88

-206

ARDÉ INC

500 WALNUT STREET, NORWOOD, NEW JERSEY 07648 (201) 784-9880
FAX 201-784-9710
TWX 710 988 5347

July 12, 1996

RECEIVED
JUL 15 1996

The Boeing Company
499 Boeing Blvd.
PO Box 240002
Huntsville, AL 35824-6402

Attention: Ms. Denise Bowden, M/S JR-17

Subject: SS-CM-230D, SS-SA-107C, SS-LS-173C

Reference: a) Boeing letter 2-4450-DMB-4743-96 dated 7/2/96
b) Boeing letter 2-4450-DMB-4740-96 dated 6/16/96

Dear Ms. Bowden:

1. The subject SDRL, SS-CM-230D, Configuration Status Accounting Report (CSAR), has been revised to reflect the comments of the above reference letter (a).

2. The subject SDRL, SS-SA-107C, System Safety Analysis Report, has been revised to reflect the comments of the above reference letter (b).

3. In accordance with reference letter (b) comment, the attached page 3 (SDRL SS-LS-173C, Logistics Elements Source Data) from EG 10030 provides further definition in regards to the nozzle attachment. Per discussion with Mariam-Berhe, for expediency the existing page 3 of the document on file will be updated via the removal and replacement of the attached copy. Note, there is no change to the revision letter of said document; document remains EG 10030, Rev. D.

Should you have any questions, please do not hesitate to contact the undersigned.

Very truly yours,

ARDÉ, INC.

for Sean P. Ryan
Contracts Manager

SPR:kh
kh02012
Enclosure

QA 10024 REV. D
July 3, 1996

SYSTEM SAFETY ANALYSIS REPORTS

FOR

PFE, CO2

SPACE STATION

SDS NO. SS-SA-107C

SEQ. NO. A076

Prepared for:

BOEING AEROSPACE & ELECTRONICS CORPORATION
HUNTSVILLE, ALABAMA

Prepared by:

/s/ V. Campo

Approved by:

/s/ Arnold Dalene
Engineering

/s/ Stephen Berko
Quality Assurance

/s/ Allan Fleming
Program Management

Submitted by:

ARDE, INC.
500 Walnut Street
Norwood, NJ 07648

QA 10024 Rev. D
July 3, 1996

ARDE, INC.	SYSTEM SAFETY ANALYSIS REPORTS FOR PORTABLE FIRE EXTINGUISHER, PFE CO2 QA 10024	FORM CR-1 DATE ISSUED: DRAWING REVISION: D PAGE 1 OF 1

CHANGE RECORD

CHG.	PAGE	INDEX	DESCRIPTION	APPROVALS QUAL ENGG	PROJ. MGR.	ENG.	MFG ENG
A	ALL		EXTENSIVELY REVISED	SMB	AF	AD	NA
B	ALL		EXTENSIVE REVISION AS A RESULT OF ISSA UPDATE PER ECR #1018	SMB	AF	KS	JFT
C	ALL		REVISION OF DOCUMENT PER (ECP013 NEW NOZZLE) ECR#2001	SMB	HF	AVE	JE
D	B9	ITEM 12	FROM: 683-10050G TO: 683-10050H				
	B24	ITEM 6	FROM: "DISCHARGE OF THE PFE W/O NOZZLE ATTACHED PRODUCES EXCESS, THRUST & PROPELS UN-RESTRAIN. OPER. IN A MICRO-GRAVITY SITU W/THE POTENT. FOR PERSONNEL INJURY." TO: "DISCHARGE OF THE PFE W/O NOZZLE ATTACHED PRODUCES EXCESS, THRUST IN THE RANGE OF 70 LBF TOTAL THRUST OCCUR. W/I THE 1ST SEC. OF OPER. THIS THRUST LEVEL HAS THE POT. TO PROPEL UNRESTD. OPER. IN A MICROGRAVITY SIT. POSSIBLY CAUSING PERSONNEL INJURY."				
	B25	ITEM 13	REPLACE THE "CONTROL" MECHANISM ASSOC. W/CAUSE 1. WAS: "PROPOSED PFE DESIGN, INCORP. A CHECK VALVE IN THE PRESS. COUPL. WHICH WILL PREVENT DISCH, IE REMAIN CLOSED UNLESS NOZ. IS ATTACH OF THE COUPL. IS INSERT. INTO A MATING FITTING."				
	B25	ITEM 14	DELETE ITEM 1: WAS: "BOEING APPRV DES. CHG INCORP. THE PROP CHK VALVE INTO THE DSGN OF THE PRESS. COUPLING." RENUMBER ITEM 2 TO 1.				

QA 10024 Rev. D
July 3, 1996

ARDE, INC.	SYSTEM SAFETY ANALYSIS REPORTS FOR PORTABLE FIRE EXTINGUISHER, PFE CO2 QA 10024	FORM CR-1 DATE ISSUED: DRAWING REVISION: D PAGE 1 OF 1

CHANGE RECORD

				APPROVALS			
CHG.	PAGE	INDEX	DESCRIPTION	QUAL ENGG	PROJ. MGR.	ENG.	MFG ENG
D	B26	ITEM 17	REVISE REMARKS: FROM:"THE ANALYSIS INDIC. THAT THE ONLY REAL. METHOD FOR ELIM. THIS POTEN. HAZARD. & LIKELY COND. IS A BOEING AUTHORIZED DESIGN CHG REQ. THE INCORP. OF A CHECK VALVE IN THE PRESS. COUP. DESIGN.	Revision D - Release per E.O. #1602 [illegible]	[illegible]	[illegible]	[illegible]

QA 10024 D

TABLE OF CONTENTS

LIST OF FIGURES AND DIAGRAMS

1.0 SCOPE/INTRODUCTION

This report has been prepared in accordance with the requirements of SDRL SS-SA-107C as required by paragraph 4.2.2 (Safety Analysis) of the Statement of Work D683-10092-1G and the instructions in the referenced SSP 30309. The report summarizes the results of the System Safety Analysis conducted on the Portable Fire Extinguisher (PFE, CO2) for the Space Station.

This System Safety Analysis Report, QA 10024 for the PFE is being revised to update document and reflect the International Space Station (ISS) program requirements associated with the Source Control Drawing 683-10050 Rev. H-Advance (dated 12/95). The primary change involves the addition of an enclosed-volume nozzle being added to the assembly along with the present open-area nozzle. The configuration for the PFE assembly is shown in Figure PFE-5.

The analysis covers all mission phases and considers hazardous conditions in manufacturing, assembly and test. Both normal and abnormal use conditions were analyzed and the possibility of misuse and human error used in determining possible causes in a Fault Tree analysis.

The hazard analysis considers the immediate impact of the hazards analyzed and speculates on some of the possible higher level hardware effects. In addition the possible atmospheric hazards associated with the release of 6 lbs of CO2 gas were considered beyond the scope of this study and should be considered in Boeing's analysis for each of the Elements.

A preliminary list of the Hazards and Causes analyzed herein were sent to Boeing Safety for review and comment because they were substantially different in format than those submitted for the CDR. These were reviewed and found to be acceptable.

2.0 ABBREVIATIONS AND ACRONYMS

ECLSS	Environmental Control and Life Support System
FDS	Fire Detection and Suppression System
ACS	Atmospheric Control and Supply Subsystem
CO2	Carbon Dioxide
ORU	Orbit Replaceable Unit
MIUL	Materials Identification Usage List
MUA	Material Usage Agreement
N2	Nitrogen
NDE	Non Destructive Examination
NDT	Non Destructive Test
IMS	Inspection Method Sheets
MOP	Maximum Operating Pressure

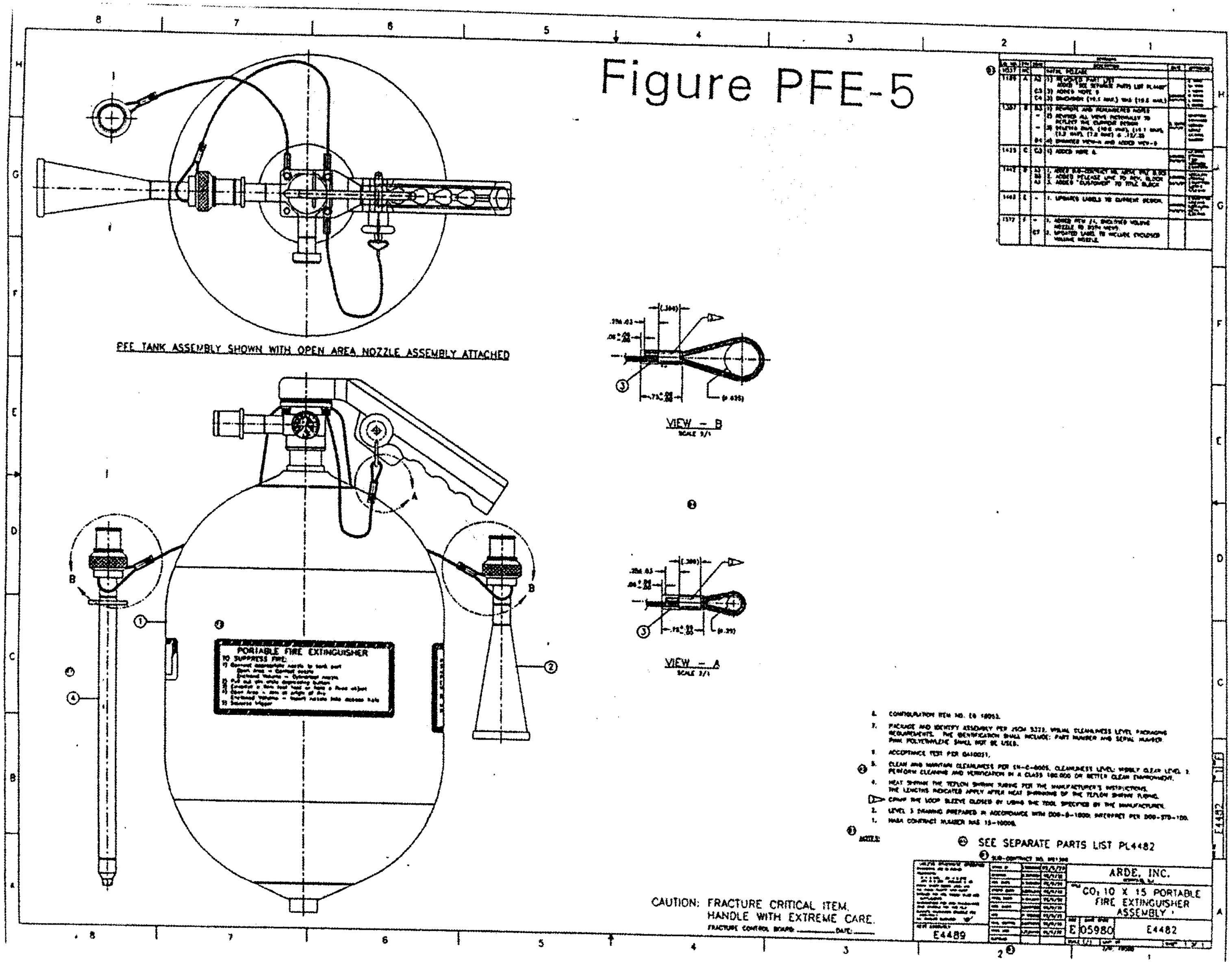


Figure PFE-5
PFE TANK ASSEMBLY SHOWN WITH OPEN AREA NOZZLE ASSEMBLY ATTACHED
PORTABLE FIRE EXTINGUISHER
VIEW - B
SCALE 2/1
VIEW - A
SCALE 2/1
SEE SEPARATE PARTS LIST PL4482
CAUTION: FRACTURE CRITICAL ITEM.
HANDLE WITH EXTREME CARE.
ARDE, INC.
CO2 10 X 15 PORTABLE
FIRE EXTINGUISHER
ASSEMBLY
E4489
05980
E4482

3.0 OBJECTIVE

The purpose of this study is to prepare Hazard Reports which identify and analyze hazards to personnel, hardware, structure and equipment inherent in the manufacture, assembly, test, installation and use of the PFE. This analysis to be used in determining possible causes for these Hazards and the methods proposed or used to control them. The methods proposed to verify the controls is also included. The Controls selected are designed to satisfy the Hazard closure criteria, Design for Minimal Hazard, Safety Devices, Warning Devices as required by paragraph 4.2.3 of the Statement of Work.

4.0 REFERENCES

D683-10092-1G	ECLSS Tank Sets Statement of Work
SSP-30558	Fracture Control Mechanics for Space Station
SSP-30559	Structural Design and Verification Requirements
683-10050H -Advance (dtd 12/95)	Source Control Drawing for Portable CO2 Fire Extinguisher Assembly
QA 10016	Individual Acceptance Test Plan for Manual Valve PFE, CO2
QA 10019	Individual Acceptance Test Plan Tank CO2 Cylinder ARDE P/N E4406
EG 10031	Stress and Fracture Analysis Report Manual Control Valve CO2 Portable Fire Extinguisher

QA 10024 D

EG 10002	Stress and Fracture Analysis Report Tank Carbon Dioxide PFE P/N E4406
EG 10103	MIUL for Portable Fire Extinguisher, PFE CO2
EG 10113	MUA for Portable Fire Extinguisher, PFE CO2
QA 10012	Qualification Test Plan PFE, CO2
PM 10005	Fracture Control Plan for WP01 ECLSSTank Sets
QA 10021	Individual Acceptance Test Procedure,PFE
QA 10009	Acceptance Test Procedure for Tank P/N E4406
QA 10014	Acceptance Test Procedure Manual Valve Sub-assembly
QA 10060	Qualification Test Plan and Procedure for PFE
QA 10049	QTP, Manual Valve

5.0 FUNCTIONAL DESCRIPTION

5.1 PORTABLE FIRE EXTINGUISHER, PFE CO2

The PFE is a Portable, hand operated CO2 dispensing system, part of the FDS, Fire Detection and Suppression System and is a complete ORU. It is used as a means of fire suppression in open areas and within enclosed volumes.

This assembly consists of a cylindrical tank with hemispherical pressure heads, hand actuated manual valve, pressure gauge welded to one of the valve ports and a pressure coupling welded to valve outlet port. The pressure coupling provides a quick disconnect for attachment to either the PFE open area nozzle or enclosed volume nozzle. The nozzles are tethered to the PFE assembly by their respective lanyards. The handle assembly includes a retention pin which is designed to prevent accidental actuation prior to intended use; it is also be used for holding the valve open during filling operations. The nozzles have been designed to provide controlled thrust at the required flow rate.

6.0 SUMMARY

6.1 PORTABLE FIRE EXTINGUISHER PFE CO_2

The principal hazards for the Portable Fire Extinguisher occur during the brief period where it is unrestrained during use, handling, filling or transportation when the hazards from a fast leak or rupture would produce the maximum effect. The PFE spends the greatest part of its life on the Space Station in the restraint and mounting provided by Boeing. The hazards resulting from failure in this condition should be minimal depending on the design of the mounting and storage compartment.

The recommended monthly inspections of the PFE minimizes the limited hazards created by the loss of the stored CO_2 gas.

One hazard, however, requires further consideration, the thrust effects of operating a PFE without the nozzle attached.

6.0 SUMMARY

6.1 PORTABLE FIRE EXTINGUISHER PFE CO2

The principal hazards for the Portable Fire Extinguisher occur during the brief period where it is unrestrained during use, handling, filling or transportation when the hazards from a fast leak or rupture would produce the maximum effect. The PFE spends the greatest part of its life on the Space Station in the restraint and mounting provided by Boeing. The hazards resulting from failure in this condition should be minimal depending on the design of the mounting and storage compartment.

The recommended monthly inspections of the PFE minimizes the limited hazards created by the loss of the stored CO2 gas.

One hazard, however, requires further consideration, the thrust effects of operating a PFE without the nozzle attached.

ARDE INC.
Space Station Hazard Report

APPENDIX B

Hazard Reports for the Portable Fire Extinguisher PFE, CO2

ARDE, INC.
Space Station Hazard Report
ARDE -02-0004

1. Title: Rupture of Pressurized PFE Tank.

2. Hazard ID No.: ARDE 02-0004, Rev. 1

3. Revision Date: 4/23/96

4. System: ECLSS
   Subsystem: FDS

5. Risk Index
   Severity: Catastrophic   Likelihood: Very Remote

6. Hazard Description:
   Tank rupture during attempted use, handling, filling leading to pressure release and thrusting effects causing injury to crew or ground personnel and possible damage to nearby structure and equipment.

7. Program Phases:
   X a) DDT&E/Manufacturing
   X b) Launch Processing
   X c) Launch
   X d) Flight
   X e) Orbital Assembly & Checkout
   On-Orbit Operation:
   X f.1) First Element Launch
   X f.2) Orbit
   X f.3) Return/Decommissioning

8. Hazard Causes:

   1) Overpressure beyond burst pressure because of overfill.
   2) Overpressure beyond burst because of overtemperature caused by exposure to a heat source.
   3) Impact during handling, shipping or servicing results in a substantial loss of tank strength.

9. Worst Case Hazard Effect

   Personnel Injury, damage to nearby structure and equipment.

10. Interfaces:

    WP02 ________ WP03 ________ WP04 ________ CSA ________

    ESA ________ NASDA ________ STS ________ Ground ________

    Other:

11. Detection and Warning Method(s):

    Detection: The pressure gauge on the PFE will provide an indication of any overpressure conditions. There are no warnings of impending failures by other causes except physical inspection for impact damage.

12. Safety Requirement(s):

    Referenced Documents are indicated below the applicable paragraph numbers.

3.1.11.2.4.1	Storage Containers
3.2.1	683-10050H (Leak Before Burst)
SSP 30559	Structural Design and Verification Requirements
3.2.1.2.1	Safe Life/Fail Safe Design
MSFC-HDBK-1453	Fracture Control Program Requirements
3.2.1.2.4.8	Proof Pressure
SSP 30559	Structural Design and Verification Requirements
3.3.10.1	683-10050H Safe-Life Fail-Safe
SSP 30558	Fracture Control Mechanics for Space Station

3.2.1.2.4.9	Safe-Life
SSP 30558	Fracture Control Mechanics for Space Station
3.2.1.2.4.10	Fail Safe
3.1.2.2.7	Fatigue
SSP 30559	Structural Design and Verification Requirements
3.2.1.3.1	Materials Selection List for Space
MSFC-HDBK-527	Hardware Programs
3.2.1.3.2.4	Fracture Control
SSP 30559	Structural Design and Verification Requirements
SSP 30233	Space Station Requirements for Materials and Processes
MSFC-STD-1249	Guidelines and Controls for Fracture Control Programs
MSFC-HDBK-1453	Fracture Control Program Requirements
3.3.10.2	683-10050H Factors of Safety
SSP 30559	Structural Design and Verification Requirements
3.3,6.3	683-10050H Failure Tolerance Requirements related to safety.

13. Control Method(s):

CAUSE	REQUIREMENTS	CONTROL
All	683-10050H, 3.2.1	1. Tanks are designed to leak before burst.
1,2		2. The pressure gauge will provide an indication of any overpressure conditions. Note: The Burst Disk and Relief Valve (Controls) were deleted from the original design after evaluation by Boeing Safety. This makes proper "Mass Filling" a Critical Safety concern.
		3. ARDE developed procedures and cautions for safe handling, filling and pressure testing will be referenced in the applicable test plans and documentation to include guidelines for mass filling.
		4. Boeing is responsible for developing procedures for proper Ground Station mass filling.

2,3	3.1.11.3.4.	5. Boeing is responsible for providing a compartment and mounting which will protect the PFE from exposure to heat sources and damage from accidental contact.
3		6. Handling of the Tank Sets internally at ARDE will be in accordance with the procedures and using handling techniques outlined in the Process Sheets. Shipping container sketches will be provided to Boeing, to be used as a guide in developing crew and ground handling procedures and equipment. Boeing is responsible to provide handling procedures for the other phases of the program.

14. Method of Verification of Control(s):
    1. Analysis - EG 10002, Fracture and Stress Analysis Report of Tank Carbon Dioxide, PFE P/N 4406 and EG 10031 Stress Analysis Report Manual Control Valve CO2 Portable Fire Extinguisher initial version presented at the CDR.
    2. Analysis - Reference Pressure Gauge design presented at the CDR:
    3. Audit - Internal and Boeing audits to verify effectiveness of ARDE procedures.
    4. Boeing responsibility.
    5. Boeing responsibility.
    6. Audit - Internal and Boeing audits to verify the effectiveness of the ARDE procedures.
    7. Test - Proof Pressure Testing and Acceptance Testing for Valve and Tank per ATP's QA 10009, QA 10014 Acceptance Test Plan Procedure Tank CO2 Cylinder ARDE P/N E4406 and QA 10060 Qualification Test Procedure for E4482, CO2 PFE provides validation of the ARDE process; equipment and procedures.
    8. Analysis - Stress and Fracture Analysis Reports: EG 10031 - Stress Analysis Report of the Manual Control Valve CO2 Portable Fire Extinguisher; EG 10002 - Fracture and Stress Analysis of Tank Carbon Dioxide, PFE P/N 4406; and Fracture Control Plan PM 10005 submitted at CDR.

15. Status of Open Work: Design completed.

16. Reference(s): EG 10002
EG 10031
QA 10009
QA 10014
QA 10060
PM 10005

17. Remark(s):
The probability of this failure mode is remote because:
(i) given the leak before burst design;

(ii) both the tank and valve have been classified as "Fracture Critical";

(iii) meeting the Safe Life requirements of SSP 30558;

(iv) being subject to Proof Pressure tests at 1.5, Maximum Operating Pressure (MOP), as well as, subjected to cryoforming pressures in excess of the Burst Pressure requirements.

A mass monitored fill is the control for preventing a potential hazard induced as a result of warming to ambient condition from developing. For in house CO2 fills ARDE will provide procedures and equipment for mass fill and pressure relief in the fill and test setups. Boeing has the responsibility for providing the controls and procedures for the Ground Fill Stations. Fill weights should not exceed 6.1 lbm maximum including allowances for instrumentation error.

18. Hazardous Materials: None identified.

19. Release and Closure Status:
Hazard Status: Open _____ Closed_____
Closure Classification:
Accepted Risk:

ARDE, INC.
Space Station Hazard Report
ARDE 02-0005

1. Title: Leak External

2. Hazard ID No.: ARDE 02-0004 Rev. 1

3. Revision Date: 4/23/96

4. System: ECLSS
   Subsystem: FDS

5. Risk Index
   Severity: Critical Likelihood: Remote

6. Hazard Description:
   Fast external valve, body, weld or tank leak resulting in thrusting effects and possible injury to crew or ground personnel during handling or attempted use when the unit is unrestrained. A slow leak will cause depletion of the stored CO2 gas and render the PFE useless for fire fighting, see hazard ARDE 02-0006.

7. Program Phases:
   ____ a) DDT&E/Manufacturing
   X b) Launch Processing
   ____ c) Launch
   X d) Flight
   X e) Orbital Assembly & Checkout
   On-Orbit Operation:
   ____ f.1) First Element Launch
   X f.2) Orbit
   ____ f.3) Return/Decommissioning

8. Hazard Causes:
   1. Overpressure beyond MOP because of overfill and or overtemperature.
   2. Impact during handling, shipping or servicing results in a loss of tank or valve strength.
   3. Overuse beyond specified limits of pressure and temperature cycles results in fatigue or fracture of tank or valve.
   4. Corrosion due to improper environmental exposure.

9. Worst Case Hazard Effect

   Personnel injury, damage to nearby equipment.

10. Interfaces:

    WPO2 ________ WP03 ________ WP04 ________ CSA ________

    ESA ________ NASDA ________ STS ________ Ground ________

    Other:

11. Detection and Warning Method(s):

    The pressure gauge on the PFE will provide an a indication of any overpressure conditions. There are no warnings of impending failures by other causes except physical inspection for impact damage.

12. Safety Requirement(s):

    Referenced Documents are indicated below the applicable paragraph numbers.

3.1.11.2.4.1	Storage Containers
3.2.1	683-10050H (Leak Before Burst)
SSP 30559	Structural Design and Verification Requirements
3.2.1.2.1	Safe Life/Fail Safe Design
MSFC-HDBK-1453	Fracture Control Program Requirements
3.2.1.2.4.8	Proof Pressure
SSP 30559	Structural Design and Verification Requirements
3.3.10.1	683-10050H Safe-Life Fail-Safe
SSP 30558	Fracture Control Mechanics for Space Station

3.2.1.2.4.9	Safe-Life
SSP 30558	Fracture Control Mechanics for Space Station
3.2.1.2.4.10	Fail Safe
3.1.2.2.7	Fatigue
SSP 30559	Structural Design and Verification Requirements
3.2.1.3.1	Materials Selection List for Space Hardware
MSFC-HDBK-527	Programs
3.2.1.3.2.4	Fracture Control
SSP 30559	Structural Design and Verification Requirements
SSP 30233	Space Station Requirements for Materials and Processes
MSFC-STD-1249	Guidelines and Controls for Fracture Control Programs
MSFC-HDBK-1453	Fracture Control Program Requirements
3.3.10.2	683-10050H Factors of Safety
SSP 30559	Structural Design and Verification Requirements
3.3.6.3	683-10050H Failure Tolerance Requirements related to safety.

13. Control Method(s):

CAUSE	REQUIREMENTS	CONTROL
1,2		1. The pressure gauge will provide an indication of any overpressure conditions or loss of gas. Note: The Burst Disk and Relief Valve (Controls) were deleted from the original design after evaluation by Boeing Safety. This makes proper "Mass Filling" a critical safety concern.
1		2. ARDE developed procedures and cautions for safe handling, filling and pressure testing will be referenced in the applicable test plans and documentation to include guidelines for mass filling.
		3. Boeing is responsible for developing procedures for proper Ground Station mass filling.

2,3	3.1.11.3.4.1	4. Boeing is responsible for providing a compartment and mounting which will protect the PFE from exposure to heat sources and damage from accidental contact.
3		5. Handling of the Tank Sets internally at ARDE will be in accordance with the handling procedures in the Process and Inspection Methods sheets. Copies of the shipping container sketches will be provided to Boeing, to be used as a guide to develop crew and ground handling procedures and equipment. Boeing is responsible to provide handling procedures for the other phases of the program.
4	3.2.1.3.2.4	6. To preclude any potential hazards as a result of corrosion there should be no unauthorized labels/attachments/straps in contact with the vessel membrane which could provide entrapment of moisture and salts.

14. Method of Verification of Control(s):

1. Analysis - Reference Pressure Gauge design presented at the CDR.
2. Audit - Internal and Boeing audits to verify effectiveness of ARDE procedures.
3. Boeing responsibility
4. Boeing responsibility
5. Audit - Internal and Boeing audits to verify the effectiveness of the ARDE procedures
6. Test - Proof Pressure Testing and Acceptance Testing for Valve and Tank per ATP's QA 10009, QA 10014 Acceptance Test Procedure Tank CO2 Cylinder ARDE P/N E4406 and QA 10060 Qualification Test Plan for E4482, CO2 PFE provides validation of the ARDE process; equipment and procedures.
7. Analysis - Stress and Fracture Analysis Reports: EG 10031 - Stress Analysis Report of the Manual Control Valve CO2 Portable Fire Extinguisher; EG 10002 - Fracture and Stress Analysis of Tank Carbon Dioxide, PFE P/N 4406; and Fracture Control Plan PM 10005 submitted at CDR.

15. Status of Open Work: Design completed.

16. Reference(s): QA 10009
QA 10014
QA 10060
EG 10031
EG 10002
PM 10005

17. Remark(s):

The probability of this failure mode is remote because: (i) both the tank and valve have been classified as "Fracture Critical"; (ii) meet the Safe Life requirements of SSP 30558; (iii) will be subject to Proof Pressure tests at 1.5 MOP, Maximum Operating Pressure as well as subjected to cryoforming pressures in excess of the Burst Pressure requirements.

ARDE, INC.
Space Station Hazard Report
ARDE 02-0006

1. Title: Failure to Operate

2. Hazard ID No.: ARDE 02-0006 Rev. 1

3. Revision Date: 4/23/96

4. System: ECLSS
   Subsystem: FDS

5. Risk Index
   Severity: Critical   Likelihood: Remote

6. Hazard Description:
   Inability to deliver CO_2 gas to extinguish a fire.

7. Program Phases:
   ____ a) DDT&E/Manufacturing
   ____ b) Launch Processing
   ____ c) Launch
   _X_ d) Flight
   _X_ e) Orbital Assembly & Checkout
   On-Orbit Operation:
   ____ f.1) First Element Launch
   _X_ f.2) Orbit
   ____ f.3) Return/Decommissioning

8. Hazard Causes:
   1. Depletion of the stored CO2 gas because of tank or valve leak for any of the causes given for the leak external failure mode or from an internal valve leak past the valve seals.
   2. Improper Pressure Gauge Reading, reads empty when the Tank is full or vice versa resulting in the discarding of a usable PFE or attempting to use an empty PFE.
   3. Internal valve failure, inability to remove retention pin, jammed or broken lever results in valve stuck closed.
   4. Inability to attach nozzle to Pressure Coupling because of handling or accidental damage to nozzle or pressure coupling connections.
   5. Material/Weld defect.

9. Worst Case Hazard Effect
   Inability to extinguish a fire.

10. Interfaces:
    WPO2 ________ WP03 ________ WP04 ________ CSA ________
    ESA ________ NASDA ________ STS ________ Ground _______
    Other:

11. Detection and Warning Method(s):
    Detection: The pressure gauge on the PFE will provide an indication of any leak, loss of gas conditions which can be discovered during the recommended monthly checks. The fits of the retention pin and nozzle coupling attachment can also be verified during the checks.

12. Safety Requirement(s):

    Referenced Documents are indicated below the applicable paragraph numbers.

3.1.11.2.4.1	Storage Containers
3.2.1	683-10050H (Leak Before Burst)
SSP 30559	Structural Design and Verification Requirements
3.2.1.2.1	Safe Life/Fail Safe Design
MSFC-HDBK-1453	Fracture Control Program Requirements

-B16-

3.2.1.2.4.8	Proof Pressure
SSP 30559	Structural Design and Verification Requirements
3.3.10.1	683-10050H Safe-Life Fail-Safe
SSP 30558	Fracture Control Mechanics for Space Station
3.2.1.2.4.9	Safe-Life
SSP 30558	Fracture Control Mechanics for Space Station
3.2.1.2.4.10	Fail Safe
3.1.2.2.7	Fatigue
SSP 30559	Structural Design and Verification Requirements
3.2.1.3.1	Materials Selection List for Space Hardware
MSFC-HDBK-527	Programs
3.2.1.3.2.4	Fracture Control
SSP 30559	Structural Design and Verification Requirements
SSP 30233	Space Station Requirements for Materials and Processes
MSFC-STD-1249	Guidelines and Controls for Fracture Control Programs
MSFC-HDBK-1453	Fracture Control Program Requirements
3.3.10.2	683-10050H Factors of Safety
SSP 30559	Structural Design and Verification Requirements
3.3.6.3	683-10050H Failure Tolerance Requirements elated to safety.

13. Control Method(s):

CAUSE	REQUIREMENTS	CONTROL
1		1. The pressure gauge will provide an indication of any overpressure or loss of gas and a leaky PFE can be replaced on orbit being an ORU, Orbital Replaceable Unit.
1		2. See controls for external leak failure mode ARDE 02-0005.
2,4		3. Problems with the Pressure Gauge, Pressure Coupling, Retention Pins or Valve operation will be picked up during filling or during the recommended monthly checks.

1,3	3.2.1.2.1.4 3.3.10.1 3.2.1.2.4.9 3.1.2.2.7 3.2.1.3.1 3.2.1.3.2.4 3.3.10.2	4. The Valve Stress Analysis and qualification testing provides functional validation of the design and moving fits and the Valve acceptance tests will provide build process validation. Inspection of the Tank, Valve and valve components will include NDE to meet SSP 30558 as specified on the individual drawing, and the applicable Inspection and Process Sheets for the various parts and assemblies. This includes Penetrant Inspection for the Tank, Valve and Valve components, Ultrasonic for the Tank and X-ray for the Valve body and welds.
1,3	3.2.1.3.1	5. Materials and parts selected have a minimum service life of 10 years; see applicable MIUL.
3,4		6. Procedures and cautions for safe handling of valve and valve component parts will be referenced in the applicable process and inspection method sheets.

3,4 7. Boeing is responsible for developing procedures for proper handling and to avoid damage during ground crew transportation and filling. Boeing is also responsible for providing a compartment and mounting which will protect the PFE Nozzle and Coupling from damage from accidental contact.

3,4 8. Handling of the Tank Sets internally at ARDE will be in accordance with the handling procedures called out in the Process and Inspection Method Sheets Copies of the container sketches will be provided to Boeing, to be used as a guide to develop crew and ground handling procedures and equipment. Boeing is responsible to provide handling procedures for the other phases of the program.

4	3.2.1.3.2.4	9. Processing and evaluation of heats of material, manufacturing and inspection of the PFE, NDE will be in accordance with internal ARDE procedures as indicated in the individual Drawings, Process Sheets and Inspection Method Sheets. Proof and Helium Leak Testing per ATP. Qualification Testing per QTP.
4	3.2.1.2.1	10. The design meets Fail Safe Requirements. Valve and Tank design margins exceed the safety factors specified for Fracture Control and Safe Life.
5		11. Materials of construction and processes have been addressed via the applicable MIULs (EG 10103) and MUAs (EG 10113).

4. Method of Verification of Control(s):
   1. Boeing responsibility
   2. Analysis - Reference Pressure Gauge design presented at the CDR.
   3. See Verification of Controls for External Leak presented in ARDE 02-0005.
   4. Boeing responsibility
   5. Analysis - Reference EG 10031 Stress Analysis Report Manual Control Valve CO2 Portable Fire Extinguisher and EG 10002 Fracture and Stress Analysis Report of Tank Carbon Dioxide, PFE P/N 4406.-

6. Analysis - Reference applicable MUAs listed in the MIUL.
7. Audit - Internal and Boeing audits to verify the effectiveness of the ARDE procedures.
8. Boeing responsibility.
9. Test - Proof Pressure Testing and Acceptance Testing for Valve and Tank per ATP's QA 10009, Acceptance Test Plan for Manual Valve, QA 10014 Acceptance Test Procedure Tank CO2 Cylinder ARDE P/N E4406 and QA 10060 Qualification Test Procedure for E4482, CO2 PFE provides validation of the ARDE process; equipment and procedures.
10. Analysis - Stress and Fracture Analysis Reports, EG 10031 - Stress Analysis Report of the Manual Control Valve CO2 Portable Fire Extinguisher; EG 10002 - Fracture and Stress Analysis of Tank Carbon Dioxide, PFE P/N 4406; and Fracture Control Plan PM 10005 submitted at CDR.

15. Status of Open Work: Design completed.

16. Reference(s): QA 10021
QA 10009
QA 10014
QA 10060
EG 10002
EG 10031
EG 10103
EG 10113
PM 10005

17. Remark(s):
This is a minor hazard considering the monthly maintenance checks will pick up most of the types of failures listed as causes and will allow sufficient time to replace defective PFE's before they are needed for fire fighting.

Problems with the Pressure Gauge, retention pins and nozzle and pressure coupling attachments can be detected by adding the required checks to the recommended monthly checks.
The probability of these failure modes developing between filling and use cycles is remote given the generally static nature of the conditions to which the tank and valve and valve components are subject to when not in use and the benign nature of CO2, the storage media. Moreover the probability of needing to use the PFE at the same time this failure mode developed undetected between maintenance checks is extremely remote, to the point that this is not a credible condition.

ARDE, INC.
Space Station Hazard Report
ARDE 02-0007

1. Title: Excessive Thrust during Operation

2. Hazard ID No.: ARDE 02-0007 Rev. 1

3. Revision Date: 7/3/96

4. System: ECLSS
   Subsystem: FDS

5. Risk Index
   Severity: Critical   Likelihood: Likely

6. Hazard Description:
   Discharge of the PFE without nozzle attached produces excessive thrust in the range of 70 lbf total thrust occurring within the first second of operation. This thrust level has the potential to propel unrestrained operator in a microgravity situation possibly causing personnel injury.

7. Program Phases:
   ____ a) DDT&E/Manufacturing
   ____ b) Launch Processing
   ____ c) Launch
   ____ d) Flight
   __X__ e) Orbital Assembly & Checkout
   On-Orbit Operation:
   ____ f.1) First Element Launch
   __X__ f.2) Orbit
   ____ f.3) Return/Decommissioning

8. Hazard Causes:
   1. Operator error, discharge to the PFE without the nozzle being attached possibly in the confusion created by an emergency situation such as fire.
9. Worst Case Hazard Effect
   Personnel injury.
10. Interfaces:
    WP02 ________ WP03 ________ WP04 ________ CSA ________
    ESA ________ NASDA ________ STS ________ Ground _______
    Other:
11. Detection and Warning Method(s):
    Proper operating procedure with nozzle attached is indicated on the Warning Label on the PFE.
12. Safety Requirement(s):

NASA-STD-3000 Vol. IV	Space Station Man-Systems Integration Standards

13. Control Method(s):

CAUSE	REQUIREMENTS	CONTROL
1		1. NASA Safety has groundruled that the crewmembers are well-trained in operational procedures and, therefore, Boeing can more easily verify that safety requirements are met without designing for contingency (e.g., performing steps in an operation out of order or not correctly performing one step of an operation.)

Further, the safety failure tolerance requirements outlined in the Envelope Drawing for the PFE specify that catastrophic hazards shall be controlled such that no single operator error can result in a hazardous event. In the case of the QD coupling, the crewmember must first connect the QDs then, secondly, look at the coupling to verify the connection. In summary, two (as opposed to one) operator errors must occur to cause the hazard of discharging the PFE with a QD missed connection. Therefore, it is felt that the PFE design meets Program safety requirements.

NASA-STD-3000

2. Warning Labels on the PFE indicate proper method for operating PFE.

14. Method of Verification of Control(s):
   1. Inspection - Reference label in the PFE drawing E4489.

15. Status of Open Work: Design completed.

16. Reference(s): E 4489, NASA-STD-3000

17. Remark(s):

Both nozzles (open-fire or enclosed-fire type) are attached to the PFE tank via mechanical wire rope lanyards. The well-trained NASA crewmembers prior to utilizing the PFE would make the assessment as to which fire condition exists and then proceed to correctly connect the appropriate nozzle with its quick disconnect coupling mechanism.

APPENDIX C – MPLM PRESSURE ANALYSIS.

AT1G-01-007
16 July 2001

To: Ken Shih
From: Greg Day 256-461-3626
Subject: ISS 7A.1 PFE Leakage / Blow-Down Impacts on MPLM
References:

A NSTS 12820, Volume C; Joint Shuttle-ISS Operational Flight Rules
B D683-10050, Rev H; Portable Fire Extinguisher Envelope Drawing
C Internal discussions with Cindy Upton / Roger VonJouanne; D683-14179
D ISS Change Request 2452; PPRA Crack Point Change
E ISS-MPLM-IDD-006; MPLM Interface Definition Document
F Space Shuttle Operations and Maintenance Requirements and Specifications Document; File VIII, Volume 3, dated 6/28/01
G SSP 57000, revision E; Pressurized Payloads Interface Requirements Document

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Summary

The Multi-Purpose Logistics Module (MPLM) will be carrying a Portable Fire Extinguisher (PFE) to the International Space Station (ISS) on Flight 7A.1. In support of this mission, both PFE leakage and blow-down analyses were completed to evaluate impacts to the nominal and contingency MPLM capabilities. The analytical results indicate that the MPLM is compatible with all PFE leakage scenarios, but the blow-down simulations show that the MPLM primary structure limits will be exceeded. A summary of the analytical results is tabulated below. For all cases, the MPLM primary structure limitation is 15.2 psid as documented in references E and G.

Simulation	Description	Result
Nominal Leakage	PFE leakage per reference B	No impact to nominal MPLM timeline
Extreme Leakage	PFE leakage requirement increased by 3 orders of magnitude	Will cause PPRA actuation but maximum pressure across MPLM shell will be less than 15.2 psid
Blow-Down	Complete discharge of PFE per reference C	Will cause PPRA actuation and will exceed MPLM pressure limit of 15.2 psid (maximum predicted is 15.3 psid)

Initial Conditions for PFE Analyses

The MPLM internal pressure is a function of many variables. As part of the KSC processing flow, the MPLM internal environment at close-out must be 70 ± 2°F and 14.85 ± 0.02 psia (reference F). For the purposes of these analyses, it was assumed that the worst case combination of temperature and pressure was present at close-out. During flight, the MPLM shell heaters are manually cycled to maintain subsystem and payload thermal limits. The operational groundrules established between the MPLM Project Office and JSC Mission Operations Directorate allows heater operation until the internal pressure reaches 14.95 psia (reference A). Previous Alenia analyses were updated to reflect the flight 7A.1 stowage manifest to determine the module free air volume. Finally, each MPLM incorporates three PPRAs in the forward endcone. This analysis updated the PPRA actuation pressures from the specification values (reference D) to the flight 7A.1-specific as-tested PPRA actuation levels as shown in the following table.

PPRA Number	Actuation Pressure (millibar differential)
1	1,039
2	1,044
3	1,044

PFE Leakage

PFE leakage rates were evaluated based on the nominal MPLM KSC timeline coupled with worst case flight 7A.1 mission parameters. The MPLM is closed out for flight approximately 3 weeks prior to launch, so a month was used as the potential leakage timeframe. The leakage rate documented in the PFE Envelope Drawing (reference B) is 1.35 scc/hr. This leakage rate (equivalent to 6.84×10^{-10} kg/sec) does not pose any adverse impact to the MPLM nominal operations for 7A.1. Even if the PFE were leaking at MPLM close-out, the resulting leakage over the 30-day prelaunch timeframe is negligible (pressure increase of less than 0.001 psia inside the MPLM).

An additional leakage analysis was completed based on increasing the specification leakage rate by a factor of 1,000. In this instance, the equivalent mass flow rate of 6.84×10^{-7} kg/sec over a 30-day timeframe would result in an internal pressure increase of 0.24 psia. This pressure increase would impact the nominal MPLM mission timeline and may result in PPRA actuation following lift-off.

A final assessment was completed to define the maximum PFE leakage rate that would actuate the PPRAs but would not pose an overpressurization risk to the MPLM primary structure. For each operational PPRA, the allowable PFE leakage would be $\sim 5 \times 10^{6}$ scc/hr. Note that this leakage value is 6 orders of magnitude higher than the PFE specification leakage rate.

In summary, the nominal PFE leakage rate can be accommodated under worst case conditions with no impact to the nominal MPLM timeline. Increasing this leakage rate by several orders of magnitude will result in PPRA actuation, but the specification leakage rate would have to be magnified by ~ 3,500,000 per functional PPRA to reach the MPLM structural limitations.

PFE Blow-Down

A PFE blow-down event will impact the MPLM nominal operations and will be treated during the 7A.1 mission as an anomalous event. For this discussion, the blow-down was evaluated to ensure compatibility with the MPLM structural requirements.

A PFE blow-down is a single short-term event as opposed to the long-term duration associated with the PFE leakage analyses. In order to analyze the blow-down cases, it was assumed that the PFE discharge rate was identical to that obtained when a crew-member discharges the PFE in a nominal fashion. In order to fully encompass the 7A.1 mission timeline, it was further assumed that the MPLM was closed out at the outer edge of the acceptable envelope (per reference F), the MPLM shell heaters were operated up the maximum temperature/pressure levels specified in the flight rules (reference A), and the cracking pressures for the PPRAs were per the KSC test data for MPLM flight module 1. The following figure (Figure 1) contains the PFE blow-down curve as provided by reference C. This curve graphically shows that the carbon dioxide contents of the tank are essentially expelled from the PFE in approximately 45 seconds.

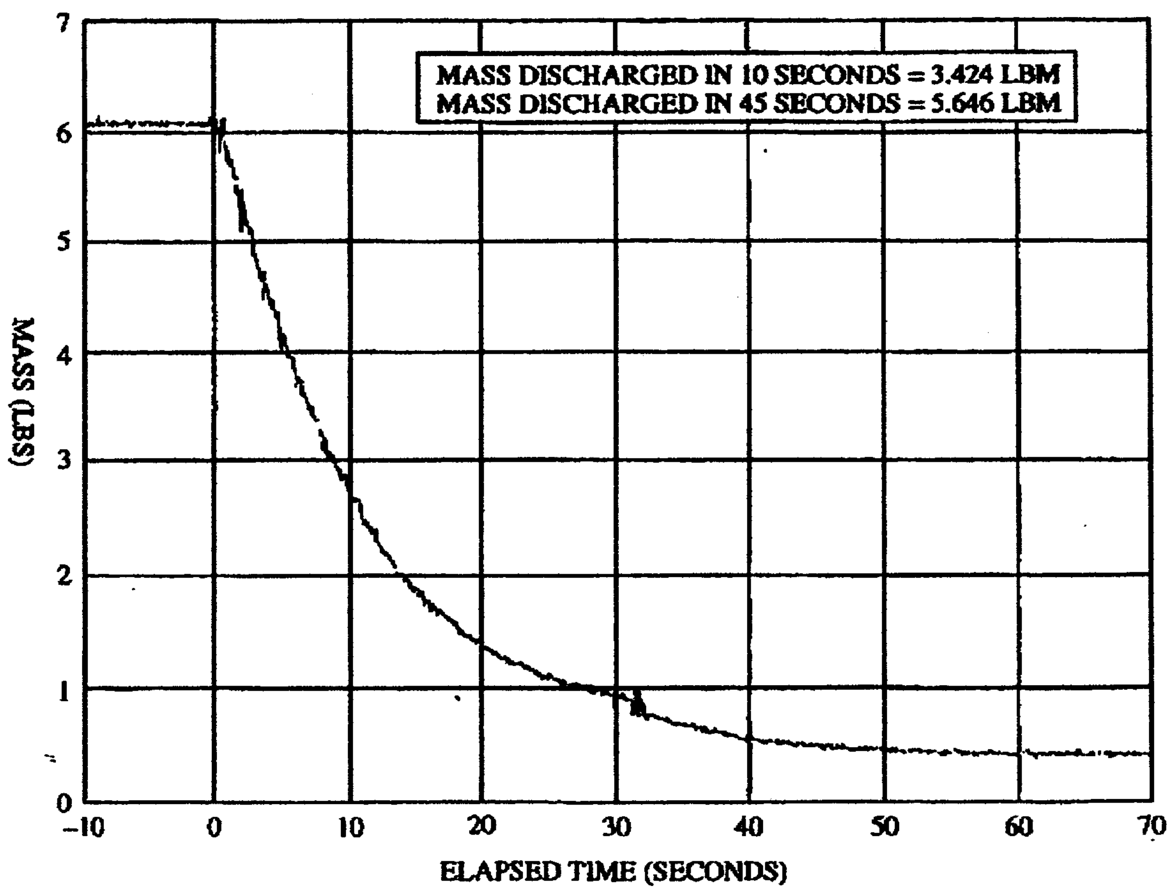

Figure 1 : PFE Blow-Down Curve

Four PFE blow-down cases were analyzed. For each case, the initial conditions and the assumed mission parameters were identical. The only difference between the cases was the number of operational PPRAs. As graphically illustrated in the following figure (Figure 2), all four cases violate the 15.2 psid MPLM structural limit. The final case with no functional PPRAs shows a peak pressure of 15.30 psia inside the MPLM.

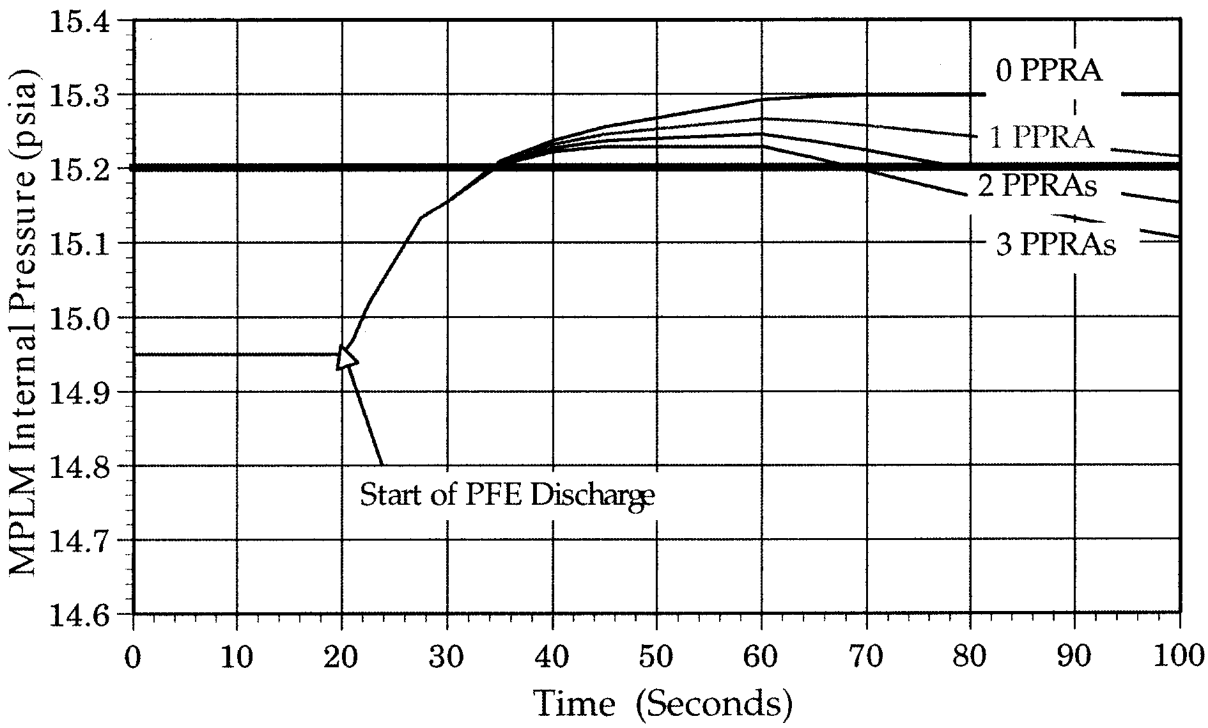

Figure 2 : PFE Blow-Down Effect on MPLM Internal Pressure

The peak internal pressure associated with each of these cases in shown in the following table. The case with no functional PPRAs results in the maximum internal pressure level of 15.30 psia.

Number of Functional PPRAs	Maximum MPLM Internal Pressure (psia)
0	15.30
1	15.27
2	15.25
3	15.23

Conclusion

PFE leakage and blow-down analyses were completed in support of the 7A.1 mission. For a PFE leaking at the specification rate, there will be no impact to the currently-planned 7A.1 timeline. For extremely high leakage rates, one of the MPLM PPRAs may actuate, but the module pressure will be maintained below the structural limit of 15.2 psid. If the PFE is accidentally discharged inside a closed-out MPLM, then all functional PPRAs will be actuated, and the MPLM pressure shell will experience a slight over-pressure condition (15.3 psid maximum versus 15.2 psid limit).

Greg Day
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APPENDIX D – FLIGHT SAFETY VERIFICATION TRACKING LOG (SVTL).

International Space Station

Mission ISS 7A.1 **Element** MPLM PFE Safety Assessment

Flight Safety Verification Tracking Log

Note: Shaded Items are considered closed.

Mission/Element: Flight 7A.1 MPLM PFE Safety Assessment **Date:** July 2001

Log No.	Hazard Report No.	Safety Ver. No.	Description (Identify Procedures by: Number and Title)	Operation(s) Constrained	Independent Verification Required (Yes/No)	Scheduled Date	Completion Date	Method of Closure Comments/Verification Completion Notice (VCN)
1	PFE-MPLM-1	1.1.1	Analysis – EG 10002, Fracture and Stress Analysis Report of Tank Carbon Dioxide, PFE P/N 4406 and EG 10031 Stress Analysis Report Manual Control Valve CO2 Portable Fire Extinguisher initial version presented at the CDR.	NONE	NO		CLOSED	**PFE** (See ARDE 02-004 Cause 1,2,3, Safety Verification Status 1) **ANALYSIS** EG 10002, Fracture and Stress Analysis Report of Tank Carbon Dioxide, PFE P/N 4406 and EG 10031 Stress Analysis Report Manual Control Valve CO2 Portable Fire Extinguisher initial version presented at the CDR. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**
2	PFE-MPLM-1	1.1.2	Test – Proof Pressure Testing and Acceptance Testing for Valve and Tank per ATP's QA 10009, QA 10014 Acceptance Test Plan Procedure Tank CO2 Cylinder ARDE P/N E4406 and QA 10060 Qualification Test Procedure for E4482, CO2 PFE provides validation of the ARDE process; equipment and procedures.	NONE	NO		CLOSED	**PFE** (See ARDE 02-004 Cause 1,2,3, Safety Verification Status 7) **TEST** Proof Pressure Testing and Acceptance Testing for Valve and Tank per ATP's QA 10009, QA 10014 Acceptance Test Plan Procedure Tank CO2 Cylinder ARDE P/N E4406 and QA 10060 Qualification Test Procedure for E4482, CO2 PFE provides validation of the ARDE process; equipment and procedures. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**
3	PFE-MPLM-1	1.2.1	Analysis – Reference Pressure Gauge design presented at the CDR.	NONE	NO		CLOSED	**PFE** (See ARDE 02-004 Cause 1,2,3, Safety Verification Status 2) **ANALYSIS** Reference Pressure Gauge design presented at the CDR. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**
4	PFE-MPLM-1	1.3.1	Audit – Internal and Boeing audits to verify effectiveness of ARDE procedures.	NONE	NO		CLOSED	**PFE** (See ARDE 02-004 Cause 1,2,3, Safety Verification Status 3) **ANALYSIS** Internal and Boeing audits to verify effectiveness of ARDE procedures. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**
5	PFE-MPLM-1	1.4.1	Boeing responsibility	NONE	NO		CLOSED	**PFE** (See ARDE 02-004 Cause 1,2,3, Safety Verification Status 4) Boeing responsibility. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**

International Space Station

Mission ISS 7A.1 **Element** MPLM PFE Safety Assessment

Flight Safety Verification Tracking Log

Note: Shaded Items are considered closed.

Mission/Element: Flight 7A.1 MPLM PFE Safety Assessment **Date:** July 2001

Log No.	Hazard Report No.	Safety Ver. No.	Description (Identify Procedures by: Number and Title)	Operation(s) Constrained	Independent Verification Required (Yes/No)	Scheduled Date	Completion Date	Method of Closure Comments/Verification Completion Notice (VCN)
		3.7.1	Analysis of the worst case depressurization rate of the PFE compaired to the cability of the two of the three PPRVs on the MPLM shows that the depressurization rate of the PFE falls within the capability of the MPLM.					**MPLM** Data: **ANALYSIS** Depressurizaion analysis of the PFE done by Boeing-Huntsville shows that the worst case credible depressurization rate of the PFE falls within the capabilities of the MPLM using two of three PPRVs. This analysis considered several scenarios including the worst case credible scenario mentioned in Control 7 above. A copy of this analysis has been provided in Appendix C. A short discussion of the scenario's considered is contained in the remarks section.

International Space Station

Mission ISS 7A.1 **Element** MPLM PFE Safety Assessment

Flight Safety Verification Tracking Log

Note: Shaded Items are considered closed.

Mission/Element: Flight 7A.1 MPLM PFE Safety Assessment **Date:** July 2001

Log No.	Hazard Report No.	Safety Ver. No.	Description (Identify Procedures by: Number and Title)	Operation(s) Constrained	Independent Verification Required (Yes/No)	Scheduled Date	Completion Date	Method of Closure Comments/Verification Completion Notice (VCN)
		3.4.1	Boeing responsibility					**PFE** (See ARDE 02-004 Cause 2,3, Safety Verification Status 5) Boeing responsibility. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**
		3.5.1	Audit – Internal and Boeing audits to verify effectiveness of ARDE procedures.					**PFE** (See ARDE 02-004 Cause 3, Safety Verification Status 5) **AUDIT** Internal and Boeing audits to verify effectiveness of ARDE procedures. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**
		3.5.2	Test – Proof Pressure Testing and Acceptance Testing for Valve and Tank per ATP's QA 10009, QA 10014 Acceptance Test Plan Procedure Tank CO2 Cylinder ARDE P/N E4406 and QA 10060 Qualification Test Procedure for E4482, CO2 PFE provides validation of the ARDE process; equipment and procedures.					**PFE** (See ARDE 02-004 Cause 3, Safety Verification Status 6 **TEST** Proof Pressure Testing and Acceptance Testing for Valve and Tank per ATP's QA 10009, QA 10014 Acceptance Test Plan Procedure Tank CO2 Cylinder ARDE P/N E4406 and QA 10060 Qualification Test Procedure for E4482, CO2 PFE provides validation of the ARDE process; equipment and procedures. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**
		3.6.1	Analysis – Stress and Fracture Analysis Reports: EG 10031 – Stress Analysis Report of the Manual Control Valve Co2 Portable Fire Extinguisher; EG 10002 – Fracture and Stress Analysis of Tank Carbon Dioxide, PFE P/N 4406; and Fracture Control Plan PM 10005 submitted at CDR.					**PFE** (See ARDE 02-004 Cause 3, Safety Verification Status 5) **ANALYSIS** Stress and Fracture Analysis Reports: EG 10031 – Stress Analysis Report of the Manual Control Valve Co2 Portable Fire Extinguisher; EG 10002 – Fracture and Stress Analysis of Tank Carbon Dioxide, PFE P/N 4406; and Fracture Control Plan PM 10005 submitted at CDR. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**

Mission ISS 7A.1

International Space Station

Element MPLM PFE Safety Assessment

Flight Safety Verification Tracking Log

Note: Shaded Items are considered closed.

Mission/Element: Flight 7A.1 MPLM PFE Safety Assessment **Date:** July 2001

Log No.	Hazard Report No.	Safety Ver. No.	Description (Identify Procedures by: Number and Title)	Operation(s) Constrained	Independent Verification Required (Yes/No)	Scheduled Date	Completion Date	Method of Closure Comments/Verification Completion Notice (VCN)
		2.3.1	Analysis – Reference applicable MUAs listed in the MIUL.				CLOSED	**PFE** (See ARDE 02-006 Cause 2,4, Safety Verification Status 6) **ANALYSIS** Reference applicable MUAs listed in the MIUL. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**
		2.4.1	Audit – Internal and Boeing audits to verify the effectiveness of the ARDE procedures.				CLOSED	**PFE** (See ARDE 02-006 Cause 2,4, Safety Verification Status 7) **ANALYSIS** Reference applicable MUAs listed in the MIUL. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**
		2.5.1	Review of drawings and CEI documentation to ensure that the PFE will be transported to and from station in a padded drawer inside an RSR and that the mass of the PFE falls well within the load capabilities of the RSR.				CLOSED	**MPLM** The MSFC MPLM program has received assurances from the MPLM CEI at JSC that the PFE has been loaded into one of the drawers of the RSRs inside the MPLM and that the PFE has been padded in such a way as to prevent any movement of the PFE during any of the mission phases. The MSFC MPLM program has also been assurred that the load of the PFE is well within the capaiblities of the RSR.
		3.1.1	Analysis – Reference Pressure Gauge design presented at the CDR.				CLOSED	**PFE** (See ARDE 02-005 Cause 1,2, Safety Verification Status 1) **ANALYSIS** Reference Pressure Gauge design presented at the CDR. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**
		3.2.1	Audit – Internal and Boeing audits to verify the effectiveness of the ARDE procedures.				CLOSED	**PFE** (See ARDE 02-005 Cause 1,2, Safety Verification Status 1) **AUDIT** Internal and Boeing audits to verify the effectiveness of the ARDE procedures. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**
		3.3.1	Boeing responsibility				CLOSED	**PFE** (See ARDE 02-005 Cause 1,2, Safety Verification Status 1) Boeing Resonsibility. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**

Mission ISS 7A.1

International Space Station

Element MPLM PFE Safety Assessment

Flight Safety Verification Tracking Log

Note: Shaded Items are considered closed.

Mission/Element: Flight 7A.1 MPLM PFE Safety Assessment **Date:** July 2001

Log No.	Hazard Report No.	Safety Ver. No.	Description (Identify Procedures by: Number and Title)	Operation(s) Constrained	Independent Verification Required (Yes/No)	Scheduled Date	Completion Date	Method of Closure Comments/Verification Completion Notice (VCN)
6	PFE-MPLM-1	1.5.1	Boeing responsibility	NONE	NO		CLOSED	**PFE** **(See ARDE 02-004 Cause 1,2,3, Safety Verification Status 5)** Boeing responsibility. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**
		1.6.1	Audit – Internal and Boeing audits to verify effectiveness of ARDE procedures.				CLOSED	**PFE** (See ARDE 02-004 Cause 1,2,3, Safety Verification Status 6) **AUDIT** Internal and Boeing audits to verify effectiveness of ARDE procedures. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**
		1.7.1	Review of drawings and CEI documentation to ensure that the PFE will be transported to and from station in a padded drawer inside an RSR and that the mass of the PFE falls well within the load capabilities of the RSR.				CLOSED	**MPLM** The MSFC MPLM program has received assurances from the MPLM CEI at JSC that the PFE has been loaded into one of the drawers of the RSRs inside the MPLM and that the PFE has been padded in such a way as to prevent any movement of the PFE during any of the mission phases. The MSFC MPLM program has also been assurred that the load of the PFE is well within the capablities of the RSR.
		2.1.1	Boeing responsibility				CLOSED	**PFE** (See ARDE 02-006 Cause 2,4, Safety Verification Status 4) Boeing responsibility. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**
		2.2.1	Analysis – Reference EG 10031 Stress Analysis Report Manual Control Valve CO2 Portable Fire Extinguisher and EG 10002 Fracture and Stress Analysis Report of Tank Carbon Dioxide, PFE P/N 4406.				CLOSED	**PFE** (See ARDE 02-006 Cause 2,4, Safety Verification Status 5) **ANALYSIS** Reference EG 10031 Stress Analysis Report Manual Control Valve CO2 Portable Fire Extinguisher and EG 10002 Fracture and Stress Analysis Report of Tank Carbon Dioxide, PFE P/N 4406. **Note: Since this verification was shown as closed in document QA 10024D "System Safety Analysis Report for PFE, CO2" it shown as being closed here as well.**

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