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A STREAMLINED APPROACH FOR THE PAYLOAD CUSTOMER IN IDENTIFYING PAYLOAD DESIGN REQUIREMENTS

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ABSTRACT

NASA payload developers from across various disciplines were asked to identify areas where process changes would simplify their task of developing and flying flight hardware. Responses to this query included a central location for consistent hardware design requirements for middeck payloads. The multidisciplinary team assigned to review the numerous payload interface design documents is assessing the Space Shuttle middeck, the SPACEHAB Inc. locker, as well as the Multi-Purpose Logistics Module (MPLM) and EXpedite the PRocessing of Experiments to Space Station (EXPRESS) rack design requirements for the payloads. They are comparing the multiple carriers and platform requirements and developing a matrix which illustrates the individual requirements, and where possible, the envelope that encompasses all of the possibilities. The matrix will be expanded to form an overall envelope that the payload developers will have the option to utilize when designing their payload's hardware. This will optimize the flexibility for payload hardware and ancillary items to be manifested on multiple carriers and platforms with minimal impact to the payload developer.

Background

Every human-rated vehicle and platform used in the extreme environment of space is incredibly complex. They have been developed to meet specific goals such as exploration, research, and construction. Each vehicle is designed to optimize the technology available at that time. Therefore, the overall characteristics of the Space Shuttle, a twenty year old design with the overall goal of being a reusable vehicle, as compared to the newer design of the International Space Station (ISS), which has the overall goal of being a continuously orbiting platform, are remarkably different. These differences are throughout the entire vehicles including the crew compartment and module interiors, and even to the rack level. With this diversity, the envelope of acceptable physical and environmental interfaces are markedly varied. These variances are due to the interface constraints and limitations inherent to both the Shuttle and the ISS. The structural, thermal, EMI/EMC and acoustical characteristics for crew compartment of the Space Shuttle differ from those of the interior of the Space Station. These types of differences cause the complexity of hardware to significantly increase if the hardware must be verified for more than one environment.

Documentation Overview

The Space Shuttle Program overall payload design requirements are documented in the Shuttle Orbiter/Cargo Standard Interface Control Document - ICD 2-19001. These requirements include pass/fail specifications such as environmental measures, e.g. electromagnetic interference and conductance, factors of safety and utilization for structural assessments, power constraints, and numerous other areas. The subset of requirements applicable to the habitable area of the Space Shuttle vehicles are documented in the Middeck Interface Definition Document - NSTS 21000-MDK-IDD. This is commonly referred to as the middeck IDD. The middeck IDD requirements were incorporated into the EXPRESS Rack requirements documen EXPRESS Rack Payloads IDD, SSP 52000-EXP-IDD. The EXPRESS IDD defines the requirements a payload developer must meet to be transported to the ISS and perform science in the EXPRESS Rack.

Status

A team of Space Shuttle Program (SSP) and ISS Program (ISSP) personnel were tasked to review the processes that a payload customer experiences when they fly a payload on both the Shuttle and the ISS. The major objective of the team was to simplify the customer interface to the ISS and the Shuttle Programs. A specific focus team addressed the concern of multiple payload requirements specifications for the various platforms. This team, known as the Common Middeck/Subrack Payload Requirement Team, had a goal of developing a global payload requirements envelope for the Shuttle middeck, a SPACEHAB locker, an EXPRESS rack, and an EXPRESS transportation rack that transports payloads in the multi-purpose logistics module (MPLM). The team started off this challenging task by reviewing existing documentation and identifying the various requirements. The requirements were then categorized as to whether or not a common envelope could be defined applicable to each of the four platforms. The structural loads requirement is still in negotiation stages to determine whether a common envelope can be identified. The categorization included negotiations with each of the platform teams to determine the potential common envelope and whether this common envelope would satisfy the requirements of each of the platforms. The following table summarizes the categories. The determination on commonality was driven by the platform with the least flexibility. Table 2, at the end of this paper, is a matrix of all of the requirements listed above with the specifications for each platform. In most cases, the limiter that establishes the common subset is easily identified. For example, ascent and descent power is constrained by the power specifications for the Shuttle middeck area. The middeck

Common	In Work	Cannot Make Common
Power	Loads	Vacuum Exhaust
Structural Attachment		Commanding and Data Downlink
Weight and Center of Gravity		Video
Environmental Temperature and Pressure		Nitrogen Services
EMI/EMC		
Payload Thermal Control		
Depressurization/Repressurization Rate		
Acoustic Noise		
Fire Protection		
Materials		

Table 1 Categorized Requirements

provides 28 +/- 4 VDC on 10 and 20 amp circuits with total available power at 400 watts (W). The SPACEHAB single module has additional DC circuits and a greater maximum total DC power available. Therefore, for ascent and descent power, the common accommodations between these two platforms is constrained by what can be provided by the middeck. An example where there is no commonality is the on-orbit vacuum exhaust. There is no vacuum exhaust capability in the Shuttle middeck, or the MPLM. Therefore, there is no commonality other than for the payload to not use on-orbit vacuum exhaust. Since this is not reasonable for many payloads, their design must take into account that they cannot have access to vacuum exhaust while their payload is located in the middeck or the MPLM.

Rationale

The common envelope is most useful to those payloads that will be transported to ISS by the Space Shuttle, transferred to ISS for on-orbit operations, and then returned on the Space Shuttle. In this scenario, the payload could be placed in the middeck, SPACEHAB single module, or the MPLM in an EXPRESS rack or EXPRESS transportation rack for ascent and descent. For on-orbit ISS operations, the payload is installed in an EXPRESS rack. While the payload designer may know the platforms their hardware will interface with at the beginning of the design phase, the dynamic nature of the manifests may change their ascent and descent platforms multiple times before the hardware actually flies. Also, on-orbit anomalies may require transport of the hardware on an unanticipated platform. The benefit of designing hardware to an overall envelope is that it will be compatible with all of the platforms and the payload team will be minimally impacted by manifest adjustments or contingency situations. The downside to designing to an overall envelope is the increase in constraints, which may decrease the operations flexibility of the hardware. The hardware will have to meet the most extreme conditions including the tightest power specifications and the largest swing in environmental temperature and pressure. Therefore, it is likely that the cost of the hardware and necessary resource accommodations such as mass will increase because of the additional design constraints. These tradeoffs will have to be made by each payload team. With the matrix identifying the requirements for each platform, the payload team will have a guide available for comparison so that they can make the best choice for their payload. The matrix shown here is not a requirements document, and the payload developer must be aware that they will be required to verify their hardware against an Interface Control Document (ICD) they establish with the integrator of the platform they choose to use to perform science.

Summary

Since the payload developers that will benefit most from a set of common requirements across platforms are EXPRESS users, the common requirements envelope is being incorporated in the EXPRESS rack IDD, SSP 52000-IDD-ERP. Payload developers performing science on the ISS design to the requirements in SSP 52000-IDD-ERP. This approach maximizes manifest opportunities for payload developers. The payload developer who plans on performing science on other platforms will have the option to design to a specific platform or to use SSP 52000-IDD-ERP for their design requirements. The advantage of using SSP 52000-IDD-ERP is the payload will be able to perform science on all platforms and minimize reworking verification products. As mentioned earlier, a unique ICD will be developed between the integrator of the platform and the payload developer based on the platform's requirements. The payload developer will have to compare the options and determine the best approach for their hardware, operations, and budget.

Acronyms

DC	direct current
EXPRESS	*EXpedite the* PRocessing of Experiments to Space Station
EMI	electromagnetic interference
ICD	Interface Control Document
IDD	Interface Definition Document
ISS	International Space Station
ISSP	International Space Station Program
JSC	Lyndon B. Johnson Space Center
MPLM	Multi-Purpose Logistics Module
MSFC	*George C. Marshall* Space Flight Center
NASA	National Aeronautics and Space Administration
NSTS	National Space Transportation System
SSP	Space Shuttle Program
USA	United States of America
VDC	volts direct current
W	watts

REQUIREMENTS	MIDDECK (NSTS 21000-MDK-IDD)	SPACEHAB SINGLE MODULE	EXPRESS/MPLM	EXPRESS/ISS (Station Operations)	NOTES	COMMONALITY ACCOMMODATION
POWER Ascent/Descent	DC Power: 28 ±4VDC 10/20 Amp circuits Total Available Power: 400W max. total DC power in MD due to limited cooling available. No AC available	DC Power: 28 ± 4VDC Rack EPSU DC Circuits - 35A, 15A, 10A, 5A. Locker DC Circuits –5A, 3A Total Available Power: 690W max. total DC power in single module due to limited cooling available. No AC available	No power available to payloads.		Payload total power available is for the entire carrier. Experiment allocation available is dependent on the mission complement.	DC Power: 28 ±4VDC 10/20 Amp Circuits 400W max. total DC power due to limited cooling available. No AC available ------------------ MPLM - No power
POWER On-Orbit	DC power 28 ±4VDC 10/20 Amp circuits Total Available Power: 1400 W w/o new power panel 1900 W with new power panel AC Power 115 ± 5 V RMS, 400 Hz 3 phase, 120° displacement 300 VA, total capability	DC Power - 28 ± 4VDC Rack EPSU DC Circuits - 35A, 15A, 10A, 5A. Locker DC Circuits –5A, 3A Total Available Power 1400W max. (3150W with 2nd Orbiter feed) 115W DC per payload-locker mounted or replacement 1000W per rack AC Power – 690 VA Max Total 115Vrms, 400 Hz, 3ø, 120° displacement PF: 0.7 lagging to 0.9 leading Ø balance: <15% of total load 115W @ 115VAC per payload Note: All above negotiable on mission-by-mission basis.	No power provided to payloads.	DC Power 28 +1.5/-3.0VDC 5, 10, 15, 20A services. Total Available Power: 2000W/rack max. (may be limited by thermal cooling restrictions) Nominal power per payload ≤150W. Max. power per payload 500W. AC Power Not available		DC Power: 28 +1/5/-3.0VDC 10/20Amp circuits No AC power Total Available DC Power: 1000W per rack with nominal 115W per payload-locker mounted or replacement.
STRUCTURAL ATTACHMENT All Phases	Lockers Soft Stowage Bags Locker replacement (Payload mounting panels, single/double adapter plates, vented payload mounting panels)	Lockers Soft Stowage Bags Locker replacement (Payload mounting panels, single/double adapter plates, vented payload mounting panels) Two single or double racks. One ISPR or EXPRESS rack.	Lockers ISIS Drawers Locker replacement (Payload mounting panels, single/double adapter plates, vented payload mounting panels)		SPACEHAB Currently cannot accommodate ISIS Drawers but can upgrade rack to accommodate as optional service. VPMPs not currently available.	Lockers Locker replacement

REQUIREMENTS	MIDDECK (NSTS 21000-MDK-IDD)	SPACEHAB SINGLE MODULE	EXPRESS/MPLM	EXPRESS/ISS (Station Operations)	NOTES	COMMONALITY ACCOMMODATION
WEIGHT & C. G. All Phases	Locker: 70 lb @ 10 in. CG (PL, locker, foam, trays, mtg hdwe) Locker Replacement: Single Plate: 69 lb @ 10 in. CG (includes mtg. plate weight) Double Plate: 120 lb @ 10 in. CG (includes mtg. plate weight)	Locker: 76 lb @ 10 in. CG (PL, locker, foam, trays, mtg. hdwe) Locker Replacement: Single Plate: 76 lb @ 10 in. CG (includes SH adapter plate wt.) Double Plate: 133 lb @ 14 in. CG (includes SH adapter plate wt.)	Locker: 72 lb @ 10 in. CG Locker replacement: Single Plate: 72 lb @ 10 in. CG Double Plate: 140 lb @ 10in. CG ISIS Drawer: 64 lb @ 15.6 in. CG (incl. Drawer, slides, and PL)		*Weight depends on stowage location; max. shown for 1.0 MLVE.	Locker: 70 lb @ 10 in. CG (PL, locker, foam, trays, mtg. hdwe) Locker Replacement: Single Plate: 69 lb @ 10 in. CG (*includes mtg. plate* weight) Double Plate: 120 lb @ 10 in. CG (includes mtg. Plate weight)
<u>LOADS</u> <u>Ascent</u>	X = 9.0 g's Y = 3.2 g's Z = 7.4 g's Orbiter coordinates. Random load factors included.	Bulkhead Payload - Quasi-Static Loads: X = 6.6g, Y = 1.5g, Z = 5.9g Orbiter coordinates. Random Loads: X-dir - 20-60 Hz +10dB/Oct. 60-400 Hz 0.036 g^2/Hz 400-2000 Hz -11dB/Oct. Composite 4.25 g_{rms} Y&Z-dir - 20-300 Hz +5dB/Oct. 300-400 Hz 0.021 g^2/Hz 400-2000 Hz -10dB/Oct. Composite 2.83 g_{rms} Rack Payload - Quasi-Static Loads: X = 5.5g, Y = 3.5g, Z = 10.0g Orbiter coordinates. Random Loads: X-dir – 20-300 Hz +3dB/Oct. 300-500 Hz 0.03 g^2/Hz 500-2000 Hz -5dB/Oct. Composite 4.91 g_{rms} Y-dir – 20-230 Hz +3dB/Oct. 230-500 Hz 0.08 g^2/Hz 500-2000 Hz -5dB/Oct. Composite 7.24 g_{rms} Z-dir – 20-175 Hz +4dB/Oct. 175-300 Hz 0.008 g^2/Hz 300-2000 Hz -4dB/Oct. Composite 2.24 g_{rms}	Quasi-Static Loads – X = 11.6 g's Y = 7.7 g's Z = 9.9 g's Orbiter coordinates. Random Loads* - 20 Hz 0.010 g^2/Hz 20-80 Hz +3.0dB/Oct. 80-120 Hz 0.04 g^2/Hz 120-2000 Hz -4.0dB/Oct. 2000 Hz 0.00095 g^2/Hz Composite 3.5 g_{rms} *Same for all directions (X,Y,Z). Loads per SSP52000-IDD-ERP, Rev B.		Note: For SPACEHAB and MPLM, the quasi-static and random loading must be combined for liftoff conditions per paragraph 4.1.2 of SSP 52005. A comparison can then be made between carriers to determine which carrier has the critical load factors. Structures working group will be contacted for input on commonality requirement.	TBD

REQUIREMENTS	MIDDECK (NSTS 21000-MDK-IDD)	SPACEHAB SINGLE MODULE	EXPRESS/MPLM	EXPRESS/ISS (Station Operations)	NOTES	COMMONALITY ACCOMMODATION
LOADS Descent	X = 6.25 g's Y = 2.50 g's Z = 12.5 g's Orbiter coordinates.	Bulkhead Payloads X = 9.5 g's Y = 2.50 g's Z = 9.00 g's Orbiter coordinates. Rack Payloads X = 6.5 g's Y = 2.5 g's Z = 12.5 g's Orbiter coordinates.	X = 9.5 g's Y = 5.4 g's Z = 12.5 g's Orbiter coordinates. Loads per SSP52000-IDD-ERP, Rev B.		Note: Random loading not applicable for descent conditions.	TBD
ENVIRONMENTAL TEMPERATURE AND PRESSURE Ascent/Descent	Air Temp.*: 65-80F Dew Pt.: 39-61F Pressure: 14.5-16.0 psia O2 max: 25.9% CO2 PP: TBD	Air Temp.: 41-95F Dew Pt.: 41-63F Pressure: 14.5-15.95 psia O2 max: 25.9% CO2 PP: 7.6 mmHg	ASCENT DESCENT Air Temp.: 57-75F 55-109F Dew Pt.: 56.8F 50F Pressure: 13.9-15.2psia 13.9-15.2 psia O2 max: 24.1% 24.1% CO2 PP: 7.5 mmHg 7.5 mmHg		* 95F max peak possible during contingency operations. No time @ Temp available.	Air Temp.: 41-109F Dew Pt.: 39-63F Pressure: 13.9-16.0 psia O2 max: 25.9% CO2 PP: 7.5 mmHg Includes MPLM.
ENVIRONMENTAL TEMPERATURE AND PRESSURE On-Orbit	Air Temp.*: 65-80F Dew Pt.: 39-61F Pressure: 14.5-16.0 psia O2 max: 25.9% CO2 PP: TBD	Air Temp: 65-80F Dew Pt.: 41-63F Press: *14.5-15.95 psia (nominal) 9.7 – 15.95 (worst case) depending on EVA constraints.	Air Temp: 73-113F Dew Pt.: 60F Press.: 13.9-15.2 psia	Air Temp.: 63-82F Dew Pt.: 40-60F Press: 14.2-14.9 psia (nominal)	*(Control by orbiter)	Air Temp.: 65-113F Dew Pt.: 39-63F Pressure: 9.7-16.0 psia O2 max: 25.9% CO2 PP: TBD
EMI/EMC All Phases	Comparable	Comparable	Comparable	Comparable	Will consult EME panel for commonality	TBD
PAYLOAD THERMAL CONTROL Ascent/Descent	Passive air cooling: 60W max. per single locker payload Cabin discharge: Front breathing, non-ducted, PL provided fan, max. air out temp. 120F. Avionics Bay: Ducted cooling, PL provided fan, rear breathing, discharge to avionics bays 1, 2, 3A. 400W max. heat load allowed in the cabin due to cooling limitations.	Passive air cooling: 60W max. per single locker payload. Cabin discharge: Front breathing, 120F max. air outlet, PD provides air circ. hdwe. SH rack provided cooling via RSCS 690W total max. cooling for payloads. 105 CFM max. air flow per rack.	Not required – no power available for payload operation.		EXPRESS rack and Middeck lockers designed for rear breathing forced air cooling. SPACEHAB can provide rear breathing on a case by case basis. SPACEHAB can provide water cooling via pump package to both racks and lockers Middeck maximum cooling capability is different for each bay. Refer to NSTS 2100-IDD-MDK, Tables 6.2.1.5.1 through 6.2.1.5.3. for cooling capability for each bay.	Passive air cooling: 60W max. per single locker payload Cabin discharge: Front breathing, non-ducted, PL provided fan, max. air out temp. 120F. 400W max. power for all middeck items allowed due to cooling limitations. - - - - - - - - - - - - - - MPLM- No requirement, no power.

REQUIREMENTS	MIDDECK (NSTS 21000-MDK-IDD)	SPACEHAB SINGLE MODULE	EXPRESS/MPLM	EXPRESS/ISS (Station Operations)	NOTES	COMMONALITY ACCOMMODATION
PAYLOAD THERMAL CONTROL On-Orbit	Cabin discharge: Non-ducted PL provided fan, max. air out temp. 120F. Avionics Bay: Ducted cooling, PL provided fan, rear breathing, discharge to avionics bays 1, 2, 3A. 1500-2000W max. heat load to cabin. - Passive cooling: 60W max. per single payload.	1400W surface air cooling. 2000 W Rack suction cooling 60W per locker – passive cooling. 120F max. exhaust air. temperature for forced air cooling.	Not applicable. No power provided to payloads.	Avionics Air Assembly: 15 ±3CFM total air available *per locker position.* 65-85F – inlet air 120F max. – outlet air (Air temp. can vary depending on payload heat load). Max. air cooling of 1200W for payloads. Payloads to provide internal fan for air flow. Water Loop: 1000W max. @ 200 lbm/hr (Limited to ≤2 payloads). 61-73F – inlet water 120F max. – outlet water. Combined payload cooling (air and water) not to exceed 2000W per rack.	EXPRESS rack and Middeck lockers designed for rear *breathing forced air cooling.* Rear breathing possible on SH for lockers at the bulkhead; selective placement required to prevent warm air suction into adjacent locker payloads. Max. cooling in this configuration is TBD.	Max. air cooling: 1200W for payloads. 120F max. outlet air temperature. PL to provide internal fan. Passive cooling: 60 W per locker - - - - - - - - - - - - - - - - MPLM: No requirement, no power.
VACUUM EXHAUST Ascent/Descent	Not available.	Not available.	Not available.			Not available.
VACUUM EXHAUST On-Orbit	Not available.	One Experiment Vent Value (EVV) Available for Experiment Shared usage. System available to locker or rack payloads on shared, time-lined basis. Gases only; flow *control and isolation* provided by payload.	Not available.	Available to each rack on shared, time-lined basis. Gases only; flow control and isolation provided by payload.		Not available.
COMMANDING (uplink) DATA (downlink) Ascent/Descent	Not Available	Not Available	Not available			Not available.

REQUIREMENTS	MIDDECK (NSTS 21000-MDK-IDD)	SPACEHAB SINGLE MODULE	EXPRESS/MPLM	EXPRESS/ISS (Station Operations)	NOTES	COMMONALITY ACCOMMODATION
COMMANDING (uplink) DATA (downlink) On-Orbit	Available from a PGSC via the OCA system.	DMU provides serial, analog, and discrete signal interfaces to the payload. The total number of DMU inputs and outputs available to a particular payload will be determined on a mission by mission basis. Racks: 16 (DILs) 12 (DIHs) 8 (DOHs) 32 (AIs) also two serial DMU channels are available at each rack location. Bulkhead mounted Payloads: 72 (DILs) 56 (DIHs) 24 (DOHs) 104 (AIs) and 8 serial DMU channels RS232 via (serial converter unit)	None	Interfaces per rack payload:* 1 – RS422 1 – Ethernet 2 – Analog** 3 – Discrete**	All Spacehab payload input/output data is via the Data Management Unit (DMU) through bulkhead mounted experiment connector panels * Data interfaces of the EXPRESS rack RIC/SSPCM, the Middeck system, and the Spacehab DMU are not compatible. ** Routed through the SSPCM * All locker mounted payload input/output data is via the Data Management Unit (DMU) through bulkhead mounted experiment connector panels in the Single Module. The EDSMU could be made available. Will state requirement capabilities in the RDM section later. * DMU & EXPRESS rack Rack Interface Controller (RIC) interface characteristics are not compatible.	TBD
VIDEO Ascent/Descent	Not Available	Not Available	Not Available	Not Available		Not available.
VIDEO On-Orbit	Standard video downlink available.	Video Switching Unit (VSU) 8 unbalanced (single ended) inputs. The VSU provides one balanced output to the Orbiter CCTV system and one unbalanced output is available as an input to a video digitizer/compressor provided by SPACEHAB. Two aux.outs for attaching LCD monitors.	None	1 – Video (2 for ISIS drawer payload)		Not available.

REQUIREMENTS	MIDDECK (NSTS 21000-MDK-IDD)	SPACEHAB SINGLE MODULE	EXPRESS/MPLM	EXPRESS/ISS (Station Operations)	NOTES	COMMONALITY ACCOMMODATION
NITROGEN Ascent/Descent	Not Available	Not Available	Not Available			Not available.
NITROGEN On-Orbit	Not available.	None	None	12 lbm/hr to rack and then to payload. No rack flow control.		Not available.
ACCESS	ASCENT: L-18 to 24 hrs DESCENT: R+3 hrs	ASCENT: L-40 hrs (L-33 hrs negotiable) DESCENT: R+5 hrs	ASCENT: L-88 hrs DESCENT: R+96 hrs			ASCENT: ≤L - 88 hrs. DESCENT: ≤R + 96 hrs
DEPRESS/ REPRESS RATES (On-Orbit)	Depress: 24.0 psi/min. Repress: 9.0 psi/min.	Depress: 9.0 psi/min. Repress: 0	Depress: 7.75 psi/min. Repress: 6.96 psi/min.	Depress: 7.64 psi/min. Repress: 2.00 psi/min		Depress: 24.0 psi/min. Repress: 9.0 psi/min.
ACOUSTIC NOISE	NSTS 2100-IDD-MDK, Section 4.7 – Environment – ascent; Continuous PL operation noise limits – on orbit. NASA Std 145A in NSTS 08080-1 – Environment – On-orbit; Intermittent payload generated noise limits.	Per MIL-STD-1474D Ref. MDC91W5023K (6.00) Para. 4.4, 4.4.1 – ascent	SSP52000-IDD-ERP, Para. 4.7.1 & Table 4-IX – Environment – ascent. No requirement for descent.	Total Rack SPL: SSP52000-IDD-ERP, Para. 4.7.2 & Fig. 4-2 Rack Payload SPL: SSP52000-IDD-ERP, Para. 4.7.2.2 & Table 4-X.	Acoustic Requirement for payload operation on ISS appears less than SH or MD operational requirements, therefore the ISS requirement is the controlling factor	SSP52000-IDD-ERP, Para. 4.7.2.2 & Table 4-X.
FIRE PROTECTION	PFE port required for actuve payloads.	Two smoke sensors in Air Mixing Box. Ten Halon Bottles (6% vol. Concentration at 14.5 psia) 1 hand held fire extinguisher 2 SEBs units	None, not powered.	No PFE port required for payloads that interface to the rack AAA cooling loop. Sealed container payloads do not require a PFE port.		PFE port required for active payloads. - - - - - - - - - - - - - - - - MPLM- No requirement, no power.
Materials						Envelope Worst Case From All Carriers