



PMASC DESIGN REQUIREMENTS DOCUMENT

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1. INTRODUCTION

1.1 INTRODUCTION

This Design Requirements Document (DRD) contains the design and verification requirements for the Primary Mirror Assembly Shipping Container (PMASC). This document is intended to describe the functional and performance requirements that must be met by the PMASC, and to enable design, verification, and fabrication thereof. The PMASC will be used for the shipment and storage of:

- Polished Mirror Assemblies (PMA) (AD1)
- Segment Support Module Assemblies, hereafter to be called SSA (AD2)

1.2 SCOPE

This document describes the user/operator characteristics and interfaces of the container. This document also covers requirements for the deliverables of the project. This document lists constraints that are considered risks to the shipping container and contents, and proceeds to lists the requirements of functions and attributes necessary to mitigate the listed risks, and satisfy the constraints and requirements.

This document covers the following in the Requirement sections

- General Constraints
- Environmental Requirements

Conditions under which the system must properly operate, survive, be safely and securely transported and handled.

- Performance Requirements
- Functional Requirements

1.3 APPLICABLE DOCUMENTS

AD1 [TMT M1 Intermediate Polished Mirror Assembly, TMT CAD Drawing M1S-001-5000, Rev C](#) (TMT.OPT.DWG.14.004.REL05)

AD2 [TMT M1 SSA Module Assembly Drawing, TMT CAD Drawing M1S-100-01200 Rev E contained in M1S Drawing Package](#) (TMT.DWG.18.001.REL02)

1.4 REFERENCE DOCUMENTS

RD1 [Design Requirements Document For Primary Mirror System](#) (TMT.OPT.DRD.07.007)

RD2 [SSA Shipping Container Assembly Procedure](#) (TMT.OPT.PRE.15.101)

RD3 [PMA shipping configuration](#) (TMT.OPT.TEC.18.131)

RD4 [Guidelines for Supplier Quality Requirements](#) (TMT.PMO.MGT.10.009)

RD5 [PSA MASS PROPERTIES – Current Best Estimate](#) (TMT.OPT.TEC.12.190)

RD6 [Standard Practice for Performance Testing of Shipping Containers and Systems](#) ASTM D4169-16

RD7 [Standard Practice for Pictorial Markings for Handling of Goods](#) ASTM D5445-05

RD8 [Regulation of Wood Packaging Material in International](#) Trade ISPM 15

RD9 [Fasteners - General Requirements for bolts, screws, studs, and nuts](#) ISO 8992

RD10 [Site-Specific Seismic Hazard Assessment Of Proposed Thirty Meter Telescope Site, Mauna Kea, Hawaii \(URS Job No.: 33761857\)](#), (TMT.STR.TEC.10.001)

RD11 [Degrees of Protection Provided by Enclosures \(IP Code\)](#): IEC 60529

1.5 ABBREVIATIONS

AD – Applicable Document

ASD – Acceleration Spectral Density

ASTM – American Society for Testing and Materials

CAD – Computer Aided Design

CBE – Current Best Estimate

DRD – Design Requirements Document

IBF – Ion Beam Figuring

IIA – Indian Institute of Astrophysics

IPPC –International Plant Protection Convention

ISO - International Standards Organization

ISPM - International Standard for Phytosanitary Measures

M1 – Primary Mirror

M1S – Primary Mirror System

MSA – Mounted Segment Assembly

NAOJ – National Astronomical Observatory of Japan

NIAOT - Nanjing Institute of Astronomical Optics and Technology

NY – New York

PMA – Polished Mirror Assembly

PMASC – Primary Mirror Assembly Shipping Container

PRV – Pressure Relief Valve

PSA – Primary Segment Assembly

PSACRS – Primary Segment Assembly Coordinate Reference System

PSD – Power Spectral Density

RD – Reference Document

RFP – Request for Proposal

SI - International System of Units

SSA – Segment Support Assembly

TBC – To Be Confirmed

TIO – TMT International Observatory

TMT – Thirty Meter Telescope

US – United States

USB – Universal Serial Bus

2. OVERALL DESCRIPTION

2.1 PERSPECTIVE

The TMT's primary mirror (M1) is made up of 492 Polished Mirror Assemblies (PMA), each consisting of a hexagonal polished mirror resting upon a support structure, the Segment Support Assembly (SSA). A total of 574 of these segments (including 82 spares) will be manufactured and shipped between several countries. SSAs are manufactured in India and then shipped to locations in India, China, Japan, and the United States, where the polished mirrors are mounted on the SSAs to form PMAs. All PMAs are then shipped to a facility in Rochester, NY, for Ion Beam Figuring (IBF) and put into storage before finally being shipped to the observatory.

The PMASC will enclose and protect PMA and SSA segments from shocks, vibrations, and environmental factors during transport and storage between its global destinations and will be compatible with most major transport methods such as sea, air, truck, and rail as well as handling equipment such as forklift trucks.

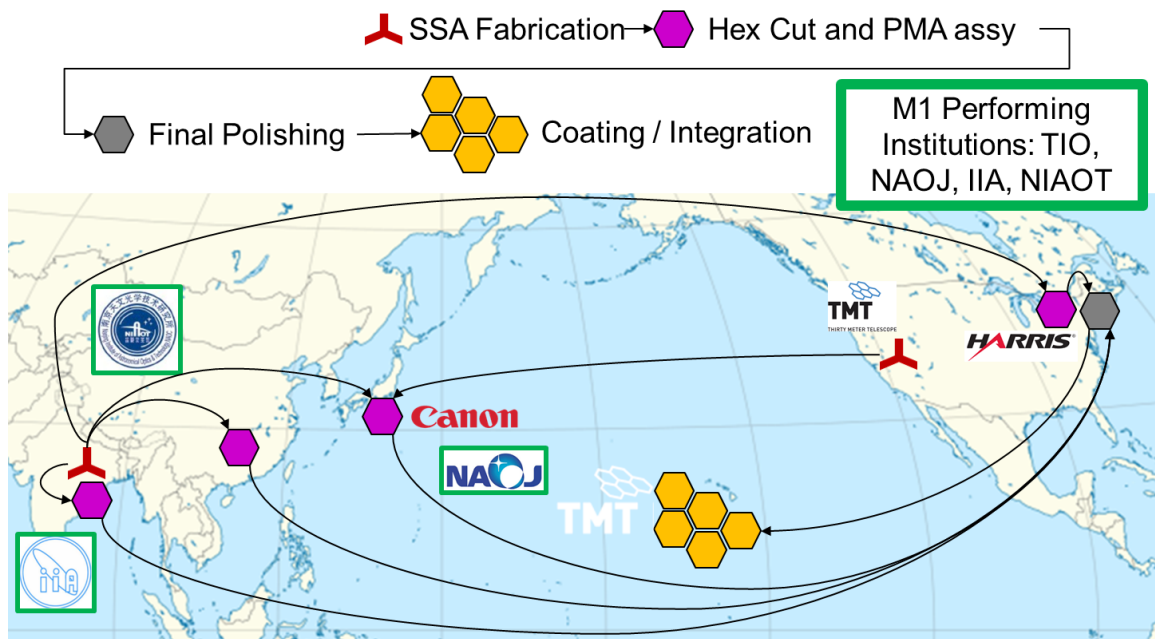


Figure 2-1. Map showing major M1 shipments (SSA and PMA)

2.2 PMASC FUNCTIONS

The major functions of the PMASC are:

- Protect the contents (PMA/SSA) from damage by shocks or vibrations associated with transport and handling
- Protect the contents from damage by environmental factors such as rain, temperature, and humidity during transport and storage
- Record and display instances where shocks, temperature, or humidity above the recommended ranges were applied in order to detect carrier negligence
- Facilitate ease of transfer of finished PMA segments from the PMASC to the Harris Handling Tooling

2.3 USER AND OPERATOR CHARACTERISTICS

Users of the PMASC will typically be trained in the use of common loading and handling tools such as forklift trucks, cranes and hoists.

For customs, inspections and assembly/disassembly procedures for the exterior and interior boxes, users will only need common hand tools such as wrenches, screwdrivers, etc. to complete the procedures.

2.4 COORDINATE SYSTEM AND MASS PROPERTIES

2.4.1 Segment Support Assembly (SSA)

The SSA is shown in Figure 2-2. The mass properties are given in Table 2-1.

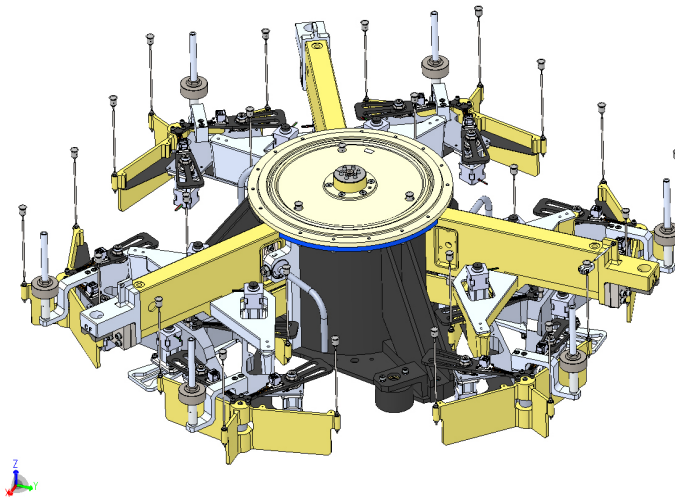


Figure 2-2. Segment Support Assembly (SSA)

Table 2-1. SSA Mass Properties

Current Best Estimate (CBE)	Mass (kg)	Mass Moments of Inertia Taken at the center of mass and aligned with the PSACRS (kg*mm ²)		
		Lxx	Lxy	Lxz
			Lyy	Lyz
			Lzy	Lzz
		5072964.8	11890.8	-5741.2
		11890.9	5078151.7	-4631.7
		-5741.2	-4631.7	9446210.5
		PSA Center of Mass in PSACRS (mm)		
		PSACRS X	0.7	
		PSACRS Y	1.0	
		PSACRS Z	-200.1	

2.4.2 Polished Mirror Assembly (PMA)

The PMA consists of the SSA + Polished Mirror Segment. The PMA and Primary Segment Assembly Coordinate Reference System (PSACRS) is shown in Figure 2-3.

The origin of the coordinate system is at the top surface in center of the segment. The PMA mass properties are derived from (RD5) and given in Table 2-2.

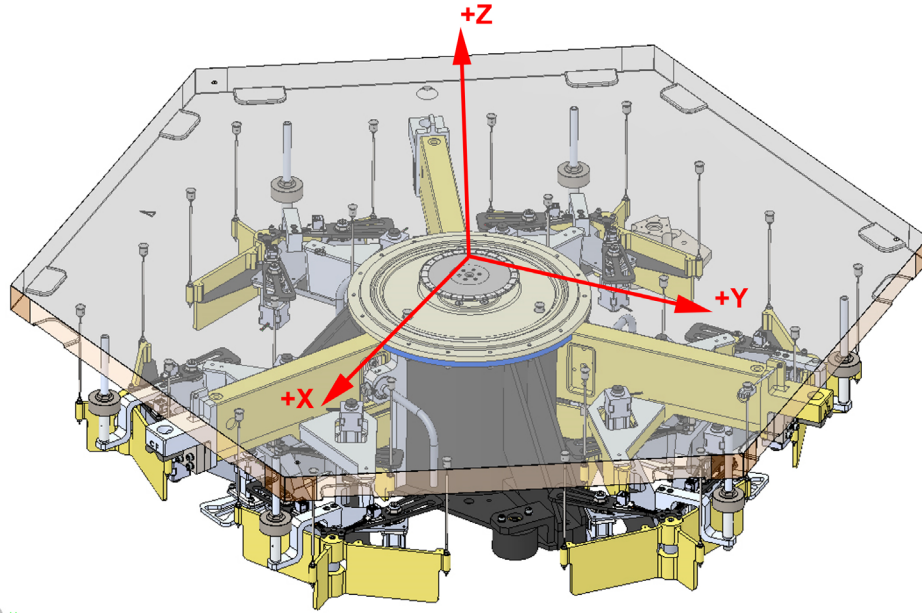


Figure 2-3. Polished Mirror Assembly (PMA) with Primary Segment Assembly Coordinate Reference System (PSACRS)

Table 2-2. PMA Mass Properties

	Mass (kg)	Mass Moments of Inertia Taken at the center of mass and aligned with the PSACRS (kg*mm ²)		
		Lxx	Lxy	Lxz
Current Best Estimate (CBE)	223.384	Lyx	Lyy	Lyz
		Lzx	Lzy	Lzz
		23338348.2	12439.6	-11775.5
		12439.6	23349233.3	-12667.7
		-11775.5	-12667.7	42847868.6
		PSA Center of Mass in PSACRS (mm)		
		PSACRS X	0.2	
		PSACRS Y	0.3	
		PSACRS Z	-76.5	

2.5 INTERFACES

2.5.1 Polished Mirror Assembly (PMA)

The PMASC will enclose the PMA during transport and storage. Each PMA will be immobilized and protected within the PMASC.

2.5.2 Segment Support Assembly (SSA)

The PMASC will enclose the SSA during transport and storage. The SSA will be held in the PMASC using connections to the whiffle tree triangles.

2.5.3 Forklift Trucks and Pallet Jacks

Forklift trucks are commonly used to load and unload cargo. Pallet Jacks are commonly used for moving crates in warehouses. Each PMASC will have slots on its underside to accommodate forks and facilitate loading.

2.5.4 Other PMASC units

PMASC units will couple to each other for greater stability in a stacked configuration for storage.

2.5.5 Intermodal Containers

Intermodal containers will be used to transport PMASCs.

2.6 ENVIRONMENTAL CONDITIONS

The transportation environments are described in Table 2-3, Table 2-4 and Figure 2-4. PMASCs may experience any combination of transportation conditions while being transported and stored.

Table 2-3. Shipping and handling environmental conditions

Conditions outside PMASC	
Ambient Temperature Range	243K to 318K (-30°C to +75 °C)
Ambient pressure	590 – 1025 hPa
Ambient Relative Humidity	0-100%, condensing
Precipitation	Rainfall of 0.25m/hour or Snow cover
Shipping loads	As defined by PSD in Table 3-9 and Figure 3-1
Handling (drop and impact, derived from (RD6))	229 mm rotational drop (opposite faces) 1.75 m/s side impact on all four sides

Table 2-4. Shipping Environment Power Spectral Density (PSD)

f (Hz)	PSD Level (g ² /Hz)
1	0.00072
3	0.03
4	0.03
5	0.02
100	0.02
300	0.0002
Overall g _{rms}	1.53

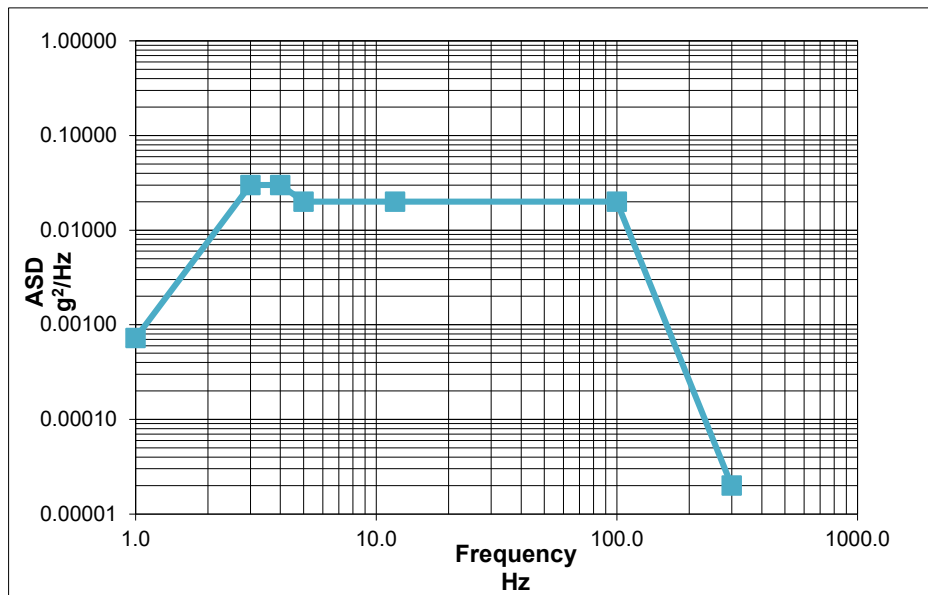


Figure 2-4. Transportation environment PSD (envelopes Truck, Rail, and Air Transportation PSDs in (RD1) and (RD6))

Horizontal Component Response Spectral Accelerations,
 5% Damping Ratio.

Period T - sec	S _a - g			
	10-yr	200-yr	1,000-yr	2,475-yr
0.01	0.069	0.245	0.409	0.525
0.10	0.130	0.544	0.962	1.265
0.15	0.153	0.608	1.056	1.384
0.20	0.152	0.590	1.018	1.322
0.25	0.144	0.555	0.958	1.242
0.30	0.132	0.512	0.885	1.149
0.35	0.121	0.472	0.819	1.072
0.40	0.111	0.440	0.769	1.015
0.45	0.101	0.399	0.697	0.919
0.50	0.091	0.365	0.637	0.840
0.55	0.082	0.334	0.585	0.772
0.60	0.075	0.309	0.541	0.717
0.70	0.064	0.268	0.473	0.628
0.80	0.055	0.236	0.419	0.557
0.90	0.049	0.211	0.376	0.501
1.00	0.042	0.189	0.339	0.452
1.25	0.031	0.150	0.269	0.360
1.50	0.025	0.125	0.227	0.305
1.75	0.022	0.110	0.198	0.265
2.00	0.019	0.098	0.176	0.236

Figure 2-5. TMT site horizontal earthquake accelerations (from (RD10))

Vertical Component Response Spectral Accelerations,
 5% Damping Ratio.

Period T - sec	S _a - g			
	10 yrs	200 yrs	1,000 yrs	2,475 yrs
0.01	0.041	0.164	0.274	0.352
0.05	0.075	0.364	0.632	0.825
0.075	0.084	0.419	0.735	0.963
0.10	0.091	0.462	0.818	1.075
0.15	0.107	0.464	0.805	1.055
0.20	0.098	0.398	0.687	0.892
0.25	0.084	0.326	0.563	0.730
0.30	0.070	0.256	0.443	0.575
0.35	0.064	0.236	0.410	0.536
0.40	0.059	0.220	0.385	0.508
0.45	0.054	0.200	0.349	0.460
0.50	0.048	0.183	0.319	0.420
0.55	0.043	0.167	0.293	0.386
0.60	0.040	0.155	0.271	0.359
0.70	0.034	0.134	0.237	0.314
0.75	0.031	0.125	0.222	0.295
0.80	0.029	0.118	0.210	0.279
0.90	0.026	0.106	0.188	0.251
1.00	0.022	0.095	0.170	0.226
1.25	0.016	0.075	0.135	0.180
1.50	0.013	0.063	0.114	0.153
1.75	0.012	0.055	0.099	0.133
2.00	0.010	0.049	0.088	0.118

Figure 2-6. TMT site horizontal earthquake accelerations (from (RD10))

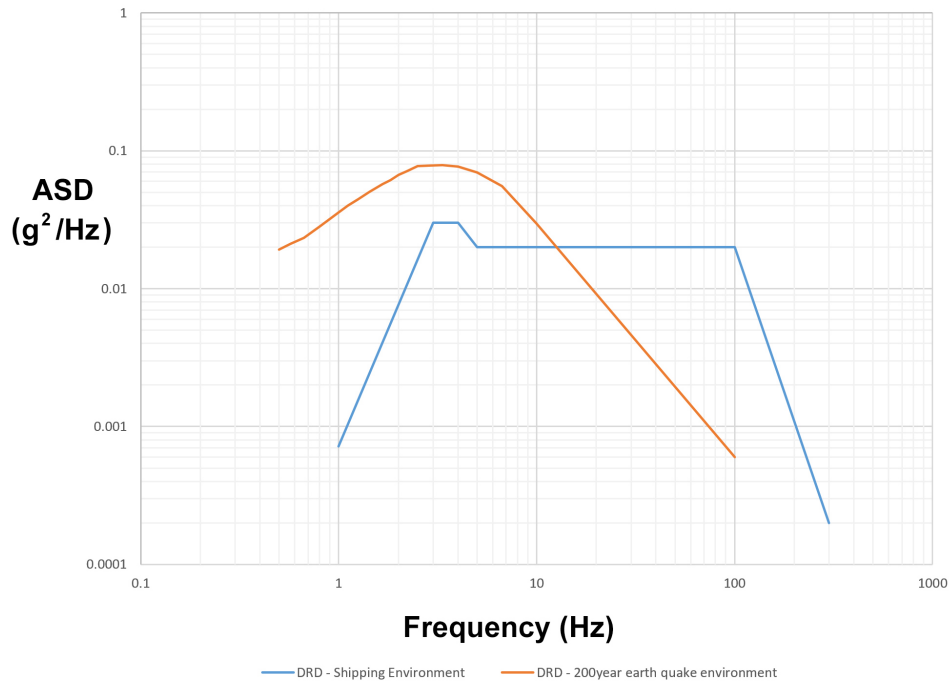


Figure 2-7. Comparison of Transportation PSD and 200 year Earthquake PSD environments

2.7 QUALITY ASSURANCE

The PMASC vendor is allowed to use its own Quality System, or follow the guidelines in (RD4).

3. REQUIREMENTS

3.1 FUNCTIONAL REQUIREMENTS

3.1.1 Lifetime

[REQ-3-M1.PMASC-0100] The PMASC shall meet all requirements over a 10 year lifetime of mixed transit and storage conditions as defined in Section 2.6.

Discussion: The temperature range is applicable for SSA transport. +75 °C is the maximum soak temperature for intermodal container transport. Restrictions of the temperature range may apply for PMA transport. Meeting these restricted temperature requirements will require climate-controlled vehicles. Meeting humidity requirements will require shipping with desiccant or under purge. Additional protection may be required to meet heavy rainfall requirements.

3.1.2 Mass and dimensions

[REQ-3-M1.PMASC-0105] The PMASC shall accommodate a 200 x 100 x 50 mm (LxBxH) area for a transport data logger. The data logger shall be mounted close to the SSA mounting interfaces.

[REQ-3-M1.PMASC-0110] The PMASC shall not weigh more than 250 kg.

[REQ-3-M1.PMASC-0115] The PMASC shall be designed for transport within a standard 20' intermodal shipping containers.

Discussion: As a goal, 9 PMASCs shall fit into a 20' container and 18 PMASCs shall fit into a 40' container.

[REQ-3-M1.PMASC-0120] The PMASC shall be designed for transport outside a standard intermodal container using aircraft, truck (semi-tractor trailer) and rail methods.

[REQ-3-M1.PMASC-0125] The PMASC shall be designed such that it can be stacked for storage purposes.

- 3 high in the loaded configuration
- 5 high in the unloaded configuration
- PMASCs shall be coupled during stacking (using cup/cones or similar)

[REQ-3-M1.PMASC-0130] The M1 design (including all drawings, analyses, etc.) shall utilize SI units. Standard hardware (fasteners, etc.) shall be metric in accordance with (RD9).

3.1.3 Shipping and Handling

[REQ-3-M1.PMASC-0135] The PMASC shall be compatible with forklift handling.

[REQ-3-M1.PMASC-0140] The PMASC shall be compatible with pallet jack handling.

[REQ-3-M1.PMASC-0145] The SSA shall be mounted upside down with the PMASC restraining lateral and axial movement. The SSA will be held in the PMASC using connections to the whiffle tree triangles as shown in Figure 3-1 - Figure 3-3. In addition, the Tower movement shall be restricted, to avoid rattling on the Lock Cams. The SSA mounting procedure is defined in (RD2). The mass properties of the SSA are given in *Table 2-1*.

Discussion: TMT will provide STEP files of the SSA support configuration (including details of components).

[REQ-3-M1.PMASC-0150] The PMA shall be shipped with the mirror surface facing downward on a layer of soft foam in accordance with (RD3). The surface of the mirror will be protected with optical tissue and strip-coat material (TBC). The PMASC shall restrain lateral and axial movement of the PMA, as shown in Figure 3-4. Segment dimension may vary with +/- 5 mm (depending on the location in the M1 array). In addition, the Tower movement shall be restricted, to avoid rattling on the Lock Cams. The PMA mounting method is defined in (RD3). The mass properties of the PMA are given in Table 2-2.

Discussion: As a goal, the PMASC shall be reconfigurable to transport a PMA with the optical surface facing up (vertically) not contacting any packing material that may cause abrasion to a coated surface.

Discussion: TMT will provide a STEP file of the PMA.

[REQ-3-M1.PMASC-0155] The PMASC shall allow installation of the Harris Handling Tooling. This requires:

- An additional load of 90.7 kg (200 lbs) to be installed on the top of the Tower
- Manual access to the bottom of the segment (without partly disassembling the container)

[REQ-3-M1.PMASC-0160] The lid shall be removable by hand (with a maximum of 4 technicians):

- o Lid not to exceed 40 kg
- o Foldable, load rated handles shall be present for safe handling (Figure 3-5)

[REQ-3-M1.PMASC-0165] The PMASC shall use re-usable fasteners or latches (such as Klimp® fasteners, Hardy-Built® fasteners, Link Lock® latches or equivalent) for panels that require removal for access to the SSA/PMA.

[REQ-3-M1.PMASC-0170] The PMASC shall be equipped with a Pressure Relief Valve (PRV), if the container is airtight.

[REQ-3-M1.PMASC-0175] The PMASC shall be equipped with a Desiccant Container.

[REQ-3-M1.PMASC-0180] The PMASC shall be equipped with a weather sealed US manifest box (A4/LTR size), see Figure 3-6.

[REQ-3-M1.PMASC-0185] The PMASC shall have a sealed (IP65) USB A port on the outside of the container (Figure 3-7). The USB port shall be located within 500 mm of the data logger.

[REQ-3-M1.PMASC-0190] The PMASC shall have the following stencils (in accordance with (RD7)):

- o Fragile (minimum on two sides)
- o This side up (minimum on two sides)
- o Keep dry (minimum on two sides)
- o Maximum stack height 3 (minimum on two sides)
- o Lift here (for forklift handling) (on two sides)
- o No step on the top of the lid (minimum on two locations)

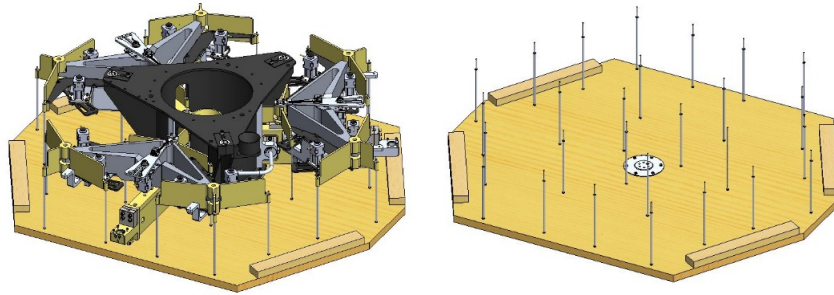


Figure 3-1. PMASC-SSA interface

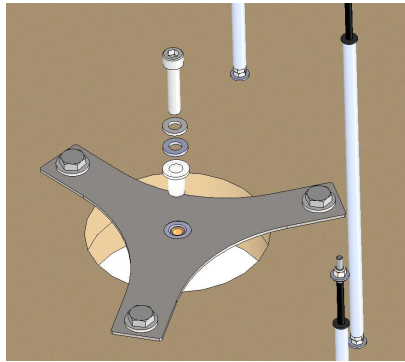


Figure 3-2. SSA Lateral Support

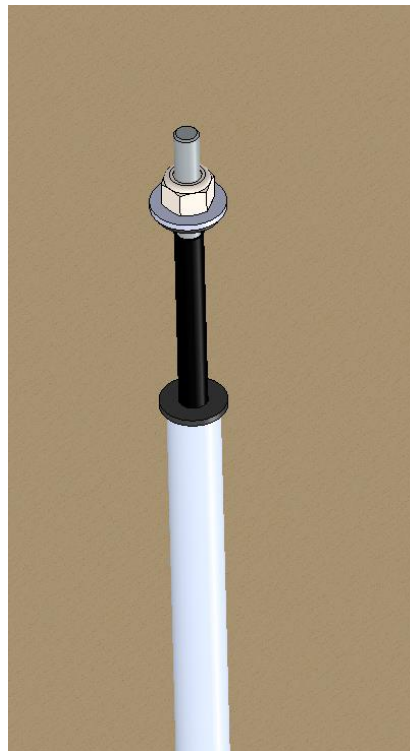


Figure 3-3. SSA Axial support (27 in total)

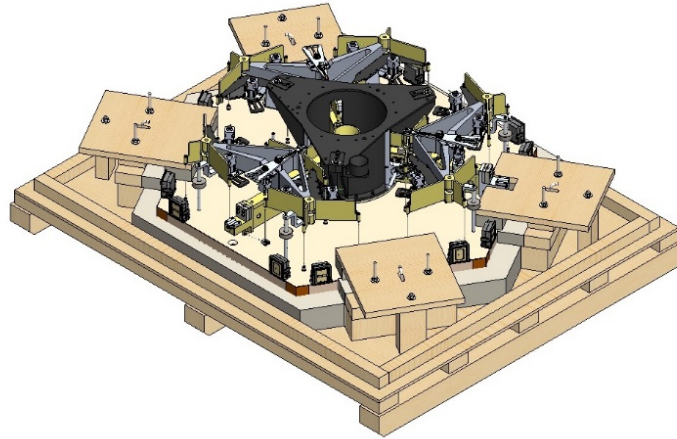


Figure 3-4. PMASC-PMA interface

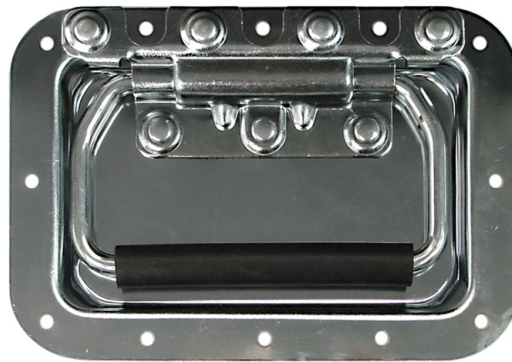


Figure 3-5. Example of Foldable handle (Monroe)



Figure 3-6. Example of Manifest Box (Kenwood)



Figure 3-7. Example of sealed USB port (Samtec)

3.2 PERFORMANCE REQUIREMENTS

[REQ-3-M1.PMASC-0200] Under any combination of transportation conditions described in section 2.6, the PMASC shall protect the PMA from acceleration and shock of greater than 7g in the vertical direction and 3.6g in the horizontal direction.

[REQ-3-M1.PMASC-0205] Under any combination of transportation conditions described in section 2.6, the PMASC shall protect the SSA from acceleration and shock of greater than 24g in the vertical direction and 24g in the horizontal direction.

[REQ-3-M1.PMASC-0210] The PMASC shall be able to withstand a rotational drop of 229 mm (9") on concrete without imparting more than 7g in the vertical direction and 3.6g in the horizontal direction to the PMA.

[REQ-3-M1.PMASC-0215] The PMASC shall be able to withstand a rotational drop of 229 mm (9") on concrete without imparting more than 24g to the SSA.

[REQ-3-M1.PMASC-0220] The PMASC shall be designed for ingress protection to a rating of IP 54 (RD11) against dust and splashing water.

[REQ-3-M1.PMASC-0225] The PMASC shall limit the loads that the MSA will experience during a 200 year earthquake as described in Figure 2-5 and Figure 2-6, to 7g in the vertical direction and 3.6g in the horizontal direction.

Discussion: Ideally, this is achieved without additional earthquake restraints, but if necessary, due to amplification of the payload at low frequencies, removable soft stops may be installed during storage on the site.

3.2.1 Availability

[REQ-3-M1.PMASC-0400] The PMASC shall be designed such that the PMA or SSA can be loaded and unloaded in less than 1 hour.

[REQ-3-M1.PMASC-0405] The PMASC shall be adaptable to ship both SSA and PMA assemblies.

[REQ-3-M1.PMASC-0410] Conversion between SSA and PMA mode and vice versa, shall take less than 60 minutes (requiring maximum 2 technicians).

3.2.2 Safety, Security and Environmental Protection

[REQ-3-M1.PMASC-0415] The PMASC shall be designed such that it can pass international customs inspection procedure in any TMT partner country (USA, Canada, Japan, China, India) as well as Europe. The PMASC shall comply with the requirements in (RD8).

Discussion: Any shipment containing wood must be stamped for ISPM 15 (RD8) to show that it has been treated per IPPC for international shipping standards for wood.

[REQ-3-M1.PMASC-0420] The PMASC design shall prevent the spread of invasive species.

[REQ-3-M1.PMASC-0425] All metallic components of the PMASC shall have sharp edges deburred.

[REQ-3-M1.PMASC-0430] All wooden components of the PMASC shall be made to prevent splinters.

[REQ-3-M1.PMASC-0435] The PMASC shall be designed to minimize pinch points on the container.

Discussion: Personnel should demonstrate proper safety procedures during PMASC opening and closing operations to ensure the top of both the inner container and outer container does not slam or cause harm to personnel or PMA/SSC hardware.

[REQ-3-M1.PMASC-0440] The PMASC interior shall not outgas any volatiles that can damage the PMA/SSA during shipping or storage, or provision must be made to bag the PMA/SSA in a separate non-outgassing envelope.

[REQ-3-M1.PMASC-0445] The PMASC shall minimize or eliminate materials that create smoke should fire occur during transport or storage of the PMASC.

3.2.3 Maintainability

[REQ-3-M1.PMASC-0450] The PMASC shall be designed such that all panels of each box are interchangeable with a corresponding panel of another PMASC if a panel needs to be replaced.