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MARTIAN MOONS EXPLORATION (MMX) MISSION

COMPONENT MECHANICAL DESIGN CRITERIA

REVISION AND HISTORY PAGE

Status	Revision Number	Change Number	Description	Release Date

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1. INTRODUCTION

1.1. Purpose and scope of this document

This document (MMX-C-MDC) describes the criteria on mechanical interface designs for Martian Moons Exploration (MMX) on-board components.

In case of conflict, the MMX-I-IRD will take precedence over this document.

For any component that raises issues in satisfying the requirements, coordinate with the MMX system team.

1.2. Reference documents

See Section 0

1.3. Notation

[TBD-Sys] [TBC-Sys]

The results of previous study for MMX or other projects are described as reference information for systems and the PI instrument. They will be established by system design in Phase A or beyond.

[TBD-Sys/PI] [TBC-Sys/PI]

The results of previous study for MMX or other projects are described as reference information for systems and the PI instrument. They will be established through coordination between the PI instrument and systems in Phase A or beyond.

[TBD-Doc] [TBC-Doc]

Information that can be described through coordination with design standards and other documents. (Phase A or beyond)

[TBD-Plan] [TBC-Plan]

Information determined after government approval of the project plan.

2. DESIGN CRITERIA

2.1. General information

2.1.1. Standards metric system

Drawings, specifications, and engineering data shall use the International System (SI) metric standard.

- Dimensions in meters [m]
- Angles in degrees
- Temperatures in degrees Celsius [°C]
- Power / Heat in watts [W]
- Energy in joules [J]
- Mass in kilograms [kg]
- Magnetic field in tesla [T]
- Time in seconds [s]
- Electric current in amperes [A]

2.2. Mechanical design and interface requirements

2.2.1. Configuration requirements

2.2.1.1. Physical properties

2.2.1.1.1 Mechanical interface control document

The mechanical interface control document shall complement the ICD.

2.2.1.1.2 Mass and mass tolerance

Components shall be designed taking into account the allocated mass with adequate margins according to the mass-margins depletion scheme.

The unit accommodation mass shall include the total component hardware that is intended for flight. The mass budget shall at least include the following (as applicable):

- Structures, mechanisms, and optics
- Electronics including interfaces with the spacecraft power and data systems
- Thermal control hardware, including any necessary radiators, heaters, thermistors, and component blankets defined by the component and not part of the spacecraft TCS
- Radiation shield
- Pigtail and interconnecting harness (if the component consists of more than one unit)
- Electrical connectors, but not the mating harness connector
- Attachment hardware excluding standard fixation bolts and washers
- Potting compounds used in the units
- Alignment references such as mirrors that are not removed before flight
- Internal balance mass (applicable for periodically operating mechanisms)
- Electrostatic screens and magnetic shielding
- In-flight covers, purge ports, and purging pigtails

Regarding the mass of component, a nominal value shall be expressed in digits of 0.01kg unit or 0.1% whichever is greater and shall be described in the ICD.

The difference between the measured mass of each structural thermal model (STM) and flight model (FM) unit and the respective estimated mass, as specified in the Interface Control Drawing current at the time of the STM and FM unit delivery to the Project, shall be less than 1% (TBC-Sys).

2.2.1.1.3 Center of mass

The CoM of a component shall be defined according to the distances (two directions) from the reference hole for mounting and the height from the mounting surface in the orthogonal three-axis (one axis shall be vertical to the mounting surface) direction, and shall be described in the ICD. In addition, dimension tolerance for the CoM position shall be +/-5 mm in each direction.

When computing CoM values, non-flight items (temporary installation items, etc.) are not taken into account.

2.2.1.1.4 Moments of inertia

The moment of inertia (MOI) for component shall be defined in CoM position rotation in the orthogonal three-axis direction and shall be described in the ICD. Tolerance for the moment of inertia shall be +/-10%. Note that the unit of the moment of inertia shall be kg•m2.

2.2.1.1.5 Unit dimensions

The dimension d of each unit is specified in the TBD-Sys to a tolerance smaller than

+0.5 / –0.0 mm	for d < 500 mm	(TBC-Sys),
+1.0 / –0.0 mm	for 500 mm < d	(TBC-Sys).

2.2.1.2. Physical envelope requirements

The component shall not exceed the physical envelope allocated. The precise envelope for each component is listed below:

Details will be fixed during the accommodation study.

2.2.1.3. Component units identification

Each unit identities shall be indicated with the following information in English or in English abbreviations and shall be specified in the ICD.

Details will be in TBD-Sys.

2.2.1.4. Connector identification

Each connector unit shall be identified by a Connector Identification Code.

Details will be in TBD-Sys.

2.2.1.5. Accessibility requirements

Where possible, the design of units and the positioning of their attachment points to the spacecraft should provide sufficient accessibility to enable mounting and removal of the units themselves and their related covers and alignment devices with normal standard tools.

Where this requirement cannot be fulfilled, PIs shall provide a toolkit such that mounting bolts can be torqued from an accessible position.

2.2.2. Requirements for Mounting

2.2.2.1. Selection and arrangement of mounting screws

The criteria when the subsystem team selects mounting screws for a spacecraft body are shown below.

Note that the MMX system team provides and manages the screws to mount component to a spacecraft body. However, if any special screws not conforming to the following criteria are to be used, the subsystem team basically supplies such screws to the MMX system team.

(1) Metric screws shall be used for mounting a component to a body. In principle, sizes shown in **Table 2.2.2.1-1** shall be used. Use of other screws shall be coordinated with the MMX system team.
(2) Component shall have three or more mounting holes. In principle, these holes shall be designed by referring to Figure 2.2.2.1-1 so that they will be arranged symmetrically with orthogonal axes in their on-board surfaces. Note, however, that the use of asymmetrical hole-patterns shall be taken into account for directional screws in order to prevent erroneous mounting.
(3) Mounting screw sizes and mounting hole pitches shall be determined by considering thermal requirements and Section 2.2.3. "Mechanical Requirements" of this document. Quantity of screws shall be kept to a minimum from the viewpoints of weight reduction, handling, etc. In this case, load per screw location shall be designed so that, in principle, it will not exceed permissible loads shown in Figure 2.2.2.1-1. The loading condition to be used for this load calculation shall be the ultimate load specified in Section 2.2.3.2. "Loading Conditions."

Table 2.2.2.1-1 Permissible Loads for Structure Insert (Preliminary)

Screw Size	Tension/Compression	Shear
M3 – 0.5P	3.9×10^2N	9.8×10^2N
M4 – 0.7P	7.8×10^2N	1.3×10^3N
M5 – 0.8P	9.8×10^2N	1.6×10^3N
M6 – 1.0P	1.8×10^3N	2.7×10^3N

Use of values exceeding the above shall be coordinated between the MMX system team.

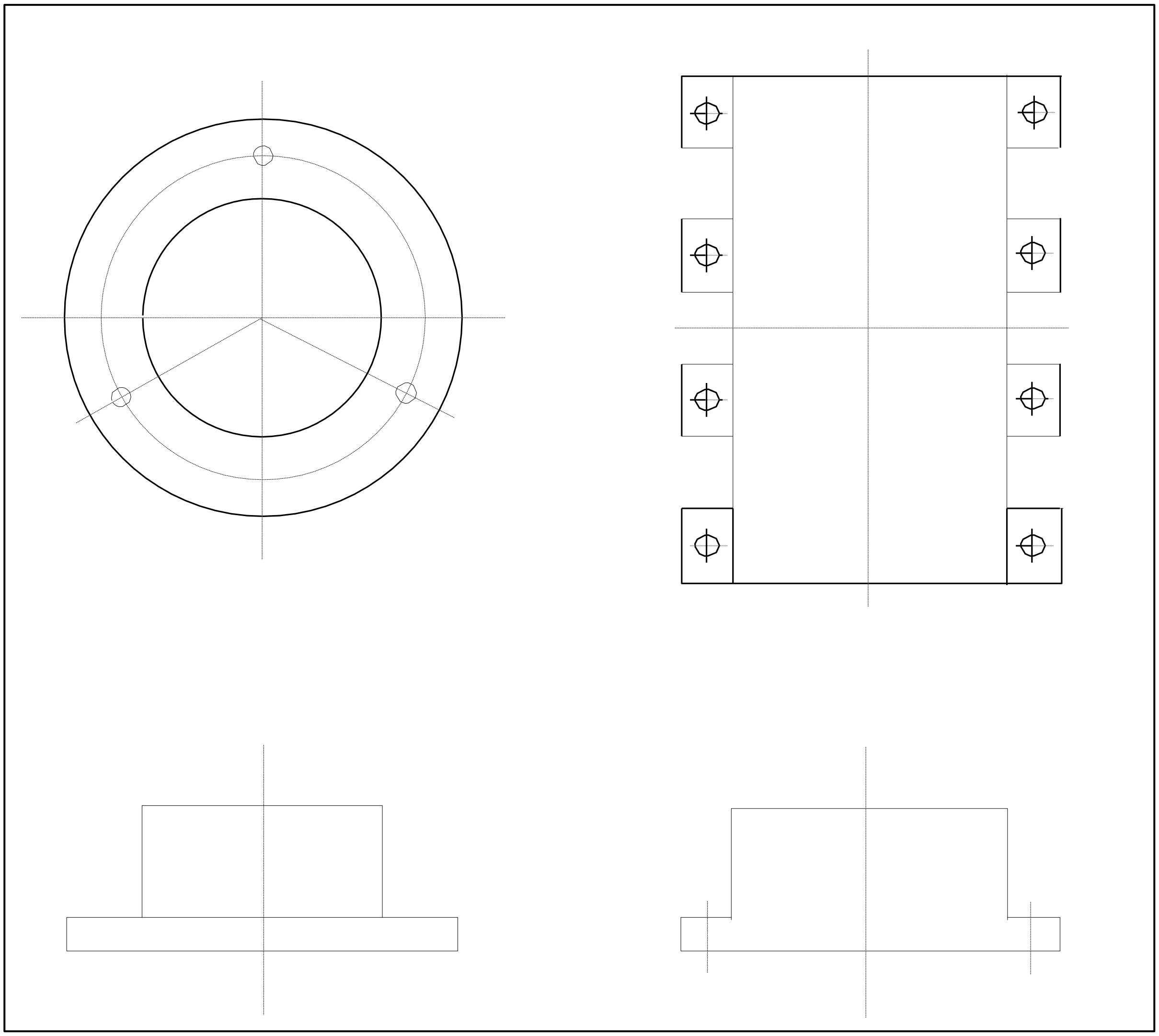

Figure 2.2.2.1-1 Arrangement of Mounting Screws for Component (For Reference)

2.2.2.2. Diameters and tolerances of mounting screws

Diameters and tolerances of mounting holes are shown in

(1) Table 2.2.2.2-1. Note that dimension tolerances shown in this table apply to component with no particular alignment requirements. Component with alignment requirements shall be described in the ICD.

(2) Dimension tolerances between mounting holes of component

Dimension tolerances between mounting holes shall be ±0.2 mm or less for one reference hole. If this condition cannot be satisfied for large component, etc., conditions shall be based on the ICD.

In principle, the component applicable to the following requirements shall use not only ordinary screws but also means of fastening for prevention of misalignment of shear bolts, etc. when such component is fixed.

① Component with special requirements for accuracy and repeatability of mounting positions when the component is mounted to a spacecraft body

② Component whose functionality or performance is affected by misalignments in mounting in-plane directions that may be caused by vibration, etc., when a spacecraft is launched

Types, sizes, arrangements, quantities, mounting hole diameter tolerances, mounting pitch tolerances, templates and other factors of fasteners for constraining in-plane directions such as shear bolts shall be determined through coordination with the MMX system team and shall be reflected in the ICD. Fasteners, which require templates shall, in principle, be provided by the subsystem team and shall be supplied to the MMX system team. Reference holes shall be the mounting holes near corners and shall be described in the ICD.

Table 2.2.2.2-1 Diameters and Tolerances of Mounting Holes

Screw Size	Diameters and Tolerances of Mounting Holes (mm)
M3 – 0.5P	$\Phi 3.5^{+0.3}_{-0.03}$
M4 – 0.7	$\Phi 4.5^{+0.3}_{-0.03}$
M5 – 0.8P	$\Phi 5.5^{+0.3}_{-0.03}$
M6 – 1.0P	$\Phi 6.5^{+0.3}_{-0.03}$

2.2.2.3. Mounting methods

(1) Component shall have flanges or tabs for mounting to a body. In principle, component shall be easily attached to the body by screws. Clearance for fastening tools shall be provided to the surroundings of mounting holes. Also, in principle, there shall be no projections, which may obstruct access from the top surfaces of component.
(2) If the mounting section is located in the component's chassis (for example, it is not possible to mount the component using flanges, etc.), and if nuts for mounting are required in the chassis or in the box, such shall be coordinated with the MMX system team.
(3) To avoid intrusion of foreign objects, holes shall not be provided to surfaces of components for the purpose of mounting. If holes, etc. are required, such matter shall be coordinated with the MMX system team.

2.2.2.4. Mounting surfaces

Mounting surfaces of component shall satisfy the following conditions:

(1) Flatness rate

0.001 mm/1 mm or less

(2) Surface roughness

Better than 6.3 micron at the highest point (contact surface with a body) or 1.6Ra

2.2.2.5. Fastening torques

Fastening torque ranges for screws used in mounting component are shown in Table 2.2.2.5-1. Fastening torques shall be specified in the ICD. Use the case with titanium screw by the initial tightening power of 50% or less of creep.

Table 2.2.2.5-1 Fastening Torque Ranges

Screw Size	Maximum Fastening Torque(N・m)
M3 – 0.5P	0.85±0.06
M4 – 0.7P	2.01±0.15
M5 – 0.8P	4.02±0.29
M6 – 1.0P	6.86±0.49

2.2.2.6. Grounding points

Applicable ranges of unpainted areas, ("Exposure Ranges") as shown in Table 2.2.2.6-1, shall apply to the surface surroundings of all components mounting holes, so that conductive surfaces are exposed.

Table 2.2.2.6-1 Conductive Surface Exposure Ranges

Screw Size	Exposure Range (mm)
M3 – 0.5P	ϕ8 or more
M4 – 0.7P	ϕ10 or more
M5 – 0.8	ϕ12 or more
M6 – 1.0P	ϕ14 or more

2.2.2.7. Connecter arrangements

(1) Mounting positions of connectors for component shall be described in the ICD.

(2) Connectors for testing shall be arranged in positions, which take account of accessibility and workability during testing.

(3) In principle, screw lock positions of connectors shall be positioned at more than 20 mm apart from body mounting surfaces, in order to secure clearance for fastening tools.

2.2.2.8. Fastening torques of connectors' screw locks and OSM connectors

Fastening torques of male screws or OSM connectors of electrical components are shown in Table 2.2.2.8-1. If other connectors are used, they shall be described in the ICD. In addition, rotation prevention measures shall be taken to the female connectors or component's OSM connectors, in order to avoid rotation when connectors are fastened at specified torques.

Table 2.2.2.8-1 Fastening Torques of Connectors' Screw Locks and OSM Connectors

Connector Type	Fastening Torque
D-Sub	0.343±0.02N･m (3.5±0.2kgf･cm)
MDM	0.216±0.01N･m (2.2±0.1kgf･cm)
OSM	0.98±0.196N･m (10±2kgf･cm)

2.2.2.9. Fixing of harnesses

In principle, system harnesses shall be fixed to a body, mechanical component brackets, etc. However, if there are connectors on the upper surface of component or on the upper section of the side surface, harnesses may be fixed to the component, too. If necessary, coordination between the subsystem team and the MMX system team shall be conducted and coordinated results shall be described in the ICD.

2.2.2.10. Dust caps

Dust caps shall be provided to component and harness connectors in order to prevent damage or contamination when they are not connected.

2.2.2.11. Criteria in use of pyrotechnics

(1) Pyrotechnics shall be placed in positions where they can be easily attached or detached from the external surface of the spacecraft. In addition, clearance space shall be provided in the proximity of pyrotechnic connectors so that short connectors, preventing erroneous ignition, can be attached or detached.

(2) There shall be continuity between mounting surfaces of pyrotechnics and those of relevant component (1 Ω or less).

2.2.2.12. Alignment

(1) Regarding spacecraft mounted components, having an angle alignment requirement with higher accuracy of more than ±0.5°, alignment criteria, correlated to performance axes

(bore sight) of the component, shall be provided together with alignment mirrors which can be measured at the time of mounting to the spacecraft. Alignment interface with spacecraft systems shall be based on these alignment criteria. Positions and collimation directions of alignment mirrors shall be described in the ICD after consultation with the MMX system team. Specifications of alignment mirrors shall satisfy the following guidelines:

(a) Collimation directions of optical reflection planes shall, in principle, be axis directions of a spacecraft coordinate system.
(b) The number of optical reflection planes shall be in collimation direction enabling the use in spacecraft systems and also shall be able to represent all performance axes which alignment of component requires.
(c) Flatness of optical reflection planes shall be λ/6 (λ: wavelength of 633 nm) or less.
(d) Reflection rate of optical reflection planes shall be 85% or more.
(e) Dimension of each side of optical reflection planes shall be 15 mm or more. Squareness and parallelism of two orthogonal planes shall be 10 arcsec or less.

(2) Relationship between alignment criteria and component's performance axes (bore sight) shall be acquired as alignment data. The subsystem team shall provide the MMX system team with this data per component. Alignment data shall be acquired according to the following specifications:

(a) Alignment data shall be represented in a coordinate system, which is parallel to a spacecraft coordinate system. Angles shall represent by θx (X-axis rotation), θy(y-axis rotation), and θz (z-axis rotation) in clockwise order.
(b) Codes of alignment data shall be based on performance axes (bore sight) of component and shall represent the amount of misalignment of the alignment reference axis.

Alignment Data = Alignment Reference Axis Direction

– Component Performance Axis Direction

(3) If devices (such as angle brackets, adjustment screws, and shims) are required for component alignment adjustments when component is mounted to spacecraft, such devices shall be designed and supplied by the subsystem team, and shall be described in the ICD.

2.2.2.13. Requirements for visual fields

Any requirements for visual fields due to optical characteristics or thermal designs shall be described in the ICD.

2.2.3. Mechanical requirements

2.2.3.1. Considerations for mechanical designs

The component shall be designed to withstand the environment it will encounter during its lifetime while maintaining nominal performance and without detrimental influence to the spacecraft or other components' performance.

The mechanical loads induced by this environment include the following:

• Fabrication and assembly loads (e.g., welding, interference fitting)

• Handling and transportation loads

• Test loads (including thermal stresses)

• Launch loads including ascent depressurization

• Operational loads

Attitude and orbit control-induced loads

Thermally induced loads

Separation loads

Touchdown/Takeoff loads

2.2.3.2. Loading conditions

Various loading conditions and environmental conditions that component will encounter from fabrication to testing, launch, and until the end of operations in orbit shall be based on MMX-EDDTC. Yield load and ultimate load of component shall be the values obtained by multiplying the maximum prediction level (limit load) and qualification test level of quasi-static acceleration and sinusoidal vibration specified in MMX-EDDTC by the safety coefficients (which are called the yield load coefficient and ultimate load coefficient respectively) shown in Table 2.2.3.5-1. At the same time, temperature environments and other accompanying environmental phenomena such as atmosphere and humidity specified in MXX-EDDTC shall be taken into account. The accompanying environmental phenomena are not multiplied by the safety coefficients.

For component using liquid or gas, the maximum expected pressure are to be multiplied by safety coefficients shown in Table 2.2.3.5-2. In addition, strengths shall be evaluated by compounding the maximum expected pressure to yield load and ultimate load respectively.

Note that safety coefficients in Table 2.2.3.5-1 and Table 2.2.3.5-2 are safety factors for setting loads. Uncertainties for material strengths, manufacturing quality, etc. shall be taken into account separately (see 2.2.3.3.3).

2.2.3.3. Requirement for strength

2.2.3.3.1 During yield load

Structures shall be designed to have sufficient strengths to simultaneously withstand yield load, supplementary temperature and other accompanying environmental phenomena without causing permanent distortion or harmful elastic deformation of 0.2% or more.

2.2.3.3.2 During ultimate load

Structures shall be designed to have sufficient strengths to simultaneously withstand ultimate load, supplementary temperature and other accompanying environmental phenomena without causing damage. However, accompanying environmental phenomena do not include safety coefficients.

2.2.3.3.3 Margin of safety (MS)

MS shall not be negative during yield load and during ultimate load under the conditions below. In particular, for composite material, bonded structure, and buckling, where destructions are catastrophic, as well as inserts, MS for ultimate load shall be 0.25 or more.

MS here is not intended to cover knock-down factors for variations of materials, uncertainties of manufacturing quality or analytical models, buckling strength, bonded section strength, strengths of mechanism parts such as antenna paddles, etc. These knock-down factors shall be considered in strength designs separately.

$$\text{Margin of safety for yield} = \frac{\text{Yield stress of materials}}{\text{Generated stress based on yield}} - 1$$

$$\text{Margin of safety for ultimate load} = \frac{\text{Breaking stress of materials}}{\text{Generated Stress based on ultimate load}} - 1$$

$$\text{OR} = \frac{\text{Buckling load of materials}}{\text{Generated load based on ultimate load}} - 1$$

Note that influence of combined loads shall be included.

2.2.3.3.4 Random vibration, acoustic and shock environments

Yield, destruction and fatigue as well as functional and performance degradation shall not be allowed under load of qualification test conditions. Dynamic characteristics of the structure shall not be changed.

Fatigue failure shall not occur for repetitive load.

Test tolerances specified in “MMX_Environmental Design Data & Test Condition” shall be taken in account.

2.2.3.4. Requirements for rigidity

2.2.3.4.1 During yield load

Harmful deformations shall not occur at structures under yield load and compound environmental conditions. Contact or interference shall not occur between adjacent parts of component due to bending during limit load.

2.2.3.4.2 During ultimate load

Excessive deformations, which may cause structural destructions, shall not occur during ultimate load and compound environmental conditions.

2.2.3.4.3 Dynamic characteristics

(a)The minimum natural frequency of component in the launch configuration shall be larger than 120 Hz in the condition where interface points are fixed rigidly.

(b)The minimum natural frequency of component in orbit configuration shall be larger than 10 Hz in the condition where interface points are fixed rigidly.

2.2.3.5. Safety coefficients

Values shown in Table 2.2.3.5-1 shall apply to safety coefficients for non-pressure structures. However, if high-pressure gas component simultaneously receives loads due to pressure and due to the environment during launch and flight, values shown in Table 2.2.3.5-2 shall apply to pressure.

Table 2.2.3.5-1 Safety Coefficients

Phase for Maximum Prediction Load		Safety Coefficient		Remarks
		Yield Load	Ultimate Load	
Quasi-static acceleration during launch/flight		1.00	1.25	
* Qualification test level (quasi-static acceleration and sinusoidal vibration)		NA**	1.00	
During transportation, handling, etc. on the ground	In case of danger to personnel	1.50	2.00	
	In case of no danger to personnel	1.25	1.50	

*: Qualification Test Level = 1.25 x Acceptance Test Level

** Flight model shall not yield under the qualification test level.

Table 2.2.3.5-2 Safety Coefficients (Pressure Containers, etc.)

Safety Coefficients for Material Strengths of Metal High-pressure Gas Component

Structural Category	Safety Coefficient		Condition (Note 1)
	Yield Stress (σy)*	Tension Strength (σu)	
Pressure container	$\frac{1 + \text{(safety coefficient for tension strength)}}{2}$ or more	1.50 or more Less than 2.0	Personnel access allowed (Note 2)
Pressure piping, fitting	1.50 or more	4.0 or more	Personnel access allowed (Note 3)
Other component	1.50 or more	2.50 or more	Personnel access allowed (Note 3)

*: or 0.2% bearing force

Note 1: Permits whether personnel access is allowed or not during a statically stabilizing condition when the maximum expected pressure is loaded. Note that personnel access is always allowed when the design destruction pressure of one fourth or less is applied.

Note 2: Personnel access shall be allowed on the assumption that LBB (Leak Before Break) is established. Note that necessary countermeasure shall be taken if substances inside has toxicity.

Note 3: If pressure pipes, fittings, or other component cannot satisfy the above safety coefficients, they shall be used as pressure containers.

Safety Coefficients for Pressures of Compound Pressure Containers

Safety Coefficient		Condition (Note 1)
Hydrostatic Test Pressure	Design Destruction Pressure	
$\frac{1 + \text{(safety coefficient for tension strength)}}{2}$ or more	1.50 or more Less than 2.0	Personnel access allowed (Note 2)

(Hydrostatic test pressure) = (Safety coefficient for hydrostatic test pressure) × (Maximum expected pressure)

(Design destruction pressure) = (Safety coefficient for design destruction pressure) × (Maximum expected pressure)

Note 1: Shows whether personnel access is allowed or not during a statically stabilizing condition when the maximum expected pressure is applied. Note that personnel access is always allowed when one fourth or less of design destruction pressure is applied

Note 2: Personnel access shall be allowed on the assumption that LBB (Leak Before Break) is established. Note that necessary countermeasure shall be taken if substances inside has toxicity.

2.2.3.6. Material characteristics

Material strengths and other mechanical / physical properties shall be based on 4.1. (1) and (2) of Section 2.1 “Applicable Documents.” Of the mechanical characteristics of each material, Values A, B, and S are specified for permissible stress. Each value shall be used differently as follows:

① Value A or of equivalent value

This would be applicable if soundness of the entire structure is damaged due to destruction or damage in structural parts or materials, which consist of a single load path in the main structure.

② Value B, Value S or an equivalent value

This would be applicable if a load path changes even in case of destruction or damage in structural parts or materials, which consist of a redundant structure and if soundness of the entire structure is not damaged due to load redistribution. If any material not described in the above official data is used, material test data shall be evaluated before use. If any new material or any material with insufficient mechanical characteristics data is used, such shall be handled as follows:

Mechanical characteristics shall be confirmed by a test which simulates the operating environment of the actual component by means of multiple (at least three, usually about five, for the same test condition) test pieces under the same processing and operating conditions as those for the materials to be used for manufacturing of the actual component. Then, permissible design values (for example, approximated 3σ lower limit) in consideration of fluctuations shall be set for use in structural designs (evaluation of strength and rigidity).

2.2.4. Mechanisms

2.2.4.1. General and functional requirements

Mechanisms shall be designed to meet the mechanical and electrical interfaces and performance requirements both on orbit and on ground, as applicable.

Structural parts of mechanisms shall be designed with the same criteria, loads, and safety factors as all other structural items. They should also fulfill the minimum structural frequency requirements.

For critical parts connected to total failure, redundancy concepts shall be selected to minimize single-point failures and to optimize reliability for the mission and life requirements.

Mechanism failures shall not obscure the FOV of another element.

Mechanism materials, parts, and components shall be selected according to ISAS/JAXA-approved qualification procedures, and shall be compatible with the requirements specified in the relevant documents. Their performance under long exposure to space environments and potential performance degradation over their ground life shall be specifically addressed.

Mechanisms shall be compatible with EMC and cleanliness requirements.

The mechanism design shall be compatible with operations in ambient and thermal vacuum conditions. These shall be representatively tested on ground according to the mechanism verification test program.

The mechanism status (e.g., stowed, deployed, and moving) shall be telemetered to the ground.

Mechanism failures shall not cause thermal loads (sun or IR) unacceptable to the thermal control system, thereby endangering the mission.

Note: Assessments will be carried out with the MMX System Team.

2.2.4.2. Mechanism perturbation

Components equipped with active mechanisms used during observation shall be designed to minimize perturbations induced on the spacecraft and the production of micro-vibrations.

Torque impulses shall be less than TBD-Sys Nms and TBD-Sys Nm around any spacecraft axis.

Vibrations shall be less than TBD-Sys N in the range 50 to 100 Hz (TBC-Sys) and TBD-Sys in the range 10e-3 to 0.1 Hz (TBC-Sys).

Shock generated by component at all mechanical interface demarcation points shall be equal to or less than the level shown in Table (TBD-Sys) when component is mounted to the spacecraft body.

2.2.4.3. Lifetime requirement

All mechanisms shall be designed for a lifetime of a number of operations during the predicted service life—including both in-orbit and ground operations necessary for functional tests, system tests, etc.—multiplied by the following factors (TBD-Sys/PI):

Minimum Mechanisms Lifetime Factor : 4.0

2.2.4.4. Pyrotechnic devices

PI instruments shall not use any pyrotechnic devices.

Note: If other actuators like thermal knives or wax actuators are necessary, consult with the MMX system team.

2.2.5. Mounting attachment and handling

Considerations shall be given to facilitate handling activities of component.

It shall be possible to handle component in a manner where its shapes are protected during the handling while being supported by the component itself or jigs, etc.

In addition, it is recommended that handles, etc. be provided as required necessary. In spacecraft system integrations, necessary jigs shall be lent to the MMX system team for activities of assembling component into a spacecraft system using sling jigs, etc.

When jigs are fabricated, attention should be made to avoid interference with other component during handling of the relevant component in spacecraft system integrations. The ICD shall include descriptions for shapes of jigs, their dimensions, how to handle them, etc. so that the MMX system team can check existence of interference.

In addition, on-board component on the external surface of a spacecraft, whose mass is 15 kg or more, shall be structured so that it can be suspended from the axis direction by means of sling jigs, etc. when it is assembled into the spacecraft.

2.2.6. Identity indications

2.2.6.1. Component identity indications

Component identities shall be indicated with the following information in English or in English abbreviations and shall be specified in the ICD.

(1) Product name or model name

(2) Part number or model number

(3) Serial number or manufacturing number

(4) Manufacturer name

(5) Manufactured year and month

(6) Ordered by: Funding agency

2.2.6.2. Connector identity indications

A connector identity indication stamp shall be easily recognized after harnesses are combined in the proximity of the connector and each identity indications shall be located in areas that can clearly distinguish each applicable connector, even when there are multiple connectors in close proximity. If there are space restrictions in the indications, the common portion of connector identity indications can be stamped on behalf of other indications, and serial numbers can be stamped for each connector indication.

2.2.6.3. Identity indication methods

Component identity indications methods shall be with rubber stamps, stencils, or equivalent methods and shall not fade or wear due to handling, brushing during tests, or by environmental conditions. Identity indications shall be indicated on the external surfaces of components.

2.2.7. Aperture covers

2.2.7.1. Requirements

Units that incorporate a detector aperture shall be delivered with a metallic dust-resistant protective cover over the aperture.

These covers shall be either removable before flight or be part of the component and be deployed and retracted in-orbit.

2.2.7.2. Removable covers (Non-flight items)

All removable covers will normally be removed during system tests where a flight configuration is mandatory, such as thermal vacuum testing or vibration testing. Therefore, they shall be as follows:

- accompanied by a detailed procedure for their removal by MMX System Team personnel or their contractors,
- easily identifiable as non-flight hardware (normally with a red anodized finish and a red flag labeled “NOT FOR FLIGHT” attached to the device) (TBC-Sys), and
- clearly marked as non-flight items on the relevant Interface Control Drawing.

2.2.7.3. Deployable covers (flight items)

Deployable covers are considered critical items for the design, health, and safety of the spacecraft and its payloads. Their implementation is therefore considered as the responsibility of the MMX System Team.

However, PIs shall identify the following:

- the necessity of a cover for mission implementation,
- the frequency of use (single-shot or multiple operations), and
- the criticality and possible performance degradation resulting from a failure to open or close with regard to the health and safety of the component.

2.2.8. Electrical connectors mechanical accommodation

Mounting positions of connectors for component shall be described in the ICD.

Connectors for testing shall be arranged in positions, which take account of accessibility and workability during testing.

In principle, screw lock positions of connectors shall be positioned at more than 20 mm apart from body mounting surfaces, in order to secure clearance for fastening tools.

2.2.9. Purging interfaces

Purging Interfaces requirements shall be clarified in ICD.

2.2.10. Payload generated disturbances

Possible disturbances shall be clarified in ICD.

3. VERIFICATION REQUIREMENTS

3.1. Definitions

The following definitions (in alphabetical order) are recommended:

Acceptance verification or certification:

Tests intended to demonstrate that hardware is acceptable for flight. These also serve as a quality control screen to detect deficiencies, and normally to provide the basis for delivery of an item under the terms of a contract or agreement.

Acoustics and random vibration:

An environment created by high-intensity acoustic noise associated with various segments of the flight profile. It manifests itself throughout the component in the form of directly transmitted acoustic excitation and as structure-borne random vibration excitation.

Design qualification verification:

Tests and analyses intended to demonstrate that the item will function within performance specifications under simulated conditions more severe than those expected from ground handling, launch, and orbital operations. The purpose is to uncover deficiencies in design and method of manufacture and is not intended to exceed design safety margins or to introduce unrealistic modes of failure.

Environmental tests

Environmental tests shall be conducted on the flight or flight-configured hardware to assure that the flight hardware will satisfactorily perform in one or more of its flight environments. This class of test includes random, thermal balance (TB)/thermal vacuum (TV) (or temperature), and EMC tests. They are normally combined with functional testing to a degree depending on the objectives of the test.

Modal survey test:

A series of mechanical investigations to determine the natural frequencies and associated modes of a structure.

Shock tests:

A test conducted to verify the design under the environment created by shocks produced by the launcher during events such as stage and spacecraft separation and by the spacecraft during events such as pyro firings.

Sinusoidal vibration test:

A test to demonstrate that the component can withstand a mechanical environment of low-frequency (less than 100 Hz) sinusoidal and transient vibrations.

This test can also be used to demonstrate compatibility with static loads.

Static Loads:

The maximum combination (longitudinal and lateral) of static loads that act on a component during the various segments of the flight profile.

This consists of steady-state accelerations such as those due to constant engine thrust or lateral wind loads, or those due to quasi-static loads, which are structure-borne loads generated by the launch vehicle in the low-frequency (less than 100 Hz) range such as engine cut-off loads or wind gusts.

Verification by analysis:

The compliance to a requirement is analytically verified. The typical method is by using mathematical models, which may be supplemented or supported by hardware simulations.

3.2. Analysis

3.2.1. Structural mathematical analysis

3.2.1.1. General

The mechanical performances of the component shall be calculated by means of structural mathematical models (SMMs).

PIs shall use models for their own design and, if required, shall also provide models to JAXA for use during spacecraft design and test results predictions. PIs shall update these models according to component and system test results.

The required delivery dates of the component SMMs are listed in MMX-I-IRD

The detailed requirements for each model and analysis are listed in the following sections.

3.2.1.2. Detailed stress analysis

This shall include at least the following:

- A description of the configuration analyzed with reference to interface-controlled drawings
- A description of the mathematical finite element model or of the assumptions taken to verify

the structure

- A description of all possible loading cases and an identification of the design-driving load cases or load combinations
- Detailed description of the most-loaded elements listed with relevant stresses, and the loading cases that generated them
- A list of the materials and structural components with characteristics data sheets (including long-life effects under space environments)
- A set of tables showing, for each structural element, the maximum value for each type of stress or combination of stresses with the allowable value, and the load case that determines it, together with its margin of safety

3.2.1.3. Mechanism functional analysis

Each mechanism shall be analyzed functionally, and the following information shall be supplied as a minimum:

- A detailed description of the mechanism, with particular reference to its discrete components (bearings, actuators, switches) and its operational and safety features
- A detailed description of the operating modes with reference to ground and orbital activations
- A definition of operating loads in various configurations with a clear definition of analysis assumptions; in particular, the functional analysis shall include the effects of the worst environmental conditions that could produce distortions or changes in clearance between movable parts (e.g., thermal gradient through bearings)
- A failure mode, effects, and criticality analysis (FMECA) defining the failure modes and the functional margins of safety against each of them
- A performance description of the control system that the mechanisms form a part of.

3.2.1.4. Dynamic model

The structural mathematical model of the component shall be detailed enough to predict the dynamic loads to size the structure elements, and the interface loads in particular, with sufficient accuracy.

This means that it shall be able to reproduce the low-frequency modes with an upper limit to the frequency range to be defined on a case-by-case basis. The model shall meet its purpose when compared to test results.

A finite-element model shall be accompanied by a clear description of the model itself and of the assumptions made in the model, particularly concerning the boundary conditions at the spacecraft interfaces. For mechanisms, two or more models (stowed, deployed, general position) may be required.

All mathematical models shall be maintained in the current configuration.

The mathematical models to be delivered to ISAS/JAXA shall comply with the MMX Requirement Specification for Structural FEM Models (TBC-Sys/PI if required).

3.2.1.5. Dynamic analysis

This shall include at least the following:

- A description of the configuration, analyzed with reference to interface controlled drawings
- A description of the mathematical finite element model and of the assumptions or reductions introduced in the analysis
- A description of the checks performed on the model to verify its quality (e.g., rigid-body modes, residual forces)
- A list of eigenfrequencies with relevant mode type and associated modal effective masses plots and lists of eigenvectors.

Where necessary (e.g., for large exposed areas such as masks), also perform:

- Frequency analysis and response
- Acoustic response analysis.
- Estimation of dynamic envelope

3.3. Testing

3.3.1. Structural test requirements

3.3.1.1. Structural test setup

The component unit shall be tested in the Launch configuration. Test adaptors and non-flight items shall be removed before the test.

The component shall be vibrated in a hard-mounted configuration through the designated spacecraft interface points.

PIs shall provide any special test adapters required for the test.

Any adaptors shall have a high first-resonance frequency (above 2 kHz) to avoid influencing the test. Any amplification from the fixture shall not contribute more than 1% to the Grms value during the random test.

3.3.1.2. Test levels

Qualification and acceptance test levels for units for each axis are specified in the MMX-EDDTC.

3.3.2. Mechanism test requirements

3.3.2.1. Mechanisms verification

The mechanisms verification test program shall ensure that the hardware conforms to the design, construction, and performance requirements as specified in the relevant documents.

Tests shall be performed to check mechanism performance in both launch and operational configurations.

Mechanisms can be considered as structures as far as strength and stiffness tests are concerned, and their design shall be verified against the same requirements as other structural components.

As a reference, the following test sequences are applicable:

- Functional tests (before and after mechanical environmental tests and thermal vacuum exposure)
- Mechanical environment tests
- Thermal vacuum functional test

The perturbation (vibration and shock) generated by mechanism shall be checked by tests.

3.3.2.2. Mechanism lifetime tests

The lifetime of a mechanism shall be demonstrated by testing in the appropriate environment, using the sum of the predicted nominal ground-test cycles and in-orbit operation cycles.

For the test demonstration, the number of predicted cycles shall be multiplied by the following factors: (TBD-Sys/PI)

4. DOCUMENTS

4.1. Applicable documents

(1) MIL-HDBK-5

METALLIC MATERIALS AND ELEMENTS FOR AEROSPACE VEHICLE STRUCTURE

(2) MIL-HDBK-17

PLASTICS FOR FLIGHT VEHICLES

(3) JAXA-RPR-MX16301

MMX Instrument Interface Requirement Document (MMX-I-IRD)

4.2. Reference documents

(1) JAXA-RPR-MX##### [to be issued]

MMX Interface Control Document (ICD)

5. ACRONYMS

CoM	Center of mass
FM	Flight model
FOV	Field of view
ISAS	Institute of Space and Astronautical Science
JAXA	Japan Aerospace Exploration Agency
MMX	Martian Moons Exploration
MS	Margin of Safety
PI	Principal investigator
STM	Structural thermal model