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MARTIAN MOONS EXPLORATION (MMX) MISSION

INSTRUMENTS-INTERFACE REQUIREMENTS DOCUMENT

REVISION AND HISTORY PAGE

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1. INTRODUCTION

1.1. Purpose and scope of this document

This document (MMX-I-IRD) describes engineering requirements related to development of the Martian Moons Exploration (MMX) instruments.

While the MMX-I-IRD contains the technical and programmatic requirements all PIs must comply with, the MMX Instrument Interface Control Document (ICD) defines the PIs' response to the technical requirements and specifies interface information applicable between the PIs and MMX Project Team. The ICD will become the formal control document related to interfaces between each instrument and the spacecraft.

In addition to the ICD, there are other managerial and programmatic documents (the Management Plan, etc.) that complement the basic documentation tree of the interface agreement.

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

1.2. Reference documents

See Section 8.

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. MISSION DESCRIPTION

2.1. Scientific objectives

See MMX Science Requirements Document (MMX-SciRD-ALL).

2.2. System description

See MMX System Description Document (MMX-SysDD).

3. ENGINEERING REQUIREMENTS

3.1. General design requirements

3.1.1. Standards

3.1.1.1. Standard 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
- 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]

3.1.1.2. Lifetime requirements

Design lifetime requirements shall be applied (if not specified differently elsewhere in the documentation for mechanical, thermal, and electrical design) with respect to environmental influences and use conditions.

Most critical requirement among the following items shall be made applicable in addition to the requirements in the nominal case for each component:

- The shelf-life shall allow for a launch delay of two years from the nominal launch date (Ground Environmental Influence)
- The nominal instrument operational lifetime shall be two Earth years in a Mars orbit environment (Space Environmental Influence and Use Conditions). If technically and financially feasible, the instrument design shall be compatible with this goal (Space Environmental Influence and Use Conditions).

3.1.1.3. Maintainability

The component shall be designed to require a minimum of special tools and test equipment to maintain calibration, perform adjustments, and accomplish fault identification.

Non-fight items (red-tag items to be removed before flight) shall be visible after integration with the spacecraft.

Items requiring integration close to launch for safety, logistical, or life reasons shall be accessible without removing component from the spacecraft.

Items that require adjustment, servicing, or maintenance before launch shall be accessible without removing component from the spacecraft.

3.1.2. Resources

3.1.2.1. Mass and power budgets

Estimated upper limits of resources available for each instrument described in MMX Science Requirement Document (MMX-SciRD-### [each instrument]).

Wire harness: The mass of the harness out of the instrument box is not included in that of the PI-instruments. However, the mass of the harness should be separately described in units of g/m (length will be defined by the MMX system team).

Note: Harness connecting between components will be designed and fabricated by MMX system team in principle.

Thermal shield: The mass of the thermal shields should be included. The configuration of the thermal shield is connected to the design of the MMX system. Details will be defined after selection through negotiations between the PI and MMX system team.

Radiation shield: The mass of radiation shields (single-point shield, etc.) should be included. The practical mass depends on the effective shield thickness. Details will be defined after selection through negotiations between the PI and MMX system team.

3.1.2.2. Design margin requirements

Mass and power shall be estimated as target values at the beginning of the flight-model (FM) phase (phases C and D). The risks of new-technology development depending on maturity will be treated as the component-level margin.

Equipment level is defined depending on the maturity level as follows:

- > 5%: TRL 6 or higher
- > 10%: TRL 5
- > 20%: TRL 4 or lower

3.1.3. Contamination control requirements

3.1.3.1. Device contamination

In principle, use materials that satisfy the following criteria to suppress contamination of other components due to outgassing caused by exposure to high vacuum in orbit.

・TML (Total Mass Loss): ≤ 1%

・CVCM (Collected Volatile Condensable Materials): ≤ 0.1%

Present a list of any nonstandard materials, and when applying countermeasures such as baking, etc., present the contents to the system and obtain system approval.

3.1.3.2. Contamination to samples

A PI of an instrument onboard MMX is required to fully recognize that MMX is a sample return mission and should make reasonable efforts in "Contamination Control (CC)" so that the main objective of the mission is not disturbed.

The PI for the Sample Science Team is responsible for collecting all the information relevant to "Contamination Knowledge (CK)" and CC. In some cases, it is not only information but materials themselves that may be collected and preserved for a potential future contamination analysis. PI of each instrument must provide the Sample Science PI with all that is requested to put the CK procedure in a complete shape.

3.2. Mechanical design and interface requirements

See MMX Component Mechanical Design Criteria (MMX-C-MDC)

3.3. Electrical power design and interface requirements

See MMX Component Electrical Design Criteria (MMX-C-EDC).

3.4. Data handling electrical interface design

See MMX Component Electrical Design Criteria (MMX-C-EDC)

3.5. Telemetry and command interface design

See MMX Component Telemetry and Component Design Criteria (MMX-C-TCDC).

3.6. Software design and interface requirements

See Flight Software Development Standard for Space Science Project (8.1.2. (4)).

4. GROUND SEGMENT AND OPERATIONAL REQUIREMENTS

4.1. Ground segment

The MMX Ground Segment will provide all the capabilities for the monitoring and for the control of the spacecraft and payload during all mission phases, as well as for the reception, archiving and distribution of payload instrument data, The Ground Segment will consist of the Operations Ground Segment and the Science Ground Segment.

4.1.1. Operational ground segment

The Operations Ground Segment will include:

- A Ground Station and Communication Network performing telemetry, command and tracking operations within the X-band and Ka-band frequencies. The ground station used throughout all mission phases will be the JAXA deep space stations, complemented by the stations of the foreign space agencies during the critical mission phases.
- The MMX Mission Operation Center (MMOC), which will consist of:
  a. The MMX Mission Control System (MMCS) to support with both hardware and software, the data processing tasks essential for controlling the mission, as well as spacecraft performance evaluation and on-board software validation and maintenance.
  b. The MMX Data Disposition System (MDDS) to support the acquisition and interim storage of raw scientific data to be accessible together with raw non-science and auxiliary data at remote locations.
  c. The MMX Mission Planning System (MMPS) to support command request handling and the planning and scheduling of spacecraft and payload operations and generation of the Mission Timeline.
  d. The Flight Dynamics System (TBC-Sys) to support all activities related to attitude and orbit determination and prediction, preparation of slew and orbit maneuvers-including reception and validation of maneuver requests-calibration of the AOCS subsystem, ground station coverage prediction, spacecraft dynamics evaluation and other navigation activities.
  e. The system Simulator (TBC-Sys), a software simulator of the ground stations and space segment, to support procedure validation, operator training and the simulation campaign before each major event of the mission.

After separation from the launch vehicle, the MMOC located at the JAXA Sagamihara Space Operation Center (SSOC) will perform the operation and control of the spacecraft during all mission phases, under the responsibility of the MMX Project Team. On the basis of a Mission Operations Requirement (TBW) and a Mission Operations Plan (TBW), the MMX Project Team will define the requirements and responsibilities for mission operations.

The MMX Project Team will, in particular, be responsible for the following tasks relevant to science operations:

- Overall mission planning of MOR and MOP
- Supplying, in near-real-time, PIs with raw data from their instrument, and spacecraft

housekeeping and auxiliary data in an agreed-upon format

- Providing the MMX Science Operation Center (SOC) with a subset of payload data and spacecraft housekeeping and auxiliary data in an agreed-upon format
- Providing and monitoring data lines between each space agency and the Japanese center as mutually agreed-upon
- Performing anomaly (out-of-limit) checks on a set of payload parameters in near-real-time
- Notifying payload anomalies to the MMX SOC and PIs

4.1.2. Science ground segment

The MMX Science Ground Segment will consists of :

A MMX Science Operation Center (MSOC), responsible for

- Scientific mission planning and experiment command request preparation for submission to the MMOC.
- Quick Look analysis and pipeline processing of science telemetry
- Development and operation of the mission archive

PI teams responsible for

- Calibration of their instrument
- Generation of the higher-level data products and their delivery to MSOC
- The monitoring of their instrument operations

The science operation will be defined by the MMX Science Working Team (SWT; See MMX-SciMP-ALL), in coordination with the MSOC, and implemented by the MSOC in close collaboration with the PI teams and the MMOC. The MSOC will, under scientific supervision of the MMX-PI (See MMX-SciMP-ALL), be responsible for the coordination, planning and execution of science operations and for data archiving.

The MDDS will process the input telemetry stream from the MMOC into the various data levels describes below.

The telemetry stream from the MMOC will be processed into telemetry files by the MSOC (Level 0). The telemetry files will consist of time-ordered telemetry packets organized by instrument and grouped into either science or housekeeping data.

The telemetry files will be processed into scientific data units (Level 1) by MSOC based on inputs (software routine, calibration files and algorithms) provided by the PI teams. These data units will be still un-calibrated but the files will be in an established scientific format (e.g. FITS, CDF, etc.).

The data in Level 1 format will be calibrated by each PI into the calibration level needed for scientific analysis (Level 2).

The Level 3 processing performed by PI teams and science community will create higher-level data, derived data or combined data from several instruments.

4.2. Mission operations

4.2.1. Mission operation concept

The MMX planning and operations would be performed by JAXA.

Operations for both spacecraft and scientific payload will only be conducted with validated event sequences and procedures documented in the Flight Operation Plan. This will encompass all operations (i.e. special operations and contingency operations as well as routine operations during the different mission operation phases).

MMX will be basically operated by an “off-line” monitoring and control approach. The spacecraft will be operated off-line by following a pre-scheduled timeline (planned sequences of operations) stored on board, and uploaded by the SOC at regular intervals. Monitoring will also be off-line due to the non-continuous contact with the ground. All telemetry generated on-board will be stored for later retrieval by ground. In order to support the off-line operations approach required for a deep-space mission, several autonomous capabilities will be provided by the spacecraft.

Events identified by MMX Project Team and PI teams that real-time operation is necessary would be carried out by “on-line”. In these cases, the spacecraft will be operated by following real-time commands uploaded by the SOC, and monitoring will also be on-line in which all telemetry generated on-board will be downlinked directly.

4.2.2. Mission phases and PIs related support

The definition of mission phases and the PI related support is briefly summarized.

a. Launch and Early Orbit Phase

- The operations will be carried out from the Main Control Room at launch site, supported by the Flight Control Team and the MMX Project Team.
- Launch support will start TBD-Sys hours before launch and includes a final readiness test.
- After spacecraft separation from the launch vehicle, a series of configuration activities will be performed automatically by the spacecraft. The post-launch spacecraft operations will start immediately following Acquisition of Signal(AOS), when the control center takes over control of the spacecraft and completes the initial configuration activities.
- Onsite support from MMX Project and Industry teams.
- Duration; 7 days (TBC-Sys).

b. Near Earth Commissioning Phase

- Any remaining subsystem initialization/switch on
- Activation and functional checkout of the spacecraft and payload; in particular, all RF links will be tested during this phase, and all science instruments will be also commissioned.
- On-site support by MMX Project and PI teams for selected operations.

- Duration: 3 months (TBC-Sys).

c. Cruise Phase

- Monitoring and maintenance activities of the spacecraft will be performed off-line.
- Reduced science operations and calibration are performed with the all instruments offline through the nominal mission planning cycle on a best effort basis in order not to drive spacecraft resources.
- Periodic pre-programmed check-out of the remote sensing instruments are planned.
- Operation of payload calibration will be conducted by the MMX Project Team, with an on-site support of each instrument team.

d. Nominal Mission Phase

- Full science operations are performed with the entire payload complement off-line through the normal mission planning cycle.
- On-site support of all instrument teams, with operation planning and data processing, will be assumed during this phase.

e. Return Phase

- TBD-Sys

4.3. Mission products

Mission products will be made available to the SOC and to the PIs in parallel, and will include all spacecraft and instrument raw telemetry data plus auxiliary data as defined in this section.

4.3.1. Science telemetry

All telemetry packets received at the SOC will be stored as raw data and made available to all mission users. Upon retrieval of raw data by external users, additional information such as quality data and packet timing will be provided to enable the users to time correlate the data with UTC.

Decompression of data compressed by the instrument itself is not supported by the SOC. These packets will be delivered as received by the on-board data handling system. The SOC will not perform any processing of science telemetry packets beyond archiving, neither for calibration nor for instrument monitoring purposes. For this reason, it is essential that any information required at the SOC for health and safety monitoring is included in the instrument non-science telemetry.

4.3.2. Other telemetry

Non-science telemetry packets will be further processed by the SOC in near real time for spacecraft control and monitoring purposes. In particular, telemetry parameters will be extracted from packets. It will be possible to calibrate, display and check them against predefined limits. A subset of telemetry packets will be systematically processed for command verification, performance assessment, trouble shooting and on-board software maintenance as required.

4.3.3. Auxiliary telemetry

Auxiliary data are non-telemetry data required to support mission planning and science data analysis. They will be stored and made available to external users in the same way as telemetry data, and will be correlated with UTC. It is foreseen to typically include:

- Spacecraft ephemeris with respect to Sun, Earth and Planets
- Spacecraft attitude prediction/reconstitution.
- Event files
- Command history data.
- The correlation history (Spacecraft time/UTC).
- Mission planning information.

Auxiliary data will be provided in a format and within coordinate systems jointly defined between MMX Project Team and the PIs through the relevant SWT.

4.4. Validation tests of ground segment

4.4.1. General

The ground system test and validation activities will begin around 2 years (TBC) before launch. Activities will be mostly performed as part of the ground segment-spacecraft interface tests and system operation validation programme, and will include tests involving the payload as described in the following sections.

4.4.2. System validation tests

Main objective of the system validation tests is:

- the verification of end-to-end communication links between spacecraft and SOC,
- the verification of database needed in support of spacecraft operations,
- the development and verification of Flight Procedures and Contingency Procedures for all spacecraft subsystems and instruments.

The system validation tests of ground segment are performed with the actual spacecraft linked to the SOC via a communication network for telemetry, command and voice connections.

The PIs team shall make available the necessary resources to support the spacecraft interface tests outlined below through preparation of related inputs, review of test plans and procedures, and if required, through actual participation in the tests.

The MMX Project Team will provide on-line access to the flight model for closed loop telemetry/command testing with the ground segment and the flight control software.

The system validation test will comprise:

- spacecraft commanding from the SOC
- telemetry flow between spacecraft and SOC. Real time non-science telemetry data processing in the SOC in parallel to the simulated science telemetry processing.

4.4.3. Pre-launch operations

Pre-launch operations support will start approximately 6 months (TBC-Sys) before the launch. During this period the SOC will perform its final simulation programme including the validation of the flight operation plan and the mission control system. PIs team specialist participation will be required for the simulations related to the first instrument switch-on and other critical operations.

5. VERIFICATION REQUIREMENTS

5.1. General

5.1.1. Introduction

The objective of the instrument verification program is to demonstrate to MMX Project Team that the instrument design is fully compliant with the following:

- Scientific goals of the instrument
- Mission environment
- Spacecraft performance
- Spacecraft interface requirements
- Operational requirements
- Provided operational documentation

This makes the instrument capable of contributing to the overall scientific goals.

This section summarizes the verification requirements for qualification and flight certification of the instrument units, giving specific test levels and durations and describing acceptance test and analytical methods for implementing the requirements.

5.1.2. Responsibilities

PIs shall, in a systematic manner, verify the instrument design and build against each requirement specified in the MMX-I-IRD. (Qualification)

PIs shall, in a systematic manner, verify the FM instrument certification for flight against each requirement specified in the MMX-I-IRD. (Acceptance)

PIs shall include a Design Development and Verification Plan (DDV-Plan) for tests and analyses that collectively demonstrate that the hardware and software comply with the requirements.

Note: Verification shall follow the classical methods approach for the review of design by testing, analysis, or similarity with an already verified design.

5.1.3. Documentation

5.1.3.1. Design development and verification plan

PIs shall prepare a Design Development and Verification Plan (DDV-Plan) as described in 5.1.3.1. The DVV-plan shall be provided to MMX Project Team at the I-PRR (and updated as changes occur).

Note: The DDV-Plan shall highlight the overall approach that will be undertaken by the instrument consortium to accomplish instrument qualification and acceptance. When appropriate, the interaction of tests and analyses shall be described.

The DDV-Plan shall be complemented by analysis reports, test procedures, and, upon test completion, by test reports.

5.1.3.2. Verification control matrix

PIs shall provide a verification matrix that summarizes all the tests that will be performed on each instrument unit at the instrument system level.

The purpose of the matrix is to provide, in a synthetic manner, a reference to the test program in order to prevent the deletion of a portion of the test program without an alternative for accomplishing the verification objectives.

It further ensures that all flight hardware has seen environmental exposures that are sufficient to demonstrate acceptable workmanship.

The matrix shall provide traceability of the qualification heritage of the instrument unit's hardware and software.

The matrix shall provide traceability of the verification of the design and test requirements contained in the MMX-I-IRD.

All flight hardware and prototypes (EM) shall be included.

The matrix shall be included as an annex to the DDV-Plan and provided to MMX Project Team at the I-PRR (and updated as changes occur). The necessity of other hardware (breadboard models, spare flight parts, etc.) shall be discussed in the DDV-Plan on a case-by-case basis.

5.1.3.3. Analysis reports

For each analysis verification activity, PIs shall submit a formal report describing the mathematical model and the relevant outputs and interpretations.

5.1.3.4. Test-related documentation

Test specification:

For each test defined in the DDV-Plan (vibration, electrical, thermal, etc.), PI shall provide a test specification, which shall be established describing the relevant configuration, test setup, facility, test goals, success criteria, etc.

Test procedures:

For each test defined in the DDV-Plan (vibration, electrical, thermal, etc.), PIs shall provide a detailed step-by-step procedure.

Test report:

For each test defined in the DDV-Plan (vibration, electrical, thermal, etc.), PIs shall provide a test report containing the objectives, results summary, and the as-run procedure.

The test-related documentation will be subject to review during the project lifetime by MMX Project Team.

5.2. Verification concept

The instrument units belong in general to the category of newly designed component with performances to be fully demonstrated by qualification and acceptance programs. These programs will be reviewed by MMX Project Team for compatibility with the overall system verification concept.

The verification methods shall be based on the following:

Assessments: (see Section 5.3.)

Analysis (structural, thermal)

when verification is achieved by performing theoretical or empirical evaluation by accepted techniques.

Tests: (see Section 5.4.)

Functional tests (FFT, AFT) or environmental tests (vibration, TB/TV, EMC)

when requirements must be verified by measuring product performance and function under various simulated environments.

Inspection (see Section 5.5.):

when verification is achieved by visual determination of physical characteristics (such as construction features, hardware conformance to document drawings, or workmanship requirements).

Review-of-design (similarity assessment):

when verification is achieved by validation of records or by evidence of validated design documents, or when approved design reports, technical descriptions, or engineering drawings unambiguously show that the requirement is met.

5.3. Analysis

5.3.1. Structural mathematical analysis

See MMX Component Mechanical Design Criteria (MMX-C-MDC).

5.3.2. Thermal analysis

See MMX Component Thermal Design Criteria (MMX-C-TDC).

5.4. Testing

5.4.1. Test sequences

The verification activities can be divided into the following:

- Qualification program
- Acceptance program
- Recertification
- Receipt inspection

No specific environmental test sequence is required, but the test program should be arranged in a way to best disclose problems and failures associated with the characteristics of the hardware and the mission objectives.

It is strongly recommended that the vibro-acoustic test precede the thermal vacuum test, unless there is an overriding reason to reverse that sequence.

<u>Qualification program:</u>

The qualification program shall demonstrate that the item will function within performance specifications under simulated conditions more severe than those expected from ground handling, launch, and orbital operations.

Limited lifetime demonstration of elements concerned shall be incorporated in the qualification test program or performed separately.

<u>Acceptance Program:</u>

Acceptance shall demonstrate that the hardware is acceptable for flight and shall serve as a quality control screen to detect deficiencies.

<u>Receipt inspections:</u>

Receipt inspection at the MMX Project Team site shall verify that the instrument is ready for integration into the spacecraft.

As a guideline, the following sequence of tests will be performed:

1. Visual inspection
2. Dimensions verification
3. Physical properties
4. Grounding / Bonding / Isolation

Deliverable documents (see 7.4.2.) will be reviewed.

Depending on the type of instrument, some tests may be waived.

5.4.2. Functional test requirements

5.4.2.1. Full functional test

The full performance test (FPT) shall be a detailed demonstration that the hardware and software meet their performance requirements within allowed tolerances.

The test shall demonstrate operations of all redundant circuitry. It shall also demonstrate satisfactory performance in all operational modes.

The initial FPT shall serve as a baseline against which the results of all later FPTs can be readily compared.

The test shall also demonstrate that, when provided with appropriate stimuli, performance is satisfactory and outputs are within allowed limits.

5.4.2.2. Abbreviated functional tests (APT [or LPT])

Abbreviated performance tests (APT) shall be a subset of the FFT.

Note: The abbreviated performance test is also called the Limited Performance of Functional Test (LPT).

The LPT shall be performed before, during, and after environmental tests, as appropriate, in order to demonstrate that functional capability has not been degraded by the environmental tests.

The limited tests may also be used in cases where comprehensive performance testing is unwarranted or impracticable. Specific items on which it is intended that the LPT will be performed shall be listed in the DDV-Plan.

The LPT shall demonstrate that the performance of selected hardware and software functions is within allowed limits.

5.4.3. Structural test requirements

See MMX Component Mechanical Design Criteria (MMX-C-MDC).

5.4.4. Mechanism test requirements

See MMX Component Mechanical Design Criteria (MMX-C-MDC).

5.4.5. Thermal tests requirements

See MMX Component Thermal Design Criteria (MMX-C-TDC).

5.5. Inspections requirements

5.5.1. Visual inspection

Visual Inspections shall be performed at the beginning and end of acceptance and qualification testing. The inspection shall include the following as a minimum:

- Completeness of hardware
- Identification of hardware
- Connectors
- Grounding Points
- Attachment Surfaces
- Thermal Surfaces
- Inspection of transport conditions
- Inspection for damage
- Inspection of interfaces
- Completeness of documentation

5.5.2. Physical properties

The measurement of physical properties shall include the following:

- Mass
- Center of mass
- Moments of inertia

5.5.3. Dimension verification

The following dimensions shall be verified, as a minimum:

- Interface dimensions
- Envelope dimensions

5.6. Calibration

PIs shall provide a calibration plan adapted to the scientific requirements and the overall development plan of the instrument and of the spacecraft.

The instrument shall be delivered fully calibrated.

Calibration activities at the system level (e.g. use of a radiation source) shall only be considered when scientifically justified, such as when the flight configuration is reached only after integration on the spacecraft. This type of activity is subject to approval by MMX Project Team. The calibration plan shall be part of the DDV plan.

5.7. Final acceptance

5.7.1. General requirements

The acceptance process will demonstrate that the instrument has been fully verified in terms of:

- Scientific performance (including calibration and characterization)
- Behavior under environmental conditions
- All functional interfaces

The acceptance of the instrument will follow the sequence below:

- Completion of acceptance tests, including calibration and characterization of the instrument
- Supplier premises, to verify that the Instrument and its ground-support equipment meets all interface specifications
- Acceptance review of the test results and of the completeness of the acceptance data package at the instrument manager's premises and release of consent to ship if the acceptability is stated by the review board
- Delivery to the spacecraft assembly integration and test (AIT) site of the instrument, together with any ground-support equipment (including test software and documentation) and the acceptance data package
- Performance (by the instrument supplier) of a post-shipment inspection and a receipt test at the AIT site
- After successful completion of verifications by the instrument team and formal receipt inspection by system-level quality assurance, the instrument will be released for integration onto the spacecraft
- Notwithstanding the mandatory instrument-level tests, the instrument software will only be accepted after successful spacecraft level tests.

5.7.2. Acceptance review

The acceptance review will check and ascertain the following topics:

- Visual inspection and completeness of the hardware to be delivered
- Compliance of the interfaces measurements (spacecraft interfaces)
- Availability of a complete set of functional performance data
  (using both the LPT and FPT procedures)
- Availability of calibration and characterization data
- Ground-support equipment relevant to characteristics and documentation
- Completeness of the Acceptance Data Package

5.8. System-level AIT

5.8.1. Model philosophy

5.8.1.1. Spacecraft model and test philosophy

The spacecraft model philosophy applied to the MMX is the classical 2-model approach:

- STM: Structural thermal model
- FM: Flight model

The different models will undergo their dedicated qualification and acceptance test program according to the agreed system-level requirements.

The instrument model will be integrated on the spacecraft and tested as an integral part of the spacecraft system.

The FM test of the spacecraft system level consists of “Electrical/Mechanical Interface Check (EMIC)“ and “System Integration Test (SIT)”.

Table 5.8.1.1-1 Summary of STM, and FM Tests (TBC-Sys/PI)

	Spacecraft System		
	STM	EM	FM
Electrical			
Electrical Performance		F	F
Software Validation		F	F
EMC/ESD		Q	A
Mechanical		N.A. for MMX system	
Static Load Test			
Sine Vibration Test	Q		P
Acoustic Test	Q		P
Shock Test	Q		A
Mechanisms/Deployment Test	Q		A
Modal Survey	C		
Structural Integrity			
Leakage	Q		A
Mass Properties and Balance	C		C
Alignment	C		C
Thermal			
Thermal Balance	Q		
Thermal Vacuum			P

Legend:
Q: Qualification A: Acceptance
P: Protoflight F: Functional
C: Characterisation Test

(1) The STM system test objectives are as follows:

- Qualification of the primary structure by testing
- Verification of mechanism functions in the system environment
- Verification of mechanical environmental conditions for components
- Verification of structural mathematical model
- Qualification of thermal design by testing
- Verification of thermal mathematical model
- If needed, PIs shall clarify any other objectives (e.g. verification of alignment, visual fields, etc.)

From this, the instrument STM-built standards described in the following section are derived.

(2) Electrical/Mechanical Interface Check (EMIC)

- Verification of system and instrument electrical and mechanical interface
- Verification of system function (and performance, if needed)
- Verification of instrument function (and performance, if needed) within the system configuration
- Verification of operational procedures

From this, the instrument FM standards described in the following section are derived for EMIC.

(3) System Integration Test (SIT)

- Completion of the qualification program
- Acceptance of the spacecraft system by functional and environmental tests

From this, the instrument FM standards described in the following section are derived for SIT.

5.8.1.2. Derived deliverable instrument models

(1) The instrument STM units

- Structure flight standard
- Mechanisms flight standard
- Pyrotechnics flight standard (including electrical interfaces)
- Thermal control hardware and properties flight standard
- Mass properties, , stiffness, mounting, shape, thermal expansion

(2) The instrument FM units for EMIC

- Electrical (including telemetry and command) control hardware and software as flight standard
- Mounting interface and shape flight standard

(3) The instrument FM units for SIT

- Full flight standards verified by formal functional and environmental acceptance tests

5.8.1.3. Spare philosophy

Generally, not required. Required on a case-by-case basis.

5.8.2. System integration and test flow

TBD-Sys

6. PRODUCT ASSURANCE REQUIREMENTS

6.1. Reliability assurance

As a rule, reliability programs will be established following the JAXA standards below. If a different but equivalent standard is followed, JAXA should be notified of the standard (document number).

- Reliability Program Standard (JMR-004C)

6.2. Quality assurance

As a rule, quality assurance programs will be established following the JAXA standards below. If a different but equivalent standard is followed, JAXA should be notified of the standard (document number).

- Quality Assurance Program Standard (JMR-005A)

6.3. Configuration management

As a rule, configuration management will be established following the JAXA standards below. If a different but equivalent standard is followed, JAXA should be notified of the standard (document number).

- Configuration Management Standard (JMR-006A)

6.4. Software product assurance

As a rule, onboard software development will be established following the JAXA standards below. If a different but equivalent standard is followed, JAXA should be notified of the standard (document number).

- Software Development Standard for Spacecraft (JERG-2-610A)

6.5. Safety assurance

Safety standards shall be based on the following JAXA rocket payload safety standards.

Launch Vehicle Payload Safety Standard (JMR-002B)

6.6. Planetary protection control

Based on the categories for solar system bodies and types of missions defined in COSPAR Planetary Protection Policy, it is supposed that category 3 for outbound and 5 (unrestricted) for inbound are applied for the MMX mission.

7. MANAGEMENT REQUIREMENTS

7.1. Organization, responsibilities, and management

See MMX Science Management Plan (MMX-SciMP-ALL).

7.2. Project phasing and related reviews

See MMX Science Management Plan (MMX-SciMP-ALL).

7.3. Progress monitoring

7.3.1. General

The technical and programmatic aspects of the instrument program will be assessed between the PIs and the MMX Project Team.

The overall scientific performance will be monitored by the MMX Project Team during the review cycle and through regular progress reporting supplied by the PIs. Detailed scientific aspects will be reviewed within the context of the SWT, as defined in the MMX Science Management Plan (MMX-SciMP-ALL).

7.3.2. Reporting

The PIs shall submit at regular instrument progress meetings (7.3.3.) a progress report in which the current status of each activity is described and problem areas or potential problem areas are highlighted together with identification of proposed remedial actions.

The report shall include the following topics:

- Overall summary, covering scientific and technical performance, status of design changes, and overall progress status
- Design development and verification status, covering status of design definition and verification of interfaces, tests and calibration, GSE, and operations
- Product assurance (PA) status
- Programmatic status, including schedule and milestone reports
- Science performance status
- Problem areas and corrective actions

The progress reports submitted will be analyzed in conjunction with the overall spacecraft program by the MMX Project Team. In the case of major conflicts, the MMX Project Team may call for special schedule meetings to resolve the issue.

7.3.3. Instrument progress meetings

Regular instrument progress meetings shall be held during the design, development, and verification program of the spacecraft and instrument. These meetings will be conducted between the PIs and the MMX Project Team with the objective of ensuring the interface technical design integrity of the instrument and its compatibility with the spacecraft.

At a minimum, the PI Instrument Team shall be represented by PIs, co-PIs, key scientists, and engineers.

These meetings shall be held on a regular basis. The frequency may be changed on request of the MMX Project Team or PIs.

Detailed technical problems related to interfaces shall be flagged during these meetings and corrective actions, including their schedule impact, shall be agreed upon and implemented.

System design meetings will also be held during the design, development, and verification phase for the purpose of sharing entire MMX program status, common issues and so on. These meetings will be held regularly (about four times each year) hosted by MMX Project Team. PIs and, if needed, other appropriate members shall attend these meetings.

7.3.4. Reviews

7.3.4.1. Objectives

The objective of the Instrument Program Reviews is to verify compliance of the overall program to JAXA's requirements. Instrument Program Reviews shall cover activities at the spacecraft, operations ground segment, and science ground segment levels.

Instrument reviews will be conducted by the PI Instrument Team and as required by the Instrument Team's funding agency. The objectives will be to ensure that the instrument design will achieve the anticipated science objectives and that it complies with the technical interface requirements of the MMX-I-IRD. Programmatic aspects like scheduled delivery dates and their compatibility with system-level requirements will also be screened.

When possible, the instrument reviews should anticipate the MMX system-level reviews, where the results of the instrument review is taken into consideration as formal input and where possible inconsistencies will be brought to a final solution.

The Instrument Review Board composition will be made up of the PI Instrument Team, MMX Project Team and invited specialists. It will be chaired by the Instrument PI or an appointed representative.

Documentation to be reviewed will consist of review data packages, and provided to the review authority in due time and in accordance to dedicated review procedures to be issued for the occasion.

The output of the review may provide recommendations for consideration by the MMX Project Manager in technical or programmatic areas.

7.3.4.2. Review sequence

The review sequence will insure a consistent approach and relationship between the instrument reviews and the spacecraft reviews, which are considered higher-level reviews. The following sections will define detailed objectives and their precise relationship.

7.3.4.3. Instrument Preliminary Requirements Review (I-PRR)

The I-PRR shall be conducted with the following purposes:

- To finalize the instrument conceptual system design
- To verify that it fulfills the science objectives
- To finalize the MMX system requirements (MMX-I-IRD)
- To approve the first issue of the ICD

7.3.4.4. Instrument Preliminary Design Review (I-PDR)

The I-PDR shall be conducted during the final stages of the design phase in preparation for the spacecraft-level MMX Preliminary Design Review (MMX-PDR). The Objective of the review is to verify by analysis that preliminary design fulfill the instrument requirements.

7.3.4.5. Instrument Critical Design Review (I-CDR)

The I-CDR shall be conducted after the completion of the spacecraft system-level STM, in preparation for spacecraft-level MMX Critical Design Review (MMX-CDR). The objective of the review is to verify that critical design fulfill the instrument requirements.

- To assess the results of the spacecraft-level STM with respect to the instrument
- To assess of the results of qualification at the instrument unit and subsystem levels
- To accept the instrument FM hardware and software design (including changes required after EM testing, if applicable) and its Instrument Users' Manual and to update the MMX-I-IRD and ICD as required

7.3.4.6. Instrument Qualification Review (I-QR)

The I-QR shall be conducted after the completion of the instrument qualification in preparation to the FM Delivery Review. The objective of the review is to verify that qualification results fulfill the instrument requirements.

- To assess the results of the instrument qualification program
- To accept the instrument FM hardware and software prior to the delivery to JAXA for final integration on the spacecraft

7.3.4.7. Instrument Flight Acceptance Review (I-FAR)

The I-FAR shall be conducted after completion of the spacecraft system-level FM electrical verification, including on-line compatibility tests, and shall precede the spacecraft-level MMX Flight Acceptance Review (MMX-FAR). The objectives of the review are as follows:

- To assess the results of the MMX system-level FM testing with respect to the instrument

- To assess the completion of qualification of instrument units and subsystems
- To update the MMX-I-IRD, ICD, and Instrument Users' Manual, as required
- To close out any outstanding issues

7.4. Deliverable items

7.4.1. Instrument deliverables

7.4.1.1. Interface documentation

PIs shall deliver and maintain all relevant interface documentation throughout the project lifetime.

7.4.1.2. Mathematical models

PIs shall deliver a Structural Mathematical Model (SMM) of the instrument.

PIs shall deliver a Thermal Mathematical Model (TMM) of the instrument.

These instrument mathematical models shall be prepared in the preliminary design phase based on instructions for structural and thermal mathematical model (TBD-Doc) and updated as the design progresses. They will serve as input to the spacecraft mathematical models.

7.4.1.3. Hardware models

PIs shall deliver the following hardware models:

- Structural and Thermal Model (STM),
- Flight Model (FM),

Each delivery shall include, as appropriate, instrument hardware, onboard software, and ground support equipment.

Each item delivered shall be accompanied by Instrument Users' Manual and End Item Data Package.

Prior to delivery, each item shall undergo formal acceptance following a mutually agreed-upon acceptance program. This acceptance shall include at a minimum the formal verification of all interfaces between the spacecraft together with review of all applicable test reports and supporting analyses and documentation.

Transportation of the instrument from each institution to JAXA for assembly, integration, and verification (AIV) at the spacecraft level is the responsibility of each instrument institution. This responsibility shall extend to returns of STM after the STM system test, of FM after the EMIC and of any models for repair.

The transportation of equipment (MGSE, EGSE, etc.) related to the instrument from the launch site to each institution after launch is the responsibility of each instrument institution.

The points of delivery will be March in 2020 (STM), April in 2022 (FM units for EMIC), April in 2023 (FM units for SIT). (TBC-Plan and TBC-Sys/PI)

The points of end of the EMIC and the return of instrument FM to each PI instrument team will be October in 2022. (TBC-Plan and TBC-Sys/PI)

The FM shall be fully calibrated before delivery.

7.4.1.4. Onboard software

The instrument onboard software shall be delivered together with the corresponding instrument model.

The onboard software shall either reside in the MMX system in non-volatile memory or be delivered in a format such that it can be loaded through the spacecraft telecommand uplink.

In addition to the flight software, special test software for diagnostics and failure investigation may be required.

PIs remain responsible for maintenance of the instrument software after delivery until the end of the mission.

PIs shall support the verification of updated instrument software.

7.4.1.5. Ground support equipment

Together with each instrument model, PIs shall deliver the Mechanical Ground Support Equipment (MGSE) necessary to transport, handle, and integrate the instrument hardware, accompanied with appropriate documentation.

Together with each instrument model, PIs shall deliver the Electrical Ground Support Equipment (EGSE) necessary to stimulate the instrument and to perform quick-look analysis of the instrument during system tests.

It shall be designed such that it can be integrated into the spacecraft EGSE set-up.

The instrument software shall be designed such that it can be reused in the Operational and Science Ground Segment to the maximum extent.

The instrument ground support equipment shall remain at the spacecraft integration site until launch.

PIs shall remain responsible for the maintenance of this equipment.

PIs shall also provide the necessary manpower and expertise support to integrate the instrument EGSE into the system EGSE.

7.4.2. Review deliverables

PIs shall deliver Review Data Packages for each scheduled Instrument Review.

The Instrument Review Data Package shall include information regarding the following:

- Configuration
- Scientific performance
- Design and verification
- Operations
- Product assurance

A contents list shall be provided by the MMX Project Team prior to the review.

7.5. Statement of compliance

A statement of compliance with the program requirements as defined above and with the scientific data policy as defined in the MMX Science Management Plan (MMX-SciMP-ALL) shall be submitted by PIs.

8. DOCUMENTS

8.1. Applicable documents

8.1.1. Project documents

(1) JAXA-RPR-MX16321
MMX Science Management Plan for all instruments (MMX-SciMP-ALL)

(2) JAXA-RPR-MX16307
MMX Environmental Design Data & Test Conditions (MMX-EDDTC)

(3) JAXA-RPR-MX16303
MMX Component Mechanical Design Criteria (MMX-C-MDC)

(4) JAXA-RPR-MX16304
MMX Component Thermal Design Criteria (MMX-C-TDC)

(5) JAXA-RPR-MX16305
MMX Component Electrical Design Criteria (MMX-C-EDC)

(6) JAXA-RPR-MX16306
MMX Component Telemetry and Command Design Criteria (MMX-C-TCDC)

8.1.2. JAXA standard documents

(1) JMR-004C
Reliability Program Standard

(2) JMR-005A
Quality Assurance Program Standard

(3) JMR-006
Configuration Management Standard

(4) JERG-2-610A
Software Development Standard for Spacecraft

(5) JMR-002B
Launch Vehicle Payload Safety Standard

8.2. Reference documents

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

MMX Interface Control Document (ICD)

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

MMX Instructions for instrument structural mathematical model

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

MMX Instructions for instrument thermal mathematical model

9. ACRONYMS

AFT	Abbreviated functional test
AIV	Assembly, Integrate integration, and verification
AOCS	Attitude and Orbit Control System
APT	Abbreviated performance test
CC	Contamination Control
CK	Contamination Knowledge
CVCM	Collected Volatile Condensable Materials
DDV-Plan	Design Development and Verification Plan
EMIC	Electrical/Mechanical Interface Check
FFT	Full functional test
FM	Flight model
FPT	Full performance test
FS	Flight spare
ISAS	Institute of Space and Astronautical Science
JAXA	Japan Aerospace Exploration Agency
MDDS	MMX Data Disposition System
MMCS	MMX Mission Control System
MMOC	MMX Mission Operation Center
MMPS	MMX Mission Planning System
MMX	Martian Moons Exploration
MOP	MMX Mission Operations Plan
MOR	MMX Mission Operations Requirement

MSOC	MMX Science Operation Center
NGRS	Neutron and Gamma-ray Spectrometer
PI	Principal investigator
SIT	System Integration Test
SMM	Structural mathematical model
SSOC	Sagamihara Space Operation Center
STM	Structural and thermal model
SWT	Science Working Team
TML	Total Mass Loss
TMM	Thermal mathematical model