James Webb Space Telescope (JWST)

Mid-Infrared Instrument (MIRI)

MISSION ASSURANCE PLAN (MAP)

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Item No.	Section	Summary	Individual/ Organization	Due Date:
1	App. 6-B	MIRI Test Analysis Matrix	513	10/04
2	App 6-D	Environmental Requirements Table for Dynamics	513	10/04
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1.0 MIRI PROJECT INTRODUCTION

1.1 General Description of the Project Organization

Management of the Mid Infrared Instrument (MIRI) Project has been assigned to the Jet Propulsion Laboratory (JPL). The MIRI will be carried aloft on the James Webb Space Telescope (JWST) Spacecraft. The Goddard Space Flight Center (GSFC) has the Management responsibility for the JWST Program and as such JPL will provide the MIRI to the GSFC Program Office and be responsive to JWST Program policies.

The JWST will be deployed to the L_2 point where there is a balance between the earth and sun gravitational fields. The JWST will remain at the L_2 from where the mission observations will be conducted. The JWST mission duration requirement is 5 years, with a goal of 10 years.

As the responsible center, JPL will be responsible for the development of the MIRI payload subsystem that will consist of 6 MIRI assemblies. 4 of the 6 assemblies will be developed at JPL or by contractors working under the direction of JPL. A European Consortium (EC) will develop the remaining 2 assemblies. JPL will develop the Focal Plane Array Assembly which consists of 3 nearly identical silicon detector chips that are each housed in an aluminum housing. A JPL contractor will develop the chips. Supporting the 3 detector arrays will be the Focal Plane Electronics Assembly, that will be an in house JPL development. MIRI command and data handling (C & DH) software will be developed by JPL. The C & DH software will reside in GSFC provided hardware. A JPL contractor will develop the solid hydrogen filled dewar that will maintain the 3 aforementioned detectors at an operational temperature of approximately 7 °K. The dewar will not be filled with hydrogen while at JPL. The EC will develop an optical module that will process/route infrared energy to the detectors. An EC electronics subsystem will interface with the JWST Spacecraft and support the EC optical module. MIRI integration, instrument level environmental qualification testing and analyses will be performed by the EC. The dewar will not be included in the aforementioned EC activities. The current JPL development plans extend from inception through launch operations.

1.2 Responsibilities

All MIRI development activities performed at JPL, by JPL contractors, JPL subcontractors, or suppliers shall be performed in accordance with all applicable requirements contained within this plan and are subject to independent verification. JPL Mission Assurance will review the EC Mission Assurance Plan and provide comments to the EC. The EC shall provide flight hardware materials and processes lists as required for interface management with their supplied hardware. All EC generated MIRI problem/failure reports (EC hardware, software, and activities as well as JPL provided items) shall be provided to JPL by the EC. Following MIRI delivery to the JWST Program Office, all MIRI related problem/failure reports will be provided to JPL for problem resolution or information. EC activities are not subject to independent JPL verification. There will, however, be insight into the EC's Mission Assurance practices throughout all phases of the MIRI project in accordance with the above and as directed by the MIRI Project Manager.

1.3 Description of the Mission Assurance and System Safety System

Implementation of the Mission Assurance and Systems Safety activities are delegated to the JPL Mission Assurance Manager (MAM). The MAM functions as a member of the project staff. The MAM has responsibility to ensure that all flight hardware and software provided by JPL, its contractors and subcontractors are developed in response to this Mission Assurance Plan (MAP). Specifically the MAM will:

a) Issue a Mission Assurance Plan (MAP) that is consistent with MIRI Project performance requirements, cost constraints, schedule considerations, and risk tolerance and JPL Institutional Practices and Policies.

b) Support the development and implementation of a project Risk Management Plan.

c) Coordinate and manage the functional support related to parts engineering and quality, hardware inspection, reliability, software assurance, systems safety, and environmental compatibility.

d) Serve as the primary interface between the MIRI Project, Program, EC, and spacecraft systems integrator for matters pertaining to systems safety, reliability, electronic parts and quality assurance.

e) Assist the Project Manager in the evaluation of project risk throughout the life cycle.

f) Provide concurrent engineering contributions to other supporting agencies (including contractors and subcontractors) mission assurance programs as appropriate.

g) Team with the MIRI assigned Systems Safety Engineer, to ensure that all Systems Safety topics are addressed and documented.

h) Be responsible for the overall OSMS management that includes budget, schedules and independent risk assessment.

i) Be a member of the MIRI project management team and independently advise project management on all aspects of project safety and mission assurance.

2.0 INTRODUCTION TO MISSION ASSURANCE PLAN

The MAP has been developed in support of the MIRI Project. The MAP is designed to assure consistency between all Mission assurance elements and the flight system to limit or eliminate areas of risk. The following characteristics have been given consideration in the development of the Mission Assurance processes for the MIRI Project.

a) Efficient design techniques that ensure sufficient performance margins through use of appropriate derating guidelines, and use of hardware redundancy to provide reliable operation for all critical functions.
b) Adequate testing of new hardware and integrated systems.
c) When appropriate, acceptance of contractors/suppliers existing Mission Assurance policies, practices and procedures.

2.1 Exceptions and Deviations

Exceptions or deviations to this MAP shall be brought to the Project for approval and documented in the form of a waiver.

2.2 Heritage Hardware and Software

The MIRI flight hardware complement may include inherited hardware and/or software that has been designed for other projects. Where appropriate, the MIRI Project will conduct inheritance reviews that will evaluate existing designs, physical characteristics, and functional capabilities. As part of this evaluation process, the MAM will work with individual developers to determine the degree to which the design heritage and pedigree satisfy MIRI requirements.

2.3 Mission Assurance Status Reporting

The MAM will prepare a Monthly Report that will include significant activities, findings and progress. The MAM will attend and be prepared to report at all major reviews the current status of the project's Mission Assurance effort. Included in the monthly report will be a current risk assessment, updates to the risk matrix, open PFRs, IRs, and other matrices that provide value to the project.

2.4 Applicable Documents

Applicable documents listed in Appendix B form a part of this document, to the extent referenced herein. If there is a conflict between a requirement in a referenced document and this MAP, the requirement in this MAP shall prevail.

3.0 GENERAL PROCUREMENT REQUIREMENTS

All purchased hardware/software items and services must meet contractual requirements by preparing source control drawings, specifications, statements of work and/or a procurement requisition for each procurement, as appropriate, in accordance with applicable JPL procurement requirements and the approved vendor clause.

3.1 Selection of Sources

The Mission Assurance Organization will assist in (1) pre-award surveys of potential suppliers, contractors, and subcontractors and (2) evaluate the subject of mission assurance in MIRI requests for proposals (RFPs) as requested. Once the supplier or subcontractor is selected and under contract, the Mission Assurance Organization may participate in contractor reviews and perform in process and final inspections.

3.2 Requirements of Subcontractors and Suppliers

Applicable mission assurance requirements will be contractually levied on MIRI contractors, subcontractors, and suppliers. Use of appropriate existing mission and quality assurance procedures by contractors, subcontractors, and suppliers is encouraged. JPL Mission Assurance Personnel will review and approve existing procedures to ensure that the applicable requirements contained within this MAP will be addressed.

3.3 Audits

During the course of hardware development, the MAM may elect to conduct audits of mission assurance program procedures, processes, records and analyses being followed at contractors, subcontractors and suppliers. The purpose of these audits will be to determine the effectiveness and suitability of the practices in use. The need for these audits will depend upon:

a) The criticality of the flight hardware or flight software involved.
b) The performance history of any suppliers involved.
c) Whether or not there are known problems or alerts related to work in progress.

The results of all mission assurance audits will be summarized and will be part of MIRI Mission Assurance reports.

4.0 MISSION ASSURANCE IMPLEMENTATION

4.1 Specifications and Requirements

The following MAP sections address programmatic and technical matters such as verification, hardware design reliability analysis, environmental analysis and tests, problem failure reporting, electronic parts reliability, materials and processes engineering, hardware quality assurance, software product assurance, systems safety and contamination control.

4.2 Responsibilities

Reliability, Quality Assurance, and System Safety activities are within the purview of the organizations producing the product. Personnel from the areas of Environmental Requirements, Reliability, Quality Assurance, EEE Parts, Materials and Processes Engineering, System Safety Engineering and Contamination Control, will implement respective responsibilities in a concurrent engineering mode with the design team developing the hardware design.

5.0 RELIABILITY ASSURANCE PROGRAM

5.1 Reliability Analyses Introduction

A set of reliability analyses shall be performed for critical hardware. Critical hardware includes all electrical/mechanical elements of the hardware for which failure to perform the desired function would result in a significant or catastrophic MIRI failure. New analyses should not be generated for heritage designs, if prior analyses have a similar environmental, interface relationships, and lifetime requirements. Heritage analyses will be reviewed to insure applicability and consistency with as-built hardware. As required, these analyses shal1 be updated to as-built items or originated on new designs.

Reliability analyses may be performed by the hardware design team and reviewed by the Product and Circuit Reliability Group. Alternately, with design team support, the Product and Circuit Reliability Group may perform the analyses.

Prior to initiating reliability analyses documents such as schematics, circuit descriptions and requirements, and the electronics parts list must be provided to the analyst. During periods of Product and Circuit Reliability Group involvement there will be frequent communications between the analyst and design team personnel.

It is recommended that reliability analyses be performed per the guidelines of JPL D-5703, "Reliability Analyses for Flight Hardware in Design, or JPL approved contractor equivalent."

5.2 Reliability Design Requirements

The following subsections define the individual analysis requirements. Mission and environmental factors (such as age, temperatures, radiation, etc.) used in the following analyses are based upon values defined in Goddard Space Flight Center (GSFC) provided MIRI Interface Requirements Document (IRD).

The following analyses are required on all applicable designs.

5.2.1 FAILURE MODES, EFFECTS, & CRITICALITY ANALYSIS (FMECA)

Interface FMECAs shall be performed at all MIRI external interfaces as well as all internal interfaces where redundancy (e.g. cross-strapping) is implemented. As a minimum, these shall:

a) Consider all operational modes.
b) Be performed at selected interfaces to the piece part level to verify that a failure in any interface circuit cannot propagate to and/or damage the interfacing circuit and or hardware in another instrument or any spacecraft system.
c) Consider all parts that could be reasonably expected to produce an anomalous condition at the interface that would not otherwise be addressed (e.g., a DC-DC converter, internal to the assembly, that does not have over-voltage protection).
d) Be performed on electrical ground support equipment (EGSE) or test equipment to assure that failures in the support equipment will not damage the flight hardware under test. See Support Equipment section.

5.2.2 STRUCTURAL STRESS ANALYSIS

A Structural Stress Analysis shall be performed on mechanical and electromechanical (e.g.-actuators) subsystems/assemblies at the board and subsystem level. The analysis shall address the effects to be experienced by the structure due to the dynamic environment (i.e., acceleration, shock, vibration and acoustic noise), including worst case estimates for design environmental conditions.

5.2.3 SINGLE POINT FAILURE LIST

An integral part of the of design processes shall be the identification of all single point failures (SPFs). No single point failure shall cause the loss of the MIRI science capability. SPFs shall be listed in order to:

- Employ enhanced reliability of electronic parts in SPF applications.
- Determine if they may be eliminated by redundancy employment.
- Determine if reliability may be enhanced through design provisions, e.g. added margin; testing, etc.

5.2.4 WORST CASE ANALYSIS (WCA)

A WCA shall be performed and documented on flight MIRI circuits. This analysis shall demonstrate that sufficient operating margin exists for all operating conditions when the individual circuits are subjected to any combination of the following:

a) WCA of electronics shall use part case temperatures (Based upon the temperatures defined in the ERD and IRD). In addition, if the board level thermal analysis indicates a temperature rise of more than 35°C from the thermal control surface to the part case, then the WCA must be amended to include the additional temperature increase).
b) Piece part manufacturing tolerance.
c) Part aging and drift for the 5 year operating life of the mission, plus one year expected ground test time.
d) Special factors such as shock, vibration, or vacuum where such conditions would contribute to variations in the circuit parameters.
e) Voltage, frequency, and load tolerances.
f) Effects of radiation (as defined in JPL D-20241).

The analysis shall be a true worst case in that the value for each of the variable parameters shall be set to limits that drive the output to a maximum (or minimum). The results of the analysis shall describe all deficiencies and performance restrictions that were identified.

5.2.5 ELECTRONIC PARTS STRESS ANALYSIS (PSA)

Parts Stress Analysis shall be performed and documented to verify that the applied stress on each piece part does not exceed the de-rating values established in JPL D-8545, or approved equivalent. All analyses shall be documented on JPL-provided or approved forms. Contractors may use their own forms with JPL reliability and cognizant technical manager approval.

The stress analysis shall use the proto-flight test temperature + 20°C (or proto-flight test temperature + temperature rise from piece part thermal analysis if available). The PSA shall be reviewed once the results of the piece part thermal analysis become available. This review shall insure that the assumed temperature rise envelops the predicated temperature rise and no part is overstressed.

5.2.6 THERMAL STRESS ANALYSIS

Thermal stress analysis shall address the effect of the thermal environment, including worst case estimates, for all anticipated environmental conditions. The analysis shall address conformal coating, other critical materials, and semiconductor junction temperatures.

5.2.7 SINGLE EVENT EFFECTS (SEE)

Circuit designs containing SEE sensitive parts shall be analyzed to determine the effect of SEE and to assure compliance with system/subsystem level requirements. Performance requirements for operation during and following SEE are as follows:

a) Temporary loss of function or loss of data shall be permitted provided that the loss does not compromise subsystem/instrument health, full performance can be recovered rapidly, and there is no time in the mission that the loss is mission critical.
b) Normal operation and function shall be restored via internal correction methods without external intervention in the event of a Single Event Upset (SEU).
c) Irreversible actions shall not be permitted. The flight hardware shall have no parts that may experience unrecoverable radiation induced latch-up or gate rupture.

5.2.8 MECHANICAL FAULT TREE ANALYSIS (FTA)

A Fault Tree Analysis (FTA) shall be performed on mechanical and electromechanical devices. The FTA will address failure modes capable of occurring down to the lowest level piece part. This analysis shall be accomplished by first defining the top event failure mode, then determining possible causes, considering effects based on the subsystem and system functional description. [Following this determination, an assessment of preventive measures and alternate modes of operation to avoid failure shall be performed. The corrective actions shall be documented as described in JPL D-5703. From the results of these analyses, engineering decisions can be made by the cognizant design organization that indicate whether or not additional analysis, testing, inspection, or other steps should be taken to increase the reliability of the assembly. These decisions shall be reported at the design reviews subsequent to completing the analysis.]

5.2.9 PROBABILISTIC RISK ASSESSMENT (PRA)

Probabilistic Risk Assessment shall be performed to assess the probabilistic reliability of the instrument. The primary intent of this analysis is to determine what elements of the design are least reliable and should be considered for design changes, redundancy, or other approaches to mitigate their risk.

The PRA shall take into consideration all elements of the MIRI which reasonably could fail. The analysis shall use data provided by proven reliability data sources (e.g., MIL-HDBK-217) for space flight applications. The analysis shall take into consideration single string hardware, redundant hardware, and hardware that could fail in such a manner as to cause loss of redundancy (such parts/hardware should be uncovered by the FMECA).

5.2.10 Mechanical Worst Case Analysis

Mechanical analyses are to be performed to ensure that worst case mechanical tolerances and thermal environments cannot adversely affect the performance of mechanical and/or optical assemblies. This should be part of the usual design analyses, as good design practice, and should be verified during assembly and test.

5.3 Reliability Development Requirements

5.3.1 SINGLE POINT FAILURE REQUIREMENTS

No single point failure shall cause the loss of all the MIRI science capability. Specific requirements shall be addressed and include:

a) Only functions critical to the health of the MIRI Instrument may be switched automatically, all other redundancy switching shall be activated from ground commands.
b) Operation of all redundant elements shall be identified, so that operational paths are unambiguously known.
c) All redundant and single point failure contingencies shall be fully testable.
d) All redundant and single point failures shall be tested and validated for all possible failure modes.
e) Fully qualified structures need not be redundant.
f) Dewar Specific Requirements: No single point failure can result in the loss of Dewar functionality. The following shall apply:
    - All mechanisms required for on-orbit function shall be redundant.
    - Drive electronics designed to activate the mechanisms for these functions cannot allow a failure.
    - A single point failure of the mechanism or of the control electronics, which results in a failure to actuate, can be tolerated if there is a back up/redundant system. This would be a minimally acceptable approach.
    - Completely redundant functions should be utilized if the above is not feasible.

5.3.2 MINIMUM OPERATING TIME REQUIREMENTS

Flight hardware electronics assemblies shall accumulate at least 300 hours of operation prior to integration into the flight system (the last 100 hours to be failure free). At the flight system level, prior to launch, each single-string electronic assembly shall have at least 1000 hours operating time and each side of a block redundant element shall have at least 500 hours operating time.

5.3.3 MECHANICAL LIFE TESTING

Mechanical and electromechanical hardware exhibiting mechanical wear-out life limiting characteristics shall be capable of at least (2) times the sum of ground and mission life requirements.

Life testing is required if it cannot be shown by cumulative experience or prior life testing, that the hardware is capable of at least two (2) times the sum of ground and mission life, for the high cycle hardware; and at least (10) times the sum of ground and mission life, for a single shot hardware element.

Life test duration shall be sized to include a margin of at least two (2) times the sum of ground and mission life requirements, for the high cycle hardware; and at least (10) times the sum of ground and mission life, for a single shot hardware element.

Life testing shall be conducted under environments representative of in-flight conditions (including some test time at expected flight extremes).

Life tests shall be conducted with loads representative of in-flight loading conditions.
Life testing is not required for electronics on/off cycles

Units exposed to life testing shall not later be used for flight.

5.3.4 SUPPORT EQUIPMENT

5.3.4.1 GSE Reliability

The level of reliability typically required for flight hardware is not warranted for ground support equipment (GSE). GSE that connects to flight units for test or evaluation shall
be analyzed for compatibility with the hardware. Particular care and attention shall be directed at providing assurance that any failure experienced in the GSE does not result in degradation or damage to the flight hardware. As a minimum, the following shall support the GSE design and use:

a) Connector savers.
b) Over-voltage protection for power source.
c) FMEAs to be performed on the GSE hardware interface to verify that a failure in the GSE will not propagate across the interface and cause degradation or damage to the hardware under test.

5.4 Problem/Failure – Anomaly Reporting

A closed-loop problem/failure reporting system is required and shall be implemented for JPL developed flight hardware and software and critical GSE. This reporting system shall also be used for engineering model hardware if there is any projected transfer of status to flight or flight spare hardware. Two types of PFRs shall be utilized as described in JPL D-8091 (latest Rev). These are the Developmental (DPFRs) and standard PFRs.   Details of DFPR/PFR starting points, requirements for PFRs, incidents covered, corrective action guidelines, risk assessment and safety rating and assessment, etc., can be found in JPL D-8091.

Contractors may use the on-line JPL anomaly reporting system as documented in JPL D-8091, JPL Standard for Anomaly Resolution or may use a JPL reviewed and approved equivalent meeting the intent of that document.

All problems, failures, and anomalies shall be initially reported to JPL within one working day of occurrence and be made available for entering into the MIRI problem/failure/anomaly database. All nonconfrmances identified as JPL supplier issues will be forwarded to PQA for appropriate MRB, supplier rating.

PFRs shall be written for flight hardware at the first application of power at the board level and for mechanical damage at the first level of acceptance testing. All significant and Red-Flag PFRs shall be entered into the JPL PFR system. Updates and closure reports shall be provided as they occur.

All reported problems, failures, and anomalies shall have a preliminary risk rating within 10 days after occurrence using the standard JPL risk rating system (Table 5.4-1), and described in JPL D-8091) or an approved equivalent. Risk ratings of 1, 1 are approved/closed by the Cognizant Engineer and next level instrument (Element Manager) or designee, with the Reliability Engineer concurrence on the risk rating. Risk ratings of other than 1, 1 shall have closure approval by the MIRI MAM and Reliability Engineer with concurrence by the PEM or CogE. Red Flag and Significant (high risk) ratings shall be approved by the MIRI Project Manager and MAM and shall be transferred to JPL's PFR system. JPL D-8091 shall be used for JPL supplied flight hardware and is applicable for anomaly report risk rating definitions and requirements.

All problem failure reports generated during assembly and test of MIRI hardware and software, and after the delivery to the EC and subsequently to ISIM will be tracked in accordance with the paths depicted below in Figure 5.4-1, "Problem Report Flow":

Path 1: All PFRs relating to the JPL dewar development will be provided to the Integrated Science Instrument Module (ISIM) Development Team at the time of the dewar pre-shipment review.

Path 2: All PFRs relating to the JPL software development will be provided to the ISIM Development Team at the time of the software pre-shipment review.

Path 3: All PFRs relating to the JPL FPE development will be provided to the ESA Optical Bench Assembly (OBA) Development Team at the time of the FPE pre-shipment review. The OBA team will be kept informed of the failures as they are recorded.

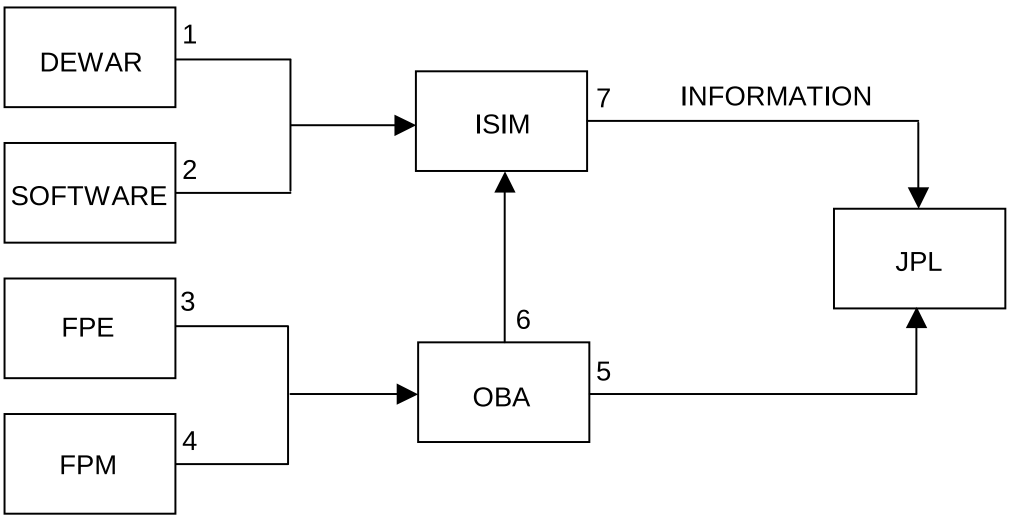
Path 4: All PFRs relating to the JPL FPM development will be provided to the ESA (OBA) Development Team at the time of the FPM pre-shipment review. The OBA team will be kept informed of the failures as they are recorded.

Path 5: All problem reports relating to the ESA OBA development, integration and testing will be provided to the JPL MIRI Project Office at the time of the pre-shipment review.
The JPL Project will be kept informed of the failures as they are recorded.

Path 6: All problem reports relating to the OBA development will be provided to the ISIM Development Team at the time of the OBA pre-shipment review.

Path 7: All problem reports relating to MIRI failures after the delivery of MIRI to ISIM will be provided to the JPL MIRI Project Office on an information only basis. The JPL MIRI Project Office will track the MIRI failures based on these reports.

Figure 5.4-1 Problem Report flow



5.5 Lessons Learned

The Project shall review applicable NASA Lessons Learned (LLIS) per the FPP.

Table 5.4-1 Problem/Failure Risk Rating System

Failure Effect & Rating (Ignoring Redundancy)		**Failure Cause/Corrective Action & Rating**	
Negligible (see definitions in D-8091)	**1**	**1**	Known Cause/Certainty in Corrective Action No known residual adverse effect, and/or no possibility of recurrence.
Significant (see definitions in D-8091)	**2**	**2**	Unknown Cause/Certainty in Corrective Action No known residual adverse effect, and/or no possibility of recurrence.
Major or Catastrophic (see definitions in D-8091)	**3**	**3**	Known Cause/Uncertainty in Corrective Action Some known residual adverse effect, and/or some known possibility of recurrence.
		4	Unknown Cause/Uncertainty in Corrective Action Some known residual adverse effect, and/or some known possibility of recurrence.
Red Flag Problem/Failure Reports Require Project Manager Approval			

6.0 ENVIRONMENTAL DESIGN AND VERIFICATION

MIRI hardware developers shall perform the qualification tests and/or analyses specified in the MIRI Test and analysis Matrix (TAM). The JPL project office will be responsible for ensuring that all necessary MIRI qualification tests and analyses are based on the GSFC MIRI IRD. The JPL Environmental Requirements Engineer (ERE) will assure that all applicable MIRI Environmental Requirements are contained in the TAM.

6.1 Introduction

The MIRI environmental program is intended to ensure that all MIRI flight hardware is reliable, robust, and compatible with the specified ground and space environments. The **“General Environmental Assurance Approach”** for the MIRI project is shown in Appendix 6-A and shall be used as a guide for the MIRI environmental test program. The MIRI environmental program defines:

Environments for all mission phases
Environmental design requirements
Environmental verification requirements and methods

The environmental program covers the following five disciplines:

Dynamics (including vibration, and shock)
Thermal and Temperatures
EMC and ESD
Natural Space and Space Radiation
Space Debris and Solid Particles Environment

Environmental categories covered are shown in Appendix 6-B, “MIRI Assembly Test and Analysis Verification Matrix” (TAM).

6.1.1 APPLICABLE DOCUMENTS

The JPL MIRI environmental program is based on:

1) JPL Doc ID 58032, “Flight Project Practices”, February 27, 2003
2) JPL Doc ID 43913 (JPL D-17868), “Design, Verification/Validation and Operations Principles for Flight Systems”, March 03, 2003
3) JPL Doc ID 85648 (JPL D-60133), “Assembly and Subsystem Level Environmental Verification Standard”, February 21, 2003

Unless waived by an formally approved Class A waiver, the MIRI environmental program shall be in compliance with these standards and documents. MIRI environmental requirements shall also be in compliance with the following documents:

1) MIRI MAP D-25631
2) MIRI IRD D- JWST-IRD-000782

3) JPL Doc ID 56172 (JPL D-22011), “System Thermal Testing Standard”, March 15, 2003
4) European Cooperation Standard ECSS-E-10-03A - “Testing – Space Engineering”

6.1.2 MISSION PHASES AND LEVELS OF ASSEMBLY

MIRI environmental program covers the following mission phases:

- Ground, Transportation, Launch, Orbiting and Mission environments

The MIRI environmental program covers all flight hardware assemblies, subsystems, and systems. Requirements for MIRI parts, components, subassemblies, and packaging are provided in Sections 5.0, 7.0 and 8.0. Life test requirements are covered in Sect. 5.3.

MIRI assemblies are defined in Appendix 6-B, “MIRI Assembly Test and Analysis Matrix” (TAM). This includes Engineering Models, Qualification Models, Protoflight Models, Flight Models, and Spares.

6.2 Approach and Policies

6.2.1 ENVIRONMENTAL DESIGN AND TEST MARGINS REQUIREMENTS

Environmental design and test margins for MIRI flight hardware are shown in Appendix 6-C, “Environmental Design and Test Margin Requirements for MIRI Assemblies”. Qualification test margins, Protoflight test margins, Flight Acceptance test margins are shown.

6.2.2 METHODS OF ENVIRONMENTAL VERIFICATIONS

The environmental design of the MIRI flight hardware shall be verified by the methods of testing, analysis, or a combination of the two. The method of verification for each MIRI assembly shall be specified in the MIRI Assembly Test and Analysis Matrix (TAM), Appendix 6-B. Environmental Test/Analysis Reporting (ETAS, EACS, RACS) forms are required for formal reporting of environmental requirements verification. ETAS are also required for environmental test authorization.

6.3 Environmental Design Requirements and Verification Levels

6.3.1 DYNAMICS ENVIRONMENTAL REQUIREMENTS

Dynamics Environmental Requirements shall be in accordance with JPL standard practices and the MIRI IRD. Specific test requirements for all JPL provided hardware shall be delineated in the. MIRI Environmental Requirements Table for Dynamics Appendix 6-D (TBD)

6.3.2 THERMAL AND TEMPERATURE REQUIREMENTS

With the exception of the dewar assembly (see Sect. App 6.K), all JPL developed assemblies not thermal vacuum qualified at higher MIRI level of assembly shall undergo the protoflight qualification test specified in App. 6I. Post repair and modification re-qualification testing shall be accomplished by performing the flight approval test specified in App. 6J. Hardware developers will specify flight allowable temperature levels.

6.3.2.1 Temperature Requirements

MIRI assembly allowable flight temperatures (AFT), qualification/protoflight test temperatures (PF), flight acceptance (FA) test temperatures are shown in Appendix 6-E .

The qualification/protoflight and flight acceptance test profiles are also shown in Appendix 6-F&G.

6.3.2.2 Dewar Thermal Vacuum Test Requirements

See App. (6-H)

6.3.3 EMC AND ESD TEST REQUIREMENTS

MIRI hardware shall be designed to function during and after exposure to the EMC and ESD values specified in Appendix 6E (TBD). EMC and ESD Environmental test requirements shall be specifically called out in App. 6B “MIRI Test Analysis Matrix” (TBD). General EMC and ESD Test requirements are delineated in the “General Environmental Assurance Approach” table Appendix 6-A.

6.3.4 NATURAL SPACE AND RADIATION ENVIRONMENTS

MIRI hardware shall be designed to function during and after exposure to the Natural Space and Radiation Environments values specified in Appendix 6F (TBD). Natural Space and Radiation Environmental test requirements shall be specifically called out in App. 6B “MIRI Test Analysis Matrix” (TBD). General test requirements for Space and Radiation Environments are delineated in the “General Environmental Assurance Approach” table Appendix 6-A.

6.3.5 SPACE DEBRIS AND SOLID PARTICLE ENVIRONMENTS

MIRI hardware shall be designed to function during and after exposure to the Space Debris and Solid Particle Environments values specified in Appendix 6G (TBD). Space Debris and Solid Particle Environmental test requirements shall be specifically called out in App. 6B “MIRI Test Analysis Matrix” (TBD). General test requirements for Space Debris and Solid Particle environments are delineated in the “General Environmental Assurance Approach” table Appendix 6-A.

6.3.6 MECHANISEM ACCEPTANCE TEST REQUIREMENTS

Flight acceptance testing is required for selected mechanisms intended for use in flight hardware or having flight spare status. Ten (10) percent of the number of qualification cycles in Table 5.3.3-1 shall be used for the flight acceptance testing. Flight acceptance testing cycles shall be performed at the same pressures as encountered during flight operations, i.e. usually in vacuum. Any element in a chain of activation (e.g. motor, bearing, gear, etc.) shall conform with the maximum number of cycles applicable to any of the remaining elements in the chain.

6.4 Test Implementation Requirements

Test tolerances are provided in Appendix C.

Appendix 6-A - General Environmental Assurance Approach

Environments

Environmental Program:

MIRI assemblies may be environmentally tested using a Protoflight program or a Qualification/ Flight Acceptance program. In certain cases a Protoflight/Flight Acceptance test program is also acceptable.

Note: Testing all flight assemblies to Protoflight levels is the preferred approach for the purpose of enhanced reliability demonstration. PF testing will be required if modifications are made to the hardware after qualification testing is completed.

Environmental Test Requirements: Dynamics

1. Assembly Level

a) Random vibration (w/ force limiting)

Powered on vibration is required for hardware powered during launch.

Powered on vibration is recommended for all other hardware for improved detection of anomalies (e.g. intermittents).

b) Pyroshock (required for electronic assemblies and for assemblies containing pyro devices).

c) Acoustic (required for assemblies with large area to mass ratio, such as antennas and solar panels, or assemblies with thin diaphragms).

2. System Level

Low level sine sweep (analytical model verification)
Random
Acoustic
Pyro firings

Environmental Test Requirements: EMC/EMI

1) Assembly /Subsystem Level:

Perform on EM/Qualification hardware provided this hardware is identical form, fit and function (flight parts not necessary) to flight. Perform on flight subsystems if no EM/Qual units available. Delta testing required on flight h/w if there are any design changes subsequent to EM/Qual testing. Isolation and grounding required on all flight h/w even if no changes since test on EM/Qual hardware.

A comprehensive suite of tests is required for all subsystems tied to the power bus including: Conducted and Radiated Emissions, Conducted and Radiated Susceptibility, Isolation/Grounding

2) System Level:

Radiated Emissions/Radiated Susceptibility

Magnetics

No Magnetics testing required.

Appendix 6-A (Cont) - General Environmental Assurance Approach

Environmental Test Requirements: Thermal/Vacuum 1) Assembly: All flight and EM/Qual assemblies shall be T/V tested. In certain cases temperature atmosphere testing may be substituted for T/V testing if approved by the E/RE. 2) System Level Tests: Combine thermal qualification with thermal balance. Drive temperatures of key hardware to FA limits for system functional verification.
Thermal cycling Design for 3 times expected number of mission/ground cycles (specific requirements to be developed for each assembly). 1) Packaging Design/Qualification Packaging Qualification: test representative packaging sample(s) or provide data to prove compliance. 2) Assembly Design/ Qualification Thermal cycling verification shall be performed as part of overall life testing program (only required for life limited items) 3) Flight assemblies Limited cycles to be performed as part of assembly level thermal vacuum test.
Environmental testing facilities shall be selected based on capabilities, safety inhibits and contamination control considerations.
Environments verified by analysis, sample/development test, etc: 1) Standard Environments: a) Radiation: TID: verify all parts meet TID requirement; radiation transport analysis required for non-compliant parts Displacement Damage: All parts shall be evaluated for displacement damage sensitivity and application acceptability. SEE: Circuit functional analysis and possible addition of shielding or part replacement required for parts not meeting SEE requirements. b) ESD: verify that ESD-prevention design rules are followed. c) Launch Pressure Decay: follow design guidelines or perform venting analysis d) Micrometeoroids: need for additional shielding based on probability of impact to s/c. Follow good design practice for shielding susceptible h/w (e.g. external cables, tanks, heat shield, etc). e) Orbital debris: assessment required to verify compliance with NASA requirement. (Assessment performed by GSFC).
Environmental Test/Analysis Reporting (ETAS, EACS, RACS) forms are required for formal reporting of environmental requirements verification. ETAS are also required for environmental test authorization.

Appendix 6-B. MIRI Assembly Test And Analysis Verification Matrix

No	Subsystem/Assemblies	Thermal vac	Pressure(Launch Decay)	Multipacting/Ionization breakdown (High Vdc or RF)	Random vib	Acoustic vib	Pyroshock	Static loads	Sine vibr	Conducted emission	Radiated emission	Radiated susceptibility	Conducted susceptibility	Touch-down ESD	Grounding/isolation	TID (Total Ionizing dose)	Displacement damage	SEE (Single event effects)	Space Debris	Solid particles (micrometeoroids, etc)
1	**Focal Plane Assemblies**																			
	STM																			
	EM																			
	FM																			
	Spares																			
2	**Focal Plane Electronics Assembly**																			
	STM																			
	EM																			
	FM																			
	Spares																			
3	**~~C & DH Software~~**																			
4	**Dewar Subsystem**																			
	Dewar Vacuum Vessel (DVV)																			
	Cryogen Tank(s)																			
	Thermal Shields and MLI																			
	Cold Buttons (2)																			
	Thermal Heat Switches																			
	External Plumbing Assembly																			
	Mechanical Mounts																			
	Dewar Control Electronics																			
5	**Optics Module (by EC)**																			
	STM																			
	EM																			
	FM																			
	Spares																			
6	**Interface Control Electronics (by EC)**																			
	Thermal Strap Interface (4)																			
	EM																			
	FM																			
	Spares																			

Appendix 6-C. Environmental Design and Test Margin Requirements

Environmental Design and Test Margin Requirements:			
Environment	**Design/ Qualification**	**Protoflight (PF)**	**Flight Acceptance (FA)**
Acoustics Level Duration	MEFL[1] + 3 dB 2 min	MEFL + 3 dB 1 min	MEFL 1 min
Random Vibration Level Duration	MEFL + 3 dB 2 min/axis	MEFL + 3 dB 1 min/axis	MEFL 1 min/axis
Pyro Shock Firings or Levels	2 firings or MEFL + 3 dB 2 shocks/axis	2 firings or MEFL + 3 dB 1 shock/axis (see note 7)	N/A (no test required)
Landing Loads	Design: apply Factors of Safety per D-19877; Qual: MEFL x 1.2 (Test Factor)	MEFL x 1.2 (Test Factor)	MEFL
Thermal Vacuum[2] Temp. Levels (C) (Cold/Hot) Test Duration[3], hrs, (Cold/Hot) # of Cycles[5]	<u>Electronics, Mechanisms, Payloads</u>: Greater of: -35/+75 or (AFT-15)/(AFT+20) <u>Optics, Detectors, etc.</u> (AFT-15)/(AFT+20) <u>Electronics</u>: 24/144 (cumulative) <u>Non-Electronics</u>: 24/24 (cumulative) 3 to 10 cycles[5] (cumulative)	<u>Electronics, Mechanisms, Payloads</u>: Greater of: -35/+75 or (AFT-15)/(AFT+20) <u>Optics, Detectors, etc.</u> (AFT-15)/(AFT+20) <u>Electronics</u>: 24/144 (cumulative) <u>Non-Electronics</u>: 24/24 (cumulative) 3 to 10 cycles[5] (cumulative)	<u>Electronics, Mechanisms, Payloads</u>: Greater of: -25/+55 or (AFT-5)/(AFT+5) <u>Optics, Detectors, etc.</u> (AFT-5)/(AFT+5) <u>Electronics</u>: 24/24 (cumulative) <u>Non-Electronics</u>: 24/24 (cumulative) 3 to 10 cycles[5] (cumulative)
Thermal Cycling Qualification (fatigue life)[6]	3x number of mission/ground	N/A (no test required)	N/A (no test required)
EMC (Radiated/Conducted Emissions and Susceptibility)	Min EFL - 6 dB (emissions) MEFL + 6 dB (susceptibility)	Min EFL - 6 dB (emissions) MEFL + 6 dB (susceptibility) (see note 7)	N/A (grounding/isolation only)
Ionizing Radiation Design Factor (RDF)	RDF = 2 Spot shielding, RDF = 3		

<u>Notes</u>:

1. MEFL = Maximum Expected Flight Level 2. Min EFL = Minimum Expected Flight Level

2. All assemblies shall be tested in vacuum (<10^{-5} torr) unless otherwise exempted.
3. Duration requirement may be cumulative.
4. AFT = Allowable Flight Temperature, typically includes both operational and non-operational limits.
5. The number of thermal cycles performed on flight hardware (PF or FA) shall be sufficient to detect any mechanical or electrical hysteresis, or workmanship defects. Typically this is 3 to 10 cycles. No more than 10 cycles (inclusive of all retest activities) shall be performed on flight hardware prior to ALTO delivery.
6. Low cycle fatigue life demonstration with 3X margin is required. May be accomplished via heritage test data , EM testing, or packaging sample testing.
7. For pyro-shock and EMC testing, if there is no EM available for Qualification, then a protoflight test shall be performed on a single PF (Flight) unit. Isolation and ground test required on all flight units.

Appendix 6-D - MIRI Environmental Requirements Table for Dynamics

(TBD)

Appendix 6-E - MIRI Environmental Requirements Table for EMC and ESD

(TBD)

Appendix 6-F - MIRI Environmental Requirements Table for Natural Space and Radiation

(TBD)

Appendix 6-G - MIRI Environmental Requirements for Space Debris and Solid Particles

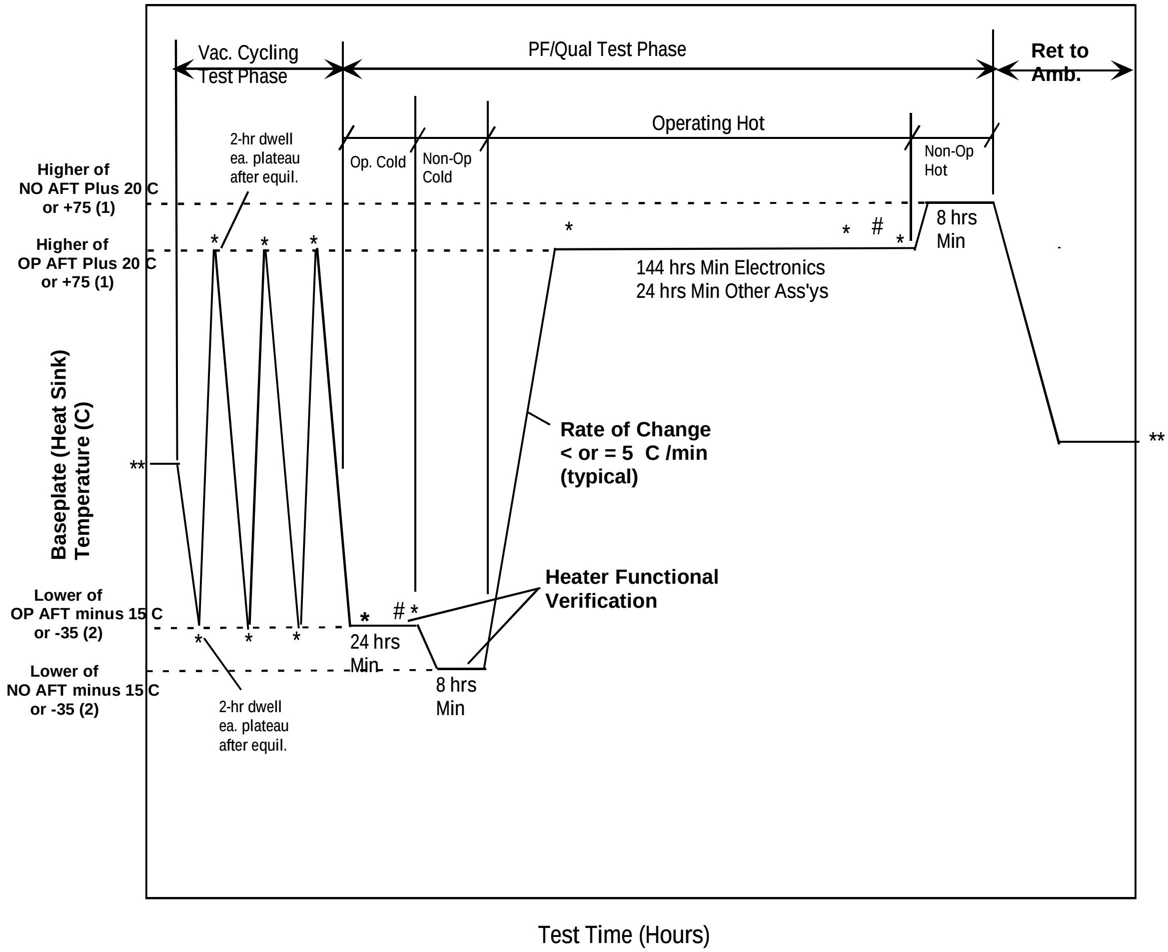
(TBD)

Appendix 6-H - MIRI Assembly Temperature Requirements Table (TBD)

Table ____. MIRI Temperature Requirements Table

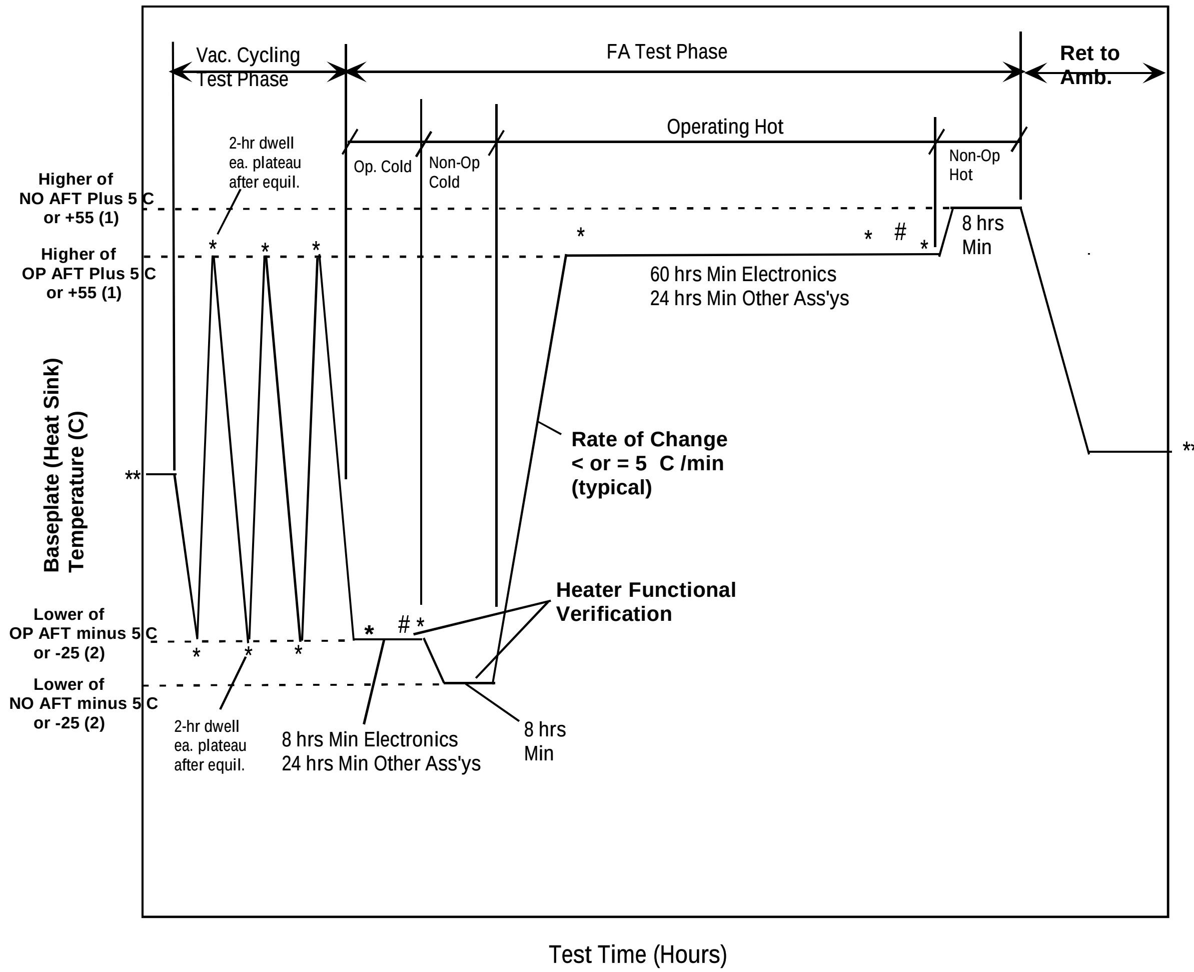
	Assembly	TEMPERATURE (°C)											
		ALLOWABLE FLIGHT				PROTOFLIGHT or QUAL				FLIGHT ACCEPTANCE			
		OP		NOP		OP		NOP		OP		NOP	
		min	max	min	max	min	max	min	max	min	max	min	max
1	**Focal Plane Assemblies**												
	STM												
	EM												
	FM												
	Spares												
2	**Focal Plane Electronics Assembly**												
	STM												
	EM												
	FM												
	Spares												
3	**~~C & DH Software~~**												
4	**Dewar Subsystem**												
	Dewar Vacuum Vessel (DVV)												
	Cryogen Tank(s)												
	Thermal Shields and MLI												
	Cold Buttons (2)												
	Thermal Heat Switches												
	External Plumbing Assembly												
	Mechanical Mounts												
	Dewar Control Electronics												
5	**Optics Module (by EC)**												
	STM												
	EM												
	FM												
	Spares												
6	**Interface Control Electronics (by EC)**												
	Thermal Strap Interface (4)												
	EM												
	FM												
	Spares												

APPENDIX 6-I - MIRI Assembly Qual/Protoflight Thermal Vacuum Test Profile



Notes
(1) Level shown is for electronics. Level for non-electronics or mechanisms is AFT plus 20 C.
(2) Level shown is for electronics. Level for non-electronics or mechanisms is AFT minus 15 C.
(3) Test environment is vacuum (i.e., pressure < 1.0E-5 torr).
(4) # indicates hot or cold starts - 3 times minimum, cold and hot.
(5) ** indicates pre- or post- test functional tests.
(6) * indicates required performance/functional tests after thermal equilibrium is established.
(7) Thermal equilibrium is defined as |dT/dt| <1 C/hour.
(8) Power on/off cycle test is not described in this profile.

APPENDIX 6-J - MIRI Assembly Flight Acceptance Thermal Vacuum Test Profile



APPENDIX 6-K - DEWAR Thermal Vacuum Test Requirements

6H-1 PRESUMPTIONS

The dewar is cryogenic and unconventional flight hardware. JPL design principles, flight and operation practices, and thermal test standards are reference documents but fundamentally do not apply.

The subsystem test requirements specified in this section will assure quality, reliability, and robustness of the dewar subsystem only if all assembly-level thermal vacuum tests have been completed separately and successfully in accordance with MIRI IRD and JPL standard environmental test requirements. Assemblies of the dewar subsystem include all functional entities such as the cryogen tank(s), vacuum vessel, heat switches, heaters, thermal shields, and the DCE.

The assembly-level thermal environmental tests also includes all specialized thermal cycling tests and thermal shock tests at the proper level of assembly (e.g., the LN2 immersion tests as specified in JPL D-25647, “MIRI Dewar Subsystem Specification” or as determined to be pertinent and necessary by the dewar subsystem cognizant engineer). This should have validated the filling operation.

The solid hydrogen (cryogen) life test has been successfully performed in accordance with JPL D-25647, “MIRI Dewar Subsystem Spec.”.

6H-2 PREREQUISITES

Dewar Engineering Test Unit and Structural Thermal Model

Dewar Engineering Test Unit (ETU) and Structural Thermal Model (STM) Vent system are developmental hardware. For the purpose of this dewar subsystem, however, these two hardware items shall be specified as under the control of the MIRI project environmental program. JPL D-25631, “MIRI Mission Assurance Plan” and JPL D-25641, “MIRI Dewar Subsystem Specification” in full shall apply and the thermal environmental tests specified therein must be completed successfully before the commencement of the flight dewar subsystem thermal vacuum test.

Proof Pressure and Associated Electrical and Mechanical Tests

Proof pressure tests and other mechanical and electrical tests shall have been performed before proceeding with this dewar subsystem thermal vacuum test of the dewar in flight-like environment.

Leak-Tightness of the Flight Dewar Subsystem

A leak check shall be preformed for the complete test setup using helium as a leak detecting medium before the start of dewar subsystem thermal vacuum test. This includes the full test setup including all GSE, vent and fill connections and all mechanical and electrical interfaces. The total system leak rate shall not exceed that specified in D-25641.

<u>Dewar Subsystem Hot Survivability Test</u>

The dewar subsystem hot survivability test at 320 K must have been separately and successfully completed in accordance with JPL D25747. This may be combined with the bakeout test for decontamination certification.

<u>Test Thermal Math Model of the Dewar Subsystem and Interfaces</u>

In addition to the thermal math model (TMM) used for the thermal analysis and thermal design of the dewar subsystem, a test thermal math model (TTMM) shall be constructed to predict the performance of the dewar subsystem in this thermal vacuum test. The TTMM shall be "test-like" and include all dewar subsystem hardware, interfaces, and test support equipment:

- Vacuum Vessel
- Tank(s)
- Heat Switches, Transducers, and Other Control Elements
- Plumbing, Vent and Fill and Others
- Thermal Shields
- All Structural Mounts
- DCE and harnesses
- Cold Buttons and Thermal Straps
- Focal Plane Module
- Optics Assembly
- Test Chamber
- In-Chamber Test Support Equipment
- Others

In particular, all potential background heat sources:

- Conduction via struts and cables
- Radiation from the outershell
- Conduction via all fill and vent lines
- Radiation from adjacent hardware
- Conduction via utility penetrations
- Convection, if any
- Power dissipations

shall be included. Dewar thermal vacuum test shall not start before this TTMM, its temperature predictions, and the background heat source predictions have been reviewed and approved by the dewar Cog. E and the Mission Assurance Manager.

<u>Test Plans, Test Procedures, and Environmental Test Authorization Summary (ETAS)</u>

Test plans, procedures, and ETAS are required test documents for this test. Test plans and procedures shall be reviewed and approved by the Cog, E and MAM before the start of this test.

Test Readiness Review

Test readiness review shall be held and the approval must be secured from the review board before the start of this test.

6H-3 DEWAR SUBSYSTEM THERMAL VACUUM TEST REQUIREMENTS

(Note: This subsystem thermal vacuum test is in addition to the outgassing test performed at higher temperature under dewar subsystem contamination control plan.)

Test Configuration

The configuration of the test article shall be flight-like. This includes all dewar assemblies, all elements of the plumbing subsystem, the DCEs, cable harness, wiring, controls, all accessories, and all GSE. This also includes the thermal straps and the thermal strap interfaces.

The tank(s) shall be filled with solid hydrogen or a surrogate substance as deemed proper by the Cog. E and the project scientist. The FPM and OS can be simulated by equivalents with equal mass and steady state and transient thermal characteristics and the capabilities of heat load control.

Test Media

The test chamber environment shall be vacuum (chamber pressure at 10^{-5} torr or lower).

Test Objectives

The objectives of this test are:

1. To verify that the dewar subsystem is leak-tight. This includes the vacuum vessel, the tank(s), all vent and fills, and all interfaces.
2. To verify that the background heat sources are as predicted by the TTMM.
3. To verify that the dewar subsystem cools down as predicted by the TTMM.
4. To verify that the thermal control performs satisfactorily and to conduct a thermal balance test to confirm heat flows and to collect thermal data for the final correlation of the thermal model for flight predictions.
5. To verify that the dewar subsystem meets all functional, operational, and control performance requirements under simulated mission conditions as specified in JPL D-25641, "Dewar Specification". This includes the rate of consumption of the cryogen in accordance with the prediction by the TTMM.
6. To calibrate all flight temperature sensors.
7. To demonstrate that the dewar subsystem meets the performance specification with ample thermal margins.

Verification of the life of the cryogen is not an objective of this test.

Interface Simulation (External Environmental Simulation)

The thermal interfaces shall be simulated according to Table 6H-1 below:

Simulation of the Internal Heat Dissipations

Max. DCE heat dissipation (6 watts) shall be simulated in this test. Heat dissipation in the control wirings and control devices shall be flight-like in this test.

Test Control Temperatures and State of Thermal Equilibrium

The temperatures which control this test shall be:

1. Temperature of the Chamber Shroud (i.e., simulation of the radiative heat transfer from the ISIM)
2. Temperature of the FPM at the Thermal Strap Interface
3. Temperature of the OA at the Thermal Strap Interface

Thermal equilibrium of this test is defined as $|dT/dt| < 0.25$ °K/hour anywhere in the test setup. This includes the dewar subsystem as well as the test facility and all test support equipment.

Test Cases

As a minimum, four (4) test cases shall be included in this test:

Case 1: Cooldown Characterization Case
Case 2: Refrigeration Performance Verification Case (Shroud at 35 °K)
Case 3: Subsystem Thermal Margin Demonstration No. 1 (Shroud at 45 °K)
Case 4: Subsystem Thermal Margin Demonstration No. 2 (Shroud at 55 °K)

Table 6H-1. Thermal Interfaces and Stability

No.	Assembly	Test Temps (Note 3)	Heat Flux or Heat Dissipation	Rate of Change
Conduction				
1	Fill and Vent Valves and Piping	40 K (Note 4)	Note 1	TBD
2	Mech. Mounts and Piping (simulating ISIM)	40 K (Note 4)	Note 1	0.2 K/min
3	DCE Heat Sink	310 K	6 watts	0.2 K/min
4	FPM Thermal Strap I/F	6.65 K	4.8 mw	0.5 mw/1000sec
5	OA Thermal Strap I/F	7.60 K	55.2 mw	5.0 mw/1000sec
6	Electrical Harness	Note 1	Note 1	Note 1
Thermal Radiation				
7	Chamber Shrouds (simulating ISIM w/emitt. = 0.7)	40 K	Note 1	TBD
Convection				
8	Residual Gases, if any	Note 1	Note 1	Note 1
9	Sublimation of SH2 or Evaporation of Substitute cryogen	Note 2	Note 2	Note 2

Notes:
(1) As calculated by the TTMM.
(2) As measured in the test.
(3) These are either the hot or cold worst case of mission operations.
(4) The Fill and Vent Valves and Plumbing will be thermally tied to either the Dewar Vacuum Vessel or the ISIM Envlosure so their test temperatures are 40 K worst case warm for the thermal balance test.

Case 1 is for the characterization of the dewar subsystem cooldown. The test duration for this case is “as required” for the collection and recording of cooldown data. The demonstration of the full cooldown period is not required. Accelerated cooldown (non-flight like) methods can be used as deemed proper by the test conductor but should be in agreement with the TTMM predictions. Thermal pre-conditioning is acceptable.

Case 2 is for the verification of dewar subsystem performance under mission operating condition in accordance with the dewar spec. Cases 3 and 4 shall demonstrate the reliability and thermal environmental margins of the dewar subsystem.

Chamber breaks between test cases can be added as determined to be necessary by the test conductor. Test cases which have been performed before the chamber breaks need not be repeated.

<u>Verification of Modes of Subsystem Operation</u>

As a minimum, the following modes of operations shall be exercised at least one time in this test:

- Start and Shutdown Operation
- Cooldown Operation
- Standby Mode
- Mission operations and performance
- Decontamination Operation
- Safing Mode
- Engineering Mode
- Autonomous performance
- Fault protection verification
- Survivability mode

<u>Performance Verification</u>

As a minimum, the following performance shall be verified in accordance with the Dewar Subsystem Spec:

1) The chamber shroud simulating the external thermal environment of the dewar subsystem is maintained at the planned levels.
2) Background heat sources are in accordance with Table 6.6.2.2.3-1 and as predicted by the TTMM.
3) Dewar control subsystem performs as per spec JPL D-25641.
4) The dewar subsystem is capable of maintaining the temperature of the FPM TSI at or below 6.65 K.
5) The dewar subsystem is capable of maintaining the temperature of the OA TSI at or below 7.60 K.
6) The dewar subsystem is capable of removing the heat energy at the FPM TSI at a rate of no less than 4.8 mw.
7) The dewar subsystem is capable of removing the heat energy at the OA TSI at a rate of no less than 55.2 mw.
8) The thermal stability of the thermal interfaces is as shown in Table 6.6.2.2.3-1.

<u>Test Profiles</u>

The temperature-time test profiles of this test are shown in Figure 6H-1. It includes the required key temperature levels and the definition of thermal equilibrium for this test. The test profile for retest is the same except that Case 3 and Case 4 need not be performed.

a) Thermal Math Model (TMM) Correlation and Final Flight Prediction

The subsystem TMM shall be correlated with the test data collected from this test. The correlated TMM shall be used to make the final mission performance predictions of the dewar subsystem per JPL D-25641, “Dewar Subsystem Spec”.

b) Retest Requirements

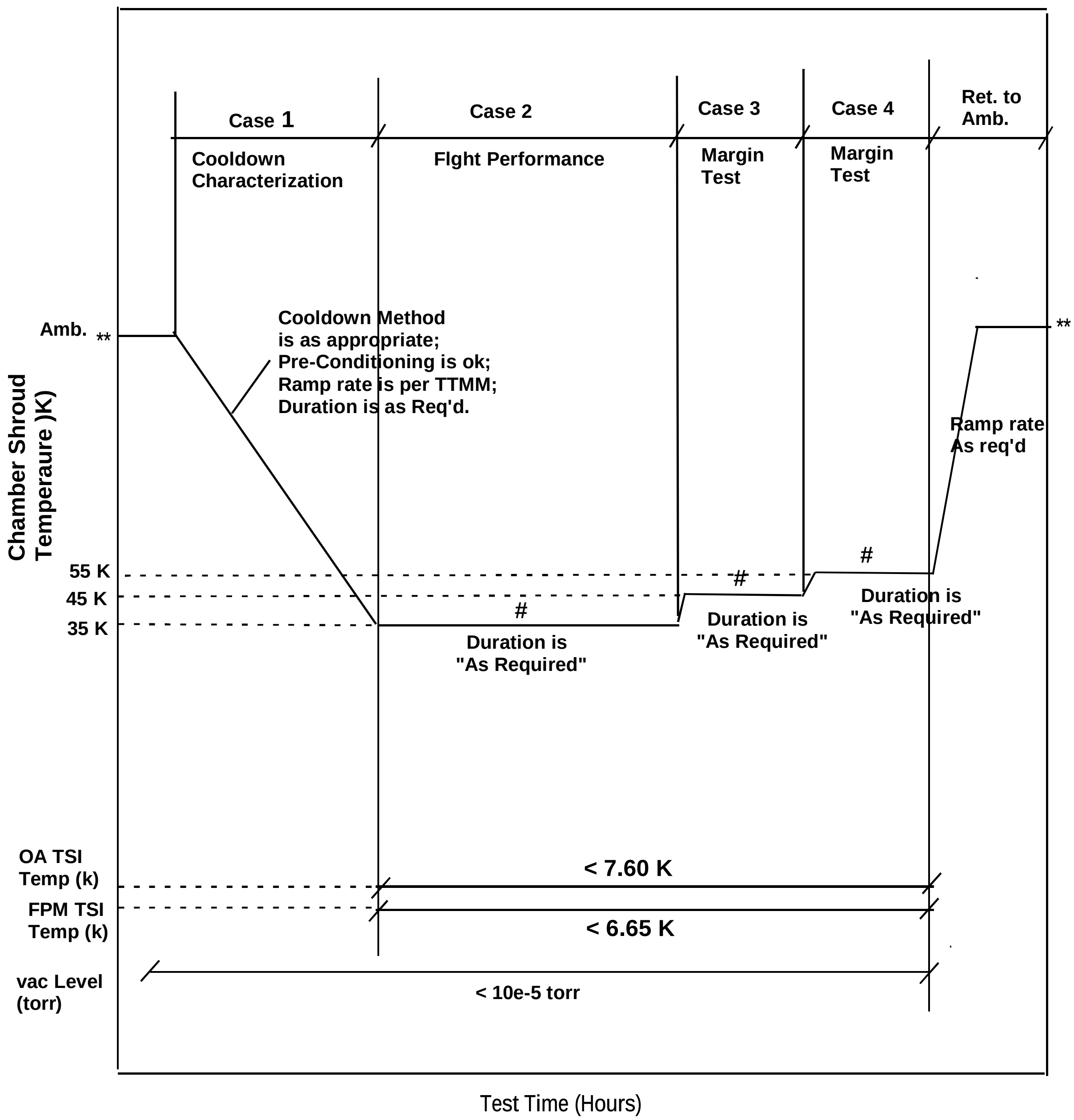
If a retest of the dewar becomes necessary, the re-qualification test shall be accomplished by performing an acceptance test with a test profile shown in Figure 6H-1.

Post-Test Report

Test report shall be prepared. This report is an item in the End Item Data Package.

Figure 6H-1 - Dewar Thermal Vacuum Test Profile

Note: Retest profile is the same except that the 45 K and 55 K test cases need not be performed



(1) ** indicates pre-test or post-test checkout
(2) # performance verification required. Performance per Spec. D-25647.
(3) Test cases are conducted after the dewar subsystem has reached thermal equilibrium which is defined as |dT/dt| < 0.25 K/hour anywhere in the dewar subsystem, not just the shroud, FPM or OA TSIs as shown.

7.0 ELECTRICAL, ELECTRONIC AND ELECTROMAGNETIC (EEE) PARTS

This plan defines the MIRI (EEE) Parts Reliability requirements, implementation plan and its applicability to organizations both within and external to JPL.

7.1 Responsibilities

The part requirements contained within this MAP Section are applicable to JPL hardware developers, contractors, and suppliers.

7.2 Parts Selection Criteria

Two sets of standard parts are defined for the MIRI Project. The two sets are:

a) Standard parts in single point failure applications (not single point fault tolerant).
b) Standard parts in single point failure tolerant applications.

7.2.1 SINGLE POINT FAILURE APPLICATIONS

The following are standard parts in single point failure applications:

a) NPSL Level 1
b) MIL-PRF-38534 Class K, QML-38534.
c) MIL-PRF-38535 Class V, QML-38535, (MIL-M-38510, Class S).
d) MIL-PRF-19500 JANS, QPL-19500.
e) Military Established Reliability (ER) passive devices, Failure Rate Level S.

7.2.2 SINGLE POINT FAILURE TOLERANT APPLICATIONS

The following are standard parts in single point failure tolerant applications:

a) NPSL Level 2.
b) MIL-PRF-38534 Class K, QML-38534 (Level 1).
c) MIL-PRF-38535 Class Q, QML-38535, (MIL-M-38510, Class B).
d) MIL-PRF-19500 JANTXV, QPL-19500.
e) ER passive devices, Failure Rate Level R (Level 2).

7.3 Custom Hybrid, MCM and HDI Microcircuits

Hybrid devices designed and fabricated by non-QML sources, such as JPL or their non-QPL contractors, shall be in conformance with requirements of Class K reliability level of MIL-PRF-38534 with a 10 piece element evaluation for each die device type. Pre-cap visual inspection and document review (e.g. element evaluation, burn-in data and rework travelers) prior to seal is required for all hybrids. All non-QML sources and APL contractors will be on JPL's Approved Suppliers List (ASL).

Substrates used for custom hybrids (as defined above) shall be subjected to additional screening to include:

100% Screening Requirements for Substrates including samples used for qualification

Test	Method	Condition	Quantity
Temperature Cycling	1010	E, 10 cycles@-65°C to 300°C	100%
Electrical testing		Per schematic	100%
*Acoustic Microscopy	JEDEC Std-035	All internal features meet specified substrate design requirements	100%
Radiographic	2012	All internal features meet specified substrate design requirements	100%

*Most Acoustic Microscopy techniques require a medium, such as de-ionized water, to propagate the sound waves that surrounds the substrate. If moisture is a concern, perform this test as a qualification.

Qualification Requirements for Substrates on at least a sample of 2 substrates

Test	Method	Condition	Quantity
Cross-section*	Defined by the Hybrid Specialist		2
High temperature aging with additional adhesion testing	Defined by the Hybrid Specialist		2

*Perform sufficient cross-sections and inspect under high magnification to verify all internal features meet specified substrate design requirements.

The Hybrid Parts Specialist shall identify in-process inspection points that ensure adequate yield per project needs. Inspection points will be called out in the travelers and inspected by QA at the parts suppliers.

7.4 Radiation Requirements

All parts shall be reviewed, evaluated, and where necessary, tested for characterization, against the program radiation requirements. These requirements will consist of tolerance to Total Ionizing Dose (TID) and/or single event effects (SEE), such as single event upset (SEU), single event burnout (SEB), single event gate rupture (SEGR), and single event latch-up (SEL).

7.4.1 TOTAL IONIZING DOSE (TID)

All flight parts are expected to operate within post-irradiation specification limits following exposure to 42.5 krads (si). 42.5 krads is based an radiation design margin of 2.0; a 10 year extended mission; and a 2.54 mm electronic box wall thickness. The TID radiation environment includes all radiation components: X-rays, gamma rays, protons, electrons, neutrons and heavy ions.

7.4.2 DOSE RATES

All linear bipolar and BiCMOS ICs shall be evaluated for susceptibility to ELDRS by the Radiation Specialist. Where testing is required (i.e., when no recent data exists), tests shall be performed at a dose rate less than or equal to 0.005 rad (Si)/s to the required radiation level, as defined above.

Testing shall be in accordance with MIL-STD-883, Method 1019.7 except that the dose rate shall be as specified above. Furthermore, such testing shall be performed on both biased as well as unbiased parts, since in many cases, the unbiased case is the most sensitive. Parametric degradation due to ELDRS should be accounted for in the circuit worst case analysis.

7.4.3 DISPLACEMENT DAMAGE

All parts shall be evaluated for displacement damage sensitivity. Potentially susceptible parts include but are not limited to optical devices, photo-detectors, charge-coupled devices, optocouplers, LEDs, laser diodes and precision bipolar linear devices.

7.4.4 SINGLE EVENT LATCHUP (SEL)

All CMOS devices (including those with epitaxial layers) shall be subject to latchup evaluation. Most bipolar, SOS, SOI and Dielectrically Isolated devices need not be evaluated. All parts shall exhibit no latchup up to LET of 75 MeV-cm^2/mg and a fluence of 10^7 ions/cm^2. The beam angle shall not exceed 60 degrees and test ions shall have a range greater than 35 microns. Bias shall be at specified maximum voltage. Tests shall be performed at room ambient and at elevated temperature of 125°C or the maximum specified operating temperature of the part.

7.4.5 SINGLE EVENT UPSET (SEU)

All microcircuits containing bi-stable elements (e.g. flip-flops, counters, RAMs, microprocessors, etc.) shall be characterized so that an upset rate calculation can be performed. A sufficient number of data points (a minimum of four) shall be taken to determine the curve of device cross section versus LET (to saturation or to an LET of 75 MeV-cm^2/mg, whichever comes first).

The requirements for parts SEU acceptability are:

a) No upsets during SEU testing to above specifications, or
b) Verification of device bit error rate of 10^{-10} per day or better in the galactic cosmic ray environment, or
c) Meets the requirements for the overall subsystem upset rate requirement.

7.4.6 SINGLE EVENT BURNOUT (SEB)

All power transistors operated in the off-mode may be susceptible to, and shall be evaluated for single event gate rupture (SEGR) at the lowest applicable VGS.

The survival voltage (VDS for MOSFETs and VCE for bipolars) shall be established from exposure to a minimum fluence of 10^6 ions/cm^2 of an ion with a minimum LET of 37 MeV-cm^2/mg and with a range greater than 35 microns. The application voltage shall be derated to 75% of the established survival voltage. Test requirements for single event burnout are similar to those for SEGR except that the drain current (or collector current for bipolar transistor) must be measured to determine if burnout occurs. Testing shall be performed with normal beam incidence and at room ambient temperature.

a) Drain voltage rating 100 V ion range 35 µm or more.
b) Drain voltage rating between 100 and 250 V ion range 40 µm or more.
c) Drain voltage rating above 250 V ion range 80 µm or more.

7.4.7 SINGLE EVENT GATE RUPTURE (SEGR)

All power MOSFETs operated in the off-mode may be susceptible to and shall be evaluated for SEGR at the worst case VGS conditions. The survival voltage VDS shall be established from exposure to a minimum fluence of 10^6 ions/cm² of an ion with a minimum LET of 37 MeV/mg/cm^2 and with a range greater than 35 microns. The application voltage shall be derated to 75% of the established survival voltage. Testing shall be performed with normal beam incidence and at room ambient temperature.

a) Drain voltage rating 100 V ion range 35 µm or more.
b) Drain voltage rating between 100 and 250 V ion range 40 µm or more.
c) Drain voltage rating above 250 V ion range 80 µm or more.

7.4.8 Single Event Transient (SET)

All linears, mixed-signal devices, optocouplers, and GaAs devices shall be evaluated for susceptibility to SETs.

7.5 Non-Standard Parts Approval

Any electronic parts that do not meet the definition of Standard Part, as defined above, are considered non-standard parts. Design organizations intending to use non-standard parts must submit a Non-Standard Parts Approval Request (NSPAR). Non-standard parts may only be used if the NSPAR is approved by JPL.

7.6 Parts List Reviews

All electronic parts lists shall be submitted to JPL in an electronic format. Parts lists provided by JPL hardware developers, contractors, and suppliers shall be submitted for review and approval. It is recommended that an initial parts list be submitted as soon as available. JPL hardware developers, contractors, and suppliers shall provide preliminary parts lists 1 month prior to the subsystem preliminary design review (PDR). Revisions to preliminary parts list are (TBD) whenever updates are entered. Deltas to the previously submitted parts list should be highlighted. JPL hardware developers, contractors, and suppliers shall provide as-designed parts lists 1 month prior to the subsystem critical design review.

7.7 Parts Acquisition

7.7.1 HERITAGE PARTS

Residual inventory (i.e., heritage parts), in this context, refers to parts previously approved and procured for prior flight Project applications. Residual electronic parts will be reviewed and subsequently be employed by MIRI hardware developers after it is determined that the parts meet the requirements of this document.

7.7.2 PARTS PROCUREMENT

Purchase orders shall not take exception to reference specifications or requirements therein unless approved by the JPL MIRI Electronics Parts Engineer (EPE) or via waiver. All parts suppliers shall be on JPL's ASL.

7.7.3 CUSTOMER SOURCE INSPECTION

Pre-seal visual inspection shall be performed on all packaged flight ASICs, hybrid microcircuits, Multi-chip Modules, crystal oscillators, and nonstandard relays. Source inspection/pre-cap inspections will be coordinated with the JPL PQA group.

7.7.4 RADIATION LOT ACCEPTANCE TESTING (RLAT)

Device types that are known or shown to be marginal by a TID characterization test or analysis, if still requested for use in flight equipment, shall be subjected to RLAT. The RLAT specifications and requirements shall be reviewed and approved by the Project cognizant engineer(s), JPL's EPE and Parts Radiation Specialist, prior to start of testing. Radiation related TID testing and evaluations shall be done in accordance with MIL-STD-883, Method 1019.4, or per recommended test methodology found in JPL D-18002, Radiation Test Requirements for Ionization and Displacement Damage, or JPL-approved contractor equivalent. Other radiation related testing, if required, shall be performed as described in Radiation Effects Requirements of this section. All CMOS devices shall be subjected to RLAT for SEL per the SEL requirements of this section, unless there is evidence of lot specific test data, manufacturer's certification and/or the wafers were produced at foundries with QML or process controlled lines.

7.7.5 DESTRUCTIVE PHYSICAL ANALYSIS (DPA)

Grade-2/Class-B (Level 2) packaged electronic parts require DPA per SSQ25000. DPAs shall also be performed on a sample of each manufacturing lot date code for all crystal oscillators, filters, ceramic capacitors (except MIL-C-123), relays, MIL-C-39010 inductors, and all nonstandard packaged parts (including multi-chip modules and hybrids), regardless of procurement to Grade-1/Class S/Class K (Level 1) levels. MIL-C-39010 inductors/transformers shall be sectioned to examine the adequacy of the termination. Relays shall have an internal visual examination. Chip capacitors and resistor networks require a DPA. The results of the DPA shall be evaluated by the procuring activity, and the lot shall be accepted or rejected based on the criteria of the specification.

7.8 Electronic Parts Application

7.8.1 PARTS DERATING

Refer to D–8545 'JPL Derating Guidelines'

7.8.2 ELECTROSTATIC DISCHARGE (ESD) CONTROL

ESD damage or degradation may occur in static-sensitive electronic parts during handling of the parts from procurement through incoming inspection, testing, screening, storing and final assembly/test.
To protect static-sensitive parts from ESD, handling of parts shall be controlled by the requirements of JPL D-1348 “JPL Standard for Electrostatic Discharge Control”, or JPL approved contractor equivalent.

7.8.3 (GIDEP) ALERTS

All hardware-delivering design agencies, both internal and external to JPL, are responsible for reviewing NASA and Government Industry Data Exchange Program (GIDEP) Alerts, and for immediately reporting corrective action for applicable Alerts (i.e. for parts, materials, etc. used in the hardware) to the project. Because of the significance of the alert system, it is important that the review process be carried throughout all phases of the project.

The JPL EPE will compare all Alerts versus all parts lists to determine if any parts identified in a specific Alert are employed in MIRI hardware. The MAM will be immediately notified when any MIRI parts are identified in an Alert. The MAM shall present a report at the CDR, and another at the Pre-Ship Review, that lists Alerts that are pertinent to the parts/materials used in the flight design and, the possible impact should the part fail.

Incidents occurring at JPL or at MIRI contractors/partners that constitute a GIDEP report will be submitted through the JPL GIDEP Point of Contact (POC). The MIRI Project, via the CM, shall inform all contractors/partners of the incident. MIRI contractors/partners may submit reports directly to GIDEP or to GIDEP via JPL. MIRI contractors/partners will notify JPL whenever they submit a report directly to GIDEP.

7.8.4 PARTS FAILURE ANALYSIS

Failure analysis is required for all part failures that occur subsequent to part-level screening. The only exception to this is for parts that are damaged by human error (e.g., improper installation). Analysis shall be carried to the point that lot dependency of the failure mode can be determined. Failure Analysis reports shall be written to document the analysis approach, the determined failure mode and mechanism (i.e., cause) responsible for the failure, and the corrective actions required to prevent recurrence of the failure. If a lot dependency is found, the JPL Mission Assurance Manager (MAM) will disposition the assemblies using the suspect lot.

7.8.5 AS-BUILT PARTS LIST

An As-Built Parts List shall be released prior to hardware integration and test. In addition to the information required in the Preliminary Parts Lists, the As-Built Parts List shall include for each different part:

- the actual part marking,
- part number purchased,
- manufacturer,
- lot date code,

- serial number (for serialized parts),
- wafer and wafer lot numbers (when applicable),
- parts test lot numbers (where applicable),
- procurement specification number,
- traceability number (when assigned by the cognizant parts organization),
- the serial number and part number of the next assembly level into which the part is installed (e.g., board or module), and
- the reference designator of the location where each part is used on the next assembly level.

The as-built parts list shall be supplied to the EPE in a computer-readable format. The EPE will ensure that all as-built parts lists will remain accessible throughout the duration of flight operations.

8.0 MATERIALS SELECTION

8.1 Purpose

The purpose of this section is to define the Materials and Processes (M&P) control program to ensure proper selection and utilization of materials and processes to meet the MIRI Project functional, reliability, and safety requirements. The program described in this section is consistent with JPL D-560, “JPL Standard for System Safety” as well as JPL Flight Project Practices FPP).

8.2 Applicability

All materials and processes used in the fabrication of flight hardware, except electronic parts (e.g. capacitors, transistors, diodes, CCD's, etc.), are covered by this document. All requirements contained in this document shall apply to JPL and its contractors and their subcontractors and shall be identified in the appropriate contractual documentation. Contractors and their Subcontractors have the option of using their own materials and processes control documents, but prior JPL approval of such documents is required. All suppliers to JPL will be on JPL’s ASL. All suppliers to subtier contractors or partners shall make their suppliers list available to JPL PQA which includes the criteria used to place them on that list.

8.3 Applicable Documents

In case of conflict between a referenced document and this MAP Materials Section, the JPL MIRI M&P Engineer shall be contacted for resolution.

8.4 Organization and Responsibilities

8.4.1 APPROACH

The M&P Engineer shall review material applications based on safety, functionality and reliability requirements for both JPL and subcontractor built hardware. Hardware Cognizant Engineers or their designee shall review material selections and concerns with the MIRI M&P Engineer as early in the design phase as practicable.

A Materials Identification and Usage List (MIUL), identifying all materials and processes used in the fabrication of all flight hardware subsystems shall be prepared by the JPL hardware cognizant engineers or sub-contractors and submitted to the MIRI M&P Engineer for review and approval. The MIUL Forms are shown in Appendix E and consist of 3 sections: Non Metallic Materials; Metallic Materials; and Processes. MIULs shall also be prepared for any Ground GSE that is in contact with a hazardous material (see 8.5.9.10). The MIULs shall be prepared prior to a subsystem Preliminary Design Review (PDR) and updated before Critical Design Review (CDR). The MIRI M&P Engineer shall provide a written approval/disapproval for all MIULs. Any open or unresolved issues are to be discussed at the CDR.

MIULs will be the primary means for the JPL MIRI M&P Engineer to monitor material usage, identify non-flight qualified materials, and verify compliance with the requirements of this document. The MIRI M&P Engineer shall maintain the approved Materials Identification and Usage Lists and provide copies as requested by MIRI Project personnel.

8.4.2 RESPONSIBILITIES

8.4.2.1 MIRI Subsystem Project Element Manager

The MIRI Subsystem Project Element Managers shall satisfy the requirements of this document, either through actions within JPL or by assignment to subcontractors or suppliers. The Subsystem Project Element Managers shall ensure timely submittal of design information to the MIRI M&P Engineer by the Hardware Cognizant Engineers.

8.4.2.2 The JPL MIRI M&P Engineer shall:

a) Be the point-of-contact for Flight Materials and Processes Engineering for the MIRI Project. The MIRI M&P Engineer will be sensitive to cost, schedule and materials availability.
b) Advise all hardware Cognizant Engineers in material selections to meet the functionality, reliability, safety, and radiation requirements.
c) Review and sign all JPL mechanical hardware drawings for the MIRI project.
d) Review MIRI hardware for compliance with the requirements contained herein. Provide the MIRI Project with notification where concerns exist regarding functionality or reliability.
e) Review MIUL lists for all MIRI hardware including all contractor submittals for compliance with the requirements contained in this document. The JPL MIRI M&P Engineer will provide written approval of the MIULs.
f) Provide separate written approval when a material is required but does not meet applicable requirements through the use of Material Usage Agreements (MUAs).
g) Provide risk assessment and approve waiver requests when MUA approval is not granted and the use of materials and processes in question is still desired.
h) Provide support to Subsystem PDRs, Peer Reviews and CDR, as required.
i) Provide input to disposition Inspection Reports (IRs) and approve Engineering Change Requests, as required.
j) Develop material and process specifications and test plans, as required.
k) Work closely with Quality Assurance Engineer and the Contamination Control Engineer during every phase of the project to ensure all requirements are met.
l) Review sub-contract procurement documents as required.

8.4.2.3 The MIRI Hardware Cognizant Engineers shall:

a) Work concurrently with the JPL MIRI M&P Engineer as early in the design phase as possible.
b) Prepare the MIUL, which identifies all materials and processes for the designed flight hardware prior to subsystem or subassembly PDR. The MIUL shall again be updated prior to subsystem or assembly CDR.
c) Identify any changes in materials or processes over those called out in existing drawings or lists.

8.5 Materials Requirements

8.5.1 INTRODUCTION

This section establishes the requirements for the selection and application of materials and processes for the design of MIRI flight hardware. Specific requirements are described in the subsequent sections. All the requirements contained in this Document shall apply to both JPL and its Contractors, and shall be identified in appropriate contractual documentation.

8.5.2 SELECTION OF MATERIALS AND PROCESSES

All materials and processes shall be qualified for the application in which they are used. Prior space flight history and/or appropriate test data may qualify materials or processes. Issues of flight qualification are very application specific and shall be reviewed by the MIRI M&P Engineer on a case-by-case basis. In the event that the designer does not have appropriate data to indicate the suitability of a material or process, a qualification/ evaluation test plan shall be generated. The MIRI M&P Engineer shall approve the qualification/evaluation test plan.

8.5.3 STANDARD MATERIALS AND PROCESSES SELECTION SOURCES

JPL Document STD-00009 and MSFC-HDBK-527/JSC 09604 are the preferred sources for general material selection. The listing of a material in JPL-STD-00009 or MSFC-HDBK-527/JSC-09604 does not assume blanket approval for all applications. The use of a listed material or process may be additionally restricted due to unique MIRI mission requirements. For example, restrictions due to molecular or particulate contamination, radiation susceptibility, electrostatic discharge, electromagnetic interference and other environmental or operation driven requirements. The particular application shall be reviewed and approved by the MIRI M&P Engineer.

8.5.4 SUBMITTAL OF MATERIAL IDENTIFICATION AND USAGE LISTS

A Material Identification and Usage List (MIUL), which identifies all materials, processes, fasteners, mechanical parts, special parts, packaging and cabling, shall be submitted by each JPL design agency.

Each MIUL shall contain the information described in the forms, shown in Appendix E. These forms, or JPL approved equivalent contractor forms, shall be filled out where applicable, and submitted for review and approval by the JPL MIRI M&P Engineer. Preliminary MIULs should be submitted as soon as practicable in the design and engineer process and in accordance with contractual requirements. Submittal of MIULs should occur one month prior to the Preliminary Design Review, unless an alternative due date has been approved, and one month prior to the Critical Design Review. Any open or unresolved issues are to be discussed at the CDR. In the case of design changes which alter material or process selection, the design agency shall submit the changes to the JPL MIRI M&P Engineer for approval.

8.5.5 CLASSIFICATION OF MIUL SUBMITTALS

The MIRI M&P Engineer shall classify the submittals according to the following criteria. The classification given to a material or process shall be based on the acceptability of the material or process, application and controlling documentation.

Class 1 – Acceptable

The identified design item combination (material/condition or cure) including specified manufacturer is acceptable when used in the indicated application and under the control of the listed documentation, and the evaluation/qualification data and applicable documents are available and are all acceptable.

Class 2 – Qualified Acceptable

The identified design item combination (material/condition or cure) including manufacturer is considered qualified acceptable when used in the indicated application, quantity and under the control of the listed documentation, even though only limited evaluation/qualification data are available. No further effect is considered warranted to improve the classification.

Class 3 – Provisional

This is a temporary classification for a design item combination (material/condition or cure) where the evaluation/qualification data or applicable documentation is available, but where a decision as to its acceptability has not yet been made. Eventual Class 1 or Class 2 assignment is anticipated and design may proceed subject to final reclassification, although the reclassification as Class 4 is not excluded. Most Class 3 combinations should be reviewed for reclassification 1, 2 or 4 prior to PDR of each system. All remaining Class 3 combinations shall be reclassified prior to each subsystem's CDR.

Class 4 – Unacceptable

One or more elements of the design item combination (material/condition or cure) are considered unacceptable for the indicated application. The Project Manager or his designee prior to or at the CDR shall review all Class 4 design item combinations. The use of a Class 4 design item requires a project approved waiver.

8.5.6 MATERIALS USAGE AGREEMENTS

Material Usage Agreement (MUA) forms (shown in Appendix F) shall be prepared by all Cognizant Engineers for applications of materials or processes that do not meet the requirements specified in paragraphs 8.5.9 through 8.5.9.13.

For JPL designed hardware, MUAs shall be submitted to the JPL MIRI M&P Engineer for approval. For non-JPL designed hardware, MUAs shall be prepared for review and approval by the contractor M&P Engineer. All contractor approved MUAs shall then be submitted to the JPL MIRI M&P Engineer for final approval.

8.5.7 WAIVERS

For design items which have been rated Class 4, Unacceptable, waiver requests shall be submitted. The submittal of a waiver is applicable to both JPL and contractor supplied subsystems. The JPL MIRI M&P Engineer shall then provide a risk assessment, following discussion with the MIRI Hardware Cognizant Engineer, Mission Assurance Manager and Subsystem Project Element Manager.

8.5.8 REVIEW OF MATERIALS AND PROCESSES

A JPL or contractor Materials and Processes Specialist shall review the use of all materials and processes based on engineering drawings prior to approval. A JPL M&P Engineer sign off on JPL mechanical drawings is required. For contractor supplied subsystems, a completed Materials Identification and Usage List (MIUL) shall be submitted for review by the JPL MIRI M&P Engineer.

A JPL or contractor M&P Engineer should review and consult with all subcontractors and vendors as early in the design phase as possible to assure that their materials and processes are acceptable for their intended applications.

8.5.9 EVALUATION OF MATERIALS AND PROCESSES

Materials and Processes shall be assessed by the combined consideration of three factors:

a) Material and Process type, including manufacturer.
b) Specific design, application or requirement.
c) Documented control provisions.

Criteria, according to which, material selections shall be reviewed, include but are not necessarily limited to the following: effects of ultraviolet and charged particle, radiation, resistance to debris and micrometeoroid impact, potential for surface charging, stress corrosion cracking, galvanic corrosion, hydrogen embrittlement, lubrication, contamination of cooled detectors, potential for molecular and particulate contamination, hazardous fluid compatibility, and weld heat-affected areas as applicable. A fracture control analysis of mission critical high strength fasteners and pressurized systems shall be performed prior to acceptance for use.

8.5.9.1 Vacuum Stability and Outgassing

Materials used in the design and fabrication of MIRI hardware shall not degrade in a vacuum environment. Materials shall meet the requirements of JSC SP-R-0022A, Total Mass Loss (TML) less than 1% and Volatile Condensable Mass (VCM) less than 0.1% when tested per JPL TS507035 or ASTM E595.

The Vacuum Stability requirement near contamination sensitive surfaces may be more stringent. In this case, the requirements shall be called out in the Contamination Control Section of the MIRI Mission Assurance Plan. Outgassing data or ratings can be found in JPL STD-00009, MSFC-HDBK-527/JSC-09604 and NASA RP-1124.

8.5.9.2 Flammability

Materials shall be noncombustible or self-extinguishing to the greatest extent possible and conform to the flammability requirements of NASA-STD-6001. Rationale for the use of and acceptability of flammable materials in amounts over 454 gm (1 lb.) or 30.5 cm (12 in.) shall be submitted in a MUA. Where flammable materials must be used, the standard hazard elimination and control requirements apply, as follows:

a) Two failure tolerance on ignition sources.
b) Physical separation of the flammable material from ignition sources.
c) Elimination of flame propagation paths.

8.5.9.3 Corrosion

In applications where dissimilar metals will be in intimate contact, the metals shall be compatible with regard to galvanic corrosion to the greatest extend possible. Methods to minimize the potential for corrosion shall be implemented. MIL-STD-889 shall be used as a guideline for controlling dissimilar metal contacts.

8.5.9.4 Stress Corrosion Cracking

Hardware shall be fabricated from materials which have high or moderated resistance to Stress Corrosion Cracking (SCC), either rated A or B in MSFC-HDBK-527/JSC-09604, or listed in Tables I or II of MSFC-STD-3029. Use of materials that have low resistance to SCC, either rated C or listed in Table III, or have not been tested shall be documented in a MUA and a Stress Corrosion Evaluation form, shown in Appendix G.

Materials that have low resistance to SCC should be considered for use only in applications where it can be demonstrated conclusively that the probability of stress corrosion is remote. When evaluating the possibility of SCC, all sources of stress must be considered; design, assembly and process residual stresses.

8.5.9.5 Welding

All welding operators using either automatic, semi-automatic, or manual welding shall be qualified in accordance with AMS-STD-1595 or a qualification procedure approved by the JPL MIRI M&P Engineer. Weld rod or wire used as a filler metal on structural parts shall be fully certified and documented for composition, type, heat number, manufacturer, and supplied with positive traceability to the end use item. All fracture critical welds shall be non-destructively inspected per the requirements of NASA-STD-5003.

8.5.9.6 Non-Destructive Inspection

Nondestructive evaluation (NDE) shall be conducted on highly stressed and mission or safety critical items. Nondestructive inspection (NDI) techniques shall meet the requirements of MIL-HDBK-6870 or contractor equivalent for magnetic particle, radiographic, eddy current, and ultrasonic inspection. Liquid penetrant inspection shall meet the requirements of ASTM E1417 or contractor equivalent.

Liquid penetrant inspection shall be performed prior to surface finishing, where applicable. Prior to penetrant examination, all surface coatings shall be removed from the area to be examined. Etching of 0.0002 inch to 0.0004 inch (0.005 mm to 0.010 mm) of the surface to be examined shall be performed per ASTM E1417 or contractor equivalent. If a different depth is used, justification shall be provided to the JPL MIRI M&P Engineer for approval. Application, removal, and quality of penetrant and developers shall meet the requirements of ASTM E1417 or contractor equivalent. Specifications shall be reviewed and approved by the JPL MIRI M&P Engineer.

8.5.9.7 Shelf-Life Limited Life Materials

All polymeric materials whose uncured constituents have a limited shelf life shall be used before the expiration date. All materials with shelf-life sensitivity, such as polymeric "O" rings, tapes, thermal control coatings and other polymerics, shall be used (installed) within their life limits.

Expired date-coded materials may only be used if demonstrated by appropriate tests and re-certified that the properties of the materials have not been compromised for the intended use. Extending the shelf life of a material shall require the prior approval of the JPL MIRI M&P Engineer.

8.5.9.8 Radiation Resistance

Materials used for MIRI flight hardware shall be able to withstand the radiation environment specified in the JWST IRD. In applications where the estimated radiation dosage exceeds the material’s threshold dose or is greater than the available test data, shielding shall be used.

In assessing the materials for space environmental resistance, vacuum UV, gamma, electron and proton radiation shall be considered. In cases where there is no available data, testing requirements shall be approved by the JPL MIRI M&P Engineer.

8.5.9.9 Electrical Arc-Tracking Resistance

Electrical wire insulation, wire accessories and materials in contact with electrical circuitry shall not be capable of arc-tracking due to electrical discharges. The use of materials that are susceptible to arc-tracking shall be documented in a MUA.

8.5.9.10 Hazardous Materials

All materials that are exposed to toxic or hazardous fluids shall be evaluated for compatibility with that fluid in their intended application. A hazardous fluid is any fluid that could chemically or physically degrade the system.

All materials that are exposed to a hazardous fluid shall be rated compatible per MSFC-HDBK-527/JCS-09604. Materials rated “A” are acceptable while those rated “B” shall be batch tested. Existing data showing compatibility may be used if it is approved by JPL MIRI M&P Engineer.

8.5.9.11 Magnetic Materials

The use of magnetic materials shall be limited, as necessary, to meet spacecraft or instrument magnetic requirements.

8.5.9.12 Static Charge Sensitivity

Materials shall be evaluated to determine if their ESD characteristics are compatible with Project requirements.

8.5.9.13 Prohibited Materials

The use of pure tin, zinc, cadmium, and mercury as either a plating or monolithic metal is prohibited. Pure tin can undergo a dendritic growth process that will result in the formation of tin "whiskers" which can result in electrical shorts of electronic components. Due to their high vapor pressures, zinc, cadmium, and mercury can vacuum metallize when exposed to a space environment, resulting in a contamination concern.

8.6 Design Allowables for Structural Parts

Statistically based material design allowables shall be used for structural analysis of MIRI hardware to the greatest extend possible. Statistically based material property data is contained in MIL-HDBK-5 or MIL-HDBK-17. Any other source of material strength or mechanics data (e.g. data sheets, handbooks, etc.) used for structural analysis shall be approved by the JPL MIRI M&P Engineer.

“A” basis materials allowables shall be used for structures where failure of a single load path would result in loss of structural integrity. For redundant structures where failure of a structural element would result in a safe redistribution of applied loads to other load-carrying members, “B” basis materials allowables may be used. Where statistical values for mechanical properties of new or existing materials are not available, they shall be determined by analytical methods described in MIL-HDBK-5. The above stated rule applies for using such derived property values. Specification allowables (“S” allowables) may be used for materials in lieu of “A” and “B” allowables where lot-to-lot testing is a specification requirement.

8.7 Fasteners

Fasteners used in the MIRI project shall be selected based on the criteria contained in SPI-4-11-8. Fasteners shall be selected from the JPL Preferred Fastener List (PFL) to the greatest extent possible. Where fasteners are used in critical applications, FS 511316 "Detail Specifications for Qualification of Critical Fasteners" shall be followed. The JPL fastener specialist shall sign-off on all JPL drawings.

8.7.1 MATERIALS

Externally threaded fasteners shall be fabricated from materials which have high or resistance to Stress Corrosion Cracking (SCC) listed in Table I of MSFC-STD-3029. Use of materials which have moderate or low resistance to SCC listed in Table II or Table III of MSFC-STD-3029 are not acceptable for use as fasteners.

The preferred material for structural fasteners is corrosion and heat resistant steel, A286. Also acceptable are, Ti-6Al-4V, MP35N and Inconel 718. For non-structural externally threaded fasteners, austenetic 300 series corrosion resistance steel is also acceptable.

8.7.2 MATERIALS FOR FRACTURE CRITICAL FASTENERS

Fracture critical fasteners shall not be fabricated from materials, which have low fracture toughness. A material is considered to have low fracture toughness if the value of K_{IC}/F_{ty} is less than 1.66 $mm^{1/2}$ (0.33 $in^{1/2}$). The preferred material is A286. Also acceptable are Inconel 718 and MP35N. Fracture critical fasteners shall not be fabricated from Ti-6Al-4V.

8.7.3 TRACEABILITY

All externally threaded fasteners used for flight applications must be certified. Fasteners used in structural applications must have critical certification as described in SPI-4-11-8. Fasteners used in non-structural applications must have, as a minimum, a certificate of conformance.

Critical certification requires documentation of chemical and physical test results traceable to both heat and lot numbers. JPL maintains a list of qualified vendors for threaded fasteners. These vendors have been audited to insure that they have procedures in place to maintain traceability of their product.

8.8 Lubricants

It shall be the responsibility of each organization, JPL and contractors, providing flight hardware that incorporates lubricants to prevent contamination of that hardware and critical adjacent hardware, i.e., mirrors, lenses, other experiments, etc., by outgassing of the lubricant or by lubricant creep or the natural wetting and wicking tendencies of the lubricants. This contamination prevention can be accomplished by the use of hermetic or labyrinth seals, directed overboard vent lines, the overall design of the hardware, etc., and by the choice of lubricants.

Graphite or lubricants with significant amounts of graphite are abrasive in vacuum and shall not be used for flight hardware.

8.9 Material Traceability

Traceability of all materials incorporated into flight hardware shall be maintained. Records of material manufacturer, date of manufacture, batch and lot identification numbers, applicable materials and process specifications, expiration date, and purchase order numbers shall be recorded.

For the acceptance and traceability of flight bulk materials, including materials received on spools, in bottles, cans or kits, Quality Assurance Procedure QAP 44.10, Receiving Inspection and Identification of Flight Bulk Materials, shall be followed.

8.10 Alerts

All hardware-delivering design agencies, both internal and external to JPL, are responsible for reviewing NASA and Government Industry Data Exchange Program (GIDEP) Alerts, and for immediately reporting corrective action for applicable Alerts (i.e. for parts, materials, etc. used in the hardware) to the project. Because of the significance of the alert system, it is important that the review process be carried throughout all phases of the project.

The JPL M&P Engineer will compare all Alerts versus all parts lists to determine if any parts identified in a specific Alert are employed in MIRI hardware. The MAM will be immediately notified when any MIRI parts are identified in an Alert. The MAM shall present a report at the CDR, and another at the Pre-Ship Review, that lists Alerts that are pertinent to the parts/materials used in the flight design and, the possible impact should the part fail.

Incidents occurring at JPL or at MIRI contractors/partners that constitute a GIDEP report will be submitted through the JPL GIDEP Point of Contact (POC). The MIRI Project, via the CM, shall inform all contractors/partners of the incident. MIRI contractors/partners may submit reports directly to GIDEP or to GIDEP via JPL. MIRI contractors/partners will notify JPL whenever they submit a report directly to GIDEP.

9.0 HARDWARE QUALITY ASSURANCE PROGRAM

9.1 Introduction

The intent of this plan is to implement an efficient, cost effective hardware quality assurance (QA) program that assists in identifying, preventing, reporting on, and resolving specific issues that may represent potential risks to mission success.

This plan covers three specific areas for the MIRI: the policies and procedures required in the JPL Product Delivery System (PDS); the processes and resources needed to achieve the desired result; and the verification activities and criteria required for acceptability.

9.2 Scope

This plan defines the detailed QA requirements and activities to be implemented during the formulation, design, build, assembly and test phases of the MIRI. It includes only those quality system requirements required by the customer, and/or by the nature of the product, necessary to produce a conforming product. It encompasses all project flight, non-flight, test and ground support hardware and software. Provisions of this plan are applicable to all participating JPL Technical Divisions, as well as JPL's domestic partners. Specific guidance for individual contractors and suppliers shall be determined jointly by engineering, procurement and QA representatives, and shall be documented in accordance with JPL's product delivery system requirements.

9.3 Management Responsibility

9.3.1 JPL PRODUCT DELIVERY SYSTEM

JPL's quality system is currently certified to the requirements of ISO 9001 "Model for QA in Design/Development, Production Installation". The policies, procedures, and processes necessary to ensure that the MIRI products conform to customer requirements are listed in JPL rules (http://rules).

9.3.2 INTERNAL COMMUNICATION

The JPL QA Organization, will provide periodic program status reporting to MIRI Project Management. The QA organization and the MIRI Project Management will determine the frequency of reporting. Reporting responsibilities will include:

a) Risk assessments.
b) Process performance/metrics and product conformance analyses
c) Status of preventive and corrective actions.
d) Results of audits.
e) Trip/activity Reports.
f) Contractor performance and status reports.
g) QA Open Items List.
h) Significant Events.
i) Customer feedback.
j) Lessons learned.

9.4 JPL Quality Assurance Organization

JPL QA is the responsibility of the Office of Quality Assurance, Office 512. The Section Manager reports directly to the Director for the Office of Safety and Mission Success Directorate (OSMS). A lead hardware Program QA Representative (QAR) shall support the MIRI Project in the implementation of this plan. The QAR reports administratively to the JPL Office of QA.

The primary responsibility of the QAR is to ensure the products produced by MIRI that are intended for design qualification, flight and critical ground support equipment usage meet the required levels of quality and functionality for their intended purposes. The QAR shall be delegated the authority and responsibility to accomplish the following:

a) Participate in proposal, financial forecasting and financial status activities.
b) Establish and implement quality assurance requirements.
c) Perform internal, partner, and supplier technical risk assessment, process assessment and product evaluation
d) Assist the MIRI Project in tailoring the hardware development processes.
e) Review and/or approve technical documents related to hardware; including drawings, equipment specifications, software system requirements, assembly procedures, test procedures, and payload integration procedures.
f) Oversee and assess critical supplier operations.
g) Assist in metrics definition and assure that the development team is following the defined processes.
h) Assure the identification, implementation, and verification of safety-critical components are performed.
i) Document and communicate quality status and problems and recommend preventative and corrective action.

9.5 Training and Certification

Individuals working on flight hardware shall be trained and certified to the requirements of D-8208 or the equivalent supplier document. Training records shall be maintained by all contractor organizations and provided on request by the QAR.

9.6 Information

The QAR shall define, monitor, collect, analyze and report to the MIRI Project the information necessary for the control of processes to ensure conformity of products. Metrics that characterize the program with respect to trends observed over time allow for both predictive behavior and continuous improvement efforts. The selection and definition of appropriate value added metrics will be a joint MAM and QA activity.

9.7 General Requirements

The Assembly and Inspection Data Sheet (AIDS), Form 2916 and 2916-1, shall be utilized for hardware fabrication, assembly, integration and testing performed onsite at JPL. The AIDS Form 2916 is presented in Appendix H. The AIDS, or equivalent planning, will provide clear and concise instructions defining specific assembly instructions, inspection points, inspection criteria and special techniques.

The AIDS, or equivalent, will be reviewed, approved and signed prior to the beginning of operations defined in the text. Flight hardware/software at JPL must be accompanied by the appropriate documentation at all times.

Workmanship standards on MIRI Flight Hardware shall meet or exceed the requirements of D-8208 or contractor equivalent.

9.8 Design and Development Review

QA shall participate in the following reviews, as appropriate:

a) Peer Reviews.
b) Preliminary Design Reviews.
c) Critical Design Reviews.
d) Design, Implementation and Cost Reviews.
e) Inheritance Reviews.
f) Readiness Reviews (Manufacturing, Pre-environmental, Test, etc.).
g) Pre-Shipment Acceptance Reviews.
h) Contractor End Item Data Package Reviews.
i) Hardware Certification Reviews.

The QAR performs risk assessment reviews early in the pre-formulation phase, during the design process, and throughout the project/program life cycle to ensure that hardware process/development issues are evaluated relative to end-user goals. The QAR shall analyze designs for completeness and correctness in addressing mission critical and interface requirements. Special attention is paid to verifying requirement traceability and monitoring performance constraints.

In addition, the QAR interfaces with applications engineering activities funded under hardware assurance applied-research accounts and provides information and feedback on relevant new developments and techniques to the MIRI personnel.

9.9 Design and Development Verification

QA support of hardware engineering models shall be on an as-requested basis. In general, quality involvement with engineering model hardware is limited to inspection for workmanship and safety, and verification of hardware and test set-up configuration. Engineering models which are later used for protoflight or flight purposes shall require additional quality review, as determined by the MAM and Section 512 quality personnel.

9.10 Design and Development Validation

QA shall participate in all MIRI test activities performed to confirm that deliverable product is capable of meeting specific customer end-item requirements. In particular, the QAR shall monitor all Protoflight and Flight Acceptance assembly, subsystem and system level environmental and acceptance tests.

9.11 Ground Support Equipment

QA involvement in GSE shall be limited to the level necessary to assure:

a) Flight Hardware interfaces, mechanical and/or electrical are compliant to requirements.
b) Current calibration of Electrical GSE.
c) Current proof-load of Mechanical GSE.
d) Cleanliness and contamination control requirements are compliant.
e) Proper and legible identification of the product.
f) Safety requirements are satisfied and potential hazards are identified and mitigated.
g) Safe to Mate procedures are followed for first power up of flight hardware.

9.12 Control of Changes

QA shall participate in the control of changes by:

a) Review drawing changes after drawings are initially released.
b) Ensure that master red-line drawing sets are maintained when necessary.
c) Verifying all approved changes are properly incorporated/implemented.
d) Verifying product as-built configuration.

Documents pre-released or not released will be written-up on an Inspection Report (IR). The IR is shown in Appendix I. Redlined drawings and other documentation shall be handled in accordance with the MIRI Configuration Management Plan, JPL D-25633 and the JPL institutional procedure for redlining, found in JPL Rules; or supplier equivalent.

9.13 Procurement Activities

Contracts, purchase orders and off-lab fabrication work orders will be coordinated with technical and QA personnel to ensure incorporation of applicable quality and technical requirements. The MIRI QAR shall support the CogEs during the implementation of the procurement phase in the following areas:

a) Review procurement documentation, including Requests For Proposals (RFP's), Statements-Of-Work (SOW's), Procurement Requisitions and Equipment Specifications to ensure appropriate quality provisions and clauses are defined, including Contractor End- Item-Data-Package requirements.

b) Provide the Cognizant Engineer or Contract Technical Manager with pertinent information about the supplier by researching the QA Documentation Center Vendor Survey Database.

c) Perform Vendor Surveys at potential suppliers, as required.

d) Interpret and clarify quality activities that are anticipated in support of the Contract Negotiator, to include review of supplier QA plans, as applicable.

e) Participate in vendor Fabrication/Manufacturing Readiness Reviews.

Contractors or suppliers providing engineering model, flight, and GSE hardware for use on MIRI shall have a QA program or activity that meets one of the following:

a) ISO 9001/2000 Quality Management Systems-Requirements.
b) ISO 9004 Quality Management Systems-Guidelines for performance improvements.
c) SAE AS9100 Quality Systems-Aerospace-Model for Quality Assurance in Design, Development, Production, Installation and Servicing.
d) Any documented 'Supplier Quality System' that meets the intent of any of the above systems. (the supplier is required to provide a GAP analysis of their system to one of the above systems and obtain approval from JPL PQA)

The contractors existing documents and controls will be used to the greatest extent practicable for MIRI.

MIRI contractors, partners and suppliers of raw materials that are to be used for flight hardware shall be required to furnish certifications indicating the materials are compliant to procurement documentation requirements in accordance to QC-06N. Reports of tests indicating chemical and physical characteristics of the materials are required when requested by the cognizant hardware engineer or the quality engineer, and will be included as required deliverable documentation on the purchase order. When necessary, QA has the authority to request independent tests to be performed on test samples taken from the same lot of material.

9.14 Verification of Purchased Product

JPL Quality Engineering shall monitor procurements at contractor's facilities. Their activities shall include, but not be limited to:

a) Providing insight/oversight (as applicable), monitoring and auditing of contractor quality assurance activities, to include source inspection when necessary, to assure compliance with documented program quality requirements.
b) Participating in contractor's design reviews.
c) Review of manufacturing processes.
d) Participating in the disposition of nonconforming hardware and acting as "NASA/Government Quality Representative" on Contractor Material Review Boards (MRB's).
e) Monitoring specified test operations.
f) Performing final, pre-ship inspections and participating in pre-ship reviews at the Contractor's facility.
g) Verifying accuracy and completeness of end-item-data-packages per purchase order.
h) Generating a Final Inspection Report (JPL Form 1898) signifying acceptance and Certification of Flight Hardware and its data package.
i) Verifying packaging, shipping/handling is appropriate for flight hardware prior to shipment to or from JPL.

Receiving inspections shall be performed to the extent necessary to assure that JPL procured hardware is compliant to specifications. QA responsibilities for receiving inspection include maintaining a system of calibrated equipment capable of measuring mechanical hardware and generating the necessary documentation required by the MIRI Project to certify hardware for flight upon its acceptance.

Additional receiving inspection activities include documenting, segregating and obtaining disposition of non-conforming hardware or material and maintaining a system that provides for continuous assessment of supplier performance.

9.15 Measurement, Analysis and Improvement

9.15.1 MEASUREMENT AND MONITORING OF SYSTEM PERFORMANCE

All hardware intended for flight shall have documented evidence of acceptance by QA. Certification of hardware for flight will be by virtue of a final IR, which will establish the flight pedigree. As a goal, all IRs should be closed-out prior to the Hardware Review and Certification Review (HRCR).

QA shall verify that all hardware is certified by virtue of completion of Hardware Review and Certification Review (HRCR). The JPL HRCR Form 1023 shall be used to verify and document the minimum MIRI requirements have been satisfied.

9.15.2 MEASUREMENT AND MONITORING OF PROCESSES

All processes used in the fabrication of MIRI Flight Hardware will be qualified in accordance with JPL's or the contractor's internal procedures. Qualification of processes shall be performed by the cognizant technical division or contractor organization, and approved by QA.

9.15.3 MEASUREMENT AND MONITORING OF PRODUCT

All hardware or material destined for Qualification: Protoflight, Flight or Flight Spare status shall be subjected to inspections performed at the level necessary to assure:

a) Mechanical and physical dimensions and conditions are compliant to applicable Interface Control Documents.
b) Work-stations and areas in which Flight Hardware will be present meet the required ESD protective measures as defined in D-1348.
c) Hardware traceability requirements are satisfied.
d) Compliance with the Training and Certification requirements specified in D-8208.
e) Evidence of Supplier/Contractor or JPL inspection acceptance has been provided by virtue of a Certificate of Conformance, or equivalent in accordance with JPL QC-02N.
f) Applicable handling, packaging, packing and storage requirements have been attained.
g) Any electrical interfaces and requirements are compliant.
h) Compliance to the requirements for workmanship, fit, form and function.
i) Identification of unacceptable workmanship and processing conditions by documenting any findings on an Inspection Report.

Precap inspections, where practical, should be performed on all hybrid microcircuits, ASICs and nonstandard relays. All Precap or integrated circuit inspections to be performed at JPL will be documented on AIDS.

Inspection status of hardware will be indicated by means of inspection stamps on applicable documentation that accompanies the hardware. Records of JPL stamp assignments will be maintained in the JPL Office of QA organization files.

Post-test hardware inspections will be performed to determine if the condition of the hardware has been adversely affected by being subjected to the specified testing. All changes that may have resulted from the testing will be documented on an IR.

9.16 Control of Nonconformity

A closed-loop system for identifying documenting, controlling and correcting, non-conformances will be implemented on the MIRI Project. When hardware, material or documentation is found to be non-compliant, it shall be identified as a nonconforming article, documented on an IR and segregated from acceptable articles. Non-compliant material will go through a preliminary review to determine if it can be reworked, returned to vendor, scrapped, or referred to the Material Review Board (MRB). At the MRB, each minor nonconformance will be reviewed and dispositioned by the Cognizant Engineer and will require concurrence by QA Engineering. Corrective action will be taken to prevent recurrence of similar discrepancies.

Contractor MRBs shall be convened by the Contractor QA organization. The JPL QA Representative will be a member of the MIRI Contractors' MRB(s). The QAE will obtain concurrence from the appropriate JPL Engineering Cognizant Engineer before signing and approving any Contractor dispositions. All Contractor nonconformance reports will become a part of the hardware's End-ltem-Data-Package.

9.17 Records

QA will maintain records that provide evidence of inspections, tests, as-built, configuration and hardware/software status during all phases of the hardware fabrication, assembly, integration and test process. Records will be clearly identified as MIRI hardware and maintained in a manner that provides accessibility for audit review. These records will become a part of the Unit History Data Package that will be retained to support the MIRI Project review program. The Engineering Data Management Group will be the focal point for compilation of End Item Data Package(s). These records will be archived at a location and for a period of time determined by the MIRI Project.

9.18 End Item Data Package

Hardware fabricated and/or assembled at JPL or procured from a contractor shall have a data package sufficient enough to validate a pedigree as flight worthy and to support a failure investigation, if necessary. Contractor End-ltem-Data-Package and As-Built-Data requirements will be clearly defined in the Purchase Order or Contract SOW.

9.19 Assembly and Test Operations Support

JPL QA will provide the necessary support, as determined by MIRI Management to ensure correct/ safe integration of MIRI deliverables. QA activities may include, but not be limited to

a) Review and certification of transportation vehicles.
b) Post-transportation inspection.
c) Performing and documenting necessary inspections.
d) Verification of completion of all required hardware and software integration testing.
e) Ensure MIRI handling constraints are clearly identified and complied with.
f) Monitoring and ensuring MIRI contamination control procedures are followed.

9.20 Improvement

The QAE shall identify opportunities for quality improvement. Special emphasis shall be placed on integrating QA research and development activities into MIRI designs and processes. In addition, lessons learned shall be reviewed, recorded and communicated throughout the life of the MIRI Project.

10.0 SOFTWARE QUALITY ASSURANCE PROGRAM

The purpose of the MIRI Software Quality Assurance program is to achieve the highest quality-to-cost ratio within the Project's constraints and policies, and to increase the probability of overall mission success. The SQA Engineer performs a series of activities throughout the project life cycle to assure that the S/W development complies with the pre-defined quality processes, and that the S/W product quality will meet the Project requirements.

10.1 Scope

This plan covers the MIRI flight software under development at JPL, JPL subcontractors and suppliers. The software addressed in this plan is for flight software only. The development and quality control of flight software shall be tracked with the requirements of both JPL and the Goddard Mission Assurance Requirements JWST-RQMT-002363 for the MIRI Instrument as well as the MIRI IRD.

10.2 Products and Services

10.2.1 IV & V SELF-ASSESSMENT CRITERIA

The MIRI project shall provide all information as required for the NASA Independent Verification and Validation (IV&V) effort. When requested, the project shall permit electronic access to the required information or furnish soft copies of requested information to NASA IV&V personnel.

10.2.2 PHASE B (PRELIMINARY DESIGN)

a) Generate SQA input to the Mission Assurance Plan.
b) Review Software Management Plan document.
c) Review Software Requirement document.
d) Attend and or support PDR.

10.2.3 PHASE C (DETAILED DESIGN)

a) Review ICD (within the instrument and at interface points only).
b) Review Software architecture and detailed design document.
c) Attend and or support CDR.

10.2.4 PHASE D (IMPLEMENTATION, INTEGRATION AND TEST)

a) Review Test Plans and procedures.
b) Perform verification of requirements traceability to test cases.
c) Track and monitor software PFR closure.

11.0 SYSTEM SAFETY

All MIRI hardware and support equipment shall be designed and operated in a manner to ensure safety of both personnel and equipment during all phases of fabrication, test and operations. This is to be accomplished to the maximum degree practical by assuring that the hardware design has the appropriate safety characteristics.

The MAM will ensure that system safety is addressed at each formal review.

11.1 Purpose

This section establishes the safety requirements for JPL MIRI Payload activities at JPL. This plan provides a management approach for assuring safety, which is compliant with JPL Standard for System Safety, JPL-D-560 and serves the JPL MIRI Payload safety needs of the systems integrator.

11.2 Objectives

This section shall apply to JPL activities in which MIRI is involved to assure safety consistency with mission requirements. Hazards associated with MIRI shall be identified, evaluated, and eliminated or controlled within acceptable levels. Identified hazards will be documented in hazard reports. The reports will provide hazard evaluations and document how the hazards are eliminated or controlled. The hazard reports will serve as the primary conduit JPL payload safety information to the systems integrator.

11.3 Responsibilities

JPL, JPL subcontractors, and suppliers, MIRI developers shall identify and resolve potential personnel and systems hazards. EC MIRI developers shall identify and resolve systems hazards using the methodologies provided in European Space Agency document ECSS-Q-40A (19 April 1996), "Space Product Assurance - Safety". The JPL Systems Safety Engineer will collaborate with the developers to create hazard reports.

11.4 Safety Checklist

A Safety Checklist is provided in Appendix J. The checklist is to be completed by the MIRI SSE for elements produced and tested at JPL as well as at other centers including the EC. The systems engineer responsible for the component to be delivered is responsible for assisting the SSE in filling out the checklist. This list will identify all applicable requirements within JPL D-560 and will be used to evaluate hardware for the presence of potential hazards. Issues identified from the list will be investigated to determine if a hazard does exist; then where appropriate a hazard report will be written, refer to Section 11.2 above.

11.5 Conflicting Requirements

The JPL MIRI MAM will resolve any conflicts in requirements discovered between various applicable documents.

11.6 MIRI Safety Policy

It is the policy of JPL and the MIRI Project to ensure personnel safety and hardware in consonance with the project achievement. JPL shall conform with all local, state, and federal regulations regarding safety, which pertain to JPL MIRI Payload. Personnel involved with MIRI shall have a thorough knowledge of system safety practices and shall apply it to assure a safe and successful mission.

11.6.1 SAFETY SURVEYS

When considered appropriate by the MAM, a Systems Safety Survey (ref. App. J) will be conducted. Attendees shall include: the hardware cognizant engineer, facility cognizant personnel, the MAM, a Systems Safety representative; and a Quality Assurance representative. The surveys will be conducted by the Systems Safety representative. The Systems Safety Survey along with the Safety Checklists will serve as the survey agenda; the safety survey checklists are provided in Appendices J.

11.7 MIRI safety Assessment Report

The MIRI JPL Systems Safety Engineer will perform and document a Safety Assessment Report, which is a comprehensive evaluation of the mishap risk of the MIRI Instrument. This safety assessment will identify all safety features of MIRI hardware and software, and system design, as well as procedural, hardware and software related hazards present in the MIRI. The assessment report will include:

a) Safety criteria and methodology used to classify hazards.
b) Results of hazard analyses and tests used to classify hazards.
c) Hazard reports documenting the results of the safety program efforts.
d) List of hazardous materials generated or used in the MIRI
e) Conclusion with a signed statement that all identified hazards have been eliminated or controlled to an acceptable level.
f) Recommendations applicable to hazards at the interface of the MIRI.

12.0 CONTAMINATION CONTROL

Contamination Control requirements are derived from specific conditions associated with the flight system and instruments, regarding functional limitations, optical performance degradation requirements, thermal surface property requirements, as well as safety and reliability requirements.

Contamination Control requirements shall be in accordance with the MIRI IRD JWST-IRD-000782 in addition to the requirements specified JWST –RQMT-002363 “Mission Assurance Requirements for the JWST Instruments”.

APPENDIX A, ABBREVIATIONS & ACRONYMS

AIDS	Assembly and Inspection Data Sheet
CCD	Charge Coupled Device
C&DH	Command and Data Handling
CDR	Critical Design Review
CMOS	Complimentary Metal on Semiconductor
ºC	Degree(s) Celsius
ºK	Degree(s) Kelvin
DCE	Dewar Control Electronics
DPA	Destructive Physical Analysis
EC	European Consortium
ECR	Engineering Change Request
EEE	Electrical, Electronic, and Electromechanical (EEE) Parts
EGSE	Electrical Ground Support Equipment
ELDRS	Extreme Low Dose Susceptibility
EM	Engineering Model
EPE	Electronic Parts Engineer
ER	Established Reliability
ERE	Environment Requirements Engineer
ESD	Electrostatic Discharge
ETAS	Environmental Test Authorization and Summary Form
ETU	Engineering Test Unit
FA	Flight Acceptance
FM	Flight Model
FMECA	Failure Modes and Effects Analysis
FPM	Focal Plan Module
FTA	Fault Tree Analysis
GaAs	Gallium Arsenide
GIDEP	NASA and Government Industry Data Exchange Program
gm	Gram
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HRCR	Hardware Review and Certification Review
ICD	Interface Control Document
in.	Inch
ions/cm^2	Ions per Square Centimeter
IR	Inspection Report
IRD	Interface Requirements Document
ISIM	Integrated Science Instrument Module
JPL	Jet Propulsion Laboratory
JWST	James Webb Space Telescope
Krad	Kilo Rad, A Unit of Absorbed Dose
L_2	Second Lagrangian Point
lb.	Pound
LED	Light Emitting Diode
LET	Linear Energy Threshold
LLIS	NASA Lessons Learned

MAM	Mission Assurance Manager
MAP	Mission Assurance Plan
M & P	Materials and Processes
MCM	Multi-Chip Module
MCO/MPL	Failure Lessons Learned
Mev-cm^2/mg	Million Electron Volts per square centimeter per milligram
MIL	Military
MIUL	Materials and Identification Usage List
MIRI	Mid Infrared Instrument
mm	Millimeter
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MRB	Material Review Board
MUA	Materials Usage Agreement
NDE	Nondestructive Evaluation
NDI	Nondestructive Inspection
NO	Non-Operating
NPSL	NASA Parts Selection List
NSPAR	Nonstandard Parts Approval Request
OBA	Optical Bench Assembly
OP	Operating
PDR	Preliminary Design Review
PDS	Product Delivery System
RFP	Request for Proposal
PFR	Problem Failure Report
PRA	Probabilistic Risk Assessment
PRF	Preferred
PQA	Product Quality Assurance
POC	Point of Contact
PSA	Parts Stress Analysis
QA	Quality Assurance
QAE	Quality Assurance Engineer
QAR	Quality Assurance Representative
QML	Qualified Materials List
QPL	Qualified Parts List
RAM	Random Access Memory
RAD	A Unit of Absorbed Dose
RFPs	Request for Proposals
RLAT	Radiation Lot Acceptance Testing
SCC	Stress Corrosion Cracking
SEB	Single Event Burnout
SEE	Single Event Effects
SEGR	Single Event Gate Rupture
SEL	Single Event Latchup
SET	Single Event Transient
SEU	Single Event Upset
SFPs	Single Point Failures
si	Silicon
SOI	Silicon on Insulator
SOS	Silicon on Sapphire

SQA	Software Quality Assurance
SOW	Statement of Work
TBD	To Be Determined
TID	Total Ionizing Dose
TML	Total Mass Loss
TMM	Thermal Math Model
TTMM	Test Thermal Math Model
UV	Ultra Violet
V	Volts
VCE	Collector/Emitter Voltage
VCM	Volatile Condensable Mass
VDS	Drain/Source Voltage
VGS	Gate/Source Voltage
WCA	Worst Case Analysis

APPENDIX B, REFERENCE DOCUMENTS

JPL Documents & Specifications

D-560	Standard for System Safety
D-1348	Electrostatic Discharge Protection Measures
D-20241	Effects of radiation
D-5703, Rev. 2	Reliability Analyses for Flight Hardware in Design
D-8091	JPL Standard for Anomaly Resolution
D-8208	Spacecraft Design and Fabrication Requirements for Electronic Packaging and Cabling
D–8545	JPL Derating Guidelines
D-9984	Flight Materials, Processes, Fasteners, Packaging and Cabling
D-17868	Design Principles for Flight Systems
D-60133	Assembly & Subsystem Level Environmental Verification Std.
D-22011	System Thermal Testing Standard", March 15, 2003
Doc ID 58032	Flight Project Practices
FS511316	Detail Specification for Qualification of Critical Fasteners
http://rules	JPL Rules
SPI 4-11-8	Selection of Fasteners for Flight Applications
STD-00009	Hardware Selection Guide
TS507035	Detail Specification for Vacuum Outgassing of Polymers (Micro-VCM Technique)

JPL Forms

1898	Final Inspection Report
2916	Assembly and Inspection Data Sheets
2847	Systems Safety Survey

NASA Documents & Specifications

JSC SP-R-0022A	Vacuum Stability Requirements of Polymeric Materials for Spacecraft Applications
MSFC-HDBK-527/ JSC-09604	Materials Selection List for Space Hardware Systems
JWST-IRD-000782	JWST Integrated Science Instrument Module Mid Infrared Instrument (MIRI) Interface Requirements Document
JWST-RQMT-0023 63	Mission Assurance Requirements for the JWST Instrument
MIL-H-38534	Hybrid Microcircuits, General Specification for
MIL-I-38535	Integrated Circuits Manufacturing, General
MIL-S-19500	Semiconductor Devices, General Specification for
MIL-STD-883	Microelectronics, Test Methods & Procedures for
MSFC-STD-3029	Guidelines for the Selection of Metallic Materials for Stress Corrosion Cracking Resistance in Sodium Chloride Environments
NASA RP-1124	Outgassing Data for Selecting Spacecraft Materials
NASA-STD-6001	Flammability, Odor and Outgassing

Military Standards & Specifications

MIL-H-38534	Hybrid Microcircuits, General Specification for
MIL-HDBK-5	Metallic Materials and Elements for Aerospace Vehicle Structures
MIL-HDBK-17	Plastics for Aerospace Vehicles
MIL-HDBK-6870	Nondestructive Inspection Program Requirements for Aircraft and Missile Materials and Parts
MIL-I-38535	Integrated Circuits Manufacturing, General
MIL-I-45208	Inspection System Requirements
MIL-Q-9858	Quality Program Requirements
MIL-S-19500	Semiconductor Devices, General Specification for
MIL-STD-883	Microelectronics, Test Methods & Procedures for
MIL-STD-889	Dissimilar Metals

Other Documents

AMS-STD-1595	Qualification of Aircraft, Missile and Aerospace Fusion Welders
ASTM-E1417	Standard Practice for Liquid Penetrant Examination
ASTM-E595	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
ISO 9001	Model for QA in Design/Development, Production Installation
ISO 9002	Quality Assurance for Production, Installation, and Servicing
ECSS-Q-40A	European Space Agency document, Space Product Assurance - Safety
ECSS-E-10-03A,	“Testing – Space Engineering”,

APPENDIX C, ENVIRONMENTAL TEST TOLERANCES

Dynamics Test Tolerances

The dynamics test tolerances shall be as follows:

a) Time: + 5%, -0%

b) Frequency: Below 50 Hz, ± 0.5 Hz.
Above 50 Hz, ± 2%

c) Acoustic Spectral Shape: ± 3 dB of the specified Sound Pressure Level (SPL) in 1/3 octave bands center frequencies.

d) Acoustic Overall Level: within ± 1.0 dB (true RMS) of the specified level.

e) Random Vibration Spectral Shape: The Power Spectral Density (PSD) shall be within ± 1.5 dB below 500 Hz, ± 3.0 dB above 500 Hz when measured in frequency bands no wider than 25 Hz.

f) Random Vibration Level: within ± 1.0 dB (true RMS) of the specified level.

g) Pyro Shock: Measured with a minimum resolution of 1/6 octave frequency band. For shaker test, the spectrum shall be within ± 3 dB of the specified shock spectrum level, above 2000 Hz the lower tolerance may be eliminated if the test hardware shock sensitive frequency is far below this frequency. For other shock-generating apparatus tests, the tolerance shall be within +/- 6 dB, but at least 50% of the spectrum values shall exceed the nominal values.

h) Sinusoidal Vibration Level: Measured sine amplitude shall be within + 5 %, -0% of the specified value.

i) Static Acceleration: + 5 %, -0% of the specified value.

Thermal/Vacuum And Temperature/Atmosphere Test Tolerances

The thermal/vacuum and temperature/atmosphere test tolerances shall be as follows:

a) Pressure: +2 to -5 percent from atmospheric to 10 percent of atmospheric. At vacuum conditions, tolerances shall be such that a pressure of $1x10^{-5}$ torr or less is assured.

b) Time: +10, -0 minutes

c) Temperature: ±2°C

d. Thermal Stability: ±2°C/hour

EMC/Magnetics Test Tolerances

The EMC/Magnetics test values shall be measured within the following tolerances:

a) Voltage: ±10 percent of the peak value

b) Current: ±10 percent of the peak value

c) RF Amplitudes: ±5 dB

d) Frequency: ±2 percent

e) Resistance: ±10 percent

f) Distance: ±5 percent of specified distance or ±5.0 cm, whichever is less.

APPENDIX D, ETAS FORM

JPL

ENVIRONMENTAL TEST AUTHORIZATION AND SUMMARY (ETAS)

AUTHORIZATION SECTION

PROJECT | LOG NO.

SUBSYSTEM / ASSEMBLY TITLE | DATE ISSUED

REFERENCE DESIGNATION NO. | PART NO. (IF MULTIPLE, ATTACH LIST) | REV. | SERIAL NO.

HARDWARE TYPE
☐ EM QUAL ☐ FLIGHT ☐ FLIGHT SPARE ☐ OTHER ______
PRE-ENVIRONMENTAL INSPECTION REPORT NUMBER (ATTACH IR)

WIRING HARNESS
☐ FLIGHT ☐ FLIGHT SPARE ☐ EM ☐ S.E.
PART NO. | REV. | SERIAL NO.

TEST DESCRIPTION (CHECK ALL APPLICABLE)
☐ SINE VIBRATION ☐ PYROSHOCK ☐ ACOUSTIC ☐ EMC ☐ OTHER ______
☐ RANDOM VIBRATION ☐ THERMAL VAC ☐ THERMAL ATMOSPHERE

TYPE OF TEST
☐ QUALIFICATION ☐ FLIGHT ACCEPTANCE
☐ PROTO FLIGHT ☐ RETEST

WILL ALL TESTS/LEVELS/DURATIONS REQUIRED BY THE PROJECT DOCUMENTS BE PERFORMED ON THIS UNIT?
☐ YES ☐ NO (IF NO, ATTACH EXCEPTIONS LIST) ENTER PROJ. DOC. NO. AND REV. ______

HAS THE UNIT PASSED ALL PRE-ENVIRONMENTAL FUNCTIONAL TESTS?
☐ YES ☐ NO (IF NO, ATTACH EXPLANATION)
BRIEF EXPLANATION

HAVE ALL DESIGN ANALYSES BEEN COMPLETED AND REQUIRED CHANGES BEEN IMPLEMENTED?
☐ YES ☐ NO (IF NO, ATTACH EXPLANATION)
BRIEF EXPLANATION

IS THE TEST ARTICLE IDENTICAL TO OTHER FLIGHT UNITS?
☐ YES ☐ NO (IF NO, LIST DIFFERENCES AND ATTACH)
BRIEF EXPLANATION

ARE ALL PFRs AGAINST THIS UNIT CLOSED?
☐ YES ☐ NO (IF NO, WILL ANY OPEN PFRs AFFECT ENVIRONMENTAL TESTING? HOW?)
BRIEF EXPLANATION

HAVE ALL WAIVERS AND ECRs BEEN APPROVED AND ARE THEY INCORPORATED?
☐ YES ☐ NO (IF NO, ATTACH EXPLANATION) ☐ N/A
BRIEF EXPLANATION

TEST AUTHORIZED BY

COGNIZANT ENG. DATE | TECHNICAL MGR./INSTR MGR./PI REP. DATE | ENVIRONMENTAL REQUIREMENTS ENG. DATE

APPENDIX D, ETAS FORM (CONTINUED)

SUMMARY SECTION

TEST AGENCY (IF MULTIPLE, ATTACH SUMMARY AND TEST DATES)	TEST INITIATION DATE	ACCUMULATED OPERATING HOURS PRIOR TO FIRST ENVIRONMENTAL TEST
SERIAL NUMBERS ACTUALLY TESTED	TEST TERMINATION DATE	OPERATING HOURS DURING ENVIRONMENTAL EXPOSURE

TEST DESCRIPTION

VIBRATION AXES: X Y Z
SINE VIBRATION ☐ ☐ ☐
RANDOM VIBRATION ☐ ☐ ☐

ACOUSTIC ☐

PYROTECHNIC SHOCK AXES: X Y Z ☐ ☐ ☐
SHOCKS/AXIS:

☐ THERMAL VACUUM
PRESSURE:
NO. OF CYCLES:

☐ TEMPERATURE ATMOSPHERE
NO. OF CYCLES:

☐ OTHER

EMC ☐ COND. SUSC. ☐ COND. EMIS. ☐ ISOLATION
☐ ESD ☐ RAD. SUSC. ☐ RAD. EMIS. ☐ MAGNETICS

TEMP. LEVEL (°C) AND ACCUMULATED DURATION (HRS.)
HOT: ______°C, ______h COLD: ______°C, ______h
HOT: ______°C, ______h COLD: ______°C, ______h

WERE THERE ANY PFRs GENERATED DURING ENVIRONMENTAL TESTS?
☐ YES ☐ NO (IF YES, ATTACH A COPY OF THE PFRs)
LIST PFR NOS. / BRIEF EXPLANATION

ARE THE POST ENVIRONMENTAL DAMAGE INSPECTIONS COMPLETE?
☐ YES ☐ NO (IF YES, ATTACH A COPY OF THE INSPECTION REPORTS. IF NO, ATTACH EXPLANATION.)
BRIEF EXPLANATION

WERE ALL PLANNED TESTS/LEVELS/DURATIONS ACHIEVED?
☐ YES ☐ NO (IF NO, ATTACH EXPLANATION)
BRIEF EXPLANATION

☐ TESTS HAVE NOT BEEN SUCCESSFULLY COMPLETED. SEE THE ATTACHED SUMMARY FOR ACTIONS THAT NEED TO BE TAKEN.

COGNIZANT ENG. DATE	TECHNICAL MGR./INSTR MGR./PI REP. DATE	ENVIRONMENTAL REQUIREMENTS ENG. DATE

☐ HARDWARE HAS SUCCESSFULLY COMPLETED THE ENVIRONMENTAL TESTS LISTED ON THIS FORM OR REMAINING ACTIONS HAVE BEEN TAKEN, INCLUDING RETEST.

COGNIZANT ENG. DATE	TECHNICAL MGR./INSTR MGR./PI REP. DATE	ENVIRONMENTAL REQUIREMENTS ENG. DATE

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APPENDIX E, MATERIALS IDENTIFICATION AND USAGE LIST (MIUL) FORM

Materials Identification and Usage List - Non-Metallic Materials

Item No.	Material Description/ Brand Name Supplier	Application	Material Specifications	Thermal Vacuum Stability (%)	JPL Rating[1]	Comments
1				TML = VCM= WVR=		
2				TML = VCM= WVR=		
3				TML = VCM= WVR=		
4				TML = VCM= WVR=		
5				TML = VCM= WVR=		
6				TML = VCM= WVR=		
7				TML = VCM= WVR=		

[1] 1 - acceptable, 2 - qualified acceptable, 3 - provisionally acceptable, 4 - unacceptable

APPENDIX E, MATERIALS IDENTIFICATION AND USAGE LIST (MIUL) FORM

Item No.	Material Description/ Condition	Application	Material Specifications	Stress Corrosion Cracking Rating	JPL Rating[1]	Comments
1						
2						
3						
4						
5						
6						
7						

1 - acceptable, 2 - qualified acceptable, 3 - provisionally acceptable, 4 - unacceptable

APPENDIX E, MATERIALS IDENTIFICATION AND USAGE LIST (MIUL) FORM

Materials Identification and Usage List - Processes

Item No.	Process	Specification	Materials Processed	Spacecraft/ Experiment Application	JPL Evaluation	
					Approve/ Disapprove[1]	Comments
1						
2						
3						
4						
5						
6						

[1] 1 - acceptable, 2 - qualified acceptable, 3 - provisionally acceptable,4 – unacceptable

APPENDIX F, MATERIALS USAGE AGREEMENT (MUA)

MATERIALS USAGE AGREEMENT	USAGE AGREEMENT NO.	REVISION	PAGE OF

PROJECT	SUBSYSTEM	ORIGINATOR	ORGANIZATION JPL

DETAIL DRAWING(S)	USING ASSEMBLY(S)	ITEM DESCRIPTION	ISSUE
MATERIAL	TRADE NAME	SPECIFICATION	MANUFACTURER

THICKNESS	WEIGHT	EXPOSED AREA	LOCATION	ENVIRONMENT		
			HABITABLE	PRESSURE	TEMPERATURE	MEDIA
			NONHABITABLE			

APPLICATION

RATIONALE

APPRVOVED BY FLIGHT MATERIALS AND PROCESSES ENGINEERING, JPL	CONCURRENCE	DATE

MATERIALS ENGINEERING EVALUATION

APPENDIX G, STRESS CORROSION EVALUATION FORM

STRESS CORROSION EVALUATION FORM

1. PART NUMBER________________________________
2. PART NAME ________________________________
3. NEXT ASSEMBLY NUMBER ________________________________
4. MANUFACTURER ________________________________
5. MATERIAL ________________________________
6. HEAT TREATMENT ________________________________
7. SIZE AND FORM ________________________________
8. SUSTAINED TENSILE STRESS-MAGNITUDE AND DIRECTION
   a. PROCESS RESIDUAL ________________________________
   b. ASSEMBLY ________________________________
   c. DESIGN, STATIC ________________________________
9. SPECIAL PROCESSING ________________________________
10. WELDMENTS
    a. ALLOY FORM, TEMPER OF PARENT METAL ________________________________
    b. FILLER ALLOY IF NONE, INDICATE ________________________________
    c. WELDING PROCESS ________________________________
    d. WELD BEAD REMOVAL - YES ( ), NO ( )________________________________
    e. POST-WELD THERMAL TREATMENT ________________________________
    f. POST-WELD STRESS RELIEF ________________________________
11. ENVIRONMENT________________________________
12. PROTECTIVE FINISH ________________________________
13. FUNCTION OF PART ________________________________

    ____
14. EFFECT OF FAILURE ________________________________

    ____
15. EVALUATION OF STRESS CORROSION SUSCEPTIBILITY ________________________________

    ____
16. REMARKS ________________________________

    ____

APPENDIX H, AIDS FORM 2916

JPL

Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California 91109

ASSEMBLY AND INSPECTION DATA SHEET

AIDS NO.

PROJECT	EQUIPMENT TITLE	DRAWING/PART NO.	REV.	SERIAL NO.	PAGE 1 OF

REMARKS	OTHER APPLICABLE AIDS	DRAWING STATUS ☐ RELEASED ☐ ENG. PRE RELEASE DATED ______

PREPARED BY	DATE	APPROVED		ACCEPTANCE		
		ENGINEERING	DATE	☐ IN PROCESS	COG.ENGR.	DATE
Filename:	Class:	Q.A.	DATE	☐ FINAL	Q.A. ENGR	DATE

STEP	INSTRUCTIONS	OPER.	INSP. REPORT	ACCEPT	
				DATE	STAMP

NOTE:

1. KIT COMPONENTS REFER TO D-8208
2. CLEANING REFER TO D-8208
3. MARKING/STAMPING REFER TO D-8208
4. COMPONENTS/BOARD ATTACHED REFER TO D-8208
5. REWORK REFER TO PROCESS IN D-8208
6. RECORD ALL TRACEBILITY OF PARTS AND MATERIALS.

A DISTRIBUTION: FIRST - CONTROL CENTER, SECOND - ACCOMPANY HARDWARE, THIRD - EXTRA COPY [ ] = QA APPROVAL

JPL 2916 R 5/96
Printed on 10/7/2003

APPENDIX I, IR FORM

JPL
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109-8099

INSPECTION REPORT

IR - 72215

PROGRAM	REF DES	NOMENCLATURE	PART NO.	JPL MFR REV	ECP/ECO	QTY	SERIAL NO.	LOT NO.	DATE

SUB SYS	COG ENGINEER + EXT	TYPE OF INSP	INSP STD / SPEC NO.	LOCATION	TYPE OF ITEM	PLANNING NO.

PO / CT NO.	LINE NO.	REL/MOD NO.	RECEIPT NO.	PROPERTY / ID	WORK ORDER NO.	SUBSYSTEM NO.	MANUFACTURER	SUPPLIER

ITEM	CODE	ZONE	DESCRIPTION	DISP.	DATE	STAMP

ITEM	DISPOSITION/CORRECTIVE ACTION

QTY. ACCPT.	QTY. REJ.	PARTS REC. BY + DATE	
OADC COGNIZANT ENGINEER + DATE	Q.A. ENGINEER + DATE	INITIATED BY + STAMP	CLOSED BY + DATE + STAMP
INSPECTION REPORT		IR - 72215	PAGE 1 OF / ALERT CAND. ☐ YES ☐ NO

DISTRIBUTION: WHITE - IF FLIGHT SYS - EDMC / - IF GROUND SYS - QADC; GREEN - ACCOMPANY HARDWARE; CANARY - COGNIZANT ENGINEER; PINK - FOR SAS REQUIRED PROCESSING - OADC / - OTHERWISE - INITIATOR'S COPY

APPENDIX J, SAFETY CHECKLIST - FLIGHT

DESCRIPTION of HAZARD	LABORATORY	ENVIRONMENTAL TEST FACILITY
Structure		
Structural Failure (Including Fasteners)		
Sharp Edges		
Mechanisms		
Stored Energy		
Other		
Ordnance		
Inadvertent Firing		
Other		
Pressure		
Rupture		
Leakage		
Pressure Vessels		
Batteries (Rupture/Leakage/Explosion)		
Other		
Ionizing Radiation		
Personnel Exposure		
Other		
Non-Ionizing Radiation		
Inadvertent RF Radiation		
Lasers		
Microwave Radiation		
Other		
Electrical/Electronic		
Exposed Circuitry		
Arcing and Sparking		
High Voltage		
Other		
Hazardous Materials		
Toxic (Personnel Exposure)		
Flammable		
Explosive		
Oxygen Displacement		
Batteries (Toxic Chemicals)		
Electrostatic Build - Up		
Other		
Temperature Extremes		
Hot Surfaces (Personnel Exposure)		
Other		

APPENDIX J, SAFETY CHECKLIST – GSE

DESCRIPTION of HAZARD	LABORATORY	ENVIR. TEST FAC.
Lifting, Support, Work Stands and Tranportation		
Structural Failure		
Sharp Edges		
Procedural		
Lack of Guardrails and Kick plates		
Instability		
Breakdown		
Other		
Ordnance GSE		
Inadvertent Firing due to a Fault Current		
Inadvertent Firing due to RF Coupling		
Inadvertent Firing		
Other		
Pressure		
Batteries (Rupture/Leakage/Explosion)		
Battery Charging		
Pressurized Bottles (K – Bottles)		
Other		
Ionizing Radiation		
Personnel Exposure		
Other		
Non-Ionizing Radiation		
Inadvertent RF Radiation		
Lasers		
Microwave Radiation		
Other		
Electrical/Electronic GSE		
Mismating Connectors		
Hazard Function Commands		
Exposed Circuitry/Surfaces (Elect. Shock)		
Other		
Hazardous Materials		
Toxic (Personnel Exposure)		
Flammable		
Explosive		
Oxygen Displacement		
Batteries (Toxic Chemicals)		
Electrostatic Build - Up		
Other		
Temperature Extremes		
Hot Surfaces (Personnel Exposure)		
Other		

JPL

APPENDIX K - SYSTEMS SAFETY SURVEY

FACILITY NAME MODIFIED SINCE LAST SURVEY? YES ☐ NO ☐ N/A ☐	FACILITY MANAGER	SURVEY NO.
BUILDING/ROOM (OR ADDRESS IF NOT JPL)	FACILITY SECTION MANAGER	DATE OF SURVEY
FACILITY EQUIPMENT	PRIMARY CONTACT	SURVEY FACILITATOR, SSE
PROJECT	COGNIZANT ENGINEER	SURVEY FILE DATE
COMPONENT / SUBSYSTEM / SYSTEM (DELIVERABLE PRODUCT)	COGE. SECT. MGT. or PEM	OPERATION START
ACTIVITY	PRIMARY CONTACT	OPERATION END/DURATION

SURVEY TYPE… (see p.8)	SURVEY FOCUS		SUPPLEMENT
☐ TEAM ☐ INFORMAL	☐ FSS & OSS COMBINED, FOS (Sect. A, B, & C)	☐ FACILITY, FSS (Sect. A & B) ☐ OPERATIONS, OSS (Sect. B & C)	☐ ENVIRONMENTAL TEST (Sect. D)

ACTION ITEM(S)

NO.	LINE ITEM	TO BE CLOSED PRIOR TO START OF ACTIVITY	ASSIGNEE	CLOSED - YES / NO

RATIONALE FOR ACCEPTING "NO" ANSWERS

LINE ITEM	RATIONALE

LIST OF ATTENDEES

NAME	ORGANIZATION	EXTENSION	NAME	ORGANIZATION	EXTENSION

RESPONSIBLE ORGANIZATION'S SIGNATURES OF APPROVAL

FACILITY MANAGER (FSS, FOS)	DATE	HARDWARE COGNIZANT ENGINEER (OSS, FOS, ETS)	DATE
FACILITY SECTION MANAGER (JPL only) (FSS, FOS)	DATE	HARDWARE COGNIZANT SECTION MANAGER (or) PROJECT ELEMENT MANAGER (JPL only) (OSS, FOS, ETS)	DATE

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JPL

SYSTEMS SAFETY SURVEY

HAZARDOUS AGENTS / CONDITIONS

TYPES*	HAZARD DESCRIPTION	QTY, VOLTAGE, PRESSURE, TEMPERATURE, ETC. (RANGE)	CONTROL MEASURE(s) (No.)**

*HAZARD TYPE KEY

1. Acoustics	8. ESD	15. Low Illumination	22. Pressure / Vacuum System	29. Vibration
2. Biohazards	9. Explosives	16. Low Temperatures	23. Process Tanks	30. Other: ______
3. Carcinogens	10. Flammable Gases	17. Organic Peroxide	24. Ionizing Radiation	31. Other: ______
4. Chemicals	11. Flammable Liquids	18. Oxidizer	25. Non-Ionizing Radiation	32. Other: ______
5. Cryogens	12. Over 600 Volts - AC / DC	19. Oxygen Deficiency	26. Reproductive Toxins	33. Other: ______
6. Confined Space	13. High Temperature	20. Physical Hazards	27. Toxic Materials	34. Other: ______
7. Electric Equipment	14. Lasers	21. Pyrophoric	28. Water Reactives	35. Other: ______

**HAZARD CONTROL MEASURE KEY

C1 Safety Glasses	C9 Gloves (list type)	C17 Stand-by Neutralize	C25 Conductive Transporters
C2 Goggles (list type)	C10 Apron	C18 Double Containment	C26 Cleanliness
C3 Faceshield	C11 Lab Coat / Coveralls	C19 Lock Out / Tag Out / Procedures	C27 Thermal Insulation
C4 Hearing Protection	C12 Bunny Suit	C20 Waste Disposal Can	C28 Automatic Fire Sprinklers
C5 Particulate Respirator	C13 Shielding or Barrier	C21 Satellite Waste Accumulation Point	C29 Portable Fire Extinguishers
C6 Chemical Respirator	C14 Oxygen Detector	C22 Wrist Straps	C30 Other: ______
C7 Self-Contained Breathing Apparatus	C15 Ventilation	C23 Insulated Ground Straps	C31 Other: ______
C8 Barrier Creams	C16 Chemical Fume Hood	C24 Conductive Garments	C32 Other: ______

OPERATION: ☐ Attended ☐ Unattended ☐ After Hours ☐ TV Surveillance ☐ Buddy System ☐ Remote

Safety warnings: ☐ Signs ☐ Lights ☐ Alarms ☐ JPL Console Alarm ☐ Other: ______

EMMISIONS, DISCHARGES, AND WASTES

WASTE GENERATED	RATE e.g., grams/hr	YEARLY TOTAL e.g., grams, liters	ROUTINE DISPOSAL	NON-ROUTINE DISPOSAL

SURVEY MEETING MINUTES, NOTES AND / OR REPORT

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JPL

SYSTEMS SAFETY SURVEY

COMPLY?

ENVIRONMENTAL COMPLIANCE CHECKLIST

It is the responsibility of the facility and operations managers to ensure that their work practices provide for compliance with JPL practices regarding protection of the environment. For more information, please contact the Environmental Affairs Program Office.

I. TRAINING

☐ ☐ ☐ 1. All required Environmental Training is up to date.
Contact the Environmental Affairs Program Office (EAPO) for status of training and to arrange training, if needed.

II. HAZARDOUS WASTE - Waste which is: ignitable, corrosive, toxic, or reactive. Also, waste contaminated with chemicals (wipes,

☐ ☐ ☐ 2. Arrangements for all hazardous waste pick-up must be completed by EAPO (ext. 4-0635) without exception.

☐ ☐ ☐ 3. Employees handling hazardous waste are trained and training is current.

☐ ☐ ☐ 4. Each container of hazardous waste is properly labeled with JPL Form 2799-S or current form.

☐ ☐ ☐ 5. No hazardous waste placed in blue recycle bin, office trash can or in outside dumpster. No hazardous waste stored in an outside cabinet. (Hazardous waste must be stored indoors at or near point of generation).

AIR QUALITY

☐ ☐ ☐ 6. Copy of the permit (i.e., the latest revision) for permitted equipment posted at the location of the equipment.
(e.g. generators, boilers, spray booths, vapor degreasers, etc.)

☐ ☐ ☐ 7. Used or contaminated rags or wipes contained in a closed container when not in use.

WASTEWATER / STORMWATER

☐ ☐ ☐ 8. Advance approval obtained from the (EAPO) before any material is placed, dumped or washed into the sanitary <u>sewer</u> system (sinks, toilets, or other drains). This includes cooling water, rinse water, steam cleaning, etc.

☐ ☐ ☐ 9. No materials of any kind will be washed into the <u>storm drain</u> system.

EPA REGULATED SOLVENTS APPROVED ONLY FOR FLIGHT HARDWARE USE

NOTE: When approved by the specific project, these ozone-depleting solvents may be used for flight hardware cleaning operations in addition to the traditionally approved alcohol acetone. These solvents may **NOT** be used for non-flight hardware cleaning operations except as noted in note 1 below.

USE /	DON'T USE	Solvent	USE /	DON'T USE	Solvent
☐	☐	1,1,1 – Trichloroethane (methyl chloroform)	☐	☐	1,1,2,2,3 – Pentafluoropropane (HFC-245ca)
☐	☐	Trichlorofluoromethane (CFC-11)	☐	☐	1,1,2,3,3 – Pentafluoropropane (HFC-245ea)
☐	☐	Dichlorodifluoromethane (CFC-12)	☐	☐	1,1,1,2,3 – Pentafluoropropane (HFC-245eb)
☐	☐	1,1,2 – Trichloro – 1,2,2 trifluoroethane (CFC-113)	☐	☐	1,1,1,3,3 – Pentafluoropropane (HFC-245fa)
☐	☐	1,2 – Dichloro – 1,1,2,2 –tetrafluoroethane (CFC-	☐	☐	1,1,1,2,3,3 – Hexafluoropropane (HFC-236ea)
☐	☐	Chloropentafluoroethane (CFC-115)	☐	☐	1,1,1,3,3 – Pentafluorobutane (HFC-365mfc)
☐	☐	Cyclic, branched, or linear, completed methylated	☐	☐	Chlorofluoromethane (HCFC-31)
☐	☐	Ethylfluoride (HCH-161)	☐	☐	1,2 – Dichloro – 1,1,2 – trifluoroethane (HCFC-123a)
☐	☐	1,1,1,3,3,3 – Hexafluoropropane (HFC-236fa)	☐	☐	1 – Chloro – 1-fluoroethane (HCFC-151a)

Constraints / Notes:

1. These solvents may not be used for any other cleaning applications. They, however, may be used for research purposes in non-cleaning applications.
2. These are ozone-depleting compounds, and they should not be used for cleaning except in applications where no non-ozone depleting substance has been identified as an acceptable alternative.
3. The word "Cleaning" refers to "wipe-cleaning" or "hand held spray bottles from which solvents are applied without a propellant-induced force."
4. For cleaning processes where a solvent-holding tank (such as ultrasonic cleaners) is used, air permits may be required before such equipment can be used. Please contact EAPO for further assistance.
5. The only solvents on this list currently used for flight hardware cleaning at JPL are 1,1,1 – Trichloroethane (Methyl Chloroform) and 1,1,2 – Trichloro – 1,2,2 – Trifluoroethane (Freon or CFC-113). Whenever possible flight projects should also avoid using these materials and use non-ozone depleting alternatives instead, such as Brulin 815 currently in use for most flight hardware cleaning in Building 233.

JPL

SYSTEM SAFETY SURVEY

YES NO N/A

A. FACILITY

☐ ☐ ☐ 1. Facility and equipment preventive maintenance plans exist, and maintenance and documentation are current.

☐ ☐ ☐ 2. Floor space, head room, accessibility are adequate. Egress doors are adequately identified (exit signs), operational, and swing in the proper direction.

☐ ☐ ☐ 3. Hazardous obstructions, uneven floors, other obstacles removed or otherwise safed, including overhead structures / fixtures.

☐ ☐ ☐ 4. Floor loading is within acceptable limits for all facility operations and posted where necessary.

☐ ☐ ☐ 5. Equipment / cabinets which could be hazardous to personnel / critical hardware during an earthquake are secured.

☐ ☐ ☐ 6. Illumination is adequate for clear visibility of operations, test article, exits and emergency signs.

☐ ☐ ☐ 7. Emergency lighting is provided and functional.

☐ ☐ ☐ 8. Fluid, pneumatic, mechanical, electrical and instrumentation configuration is documented, controlled and readily available.

☐ ☐ ☐ 9. Venting systems are adequately sized and appropriately isolated from one another (e.g. vacuum chamber GN_2 vents.)

☐ ☐ ☐ 10. Fire blocking in service trenches and feed-throughs in place and effective. Trenches secure from flooding.

☐ ☐ ☐ 11. List of qualified operators of cranes and or other lifting / elevating devices is posted and current.

☐ ☐ ☐ 12. Adjacent activities which could impact critical hardware, GSE, or test activities controlled or eliminated.

☐ ☐ ☐ 13. Automatic fire sprinkler system in service with protection in all areas.

☐ ☐ ☐ 14. Fire alarm system and panel in service and in "normal" condition.

B. FACILITY AND OPERATION

☐ ☐ ☐ 1. Date of previous Facility Safety Survey ______________ . All action items are closed.

☐ ☐ ☐ 2. Annual Institutional Inspection (conducted by OSPO) current and action items are closed.

☐ ☐ ☐ 3. Flight Hardware Location Summary (FHLS) updated.

☐ ☐ ☐ 4. Fire department and JPL security notified and informed of special responses required for critical hardware / personnel.

☐ ☐ ☐ 5. Area secured and checked by security during non-working hours and security informed when flight hardware present.

☐ ☐ ☐ 6. Suitable clean agent fire extinguishers available and personnel trained in proper selection and use.

☐ ☐ ☐ 7. Hardware protected from overhead leaks.

☐ ☐ ☐ 8. Material Safety Data Sheets (MSDS) current and readily available.

☐ ☐ ☐ 9. Hazardous / flammable materials identified, minimized, properly contained, disposal methods authorized and Satellite Accumulation Point identified.

☐ ☐ ☐ 10. Appropriate lightning, surge, and over-voltage protection implemented. Facility ground verified. Date ________________ .)

☐ ☐ ☐ 11. Cranes, hoists, slings, fixtures, dollies, portable and other lifting equipment currently certified and proof tested. Cranes are grounded.

☐ ☐ ☐ 12. Lifting equipment is equipped with umbrella or drip shield for hardware protection.

☐ ☐ ☐ 13. Pre-lift briefing and inspection included in procedure (Assembly and Inspection Data Sheet (AIDS)).

☐ ☐ ☐ 14. Temperature / humidity control and monitoring system in place and calibrated. Limits appropriate for specific hardware.

☐ ☐ ☐ 15. Planetary protection and environmental contamination controls in place and maintained at appropriate levels in process area and for transportation of hardware (volatiles, particulates, food, beverages, smoking prohibited, waste disposal cans, etc.)

JPL

SYSTEMS SAFETY SURVEY

YES NO N/A

B. FACILITY AND OPERATION, CONTINUED

☐ ☐ ☐ 16. ESD survey completed by Q.A.

☐ ☐ ☐ 17. ESD precautionary measures / techniques are in place (i.e. grounding, garments, wrist straps, insulated traveling ground straps, etc.) to protect sensitive electronics per Q.A. procedure JPL D-1348.

☐ ☐ ☐ 18. All cabling is properly rated, routed, secured, protected and labeled.

☐ ☐ ☐ 19. GSE and facility designed to "fail-safe" for personnel and critical hardware.

☐ ☐ ☐ 20. Facility and GSE electrical configurations conform to code requirements, properly labeled, protected, insolated, fused, and insulated.

☐ ☐ ☐ 21. Facility and GSE data displays and alarms are adequate to indicate in-and out-of-specifications conditions.

☐ ☐ ☐ 22. GSE and facility pressure / vacuum vessels / systems conform to code requirements, components properly labeled, restrained, relieved,

☐ ☐ ☐ 23. Facility / GSE / Flight Hardware systems safe in power-off state (i.e. power <u>not</u> required to remain safe).

☐ ☐ ☐ 24. Backup facility and / or GSE electrical power (UPS) available / verified for hardware protection and / or emergency situations (UPS system location and battery condition is verified safe).

☐ ☐ ☐ 25. Flight Hardware interface to Facility / GSE has been appropriately analyzed and documented. (FMECA)

☐ ☐ ☐ 26. Safe-to-Mate verification testing completed on EGSE and interface cabling.

☐ ☐ ☐ 27. At least one over test protection device and sensor(s), independent of the automatic primary controller**,** closely coupled to the critical hardware calibrated and verified operational.

☐ ☐ ☐ 28. Live mechanical / electrical parts suitably guarded (belts, vents, gauges, rotating machinery, Ground Fault Circuit Interrupters, etc.). hardware is in place, calibrated, and verified operational.

☐ ☐ ☐ 29. An approved written detailed test procedure(s) exists for operation of the facility for this specific activity, including approved test levels and specific facility / test item interactions.

☐ ☐ ☐ 30. Key test parameters (vital for flight hardware protection and verification) continuously and automatically recorded and incorporated in shut-down circuit as appropriate.

☐ ☐ ☐ 31. Full time operator coverage available during critical operations / transitions or as required when flight hardware accessible.

☐ ☐ ☐ 32. Sufficient qualified personnel available to avoid overload or fatigue during test operations.

☐ ☐ ☐ 33. Personnel are qualified and trained on normal facility and test hardware operation and with emergency test response and operation, including power, water, communication, heating / cooling, gas / fuel, LN_2 or other utility failure responses.

☐ ☐ ☐ 34. Personnel warning (alarm) and vapor detection systems are appropriately located, calibrated and functional.

☐ ☐ ☐ 35. Facility and Operation Personnel have been briefed on Facility and Operation specific (GSE) alarms.

☐ ☐ ☐ 36. Personnel trained & qualified for specific hazardous and non-hazardous operations. (lasers, radiation, HAZ COM, ESD, Critical Hardware Handlers, etc.).

☐ ☐ ☐ 37. Personnel conducting hazardous operations involving radiation or chemical exposure and / or lifting devices, etc., are included in a medical surveillance program.

☐ ☐ ☐ 38. Personnel access to test areas and equipment is controlled to levels appropriate to the sensitivity / criticality of hardware.

☐ ☐ ☐ 39. Operation personnel understand that, in case of an anomaly, all actions must be toward returning to a safe condition for personnel and hardware. Anomaly and troubleshooting activities require approved procedures.

☐ ☐ ☐ 40. Specific personnel responsibilities and chain of command is documented and understood. A Test is Director designated.

☐ ☐ ☐ 41. Emergency plan and procedures are in place covering contingencies for both facility and operation for events such as earthquake, fire,

☐ ☐ ☐ 42. Emergency communication services are appropriate and readied, including fire and security departments. Emergency vehicle access adequate.

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SYSTEMS SAFETY SURVEY

YES NO N/A **B. FACILITY AND OPERATION, CONTINUED**

☐ ☐ ☐ 43. Emergency phone list of critical test personnel is conspicuously posted in test area. Copy provided to security for approved unattended operations. (Note: List facility analog phones because digital phones are non-operable during power outage.)

☐ ☐ ☐ 44. Personnel Protective Equipment (PPE) is available for planned or emergency use and personnel are trained in it's use (i.e. Low O_2, emergency breathing, toxic vapor warning and protection, etc.).

☐ ☐ ☐ 45. Warning placards and shielding is in place for hazardous environments, explosives, flammables, toxic vapors, oxygen depletion, high pressures, temperatures, voltages, cryogenics, radiation (ionizing or non-ionizing, laser), sonic or audio levels, unattended operation equipment.

☐ ☐ ☐ 46. Integrated hardware / facility hazard analysis or fault tree calculated to sufficient level and formality to assure personnel, facility, and hardware safety. (Note: This survey may suffice in most cases.)

☐ ☐ ☐ 47. Previous problems / failures have been resolved to prevent recurrence.

☐ ☐ ☐ 48. Other items that could affect personnel, facility or hardware safety. Record items below, use Survey Meeting Minutes, Notes, and / or Report section on page two if needed.

C. OPERATION

☐ ☐ ☐ 1. Hardware functional test procedures (AIDS) are written and approved, and a dry run included, if appropriate.

☐ ☐ ☐ 2. Effects of power failures, loss of utilities (H_2O, gas / fuel, LN_2, GN_2, etc.), glitches, or transients are understood and acceptable.

☐ ☐ ☐ 3. GSE and facility calibration / validation / proofing is current (ISO Compliant).

☐ ☐ ☐ 4. Hardware stable / secured during all phases of testing and non-test conditions, including storage.

☐ ☐ ☐ 5. Flight hardware signs are posted in test areas and on all flight hardware transport containers.

☐ ☐ ☐ 6. Flight hardware / test item and GSE configuration is documented and photographed.

☐ ☐ ☐ 7. All facility and hardware personnel involved briefed on test objectives / conduct / procedures.

☐ ☐ ☐ 8. Communications properly coordinated and tested (i.e., test conductor, facility and hardware test personnel, emergency

☐ ☐ ☐ 9. Personnel location during test or activity is safe.

☐ ☐ ☐ 10. Buddy system is in effect when critical hardware is accessible or operating.

☐ ☐ ☐ 11. Q.A. coverage in place during test setup, hardware handling, pre-test / post-test operations, and critical transitions.

☐ ☐ ☐ 12. Personnel will be working normal shift(s), not weekends, evenings or extended shift(s). If no, describe below:

☐ ☐ ☐ 13. Protective clothing / equipment for personnel and hardware interface available for planned and contingency conditions.

☐ ☐ ☐ 14. Personal Protective Equipment (PPE) not provided by facility, is appropriate and JPL Forms 2694 and 2693 are attached.

D. ENVIRONMENTAL TESTING – CHAMBERS

☐ ☐ ☐ 1. An environmental Test Authorization and Summary (ETAS) has been completed for this test.

☐ ☐ ☐ 2. The chamber is certified as prescribed by Doc. ID 64395
Record Chamber ID No.__________, and Expiration Date _______________ (found on ETL Chamber Certification form.)

☐ ☐ ☐ 3. Chamber operator(s) have been trained and certified as per Doc. ID 64395 and certification is current.

☐ ☐ ☐ 4. The chamber has been cleaned and verified by Contamination Control.

☐ ☐ ☐ 5. The chamber has been thermally mapped to indicate any hot or cold spots.

☐ ☐ ☐ 6. The chamber has been thermally cycled (dry run) prior to the test to verify the set (temperature) limits or overrides.

☐ ☐ ☐ 7. A mass simulator has been included in the chamber thermal cycling.

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SYSTEMS SAFETY SURVEY

YES NO N/A

D. ENVIRONMENTAL TESTING – CHAMBERS, CONTINUED

☐ ☐ ☐ 8. No condensation resulted during the dry run of the Chamber Temperature Test.

☐ ☐ ☐ 9. The independent temperature controller is set for this test and is functionally verified.

☐ ☐ ☐ 10. The redundant temperature controller is sensitive enough to ensure that QUAL temperatures are not exceeded and it is not used for

rough indication only.

☐ ☐ ☐ 11. All temperature conditions that the hardware will experience are recorded, including the independent temperature controller.

☐ ☐ ☐ 12. All potential air holes have been plugged especially around cable pass-throughs.

☐ ☐ ☐ 13. Cable runs in the chamber have been designed to prevent hardware damage from condensation, expansion, etc.

☐ ☐ ☐ 14. A leak test has been performed on all heat exchangers inside the vacuum chamber and bulkhead fittings.

☐ ☐ ☐ 15. Purge / coolant / back-fill gases (e.g. GN_2 / LN_2) are safely vented and do not present an asphyxiation hazard to personnel.

☐ ☐ ☐ 16. Purge requirements for this test have been verified as appropriate for the chamber volume and size of the article under test.

☐ ☐ ☐ 17. The gaseous nitrogen purge introduced into the chamber is verified for quality and continuously monitored for flow as appropriate.

☐ ☐ ☐ 18. Pressure overrides have been set for this test and are functionally verified.

☐ ☐ ☐ 19. The chamber will hold vacuum in the event of a power failure with no damage to the hardware (e.g. condensation).

☐ ☐ ☐ 20. An emergency backfill procedure is in place and presents no hazard to the hardware under test.

☐ ☐ ☐ 21. Chamber blower / exhaust fan does not override the GN_2 flow and introduce air into the chamber.

☐ ☐ ☐ 22. There is no potential for contamination to fall back onto the hardware in chamber(s) with top blowers.

☐ ☐ ☐ 23. Chamber doors are opened only when the hardware is at room temperature to avoid condensation.

☐ ☐ ☐ 24. There is a trained back-up operator in the event that the primary is not available.

☐ ☐ ☐ 25. There are thermal sensors installed on hardware areas subject to temperature increases exceeding the chamber temperature (e.g. heat

Generated by hardware power supplies, or hardware that fills the chamber and is subject to chamber wall heating).

☐ ☐ ☐ 26. Peripheral hardware, such as cables / connectors, etc., have been baked-out to avoid non-volatile residue (NVR).

☐ ☐ ☐ 27. Witness plates or Thermal-Electric Quartz Crystal Microbalance(s) (TQCM's), if required, are in place and calibrated and procedures exists for monitoring.

☐ ☐ ☐ 28. Liquid temperature control systems are protected from flow loss or flow interruption.

☐ ☐ ☐ 29. A power distribution analysis has been conducted to assure that additional powered elements, such as lamp arrays, cameras, lasers, Heating or cooling coils, etc., used with the chamber will not compromise or overload the circuit limits.

D. ENVIRONMENTAL TESTING – DYNAMIC

☐ ☐ ☐ 30. An Environmental Test Authorization and Summary (ETAS) has been completed for this test.

☐ ☐ ☐ 31. A fit check between the vibe plate and hardware has been conducted.

☐ ☐ ☐ 32. The dynamic spectrum that is representative of the actual test conditions is run with a mass simulator prior to the actual test.

☐ ☐ ☐ 33. Test equipment behavior has been characterized to avoid anomalous readings not attributable to the tested hardware.

☐ ☐ ☐ 34. Critical control system response data are evaluated real-time during testing.

☐ ☐ ☐ 35. A dynamacist will be available to support the test or has reviewed the test parameters / control measures.

☐ ☐ ☐ 36. Emergency shut down capability is in place and verified.

☐ ☐ ☐ 37. Vibration facility maintenance schedules have been adhered to.

SYSTEMS SAFETY SURVEY

SURVEY Applicability

The purpose of this checklist is to ensure that all personnel and hardware safety aspects of an activity are addressed by appropriate responsible and knowledgeable persons in a structured and orderly manner. Specific emphasis shall be made on aspects of the activity which have the potential for personnel injury or hardware damage. This survey does not take the place of an Occupational Safety Program, nor does it absolve any organization of their responsibility to assure themselves of a safe working environment. Contractors are encouraged to employ their own checklist or survey process providing that their process has been reviewed and approved by JPL for its equivalent scope and applicability to the specific contract for the planned activity.

Assembly, inspection, test, or storage facilities used for flight-critical hardware or JPL Critical Items (JCI) shall be surveyed annually. JCI is defined as critical hardware, software, test and / or handling equipment, including fixturing or ground support equipment which if damaged or lost would: (a) Jeopardize the successful accomplishment of the experiment or task; or (b) Result in a substantial cost increase or schedule impact to the task; or (c) Result in an impact of $100K or greater, regardless of program / experiment.

This survey assesses readiness for flight-critical hardware operations, such as assembly, inspection, test activities or storage and Safety Survey shall include the integrated facility / hardware hazard analysis relationship (Figure 1 below shows the relationship of the Facility to the Operation). The survey shall be conducted sufficiently in advance to allow for action item closure prior to the commencement of the activity, and annually thereafter until completion.

All items in this survey shall be assessed by the Facility Manager and / or the hardware Cognizant Engineer and marked "YES", "NO", or "N/A" (Not Applicable) as appropriate for the scope of this survey. Corrective action or acceptance rationale for items assessed as "NO" shall be documented in the written minutes of the survey or where appropriate within this Systems Safety Survey. **Action items will be defined and documented on the front page of this survey and verified by Quality Assurance to be closed out prior to start of any test activity.** This checklist includes areas of concern that need to be addressed, but they are not necessarily all requirements. Checklist items may be modified by crossing out or modifying as appropriate to properly convey tailored context.

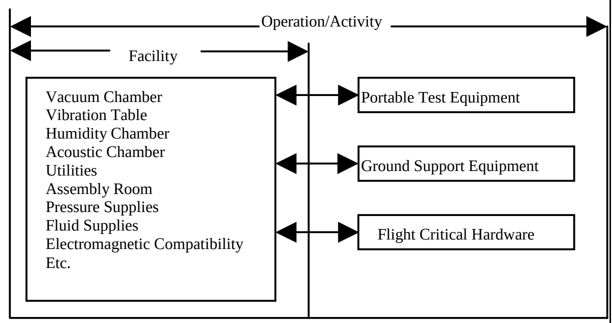

Figure 1: Relationship of Facility to Operation

1 - Operations Safety Survey (OSS) -- Review specific activity for integrate flight hardware / GSE / test equipment into facility

2 - Facility Safety Survey (FSS) -- Review permanent facility at least annually.

Note: Exact boundaries of boxes in above figure must be agreed upon and documented prior to either survey to ensure complete coverage.

SURVEY TYPE

Facilities and operations involving flight-critical hardware or JCI require a Survey. The choice of Team (T) Survey or Informal (I) Survey is determined by the nature of the operations and the level of assembly of the hardware. Flight-critical hardware is defined as hardware whose loss or damage would significantly impact the Project in either cost or schedule, as determined by the hardware Section Manager and / or Project.

<u>T = Team Survey</u>: Requires completion of a Facility / Operations Safety Survey by the Facility Manager and / or Hardware Cognizant Engineer, concurrence and signature by the appropriate supervisory Manager(s), and then review by a survey team comprised of: (1) the Hardware Cognizant Engineer, (2) the Facility Manager, (3) Systems Safety Program Office Representative, (4) an Occupational Safety Program Office Representative (if personnel hazards are involved in the operation), (5) Environmental Test Laboratory Representative (if environmental testing is involved), and (6) the Quality Assurance Representative. The Project Office and / or the Division Project Representative of potential users shall be notified and given the option of attending.

	Assy	Storage	Insp	Funct Test (non-Env)	Funct Test (Env)	Env Qual PF, FA
System	T	T	T	T	T	T
Subsystem	T	T	T	T	T	T
Assy	I	I	I	T	T	T
Subassy	I	I	I	I	T	T
Comp	I	I	I	I	I	I

Table 1. Survey Type

Items assessed as NO during the survey must be dispositioned by the Team (accepted or referred to a higher authority) prior to the operation. Changes in the initial assessment shall be marked with an "*" and the rationale for change stated in the written minutes of the meeting. If this survey is solely for the facility, the Cognizant Hardware Engineer and the Quality Assurance Representative team members should be representative of typical users. Completion of the Team Survey constitutes consent to proceed pending QA verification of action item closure prior to the activity (or within 30 days if the activity is a continuing activity) or as stated in the minutes.

<u>NOTE</u>: If a formal Test Readiness Review is conducted by the Project, the results of this survey shall be reported at that review.

<u>I = Informal Survey:</u> Necessitates the completion of a Systems Safety Survey by the Facility and / or Operation Manager prior to the operation. **Action items and all items assessed as NO or N/A should be reviewed by the appropriate Section Manager for concurrence.** Action items may remain open with approval of the Section Manager, but must be closed prior to any activity requiring a higher level of review.