JPL D25614
OSTM-31-5006

OCEAN SURFACE TOPOGRAPHY MISSION

STRUCTURAL REQUIREMENTS & VERIFICATION

PLAN

February 12, 2003

(A Hyper-linked Document)

Prepared by:

John Alpay
Structural Analyst

Approved by:

Richard Rainen
Mechanical/Thermal PEM

Dennis Kern
Dynamics Environment

Robin Bruno
Instrument Structures & Dynamics

Parag Vaze
Acting Payload Manager, OSTM

JPL
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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1.0 SCOPE

This document establishes the structural design and verification criteria for all OSTM project flight and ground hardware systems.

It encompasses the flight, flight spare, and ground support hardware systems, subsystems, assemblies, and components designed and/or fabricated by the Jet Propulsion Laboratory (JPL) or its contractors. It covers all phases of the project including fabrication, test, transportation, launch and on-orbit operations.

This document does not contain the project mission assurance requirements.

2.0 APPLICABLE DOCUMENTS

The following documents in their latest versions are applicable to this plan to the extent specified herein. Any conflicts that may arise between applicable documents shall be brought to the attention of the OSTM Cognizant Mechanical Engineer.

NASA Documents

NASA-STD-7001	NASA Technical Standard, "Payload Vibroacoustic Test Criteria," Dated: June 21, 1996.
NASA-STD-5001	NASA Technical Standard, "Structural Design Test Factors of Safety for Spacecraft Hardware", Dated: June 21, 1969.
NASA-HDBK-7004A	Force Limited Vibration Testing, November 5, 2002

Military Documents

MIL-HDBK-5	Metallic Materials and Elements for Aerospace Vehicle Structures

Jet Propulsion Laboratory Documents

TBD	OSTM Mission Assurance Plan. (*Appendix C of this document contains the OSTM Environmental Requirements Document (ERD)*)
JPL ES501492	Safety Requirements for Mechanical Support Equipment for JPL Critical Items, July 6, 2000.
JPL FS511316	Qualification of Critical Fasteners, July 26, 1993
TBD	OSTM Materials & Processes Control Plan

IOM 3541-93-114	Notes on the Usage of the Mass Acceleration Curve, Frank Tillman May 12, 1995
IOM 352F:00:043	Finite Element Model Checkout with MSC/NASTRAN C.P. Landry, November 8, 2001

CNES Documents

TBD	Jason-2 Payload Design and Interface Specification
TBD	Jason-2 Payload Instrument General Design and Interface Specification (GDIS)

3.0 STRUCTURAL REQUIREMENTS

All OSTM hardware shall be designed to withstand launch, operational and ground handling loads with positive margins of safety. The design shall be structurally safe and compatible with the Proteus S/C and shall not impose excessive deformation or deflection on other hardware.

3.1 Strength

3.1.1 Metallic Materials

Type "A" basis material properties (99% probability of survival with 95% confidence level) or equivalent shall be used for metallic primary structures as documented in MIL-HDBK-5. Other sources approved by the JPL Materials & Processes engineer may also be used. The documentation of the source and the design allowables for all material used shall be submitted to OSTM Project Office.

3.1.2 Composite Materials

The JPL Materials & Processes engineer shall approve allowable material property data for composite materials. Composite structures shall be proof tested and the proof test loads shall not exceed 80% of ultimate strength as determined by analysis.

3.1.3 Factors of Safety

The minimum factors of safety (F.S.) to be used for the design and testing of OSTM hardware are listed in **Table 1**. The hardware shall be capable of withstanding the design limit loads times the yield factor of safety ($F.S._y$) without permanent deformation and withstanding the design limit loads times the ultimate factor of safety ($F.S._{ult}$) without failure.

Table 1 OSTM Hardware Minimum Factors of Safety

No.	Structure/Component	Design Factor of Safety		Test Factors
		Yield FS_y	Ultimate FS_{ult}	Proto-Flight [3]
1	Metallic Structures Qualified by Testing	1.25	1.56	1.20
2	Metallic Structures Qualified by Analysis only	1.60	2.00	-
3	Composite Structures	-	1.56	1.20
4	Composite Structural joints/Discontinuities	-	2.00	1.20
5	Bonded Joints	-	2.00	1.20
6	Bolted Joint Separation and Slippage	-	1.00 [2]	1.20
7	Ground Support Equipment (GSE) [1]	1.875	2.50	-

1. For GSE a dynamic factor of 2.0 must be applied to the limit load. The values given here are for handling frames and spreader bars. Higher factors are required for other lifting equipment per JPL ES501492.

2. For alignment sensitive hardware use a Factor of Safety of 1.20.

3. If the Structure to be tested is not proto-flight see the JPL Structures specialist.

3.2 Stiffness Goals

The following shall be designed towards meeting the first global resonance frequency goals, as shown below, when rigidly attached at their flight interfaces (SPC 123456) to rigid test fixtures.

WSOA	55 Hz	(stowed configuration)
AMR	65 Hz	
Black Boxes	150 Hz	

3.3 Deflection

A structural member shall have sufficient rigidity to withstand its design loads without deformation or deflections of a magnitude that would be excessive. Deformation or deflections shall be considered excessive if they are greater than the requirements placed on the structure or can cause:

a) Unintentional deleterious contact between adjacent assemblies,

b) Physical separation of any preloaded joint at limit load times the appropriate yield factor of safety,

c) Encroachment upon the launch vehicle dynamic envelope.

The stress analysis shall include a deformation analysis to insure that the OSTM is capable of withstanding all loads up to limit without violating the L/V faring dynamic envelope. All critical conditions will be considered, including applied loads, thermal loads and manufacturing tolerances.

3.4 Materials and Processes

3.4.1 Metallic Materials

Whenever possible, structures shall be made of materials resistant to stress-corrosion cracking, i.e., Table I materials per MSFC-SPEC-522B "Design Criteria for Controlling Stress Corrosion Cracking" or "A" rated materials per MSFC-HDBK-527/JSC 09604 "Materials Selection List for Space Hardware Systems."

3.4.2 Composite Materials

All composite/bonded structures (which includes metallic honeycomb structures) shall, as a minimum, meet prescribed structural verification requirements specified in this document. Furthermore, the designer/manufacturer shall use only manufacturing processes and controls (coupon tests, sampling techniques, etc.) that are demonstrated to be reliable and consistent with established aerospace industry practices for composite/bonded structures. Supporting data shall be available to verify that as-built flight articles satisfy design and analysis assumptions, models, and all technical requirements. Test articles shall be designed and fabricated to the same requirements, drawings, and specifications as the flight article.

3.4.2.1 Composite/Bonded Structures

All composite/bonded structures deemed shall be tested to meet the following requirements:

> *A proof test (static or dynamic) to no less than 120 percent of the limit load. The proof test shall be conducted on the flight article. The test may be accomplished at the component or subassembly level if the loads on the test article duplicate those that would be seen in a fully assembled test article. Caution should be exercised when testing the flight article to 1.20 to prevent detrimental yielding to the metallic fittings and fasteners in the flight assembly and damage to the composite. Test loads on the composite should not exceed 80 percent of ultimate strength.*

3.5 Fasteners

Installation of pre-loaded hardware elements shall provide for sufficient pre-load such that no physical separation or slippage shall occur at limit load times the appropriate yield factor of safety.

All bolted assemblies of the OSTM Payload shall include a positive locking device, to prevent fasteners from losing pre-load and backing out. All structural fasteners may use a mechanical locking device, or the application of adhesive to the bolt threads and/or staking heads.

3.6 Joint Preload

Installation of pre-loaded hardware shall provide pre-load such that no physical separation or slippage shall occur at limit loads times the appropriate factor of safety.

4.0 DESIGN LOADS

OSTM structures shall be designed to withstand limit loads without experiencing yielding or failure. Limit loads are the maximum physical loads that a given structure will experience under all expected conditions of operation and use. Limit Loads are intended to provide upper bounds on loads in structures. These loads may result from the expected ground support, launch and operational environments.

All secondary structures, black-boxes and non-structural components shall be designed to survive the entire frequency range of the vibro/acoustic/shock environments.

4.1 Launch Loads

Limit loads resulting from launch vehicle dynamic response are intended to provide an upper bound loads and shall be used for assessing the integrity of structural elements in the low to mid frequency (approximately 0 to 80 Hz) range. For components with fundamental resonances greater than 80 Hz, these limit loads may not account for the vibro/acoustic/shock environments.

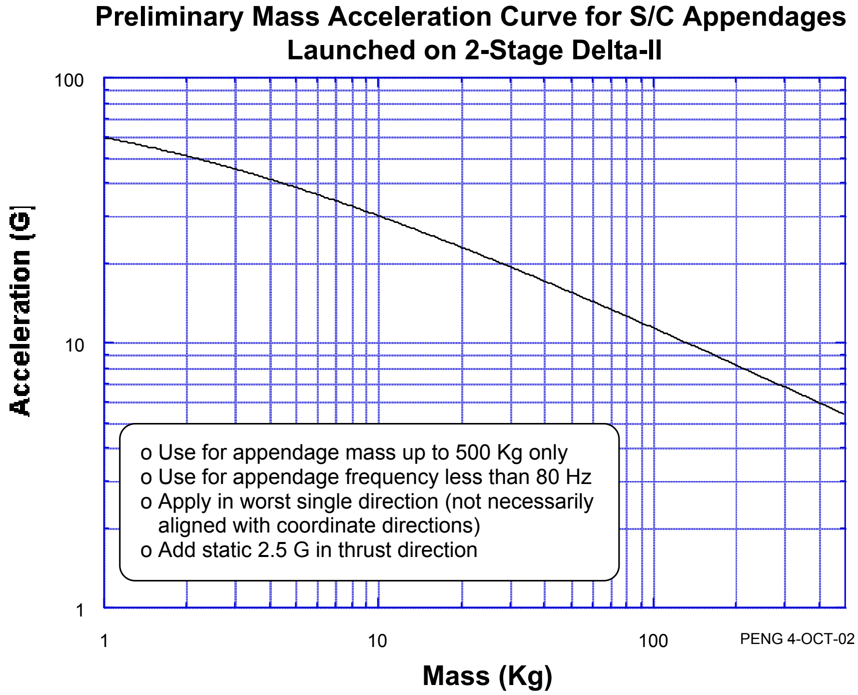
4.1.1 MAC Quasi-Static Loads

During the preliminary design, the limit loads shall be conservatively bounded by the use of the JPL developed Mass Acceleration Curve (MAC). MAC loads are applicable to structures and components weighing more than 1 kg and with first resonance frequencies less than 80 Hz.

The preliminary structural design of OSTM structures shall be based on the Mass Acceleration Curve (MAC) shown in **Figure 1.** This particular data is based on the dynamic characteristics for the Delta II Launch Vehicle. The g levels shown on the MAC curve should be treated as design limit loads and applied at the c.g. of the component or assembly being analyzed acting in the worst direction.

The limit loads derived from the MAC are considered preliminary until validated by the development of the design Flight Limit Loads (FLL). The FLL shall be developed from the raw CLA results multiplied by appropriate dynamic and uncertainty factors. The FLL shall be subsequently used in the final structural design analysis and margin assessment.

Figure 1 OSTM Mass Acceleration Curve



4.1.2 Coupled Loads Analysis

During the project execution process, JPL will integrate all the OSTM subsystem FEMs and develop an integrated payload FEM. The combined model will then be delivered to the S/C contractor for integration with their FEM. The S/C team, in turn, will deliver a model to the L/V staff for use in the CLA. The loads obtained from the CLA shall be used in arriving at the FLL.

4.2 Thermal Loads

Thermal stresses, thermal distortion and material property degradation shall be considered in the analysis of structures. Thermal conditions, such as temperature change and thermal gradient extremes, which could affect structural alignment shall be analyzed or tested.

Thermally induced structural loads shall be based on thermal analyses, where applicable. All potentially critical thermal conditions shall be checked including temperature and thermal gradient extremes. Thermal stresses with a F.S. of 1.0 shall be combined with all other simultaneously occurring stresses with appropriate F.S..

4.3 Dynamic Loads

The required environmental design and test loads are discussed in detail in the OSTM ERD. Extractions of the environmental loads are provided in this document for convenience. However, for the official project requirements, please refer to the OSTM ERD.

4.3.1 Random Signature Survey

Vibration tests, shall be preceded and followed by a 0.0004 g^2/Hz gpk random signature survey to identify all major resonances and verify the stiffness goals attained.

4.3.2 Sinusoidal Vibration

Sinusoidal vibration design and test requirements are imposed to cover low frequency (5-100 Hz) launch vehicle-induced transient loading. OSTM System and its assemblies shall be designed to withstand the sinusoidal vibration requirements as shown in **Table 3.** Analytical models shall be exercised to capture all MECO events up to 140 Hz along with the Coupled Loads Analysis (CLA).

4.3.3 Random Vibration

The random vibration environment results from a combination of vibration transmitted mechanically through the base of the spacecraft and acoustically excited vibration. OSTM System and its assemblies shall be designed and tested to withstand the random vibration design requirements as specified in **Table 4.**

The preliminary force spectrum in **Table 2** may be used to notch the input acceleration. Refined force limits may be calculated using the simple or complex method described in NASA-HDBK-7004A when details of the assemblies and the spacecraft mounting structure are available. The JPL Dynamics Environment group should be consulted for derivation of refined force limits. The interface force must be measured and controlled via force transducers installed for the vibration test. The force limit values may be modified based on information gathered during shaker testing.

Table 2 Assembly Random Vibration Force Limit Specification

Frequency, Hz	Force Spectral Density Level
$f < f_o$	$S_{FF} = C^2 M_o^2 S_{AA}$
$f >/= f_o$	$S_{FF} = C^2 M_o^2 S_{AA} (f_o/f)$

where, f is frequency, f_o is the frequency of the primary mode, i.e. the mode with the greatest effective mass, S_{FF} is the force spectral density, C is a dimensionless constant which depends on the configuration, M_o is the total mass of the test item, and S_{AA} is the acceleration spectral density level from **Table 4**. For preliminary specification, the value of C shall be 3.0. The equations of **Table 2** must be in consistent units. If it is desired to use metric units, the acceleration specification of **Table 4** must be expressed in meters per second squared.

4.3.4 Acoustic Loads

The OSTM Payload and its assemblies shall be designed to survive the acoustic noise design levels shown in **Table 5.** The acoustic noise is a reverberant random-incidence field specified in one-third octave bands. Selected subsystems shall be tested per **Table 6.**

4.4 Ground Handling Loads

Payload assembly, handling and shipping loads and dynamic factors shall be separately determined for use in the analysis of all hardware. Ground handling equipment design loads shall be the static weight supported by the ground handling structure times the dynamic factor. The ground handling equipment dynamic factor in the vertical direction shall be equal to 2.0 unless there is reason to believe that a higher dynamic factor is required. The ground handling equipment dynamic factor in the lateral direction shall be equal to 0.25 unless there is reason to believe that a higher dynamic factor is required. Also see section **5.3.1.3** for additional related details.

4.4.1 Pyrotechnic Shock

Pyrotechnic shock is induced by the launch vehicle & spacecraft separation deployment event and is transmitted through spacecraft structure. It is anticipated that the shock levels at the instrument hardware locations will be benign. However, the requirements are to be provided as the design matures.

Table 3 Sinusoidal Vibration Levels

No	Subsystem	Axis	Frequency (Hz)	Flight Acceptance (FA)		Protoflight (PF)	
1	Tip Electronics	all	5 - 21	7.8 mm	(0 to peak)	11 mm	(0 to peak)
			21 - 100	14.1 g	(0 to peak)	20g	(0 to peak)
2	AMR	all	5 - 18	7.8 mm	(0 to peak)	11 mm	(0 to peak)
			18 - 100	10.6 g	(0 to peak)	15 g	(0 to peak)
3	WSOA	all	5 - 15	7.8 mm	(0 to peak)	11 mm	(0 to peak)
			15 - 100	7.1 g	(0 to peak)	10 g	(0 to peak)
4	WDES/WRFS	all	5 - 18	7.8 mm	(0 to peak)	11 mm	(0 to peak)
			18 - 100	10.6 g	(0 to peak)	15 g	(0 to peak)
5	GPSR & LRA	out of plane	5 - 24	7.8 mm	(0 to peak)	11 mm	(0 to peak)
			24 - 100	17.7 g	(0 to peak)	25 g	(0 to peak)
6	GPSR & LRA	in plane	5 - 18	7.8 mm	(0 to peak)	11 mm	(0 to peak)
			18 - 100	10.6 g	(0 to peak)	15 g	(0 to peak)

Table 4 Random Vibration Levels

No	Subsystem	Axis	Frequency (Hz)	Flight Acceptance (FA)	Protoflight (PF)
1	AMR Subsystem & WSOA PIM External Assembly	all	20	0.065 g^2/Hz	0.13 g^2/Hz
			20 50	+3 db/octave	+3 db/octave
			50 - 300	0.16 g^2/Hz	0.32 g^2/Hz
			300 - 2000	- 5 dB/octave	- 5 dB/octave
			2000	0.007 g^2/Hz	0.014 g^2/Hz
			Overall Level	9.8 g_{rms}	13.8 g_{rms}
2	WSOA Canister	all	20	0.008 g^2/Hz	0.016 g^2/Hz
			20 100	+3 dB/octave	+3 dB/octave
			100 - 300	0.04 g^2/Hz	0.08 g^2/Hz
			300 - 2000	-5 dB/octave	-5 dB/octave
			2000	0.0017 g^2/Hz	0.0034 g^2/Hz
			Overall Level	4.8 g_{rms}	6.8 g_{rms}

Table 4 Random Vibration Levels (Cont'd)

No	Subsystem	Axis	Frequency (Hz)	Flight Acceptance (FA)	Protoflight (PF)
3	GPSR Electronics & WSOA Electronics	out of plane	20	0.03 g^2/Hz	0.06 g^2/Hz
			20 100	+3 dB/octave	+3 dB/octave
			100 - 300	0.15 g^2/Hz	0.30 g^2/Hz
			300 - 2000	-5 dB/octave	-5 dB/octave
			2000	0.0065 g^2/Hz	0.013 g^2/Hz
			Overall Level	9.3 g_{rms}	13.1 g_{rms}
4	GPSR Electronics & WSOA Electronics	in-plane	20	0.016 g^2/Hz	0.03 g^2/Hz
			20 100	+3 dB/octave	+3 dB/octave
			100 - 300	0.075 g^2/Hz	0.15 g^2/Hz
			300 - 2000	-5 dB/octave	-5 dB/octave
			2000	0.003 g^2/Hz	0.006 g^2/Hz
			Overall Level	6.6 g_{rms}	9.3 g_{rms}

Table 4 Random Vibration Levels (Cont'd)

No	Subsystem	Axis	Frequency (Hz)	Flight Acceptance (FA)	Protoflight (PF)
5	GPSR Antenna & LRA Subsystems	all	20	0.1 g^2/Hz	0.2 g^2/Hz
			20 100	+3 dB/octave	+3 dB/octave
			100 - 300	0.5 g^2/Hz	1.0 g^2/Hz
			300 - 2000	-5 dB/octave	-5 dB/octave
			2000	0.02 g^2/Hz	0.04 g^2/Hz
			Overall Level	16.9 g_{rms}	23.9 g_{rms}

Table 5 Acoustic Noise Levels

No	1/3 Octave Band	
	Center Frequency (Hz)	Sound Pressure Level (dB)
1	31.5	122.5
2	40.0	125.5
3	50.0	129.5
4	63.0	131.0
5	80.0	131.5
6	100.0	132.5
7	125.0	133.0
8	160.0	133.0
9	200.0	133.5
10	250.0	134.5
11	315.0	135.5
12	400.0	134.5
13	500.0	131.0
14	630	128.0
15	800	125.0
16	1000	123.0
17	1250	121.0
18	1600	120.0
19	2000	119.5
20	2500	119.0
21	3150	118.0
22	4000	116.5
23	5000	114.0
24	6300	110.0
25	8000	106.0
26	10000	103.0

5.0 STRUCTURAL VERIFICATION

5.1 Structural Analysis

Stress analyses shall be performed on all OSTM hardware. The cognizant structural analyst shall carry out comprehensive analyses to facilitate the margins of safety assessment and drawing sign-off following acceptable aerospace industry standards. Approaches and results of stress analyses shall be adequately documented and delivered to OSTM project office for reviews.

5.1.1 Margins of Safety

The structural adequacy of a hardware component is expressed in terms of its Margin of Safety (M.S.) as defined by the following relationship:

$$\text{M.S.} = \frac{f_{\text{allowable stress}}}{f_{\text{applied stress}} \text{ x F.S.}} - 1$$

The Margins of Safety shall be calculated using material strengths at appropriate worst-case temperatures. An acceptable design demonstrates positive margins under all design loads with appropriate factors of safety applied.

The drawing "mean/average" thickness values may be used for the stress calculations of structures. Actual "as-built" dimensions may be used in the stress analysis when available.

5.1.2 Analysis Documentation

Stress analysis documentation shall include the applied limit loads, factors of safety, assumptions, and methodologies and calculations of margins of safety for each structural component. A margin of safety summary table shall be included. All stress analyses shall be updated as the design matures and/or the predicted design loads change.

5.2 Mathematical Models

A detailed mathematical Finite Element Model (FEM) of the OSTM Payload, its subsystems, subassemblies and assemblies shall be developed and kept current. The Payload FEM will be used by JPL to support the L/V - S/C - Payload coupled loads analyses (CLA) and analyses in support of environmental vibration tests. Detailed component FEMs may also be created and maintained in support of structural analyses of piece parts.

In assembling a FEM, modeling assumptions and idealizations should be realistic, accurately reflect the nominal stiffness, and be properly documented. For cases where approximations have to be made, they must be conservative with respect to the particular analytic purpose of the model. The assembled FEM shall be thoroughly checked out by following a set of established FEM-checking procedures.

Through the entire development effort of a hardware system, the mathematical model of the system shall be periodically updated and kept current. It shall also be modified to match test data as available.

S/C contractor stipulated additional requirements on the mathematical model are documented in Jason-2 Payload Design and Interface Specification (PDIS), Section 4.6.

5.2.1 NASTRAN

All structural models to be exchanged between OSTM contractors and JPL shall be in MSC/NASTRAN Version 70 BULKDATA format.

5.2.2 Subsystem Finite Element Model Requirements

1. The model shall be a loads model rather than detailed stress model and be consistent with the low frequency ($\leq$ 50 Hz.) coupled loads analysis. Models shall be "full" models with no symmetry assumptions made to reduce model size. Super-elements shall not be used.

2. Replication features of NASTRAN shall not be used.

3. SI units shall be used and defined as follows: mass (kg); length (m); time, (seconds); and force data in (Newtons).

4. The bulk data deck shall not contain BAROR, BEAMOR, GRDSET, PARAM K6ROT, or PARAM, AUTOSPC NASTRAN cards.

5. Model shall adequately represent all modes up to 100 Hz when rigidly supported at the interface(s).

6. Duplicate grid, element, material, property, coordinate system or constraint identification numbers shall not be permitted.

7. A unique numbering system (TBD) for all NASTRAN model identification numbers shall be used (grids, elements, coordinate systems, properties, materials, constraints, and loading IDs).

8. The OUTPUT coordinate system of all grids that are defined anywhere along the hardware X-axis MUST be a RECTANGULAR coordinate system NOT a cylindrical system.

5.2.3 FEM Interfaces

The physical location of the major interfaces between system and assemblies shall conform to the existing ICDs. The number and location of grids along these interfaces shall be agreed upon.

5.2.4 Deliverable MSC/NASTRAN Model Data

1. Complete documentation of the structural model shall be provided. This documentation shall include description of the model, modeling method rationale, assumptions, idealizations, model schematics (roadmaps), material and member properties, checkout procedure and results.

2. The model shall be able to define the loads at instrument/support structure interface due to gravity loads.

3. The model file transfer shall be provided using either PC compatible disks or e-mail attachment files.

5.2.5 Deliverable Model Validity Checks

Checkout procedures should include the following as a minimum:

1. Grid Point Weight Generator shall yield correct weight, center of mass, and moments of inertia.

2. Static analysis for unit gravity loading in each of the three axis directions. Reaction forces from this analysis shall equal the weight of the structure as given by the Grid Point Weight Generator output. No large displacements or forces shall be generated. The maximum absolute value of epsilon (solution error ratio) for each of the three load cases should be a value less than 1.0×10^{-6}.

3. The rigid body displacement check shall be run with the model constrained at one point by applying an enforced displacement of one unit in each of the three translation directions and an enforced rotation of one unit in each of the three rotational directions. Rigid body strain energies shall be less than 4.5×10^{-4} N/m for the translation cases and less than 1.1×10^{-3} N/m for rotational cases. In addition, verify the maximum ratio of matrix diagonal to factor diagonal (Max Ratio) is < 1.0x10E5.

4. Eigenvalue analysis for modes up to 135 Hz with the instrument constrained, in the appropriate degrees of freedom, at the instrument/support structure interface.

5. Eigenvalue analysis for modes up to 135 Hz of the instrument in the free-free (unconstrained) condition. This analysis shall be made without the

NASTRAN SUPORT card. The rigid body modes from this analysis without the SUPORT card should yield frequencies less than 0.001 Hz.

5.2.6 Output Request Items

A separate list of output request items shall be supplied. These items may contain any combination of element force, joint load, station cut, and acceleration or displacement components. Each component, however, shall count as a single output request item.

This output list shall comprise structurally significantly loaded areas. JPL will use these results from the Coupled Loads Analyses for in-house checking of the Mass Acceleration Curve.

5.3 Structural Testing

Structural tests may be devised and performed to verify design concepts and analysis results, or to qualify flight hardware, ground handling equipment, and test fixtures. Tests may be conducted at the system, subsystem, assembly, and/or component levels as appropriate. The performance of structural tests on flight hardware shall be supported by analysis.

5.3.1 Structural Qualification

Structural integrity qualification is achieved through a combination of analysis and testing. Functional integrity of equipment is qualified through the environmental design and test requirements given in Section 4.3 and in the OSTM ERD.

5.3.1.1 Structure

Evaluation of primary structure shall be accomplished through a combination of analysis and testing. Testing shall be completed in order to exercise the structure to the required test factor times the design limit load. This testing can be accomplished with static testing, sinusoidal testing, or upon JPL's approval, via random vibration testing. Pretest analyses must be carried out. Test instrumentation must be adequate to ensure that primary structure is loaded to the desired levels. The test article shall be flight or flight-like structure. When testing the flight structure to 1.20 times design limit loads, caution must be used to prevent detrimental yield to metallic fittings and fasteners in the flight assembly and damage to composite structure.

5.3.1.2 Electronics Boxes & Non-Structural Items

Evaluation of secondary structure, black boxes, and non-structure shall be accomplished through a combination of analysis and environmental testing. The test article shall be flight or flight-like structure. Test input levels are specified in the OSTM ERD and Section **4.3**.

5.3.1.3 Ground Test Fixtures & Handling Equipment

Ground test fixtures and handling equipment for flight hardware shall be qualified by proof testing as required by JPL ES501492. The proof test loads shall be 1.75 times the static weight supported by the ground handling structure times a dynamic factor.

The dynamic factor in the vertical direction shall be equal to the acceleration measured on similar equipment with appropriate provisions for uncertainty, but no less than 1.25, or equal to 2.0 if there is no measurement data available and no reason to expect the dynamic factor to be greater than that due to a suddenly applied load. The dynamic factor in the horizontal direction shall be equal to 0.25 unless there is reason to believe that a higher dynamic factor is required.

Proof loading may be applied statically, or where it is possible and desirable to operate the equipment during proof loading, dynamically. For dynamic proof loading to be valid, maximum possible accelerations and worst case conditions shall be demonstrated, over the full span of operation of the equipment with the proof load (1.75 x supported weight) installed. If the dynamic factor during proof testing is less than 1.25, the proof weight shall be increased enough to compensate for the deficiency.

5.3.1.4 Flight Hardware Interfaces with Hoisting & Handling GSE

All permanently attached flight hardware interfaces with mechanical GSE (such as inserts), that will be loaded as a result of hoisting, lifting, or supporting structure, shall be qualified by proof testing. Proof testing for mechanical GSE loading is not required if it could be demonstrated that the planned proto-flight static testing for flight limit loads (1.20 x FLL) exceeds the required GSE proof test load.

5.3.1.5 Non-Metallic Structure and Bonded Joints Proof Test Factors

The minimum proof test factor for all non-metallic structure and bonded joints shall be 1.20. This must be demonstrated by test for every item or assembly. The proof test loads on composite structure should not exceed 80% of ultimate strength. A qualification test to failure or ultimate is not applicable for non-metallic structure and bonded joints.

5.3.2 Load Limitation during Vibration Testing

During vibration testing, loads induced in structural members resulting from the low to mid frequency (approximately 0-80 Hz) vibration environment shall not exceed the limit loads determined per the loads analysis of Section **4.0** times a minimum 1.00 dynamic test factor. Higher test loads may be allowed depending on the following:

1. Fidelity of the test article (developmental, dedicated test article, flight spare, Flight, etc.)
2. The as built load-bearing capability of a member is significantly in excess of the loads in Section **4.0**.
3. A test objective to verify structural integrity of a particular structural element that has not been sufficiently verified by previous testing and/or analysis.
4. Level of conservatism of load source.

Test inputs shall be "notched", if necessary, to prevent exceeding the low to mid-frequency limit loads. However, in cases where vibration test requirements have significant design impacts, other types of testing may be considered. Test methods such as transient pulse or impedance mismatch compensation (force limiting) may be implemented to give more realistic results. These methods may be considered upon approval by JPL OSTM project office. Test inputs shall be approved by the OSTM Mechanical Engineer and the Dynamics Test Conductor.

6.0 VERIFICATION APPROACH

6.1 Strength Qualification

All structures shall be designed to sustain the limit loads times appropriate factors of safety. All margins of safety shall be positive. The current OSTM Payload verification matrix is described in detail in the OSTM ERD. It is also shown in **Table 6** for convenience.

Table 6 Verification Matrix

SUBSYSTEM/SUBASSMBLY	QUASI-STATIC LOADS	SINE SURVEY	SINUSOIDAL VIBRATION	RANDOM VIBRATION	ACOUSTIC VIBRATION	PYROTECHNIC SHOCK	PRESSURE CHANGES	VOLTAGE MARGIN TEST	THERMAL VACUUM TEST	GROUNDING AND BONDING	ELECTRICAL ISOLATION	CONDUCTED EMISSIONS	CONDUCTED SUSCEPTIBILITY	RADIATED EMISSIONS	RADIATED SUSCEPTIBILITY	MAGNETIC EMISSIONS	MAGNETIC SUSCEPTIBILITY	PARTICLE NATURAL ENVIRONMENTS
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
FLIGHT SPARE ANTENNA	A	T	T	T	T	N/A	N/A	N/A	A	2	2	N/A	N/A	N/A	N/A	T/A	N/A	A
AMR ANTENNA	A	T	T	T	2	2	N/A	N/A	A	2	2	N/A	N/A	N/A	N/A	T/A	N/A	A
AMR ELECTRONICS	A	T	T	T	2	2	A	N/A	T	2	2	T	T	T	T	T/A	A	N/A
LRA	A	T	N/A	T	N/A	T	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	T/A	N/A	A
GPSR ANTENNA #1	A	T	T	T	N/A	T	N/A	N/A	N/A	2	2	N/A	N/A	2	2	T/A	N/A	A
GPSR ELECTRONICS #1	A	T	T	T	N/A	T	A	T	T	2	2	2	2	2	2	T/A	N/A	N/A
GPSR ANTENNA #2	A	T	T	T	N/A	T	N/A	N/A	N/A	2	2	N/A	N/A	2	2	T/A	N/A	A
GPSR ELECTRONICS #2	A	T	T	T	N/A	T	A	T	T	2	2	2	2	2	2	T/A	N/A	N/A
GPSR SUBSYSTEM	1	1	1	1	N/A	1	1	TBD	1	T	T	T	T	T	T	1	N/A	1
WSOA Digital Electronics	A	T	T	T	2	2	A	2	2	2	2	2	2	2	2	T/A	N/A	N/A
WSOA RF PIM-Mtd Electronics	A	T	T	T	2	2	A	2	2	2	2	2	2	2	2	T/A	A	N/A
WSOA -Y Electronics Assembly	A	1	1	1	TBD	TBD	1	T	T	T	T	T	T	T	T	1	1	1

Table 6 Verification Matrix (Cont'd)

SUBSYSTEM/SUBASSMBLY	QUASI-STATIC LOADS	SINE SURVEY	SINUSOIDAL VIBRATION	RANDOM VIBRATION	ACOUSTIC VIBRATION	PYROTECHNIC SHOCK	PRESSURE CHANGES	VOLTAGE MARGIN TEST	THERMAL VACUUM TEST	GROUNDING AND BONDING	ELECTRICAL ISOLATION	CONDUCTED EMISSIONS	CONDUCTED SUSCEPTIBILITY	RADIATED EMISSIONS	RADIATED SUSCEPTIBILITY	MAGNETIC EMISSIONS	MAGNETIC SUSCEPTIBILITY	PARTICLE NATURAL ENVIRONMENTS
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
WSOA RF Tip-Mounted Electronics	A	T	T	T	N/A	N/A	A	T	T	2	2	2	2	2	2	T/A	A	A
WSOA Antenna Panels	A	2	2	2	N/A	2	A	N/A	2	2	2	N/A	N/A	N/A	N/A	T/A	N/A	A
WSOA Antenna Feed	A	2	2	2	N/A	2	A	N/A	2	2	2	N/A	N/A	N/A	N/A	T/A	N/A	A
WSOA Mechanisms (DAS/DFS/Mast/Can)	A	TBD	TBD	TBD	N/A	N/A	A	T/A	T	2	2	T	T	T	T	T/A	A	A
JPL Payload +X Assembly (excludes GPSP components)	1	T	T	T	T	T	1	1	1	T	T	1,2	1,2	1,2	1,2	1	1	1
JPL Integrated Payload (+X & -Y PIM Panels)	1	1	1	1	1	1	1	1	1	1	1	T	T	T	T	1	1	1

Table 6 Verification Matrix (Cont'd)

Notes:

1. "1" qualified at a lower level of assembly
2. "2" qualified at a higher level of assembly
3. "A" qualified by analysis.
4. "T" qualified by test.
5. "T/A"qualified by test and/or analysis.
6. "N/A" not applicable (no action required).
7. "TBD" to be defined by CDR review
8. Redundant Electronics units (GPSR, etc.) CE, RE, CS, and RS tests may be deleted if respective test passes on first electronics unit tested.
9. At the box-level, thermal cycle tests may be substituted (with adjusted temperature limits for ambient conditions) in lieu of T/V tests
10. WSOA Antenna Panels & Deployable Antenna Structure are thermally tested as an integrated assembly
11. WDES & WRES to be thermally tested as an integrated assembly