Jet Propulsion Laboratory
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Jet Propulsion Laboratory

ENVIRONMENTAL TEST LABORATORY

USER's GUIDE & HANDBOOK

Building 150, 25-ft Space Simulator

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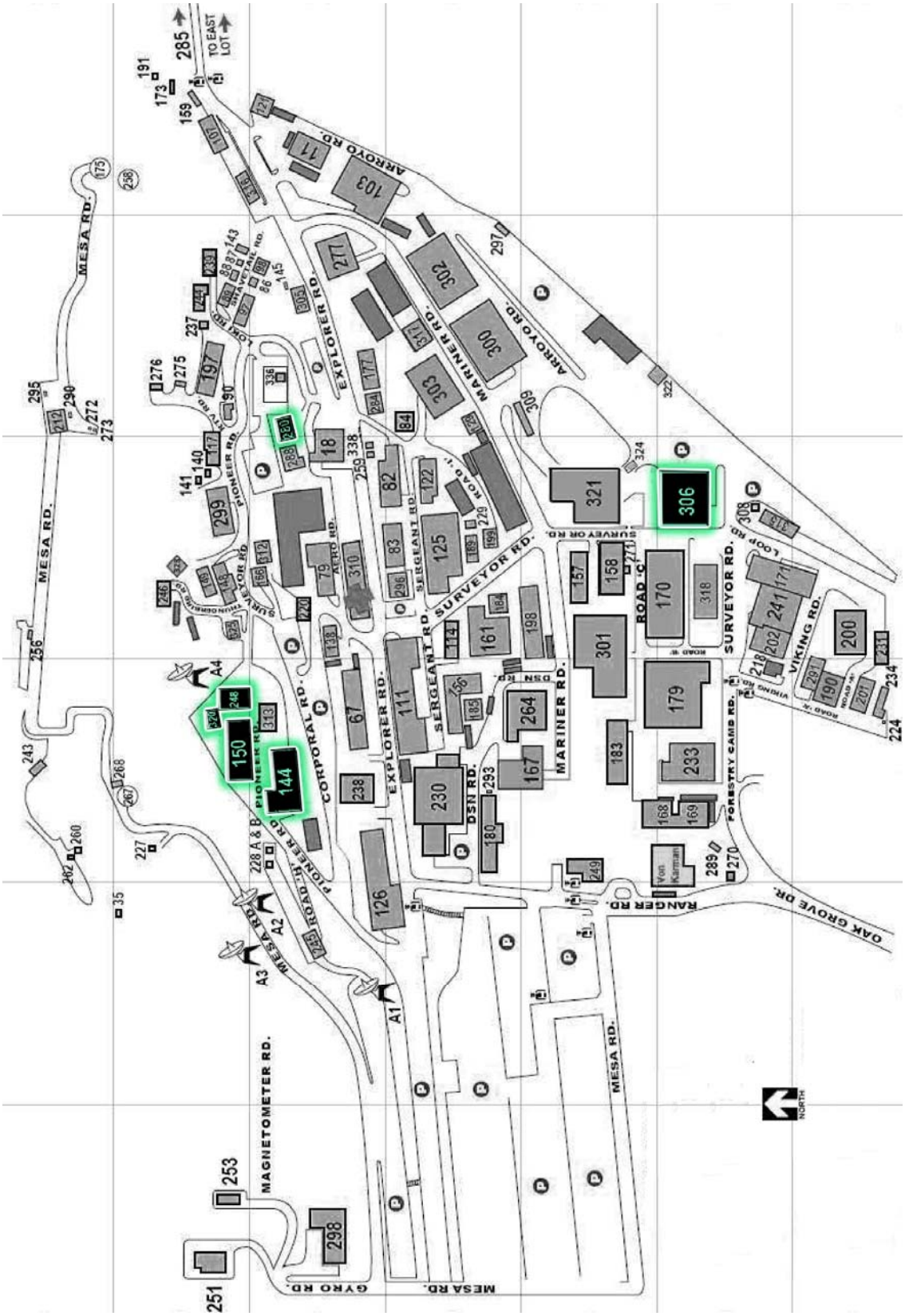

JPL Environmental Test Laboratory – Buildings 144, 150, 248, 280, 320 & 306

FOREWORD

As part of the NASA team, the mission of the Jet Propulsion Laboratory (JPL) is to enable the nation to explore space for the benefit of humankind by developing robotic space missions to: explore our own and neighboring planetary systems, search for life beyond the Earth's confines, further our understanding of the origins and evolution of the Universe and the laws that govern it, make critical measurements to understand our home planet and help protect its environment, enable a virtual presence throughout the solar system using the Deep Space Network and evolving it to the Interplanetary Network of the future, apply JPL's unique skills to address problems of national significance, and inspire the next generation of explorers.

To fulfill this mission, JPL maintains the on-site capability to function as a full spectrum end-to-end research and development laboratory. Scientific missions can be carried out from concept, through design, manufacture, test, and operations. JPL is committed through its strategic institutional goals to maintaining and upgrading JPL's core infrastructure, laboratory facilities, and equipment to preserve the Laboratory's preeminence as a national resource and Center of Excellence. The capabilities provided by the JPL Environmental Test Laboratory are a key element to realizing this goal.

The JPL Environmental Test Laboratory is managed by the Engineering and Science Directorate's Enterprise Engineering Division to provide environmental test capabilities that ensure spacecraft, flight experiments, and landing probes will withstand the rigors of launch and will operate properly in their intended environments.

This user's guide and handbook explains JPL's Environmental Test Laboratory capabilities and facilities. A layout map of JPL, showing the building locations of these facilities, appears on the following page. Included in each section is a User's Guide that lists Organizational Contacts and explains how to obtain services from the Environmental Test Laboratory and how best to prepare for these services.

Further information on the JPL Environmental Test Laboratory's facilities, capabilities and services can be obtained from:

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1 INTRODUCTION

The JPL Environmental Test Laboratory (ETL) facilities provide vibration, shock, acoustic, static loads testing and mass properties (both center of gravity and spin balance) as well as the necessary instrumentation and data acquisition equipment to support that testing. These activities include scheduling, maintenance and operations of test equipment and facilities.

Environmental Test Laboratory personnel operate and maintain the ETL in Building 144, Building 306, and the Space/Solar Simulator Facilities in Buildings 150 and 248. The ETL provides JPL projects and external customers with complete facilities for thermal ambient, thermal-vacuum, solar-thermal-vacuum, vibration, mechanical shock, and acoustic testing for all types of space flight hardware (B-144, B-248, and B-306). Building 280 houses a static test tower with a 10-ton (9100-kg) overhead crane and structural test support equipment, Building 320 is a storage facility for ETL support equipment. Expertise includes dynamic and thermal-vacuum test operations, instrumentation/data acquisition to support all testing, test method consultation, "off-site" chamber certification, spin balance and center of gravity measurements, as well as post-test detailed test documentation.

The Laboratory's environmental testing activities are directed toward achieving safe, accurate, reliable, and cost-effective tests to verify compliance with design requirements and achieve mission success. The Environmental Test Laboratory's functions include six environmental test disciplines plus data acquisition and analysis (Table 1-1) as follows:

Table 1-1 ETL Disciplines

Discipline	Description
Dynamics Testing	Sinusoidal vibration, random vibration, synthesized shock, acoustic reverberation
Thermal Vacuum Testing	Thermal ambient, thermal vacuum, bake-out, space/solar simulation
Chamber Certification	Survey JPL and vendor chambers for proper maintenance, failsafe capability, and operation
Mass Properties	Mass properties: spin balance and center of gravity
Static Testing	Mechanical and static load
Instrumentation	Data acquisition systems: Thermocouples, strain gages, accelerometers, force gages, electronic signal conditioning

Details of environmental test facilities and their capabilities are described in the following sections.

1.1 Environmental Test Laboratory as a Service Center

The Environmental Test Laboratory (ETL) is operated as a service center charging a fee for labor, facility usage, and consumables. Customers only pay hourly for services. Charging stops when the testing is completed and ETL personnel and equipment are no longer required.

Service center rates are determined prior to the start of each fiscal year based on the forecasted work for that fiscal year. If there was only one customer in a year that customer would have to pay the entire annual cost of the service center without the institutional funding subsidy.

Fortunately this has never been the case; however, institutional funding sources are becoming more difficult to obtain as a subsidy for keeping costs flat.

The rules that govern services centers require all charging to be equal across each project for the same service. In other words, there are no deals to be made.

1.2 Reference Documents

The following documents can be found in the JPL Rules document archive or they are stored locally within the ETL facility or document storage. The list below contains documents provided by ETL and other organizations for reference purposes only; please review each document in Rules for the most current version.

- JPL Rules 33472, Environmental Test Laboratory Services Policy
- JPL Rules 33832, Environmental Testing Procedure
- JPL Rules 34880, JPL Standard for Systems Safety
- JPL Rules 35492, Standard Environmental Testing Facilities and Practices
- JPL Rules 35506, Anomaly Resolution Standard
- JPL Rules 35515, Detail Specification for Evaluation and Acceptance of Dynamic Test Fixtures Used in Vibration and Shock Environmental Tests
- JPL Rules 35603, Instructions for Use of the Assembly and Inspection Data Sheet
- JPL Rules 36052, Use of Non-Environmental Test Lab Facilities for Environmental Testing
- JPL Rules 58032, Flight Project Practices
- JPL Rules 55833, Spacecraft System Dynamic and Static Testing
- JPL Rules 58172, System Thermal Testing
- JPL Rules 64395, Control and Use of Environmental Chambers
- JPL Rules 64572, ETL Chamber Certification Survey
- Test Plan (supplied by the Test Article Engineer or his/her designee for the article being tested)
- Systems Safety Survey – JPL Form 2847, available at JPL Forms, http://jplforms.jpl.nasa.gov/general_forms/
- M+P International Standard operating manual for Vibrunner software (stored in ETL)

Note: If there is any contradiction between the JPL Rules and this guide, the JPL Rules documents rule.

2 DYNAMICS TESTING

GENERAL: The Dynamics Laboratory provides all necessary services and equipment to perform shock, acoustic, and vibration testing of spacecraft and subsystems. Digital control systems provide sinusoidal, random, and transient waveform control to three separate electro-dynamic exciters. Data acquisition systems condition and record accelerometer, force, and strain-gage signals.

2.1 Dynamic Test Users Guide

Types of Testing: ETL provides dynamic testing of hardware, including simulated pyrotechnic shock from 1000 g to 5000 g (2.2 to 11 kg), dependent on the size and shape of the test article; vibration testing in three orthogonal axes with two small 20,000-force-pound (9000-kg) shakers and one larger system-level 60,000-force-pound (27,000-kg) shaker; and acoustic noise testing in the 110-dB to 153-dB ranges to simulate launch-vehicle lift off. Dynamic testing is implemented in accordance with "Spacecraft System Dynamic and Static Testing" standard, JPL Rules, DocID 55833.

Test Conductor: The Environmental Test Laboratory requires the use of a "Dynamic Environments Engineer" from Group 352G (JPL Employee) to direct all dynamics test operations during the physical testing of hardware acting as the overall "Test Conductor" for each operation.

The dynamic testing process guide:

a) Test Article Engineer (TAE) makes an online reservation with Technical Facilities Management (TFM) using the TFM web-tool as soon as possible after the need for a test is noted.

b) TAE makes arrangement with "Dynamic Environments Engineering Group (Sec. 352G) to act as "Test Conductor" during all aspects of the physical testing of hardware.

c) TAE calls ETL contact for cost estimate.

d) Test Article Engineer provides the Test Plan to ETL.

e) TAE provides ETL a mass/test model as required (mass models are required two weeks in advance of the scheduled shock testing to setup the test equipment): a mass model for vibration of system level structures is highly recommended.

f) TAE designs fixture and fit check with the ETL test equipment and reviews the design with the Test Conductor (Dynamic Environments Engineer).

g) TAE works with ETL instrumentation to insure available equipment and location of accelerometers, strain gages etc. (Fly-away instrumentation may require several weeks to prepare in advance).

h) The Dynamic Environments Engineer generates a Test Plan.

i) TAE reviews and approves the Test Plan and submits the approved Test Plan to ETL.

j) TAE arranges for systems safety survey.

k) TAE arrives with hardware and participates in performance of test.

l) ETL provides customer (TAE) with a completed test report within a few days of test completion.

The Cost of Testing: Test costs can very due to many factors, and a comprehensive estimate can be prepared upon request.

For basic cost planning, most vibration and acoustic tests take about two days, and current cost is approximately $10K per day. For tests requiring the large shaker, a typical test takes four to six days and runs $10K per day plus the additional cost of instrumentation at $60 per channel.

2.2 Shock Testing

General: Shock testing can be performed in several ways: (1) The electro-dynamic shakers can be used to perform low-level shock testing depending on the mass of the test article. (2) Pyro devices can be used to excite the test article. (3) The ETL developed and built a tunable-beam shock test bench based on a design built by Sandia National Laboratory many years ago. ETL has been using this test system successfully since October 2008.

Note: The ETL does not handle setup of or perform testing with pyrotechnic devices!

Figure 2-1 Tunable-Beam Shock-Test System

The tunable-beam system works on the principal surrounding the tuning of the system with a center-of-gravity (CG) mass and footprint model of the test article. The test article is mounted in the test axis with the appropriate accelerometers installed as they would be for the testing the test article; then the system is tuned by performing test runs until the data plots meet the requirement. The system is very repeatable; however, there can be a few subtle differences between the mass model test and the test article test. This issue should be discussed prior to testing with the Test Conductor (Dynamic Environments Engineer scheduled to conduct the test.

Shock Test Guide: The TAE will need to provide a mass model (per the Dynamic Environment Engineer's specification). If possible, this will be several weeks in advance of the test article's scheduled test to ensure the Test Plan requirements can be met. Testing typically takes two to three days, and test costs are $4200 per day.

2.3 Vibration Testing

CONTROL SYSTEM: The M+P Vibrunner digital vibration control system processes two control accelerometer signals and controls on the maximum of the signals. The control signals are also sent to a peak-limited abort system that is part of the signal-conditioning hardware to provide independent overtest protection. In addition, force and/or response limiting can be imposed on as many channels as are available on the control system. Also, additional control accelerometers can be established for larger test articles. A maximum of 32 channels can be used for controlling the test.

Table 2-1 Control System Sine and Random Parameters

Vibration Parameter	Sine	Random
Frequency range	5 Hz to 2000 Hz	5 Hz to 2000 Hz
Output dynamic range	72 dB	72 dB
Sweep rate, linear	1 to 1000 Hz/second	N/A
Sweep rate, log	1 to 200 octaves/minute	N/A
Break points per spectrum	Up to 99	Up to 99
Loss of signal protection	Automatic shut-down	Automatic shut-down

VIBRATION EXCITERS: LDS 964 (2 each, 20,000 force-pound, 9000 kg) and LDS 994 (1 each, 60,000 force pound, 27,000 kg) exciters are located on isolated seismic blocks. Payloads with a footprint as large as 24 in. square are tested on the LDS 964 exciters, and larger payloads can be accommodated as large as 54 in. (137 cm) using the current lead expander in the Z-axis for testing on the LDS 994 exciter.

The LDS 994 exciter is located in its own test cell. It is rotated vertically and horizontally as required for testing. It is also installed in an integrated base. It has a 10-ft (3-m) square slip table (see appendix for drawing). It is serviced by its own 10-ton overhead bridge crane. There is a 54 in. (137 cm) head expander available for use in the vertical configuration (see appendix for drawing).

The two LDS 964 exciters share a common test cell, with one set-up for vertical and the other set-up for horizontal testing. The exciters can be rotated from vertical to horizontal and back again as required to accommodate specific test requirements. They are installed in integrated bases from the factory. One of the LDS 964 exciters has a 2-ft (0.6-m) square slip table, and

the other has a 3-ft (0.9-m) square slip table. A 5-ton (4500-kg) bridge crane services both exciters.

The small dynamics lab has several electrical power panels to support most types of instrumentation racks. Please verify your requirement with the facility power due to ever-changing requirements.

Figure 2-2 Vibration Control Console

Figure 2-3 LDS-964 Exciters in "Small Shaker Room 102"

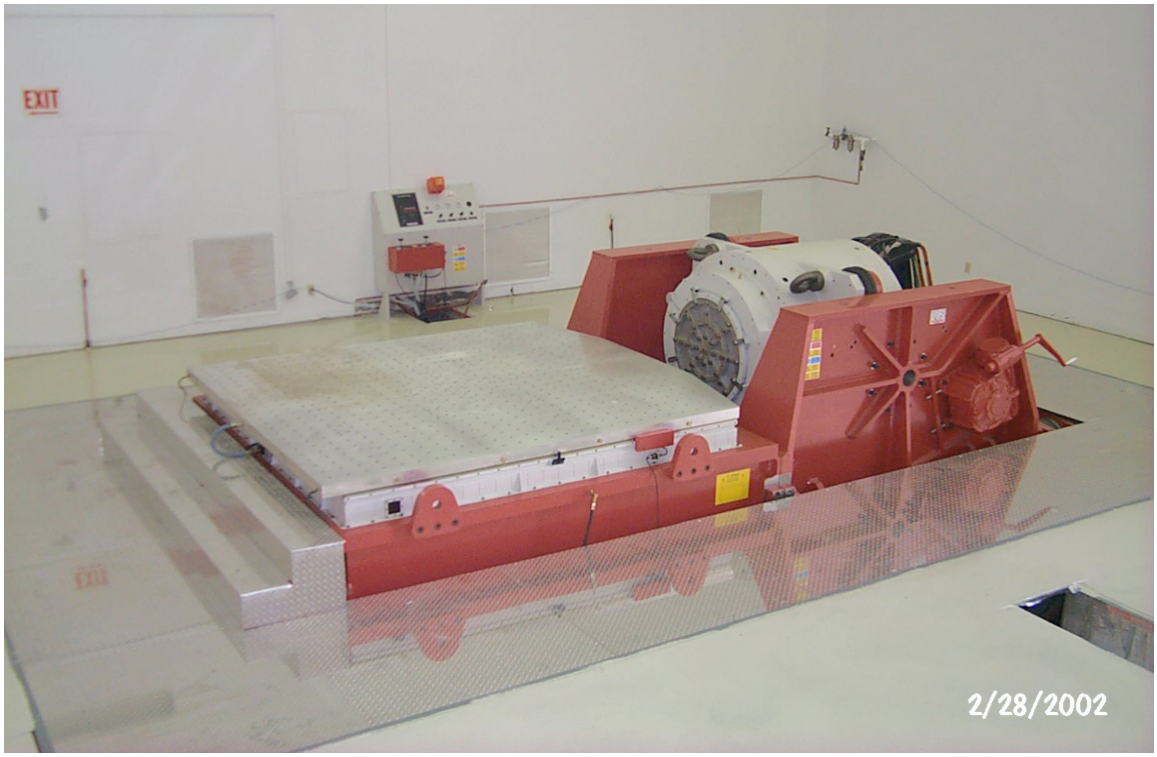


Figure 2-4 LDS 994 Exciter in 2600 ft^2 Class 10,000 Cleanroom

Table 2-2 Vibration Exciter and Test Cell Parameters

Parameter	LDS 964	LDS 994
Force rating	Sine vector -89 kN (20,000 lbf) Random rms -89 kN (20,000 lbf)	Sine vector -253.5 kN (57,000 lbf) Random rms -266.9 kN (60,000 lbf)
Exciter power amplifier:	A single LDS DPA210K (210 KVA) drives either exciter	A single LDS DPA280K (280 KVA) drives the exciter
Displacement limit:	5.1 cm (2.0 in.) double amplitude	5.1 cm (2.0") double amplitude
Velocity limit:	199 cm/s (78.7 in./sec)	123-cm/ (48.4 in./sec)
Frequency range:	5 Hz to 2 kHz	5 Hz to 2 kHz
Payload vertical centering:	Centers up to 907 kg (2,000 lb) via pneumatic system	Centers up to 5010 kg (11023 lb) via pneumatic system
Lateral slip table:	LDS 964 #1 has an integrated 2-ft (0.6-m) square slip table mounted on two team bearings. LDA 964 #2 has an integrated 3-ft square slip table mounted on three team bearings.	LDS 994 has an integrated 10-ft square slip table mounted on 20 team bearings
Crane capacity:	4545-kg (5-ton) monorail crane	9090-kg (10-ton) bridge crane
Access doors:	Badge Reader Access	Badge Reader Access
Cleanroom capability (when required):	Payload can be bagged in Amerstat or equivalent electrostatic discharge (ESD) material with a purge system.	Payload can be bagged in Amerstat or equivalent ESD material with a purge system. Room 100 is a class 10,000 clean room.

2.4 Acoustic Noise Test Facility

GENERAL: The Acoustic Noise Test Laboratory provides all necessary services and equipment to perform acoustic noise testing of spacecraft and subsystems. A digital control system provides 1/3 octave bandwidth control to the Acoustic Noise Test Cell and Data acquisition systems condition and record microphone, accelerometer, force, and strain-gage signals for review at each test level.

CONTROL SYSTEM: The M+P Vibrunner digital vibration control system processes eight control microphone signals and controls on the average of the signals. The amplifier current signal is also sent to a peak-limited abort system to provide independent overtest protection.

Table 2-3 Acoustic Noise Test Parameters and Noise Conditions

Test Parameter	Acoustic Noise
Frequency range	20 Hz to 10000 HZ in 1/3 octave
Output dynamic range	72 dB
1/3 octave bands per spectrum	26–28

Figure 2-5 Acoustic Noise Test-Control Console

CONTROL SYSTEM: The M+P Vibrunner digital vibration control system processes eight control microphone signals and controls on the average of the signals. The amplifier current signal is also sent to a peak-limited abort system to provide independent overtest protection.

Figure 2-6 Acoustic Noise Test Facility

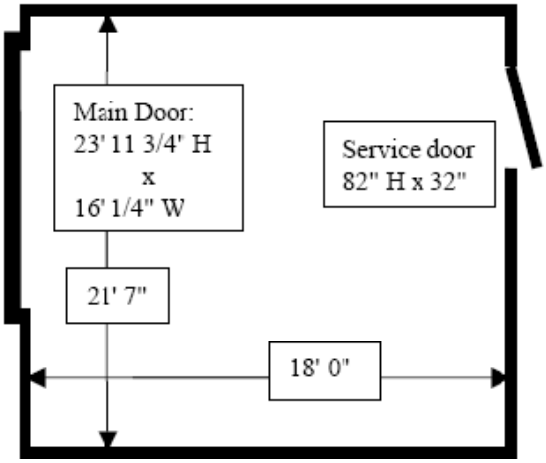


Figure 2-7 Acoustic Noise Test Facility Floor Plan

WAS 3000: This is a vibrating vane air valve, which regulates large volumes of gas at moderate pressure with a switching time capability of one or two milliseconds. The device is normally operated with a continuous input nitrogen gas (GN_2) stream to produce high-intensity acoustic energy. Modulation is accomplished through rapid interruption of the gas stream by a moving coil and valve having sufficient stiffness to assure constant displacement characteristics throughout its operating range.

Table 2-4 WAS 3000 Parameters and Acoustic Noise

Parameter	Acoustic Noise
Maximum acoustic power output	30,000 W
Input frequency range	0–630 Hz
Output frequency range	25–10,000 Hz
Maximum electrical drive input power	600 VA

2.5 Dynamics Instrumentation and Digital Data Acquisition

The Dynamic Instrumentation Lab has the capability of recording as many as 240 channels in support of vibration and acoustic testing. The typical tests are recorded on one of its two DSPcon Piranha II digital data acquisition systems (Figure 2-8). Additional channels (as required) can be rented with advance notice of testing.

One system can record as many as 64 channels, and the other can record as many as 32 channels. Both systems can provide a constant current source to supply power to transducers or can be used with external signal conditioning. They also have an internal database that keeps records of transducer sensitivity, calibration date, serial number, and model number. This data is embedded into the set-up file for each test that is archived. The systems are mostly used for vibration testing, but they can also be used to support acoustic testing or shock testing with a maximum sample rate of 100 kHz. Recorded data can be processed using the DSPcon Piranha III software to produce numerous plots for different types of tests, or the raw data can be given to the customer in an ASCII-file format.

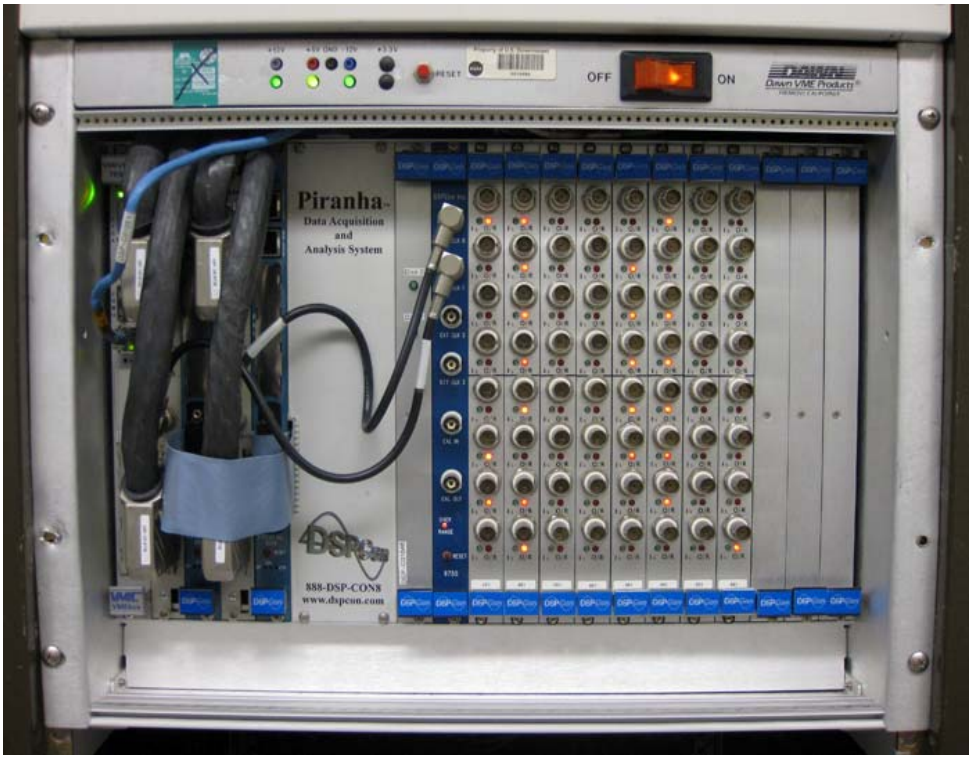


Figure 2-8 DSPcon Piranha II Digital Data Acquisition System

The Lab also contains a DSPcon Piranha III digital data acquisition system (Figure 2-9Figure 2-10) with printed circuit board (PCB) signal conditioning. This system has the same functionality as the Piranha II system but does not include the transducer database. This system, however, can record at speeds up to 200 kHz and is primarily used for tunable beam shock testing.

Figure 2-9 DSPcon Piranha III Digital Data Acquisition System

Piranha III™ Technical Specifications Summary

Sample Rate:

- Range: 1000 to 256,000 samples/second
- Resolution: 0.001 samples/second

Bandwidth: Up to 115 kHz

Simultaneous Sampling:

- Inter-channel Skew: <50 ns
- Inter-channel Phase Match: <0.1 degree at 10 kHz, <1 degree at 90 kHz

Input Slew Rate: 15V/μs

Frequency Response: ± 0.1dB, DC to 90 kHz

Input Type: Differential inputs ± 10 V at gain of 1

Gain (optional): 1, 10, 100

Input Impedance: 100 kΩ

Common-Mode Rejection Ratio (CMMR): 100 dB typical

Input Anti-alias Filter

- Analog: 2-pole Butterworth at 320 kHz
- Digital: Sigma-Delta at 0.4535 × Sample Rate

Coupling: AC and DC

For tests outside of ETL, a 16 channel (M+P) data acquisition system is used (Figure 2-10). This system is all contained in a tower computer case and can be easily transported to the location of any test, at JPL or elsewhere. This system contains two National Instruments data acquisition PCI cards that can record as many as 16 channels at frequencies as great as 100 kHz. The M+P Smart Office software package is used to record, organize, and process data. The data can be given to the test conductor in Matlab format or embedded into a Microsoft Word document. This system is mostly used for pyro-shock tests that take place in various labs around JPL.

If extra recorded channels are needed, a Metrum digital tape recorder can be used. This recorder can record data from as many as 64 channels at a rate of up to 80 kHz using external signal conditioning. The recorded data is normally played back into one of the digital data acquisition systems after the test for data processing. This system is normally only used for large tests that use all other available recording systems.

Figure 2-10 Dynamics Digital Data Acquisition System

3 MASS PROPERTIES MEASUREMENTS

GENERAL: ETL has three machines outlined below that can be used to measure different types of mass properties. The two small CG machines can be relocated to other facilities to support the projects needs. The Spin Balance machine requires a properly installed 100,000-lb (45,000 kg) reaction mass and a semi-permanent installation in a facility, such as the Building 179 hi-bay I model mass

3.1 Mass Properties User Guide

Spin Balance and Static Center-of-Gravity Measurements: ETL can perform mass-properties measurements by several means, including spin balance, moments of inertia, and static center of gravity. These measurements are performed on different types of equipment as follows:

Spin Balance Machine POI12000 – 100 lb to 12,000 lb max - Capability to measure POI (Product of Inertia), MOI (Moment of Inertia), and CG (Center of Gravity).

CG Machine KGR500 – 500 lb (230 kg) max - MOI and CG

CG Machine SE1389B – 11 lb (5 kg) max (Desktop model) - Capable of measuring only CG

Mass properties measurement process for customer to follow:

Test Article Engineer (TAE) makes an online reservation using the TFM Web-tool as soon as TAE knows he/she has a test to perform

a) TAE calls ETL contact for cost estimate.

b) TAE provides ETL with Test Plan including test objective.

c) TAE identifies required equipment applicable to support specific test.

d) TAE design hardware fixture and fit check on CG machine.

e) TAE arrives with hardware on test day to perform test.

f) ETL engineering provides Test Report to TAE within a few days of test completion.

The cost of Testing: Cost estimating for performing mass properties measurement is dependent on the size of the hardware, which determines the equipment to be used. The POI12000 cost is about $9K per day, the KGR500 and the SE1389B are about $2500 per day, and both include the operator. Mass properties equipment may be transportable to Kennedy Space Center, Florida (KSC) and certain other facilities. The TAE shall verify any transportation, cabling, or operator location requirements with the ETL test engineer with enough notice to allow for proper setup and operation of the equipment.

3.2 Spin Balance Machine POI 12000

The Space Electronics Spin Balance machine (Figure 3-1) is designed to measure product of inertia (POI), dynamic center of gravity (CG), and moment of inertia (MOI) of objects weighing as much as 12000 lb (5440 kg). The machine is of the "vertical" type (rotation axis vertical) with true two-plane measurement and correction capability.

Figure 3-1 Spin Balance Machine

There are three modes of measurement:

(1) Spin testing to measure POI and CG offset unbalance

(2)Torsion Pendulum Oscillation to measure MOI

(3) Static Measurement of CG offset moment.

The menu selections are POI, MOI, and CG, where CG refers to static measurement of CG offset moment.

This instrument is configured to have maximum sensitivity when measuring objects weighing between 200 and 12000 lb (90–5440 kg). Recommended range of spin speeds is 20 to 200 rpm. This instrument uses a spherical gas bearing, which is virtually frictionless and has bearing noise and run-out that is so small that it cannot be measured using conventional means. This results in extremely high measurement sensitivity and accuracy.

Operation is fully automatic, using a Windows-based computer supplied with the machine. Older style balancing machines required tedious procedures to adjust the circuitry for correction-plane parameters and minimum measurement error. On the Space Electronics model POI-12000-BL, these adjustments are eliminated. Correction-plane values are typed into the computer. Manual adjustment of spin speed is not required. The operator types in the desired rpm, and the spin balance machine automatically accelerates to exactly the specified speed. There are no manual data corrections necessary; these are accomplished automatically by use of the precision calibration weights and the proving rotor supplied with the machine. These weights can be mounted to the rotor at known locations. The system software then measures the known unbalance at different speeds and creates a data table to correct the raw measurements for phase shift and amplitude non-linearity. This results in such high accuracy that many items can be balanced in a single spin measurement. The computer displays the

operating instructions in succession as the measurements are made, minimizing the need for using the instruction manual.

There are three modes of measurement: spin testing to measure POI and CG offset unbalance; torsion pendulum oscillation to measure MOI: and static measurement of CG offset moment.

Specifications

Maximum Measurable Moment due to test article offset CG	16000 lb-in. (184 kg-m)
Moment Resolution (smallest increment of moment display)	0.27 lb-in. (3.6 kg-mm)
Moment Accuracy	0.1% of reading + 5 lb-in. (57.6 kg-mm)
Maximum CG displacement (if not limited by moment)	12 in. (305 mm)
Mechanical Centering Error (interface plate pilot)	0.001in. (0.0250 mm)

3.3 CG Machine KGR 5000

The model KGR500 (Figure 3-2) is a general purpose mass properties instrument capable of testing articles with a combined weight (including the test fixture) not exceeding 500 lb (230 kg). The KGR instrument determines the moment of inertia (MOI) of the test article and locates its center of gravity (CG). A computer interfaced with the system controls machine operation, performs calculations, and prints the test results.

Figure 3-2 KGR5000 Mass Properties

The operator is required to measure the test-article weight on a scale either prior to the start of a CG measurement or prior to the start of the calculations sequence. This test-article weight is then keyed into the calculation screen in the software to generate a CG offset result.

Test-article MOI is measured by the inverted torsion-pendulum method. The change in time period of this pendulum that results from the addition of the test article is proportional to the MOI of the test article.

Test article CG is located by measuring the offset moment due to the displacement of the test article CG from the center of rotation of the instrument and dividing by the weight. The test surface on the instrument is rotated so that CG may be measured in two axes. The computer converts the raw time period and moment data into calculated values for MOI and CG location relative to the rotational center of the test table. Additional computations may be made by the computer to yield MOI and CG relative to any other reference axis.

Specifications

Maximum Weight of Test Article and Fixture ..... 500 lb (230 kg)
Maximum CG Offset ..... 2 in. (5 cm)
Maximum Moment during Loading..... 750 in.-lb (84.7 Nm)
Maximum offset Moment Due to Test Article CG…… 500 in.-lb (56.5 Nm)
Moment Sensitivity (smallest detectable change) ..... 0.25 in.-lb (0.03 Nm)
Moment Linearity 0.5%
Rotary Table Centering Error ……0.0005 in. (13 µm)

3.4 CG Machine SE8913B

The SE8913B high-sensitivity static balance instrument measures the unbalance moment due to the displacement of test object CG from the pivot axis of the instrument. This instrument contains a precision horizontal rotary table, on which the test article may be mounted. The test table is attached to a structure that is pivoted on a flexure assembly. A moment arm on the structure measures the tilt of the test surface.

The flexure assembly acts in the same manner as the knife edge on a balance beam scale. The pivot supports most of the weight of the test article; a low force transducer then measures the moment due to displacement between test object CG and the pivot axis. Four moment readings provide sufficient moment data to determine CG location.

When the test article is placed in the fixture, a moment is created downward in the direction of the CG of the test article. To locate this CG in two axes, moment readings are taken at angular positions of 0°, 90°, 180°, and 270°. The net moment in the X direction is computed by averaging the moment readings at 0° and 180°. The net moment in the Y direction is the average of moments at 90° and 270°. Multiplying these moment coordinates by the calibration constant, and then dividing by the test article weight, yields the CG offset of the test article in inches.

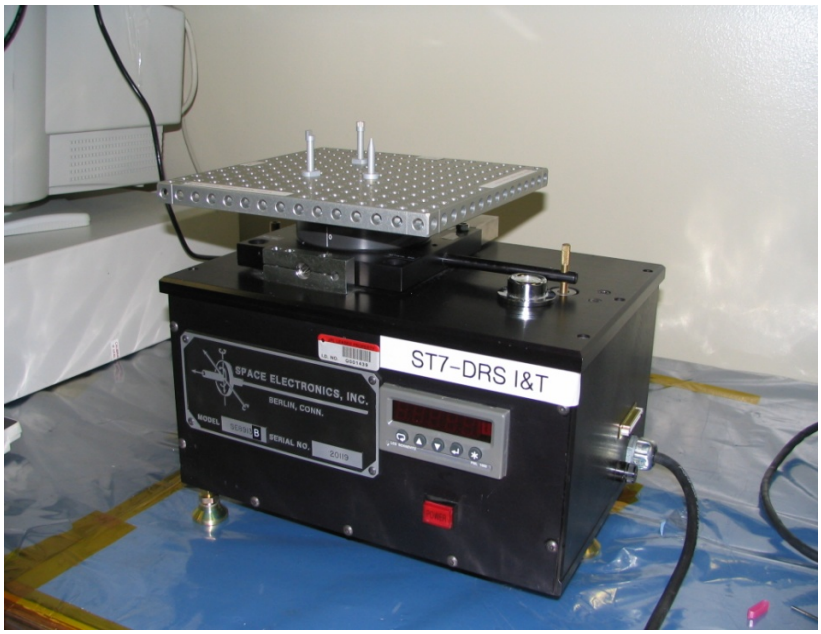


Figure 3-3 Space Electronics SE8913B Static Balance

Technical Specifications

Maximum Weight (test article and fixture)..... 11 lb (5 kg)
Full Scale Moment ..... 2 in.-lb (0.236 Nm)
Moment Sensitivity..... 0.002 in.-lb (0.00023 Nm)
Maximum CG Height ..... 5 in. (12.7 cm)
CG Type: Two-axis CG instrument, high sensitivity

4 STATIC LOADS TESTING

The Environmental Test Laboratory (ETL) manages and operates the Static Test Facility (JPL Bldg. 280) for the primary purpose of providing static test services. In addition, ETL also provides other types of testing services in this facility.

Policies have been developed in order to insure the safe and successful operation of tests for equipment and personnel, and to capture knowledge and lessons learned in order to benefit the costs and quality of future test operations.

4.1 Static Test Facility User Guide

Static Loads Testing: The Static Loads Testing Facility, located in JPL Building 280, provides the ability to apply single or multiple static-tension or compression forces to test articles, with forces ranging from hundreds of pounds to 100,000 pounds (45,000 kg). The types of supported tests range from multi-force complex testing of major spacecraft assemblies, to the proofing of fixtures and linkages. A flexible Moog SmarTest system provides closed-loop computer control capabilities, the output of which is used to drive servo valves, which in turn drive hydraulic actuators (cylinders).

Data acquisition is most often supported by a LabVIEW-based system that was developed and operated by the Measurement Systems Group within Section 376. This system also provides an additional and independent emergency shutdown capability of the force-application systems. Specific customer requirements can be implemented as customizations to this system. Typical instrumentation includes strain gauges and displacement measurement devices.

Two steel towers and a seismic mass concrete floor provide anchor points for a test article and for the associated fixtures and hydraulic actuators. The steel towers in this facility also support additional types of testing, such as the Mars Science Laboratory Scarecrow Rover Touchdown Testing. Customers must include key ETL personnel in the planning process as early as possible due to configuration requirements and possible facility, ground support equipment (GSE), or system modifications.

4.1.1 Scheduling

Due to configuration requirements and possible facility, GSE, or system modifications, customers must include key ETL personnel as early in the planning process as possible.

Since there may be more requests for services than the facility can support, and preparation of the facility and associated equipment may require significant lead time (typically several months), coordination of facility use and testing activity must be made via the Technical Facilities Management Tool (TFM) at the following website TFM Schedule Tool. Some work may require support from other organizations, with their own schedules.

Typical process steps that can greatly contribute to safe and timely execution of a test include:

a) Test Article Engineer (TAE) and/or Test Conductor walkthrough of the facility with ETL personnel to get a clear understanding of hardware, equipment and operational flow.

b) TAE submits estimated load ranges to ETL. This will allow verification of equipment available, and/or purchase equipment required for test.

c) TAE determines what sort of data acquisition is required.

d) TAE submits a plan for GSE involved with the facility. This may require different tower configurations, schedule conflicts, etc.

e) TAE involves ETL personnel in preparatory test discussions/meetings.

f) TAE begins verification test hardware design/fabrication (if required).

g) TAE submits Test Plan to ETL.

h) TAE fit checks verification test hardware.

i) ETL verifies that all essential hardware and equipment are current in calibration, and that they will continue to be current throughout the duration of the actual test.

Verification tests performed by key personnel to ensure that displays and measurements are correct (i.e., Test Conductor, Control System, and Data Acquisition (DAQ) Personnel, Quality Assurance (QA) if required, etc.).

4.1.2 Costs

A charge number must be supplied prior to beginning use of ETL resources (including the facility).

The requestor must supply sufficient information so that the costs of ETL's involvement can be estimated and provided to the customer. In general, a charge number associated with sufficient funds must be provided before access to the facility will be granted.

Funding is provided for the following tasks:

a) Preparation/programming, configuring of test equipment

b) Technician and/or machine shop services (Fab-services)

c) Preparation of facility

d) ETL participation in Test Readiness Review

e) End-to-end testing and verification of test setup

f) Operation of test equipment during testing

g) Restoration/cleanup of facility upon test completion

For complex tests or tests on JPL Critical Items (JCI), an end-to-end test may be desirable in order to verify proper configuration of hardware, software, control elements, and procedures.

Note: The cost of setup and performance of a static-load test on critical project hardware has many factors that can affect the total cost. The TAE must provide a draft Test Plan to provide a basis for planning what the test will encompass.

User Checklist

Typical process steps that can greatly contribute to safe and timely execution of a test include the following:

Three to six months prior to test:

a) TAE makes an online reservation using the TFM Web-tool as soon as he/she knows there is a test to be performed. It is Ok to slip the schedule if ETL can see the test on the schedule.

b) TAE and/or Test Conductor walkthrough the facility with ETL personnel to get a clear understanding of hardware, equipment, and operational flow.

c) TAE submits a draft test plan with the estimated load ranges to ETL. This will allow verification of equipment available, and/or purchase of equipment required for test.

d) Instrumentation Engineering determines what sort of Data Acquisition is required.

e) TAE submits a plan for GSE involved with the facility. This may require different tower configurations, schedule conflicts, etc.

f) TAE and Test Conductor Involve ETL personnel in preparatory test discussions/meetings.

g) TAE begins verification test hardware design/fabrication (if required).

Six plus weeks prior to test:

a) TAE or Test Conductor submits test plan to ETL

b) TAE performs fit check verification test hardware.

Four plus weeks prior to verification test:

a) ETL Test Engineer assigned to the test verifies that all essential hardware and equipment are current in calibration, and will continue to be throughout the duration of the actual test.

Two to four weeks prior to test:

a) TAE invites key ETL personnel to test readiness review(s).

b) Key personnel perform verification tests to ensure that displays and measurements are correct (i.e., Test Conductor, Control System and DAQ Personnel, QA if required, etc).

Figure 4-1 MSL Chassis Test in Static Loads Test Facility

4.2 Basic Capabilities

The static loads testing capabilities include the ability to apply single or multiple static-tension or compression forces (produced by hydraulic cylinders) to test articles, and the hydraulic load controller can apply forces ranging from hundreds of pounds to one hundred thousand pounds (45,000 kg).

The types of tests supported range from multi-force complex testing of major spacecraft assemblies, to the proofing of fixtures and linkages per Figure 4-1.

This facility also supports additional types of testing, such as the Mars Science Laboratory Scarecrow Rover Touchdown Testing and the MSL Mobility deflection test, as well as structural tests on older missions including: Galileo, Cassini, Mars Exploration Rovers, and Mars Pathfinder.

4.3 Facility Description

The core of the facility consists of an I-beam tower, approximately 45 ft (14 m) high, enclosed within a building (Figure 4-2). Test articles as large as 15 ft (4.6 m) in diameter can be placed within the tower, and the large door at the front of the building can be opened to a height of 24 ft 8 in. (7.52 m). A crane, attached to the top of the tower, has a rated capacity of 10,000 lb (4500 kg).

A smaller, stronger tower can be assembled within the main tower for tests requiring larger loads or an increased rating for anchor points above the test article. A seismic mass concrete floor provides additional anchor points for the test article and for the associated fixtures and hydraulic actuators.

(a) Looking up at tower

(b) Building enclosing tower

Figure 4-2 Static Test Facility

4.4 Test Systems Overview

A flexible closed-loop computer control system (using force or displacement for the primary feedback signal), provides an output signal that is used to drive servo valves, that in turn drive hydraulic actuators (cylinders). The components of the overall system are:

a) Computer-based control system (16-channel Moog SmarTest)

b) Hydraulic power unit (pump) capable of up to 3000 psi (21 kPa) pressure.

c) Hydraulic Load Controller containing jet pipe servo-valves, per-channel pressure transducers, per-channel pressure relief valves, and electrically controlled dump valve

d) Hydraulic actuators (cylinders)

e) Load cells

f) Displacement transducers

4.5 Ground Support Equipment (GSE) Interfaces

Static-load testing often requires the design and construction of custom hardware to be used between the test article and the associated actuators and anchor points. Such hardware should preserve the capabilities of the building and must not present ongoing safety hazards.

Test documentation should be provided to ETL early (including draft versions) in order to understand requirements (especially when fixture fabrication is required)

Permanent modifications to the facility should be avoided whenever possible and in all cases must be approved by ETL. A better approach is to use adapter fixtures in order to avoid modifications of the facility.

Example: Anchor points at floor level may be needed by a given test.

The preferred solution would be to anchor to adapter plates or fixtures (that use existing permanent anchor points).

In the event that there are requirements that cannot be satisfied through the use of adapter plates, one alternative would be to install threaded inserts (in the floor) rather than threaded studs (which may interfere with following tests and may present a tripping hazard if left in place).

Lessons Learned from Previous Testing Activities

a) When designing GSE hardware, it is helpful to use a square-hole pattern instead of a rectangular pattern, so that during fit check and testing, if the hardware needs to be turned 90°, it can be done so easily. On previous tests, clevis blocks had to be turned 90 degrees in order to prevent unacceptable bending forces on load cells or other instrumentation.

b) Cabling for instrumentation or other functions should be long enough to extend outside of any ESD/dust protection bagging. Technicians should not have to reach inside of protective bagging in order to make electrical connections.

c) When appropriate, bundle cables into one single connector. This will save time and money before and after the test.

d) We have been advised against the use of certain kinds of repairs. For example, if a hole is drilled in a tower beam, welding on a doubler plate in order to maintain original strength. In this example, the welding process may produce undesirable effects in the primary tower I-beams.

e) When designing GSE hardware, it is helpful to use a square-hole pattern instead of a rectangular pattern, so that during fit check and testing, if the hardware needs to be turned 90°, it can be done so easily.

f) Batch all strain-gage or thermocouple wires into one single connector. This will save time and money when preparing for the test.

Figure 4-3 Control System (user interface system not shown)

Figure 4-5 Hydraulic Power Unit (pump)

Figure 4-4 Hydraulic Load Controller

Figure 4-6 Hydraulic Actuators (cylinders)

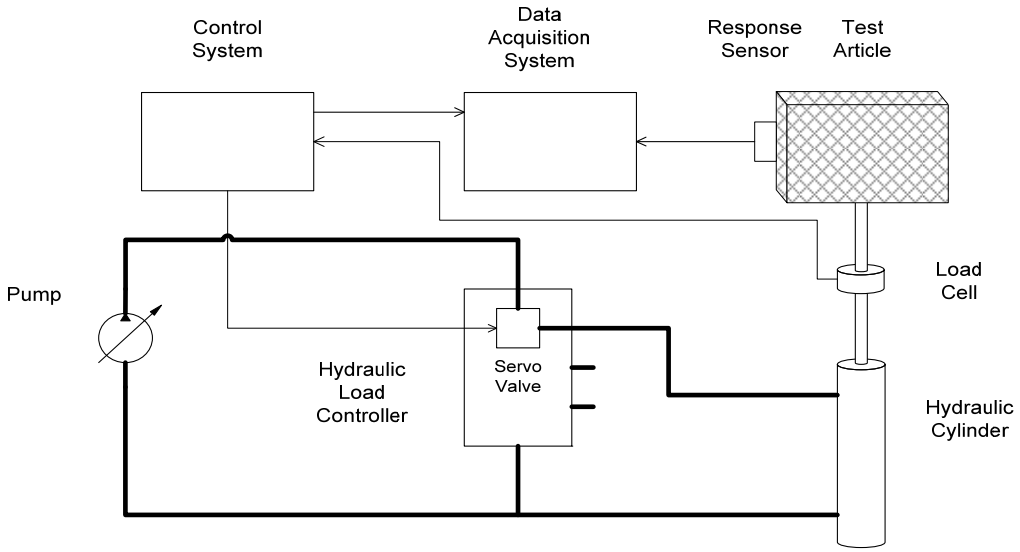


Figure 4-7 Simplified Hydraulic Load Controller Schematic

4.6 Data Acquisition and Instrumentation

The complexity of data acquisition and instrumentation can vary greatly, depending upon the type of test and the requirements of the customer. Although one customer may be satisfied with a simple readout of force and displacement values, another customer may wish to have real-time displays that also include time history graphs of, for example, force vs. strain.

Customers requiring more complex data acquisition and instrumentation should allow sufficient lead time for implementation. ETL personnel will either directly provide data acquisition and recording capabilities, or the ETL personnel may make arrangements with another Section 376 group for the data-related activities.

Individuals actively participating in a given test may need to meet various class/certification requirements (partial list):

a) JCI (JPL Critical Item handling)

b) ESD (electrostatic discharge)

c) Lifting Devices

d) Building Crane

e) Fork Lifts

f) Man-lift

g) Fall Protection

h) Hazardous Waste Generator

i) Connector Mate/De-mate

j) Pressure System Safety

k) Oil Spill Prevention

Since classes vary greatly with respect to frequency of presentation, it is advisable to complete required classes/certification programs well in advance of the start of testing.

4.7 Documentation

ETL must be in loop for any use of the static facility including documentation and authorizations/approvals from other organizations such as QA and safety. All tests require the generation of a Test Plan, to be written by the customer (TAE) with a draft provided well in advance of the testing.

Tests typically also require a test procedure or Assembly and Inspection Data Sheet (AIDS) document to be generated by the customer (or in some cases by an ETL representative).

Any facility-related waivers generated in relation to a set of tests must be captured and provided to ETL.

Building modifications must be documented in electronic form and a copy provided to ETL.

5 CHAMBER CERTIFICATIONS

The chamber certification program protects the critical hardware during environmental testing. A chamber survey is performed in addition to a facility or operational safety survey. This survey provides another layer of protection for the hardware.

There are numerous variables that can harm the hardware if not recognized and prevented early when setting up a chamber for testing critical hardware. Chamber owners/operators are required to contact ETL to certify each chamber for each test configuration of hardware testing.

ETL will come to your site and perform a preliminary survey, creating an action list to address any deficiencies and provide final verification of action items and a certification certificate. Responsibility for correcting any and all deficiencies and making the chamber compliant to the certification survey requirements falls on the chamber owner/operator.

The Chamber Certification Survey Checklist is required per Control and Use of Environmental Chambers (JPL Rules! DocID 64395, invoked by JPL Rules DocID 34880 (JPL D-560). The Environmental Test Laboratory (ETL) is required to certify that environmental chambers used for testing a deliverable product including JPL Critical Items are in compliance with Standard Environmental Testing Facilities and Practices (JPL Rules DocID 35492), and JPL Standard for System Safety (JPL Rules! DocID 34880). An environmental chamber is defined as any enclosure or device, including attached equipment, capable of creating a temperature, vacuum, pressure, humidity, and/or gaseous environment that can be used for the purposes of stressing, testing, characterizing, baking out, or verifying deliverable product.

A nominal labor fee to support this task usually falls in the $2000 to $4000 range depending on how much time is required, and additional fees would result if travel to a vendor is needed. The Quality Assurance organization will need to verify the certification of the chamber prior to the start of the testing of any JCI hardware.

a) The chamber certification process flow:

b) Chamber owner/operator calls ETL contact for cost estimate.

c) Chamber owner/operator arranges for ETL Test engineer to perform survey of chamber.

d) Chamber owner/operator resolves any action items from survey (this can take time).

e) ETL test engineer verifies action item conformance.

f) ETL supervisor and section manager review completed survey form and make recommend changes or approve as required.

g) ETL test engineer provides chamber sticker and copy of chamber certification form for JPL chambers.

Note: The process of chamber certification can take several weeks depending on how much time the owner/operator requires to resolve action items.

6 THERMAL, THERMAL-VACUUM, AND SPACE-SIMULATION TESTING

DESCRIPTION: The Jet Propulsion Laboratory maintains NASA environmental test facilities for research, development, and qualification testing of JPL's space-related test articles. These facilities are also available to other government agencies and to private industry.

The JPL ETL (Environmental Testing Laboratory) has numerous thermal and thermal vacuum chambers ranging in size from 3 ft diameter by 3 ft (0.9 m) long, up to 85 (26 m) high by 25 ft (7.6 m) in diameter. These chambers are capable of simulating the space environment to better than 1×10^{-6} torr (1.3×10^{-4} Pa) at –175°C.

The ETL also has several vacuum bake-out chambers, which are capable of attaining high vacuum conditions at temperatures of over 100°C. The facility has staff experts in the fields of helium-leak detection, molecular-contamination monitoring, cryogenics, and high-vacuum technology. The ETL uses state-of-the-art helium cryo-pump and turbo-molecular pumping systems to provide an ultra-clean vacuum environment for sensitive optical space flight instruments.

6.1 T-Vac Users Guide

Thermal, thermal-vacuum, and solar thermal-vacuum test chambers are maintained and provided to support the temperature cycling, contamination control bake-outs, and planetary-protection bake-outs of GSE and flight hardware. Chambers are also provided for Developmental, Qualification, Proto-flight, and Flight Acceptance testing of system level hardware and flight spacecraft. These chambers are available with working diameters ranging from 2 ft to 10 ft (0.6 to 3 m).

A large solar simulator capable of providing solar thermal-vacuum testing with a collimated 19-ft (5.8-m) diameter xenon beam of simulated solar energy is available. The large solar simulator can accommodate a test volume 20 ft (6.1 m) in diameter and 25 ft (7.6 m) high. Limited infrared (IR) lamp arrays and two high-power manually operated controllers are available to operate IR lamp arrays provided by the project.

In the thermal-vacuum test process, the TAE:

a) Makes an online reservation using the TFM Web-tool as soon as he/she decides there is a test to perform. (It is ok to slip the schedule).

b) Calls ETL contact for cost estimate.

c) Works with the ETL Test Engineer to determine the best chamber and support equipment required to make each test as successful and cost effective as possible.

d) Provides a Test Plan to the ETL Environmental Test Engineer with the following information:

   1) Name of project and test article (not just acronyms)

   2) Detailed description of test objectives and test article

   3) Temperature or thermal-vacuum (TV) test profile with requirements and tolerances

   4) Instrumentation and data requirements (number and locations of thermocouples, number of electric strip heaters to be installed and controlled, number of platinum resistance thermometers (PRT) to be monitored, voltage channels to be monitored, number of cable bulkhead feed-throughs required, etc.)

5) Description of test set-up (test article mounting fixtures, location of heat exchangers, location of IR lamps, etc.)

6) Contamination control requirements (including use of QCM or RGA for contamination detection)

7) Planetary-protection requirements

e) Is responsible for reviewing and approving the DTP prior to the start of test.

The Environmental Test Engineer:

a) Provides a cost estimate for conducting the test in the ETL.

b) Opens a service order for conducting the test in an ETL chamber.

c) Prepares a Detailed Test Procedure (DTP) for operating the ETL chamber.

d) Arranges with ETL technical personnel to support the testing schedule as required.

e) Provides a final test report (the as-run procedure and associated documentation) several days after the completion of the test.

6.1.1 Additional Considerations:

a) Support fixtures and heat-exchanger adapter plates should be fabricated through JPL Mechanical Fabrication (M-Fab) section.

b) The ETL will leak check the cable bulkhead feed-throughs provided by the project.

c) An Operational Safety Survey is to be conducted with participation of the TAE, System Safety Engineer, ETL Test Engineer, and QA.

d) Project personnel certified to handle flight hardware (usually flight technicians) will mount the test articles to support fixtures and heat exchangers and install them in the chamber.

e) ETL technicians will plumb and leak check any required heat exchangers, QCMs, and video cameras.

f) The test will be supported by ETL technicians operating the chamber while project personnel perform any required performance tests on the hardware under test. A JPL "Test Conductor," appointed by the project will monitor all test activities, direct all temperature transitions, and will provide instruction to the ETL operator on behalf of the project.

g) In cases where the testing will continue overnight or through weekends, additional "Test Conductors" may be assigned to support the overall test.

h) Upon completion of the test, the test articles will be removed from the chamber by personnel certified to handle flight hardware.

i) The Environmental Test Engineer will:

1) Provide a data package to the TAE with the completed DTP, ETL test log sheets, and control temperature plots.

2) Submit the billing for facility and material usage.

6.1.2 Test Costs

Test costs can vary significantly depending on the type of test, the chamber used, the length of time, and the test profile. ETL highly recommends that the TAE obtain a comprehensive cost estimate for each test. For planning purposes the following average costs are provided for flight hardware tests:

Hardware Bakeout

- $4500 per day small chamber (8, 14, 18/19, 20/21, 23)
- $15K to $17K per day for a medium chamber (7 or 10)

Thermal Ambient

- $3500 per day (T1, T4, T5, T6)

Thermal Vacuum (temperature cycling)

- $12K to $15K per day for small chamber (8, 12, 13, 14, 15,16, 18/19, 20/21, 22, 24)
- $18K to $26K per day for medium chamber (7 or 10)

Solar Thermal Vacuum Testing

- $50K to $85K per day in 25-ft (7.6-m) Space Simulator – This facility has many factors that can affect the costs. Most 10-day tests are in the $1M range, including support for set-up and operation.

Note: The above costs may be decreased for development tests with non-flight test articles since ETL has a lower rate to encourage use of their facilities.]

6.2 Small T-Vac Chambers (B-144)

DESCRIPTION: There are nine horizontal-loading thermal-vacuum (TV) chambers of this size, equipped with radiative shrouds and/or conductive heat exchangers and they are located in building 144, room 119 (Figure 6-1). One of these chambers is an ultra-clean TV bake-out chamber, and another is equipped with a viewport to accommodate an external solar simulator. The facility is used for thermal vacuum and thermal balance testing, and baking out test items.

TEST PRESSURE: $< 1 \times 10^{-5}$ torr (1.3×10^{-3} Pa)

TEMPERATURE RANGE: –185°C to 125°C (–301°F to 257°F)

INSIDE WORKING DIMENSIONS: 2 ft × 3 ft. chambers (0.6 × 0.9 m)

Chambers: TV-12, TV-13, TV-14, TV-15, TV-16, TV-18/19 & TV-20/21

AUXILIARY EQUIPMENT:

Portable thermal systems (roll-around) are available to control multiple heat exchangers required for testing. ETL carries both the cryo quartz crystal microbalance (CQCM) and some older thermoelectric quartz crystal microbalances (TQCM) used to measure contamination levels. An independent temperature failsafe is used for instrument protection. A portable clean tent can be installed over the payload and facility entrance during test setup.

Solar Simulator:

A small solar simulator is available with a 19 in. × 16 in. (0.48 m × 0.41 m) beam diameter and developing up to 1.6 suns. More than 100 thermocouples are available for payload temperature monitoring. The test article must be 6 ft (1.8 m) from the beam window of the solar simulator.

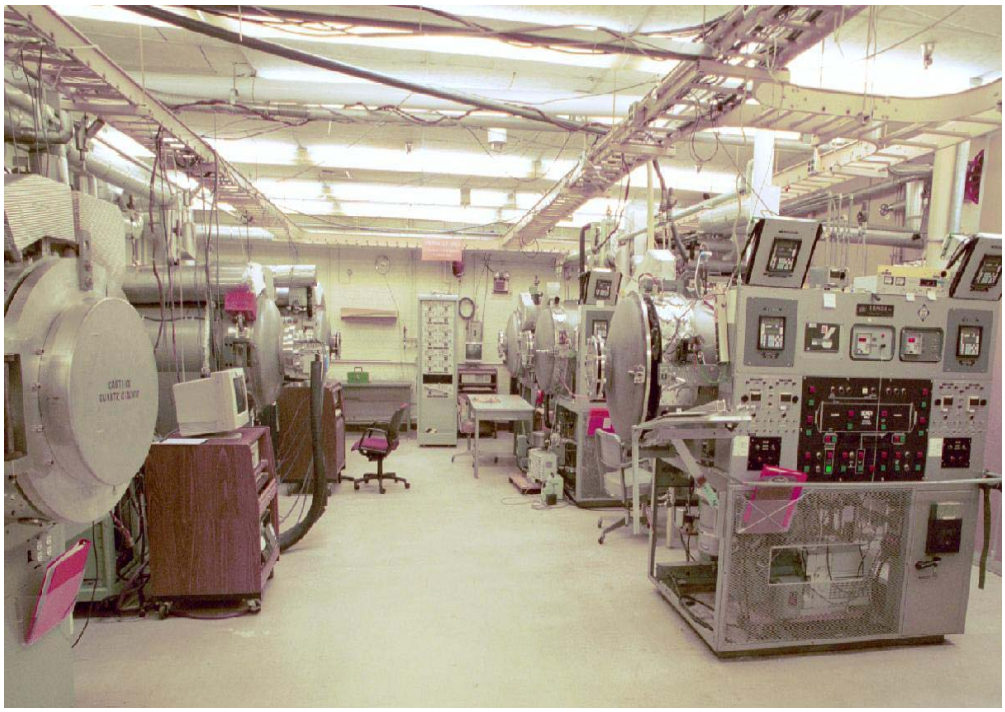


Figure 6-1 Small T-Vac Chamber Lab (B-144)

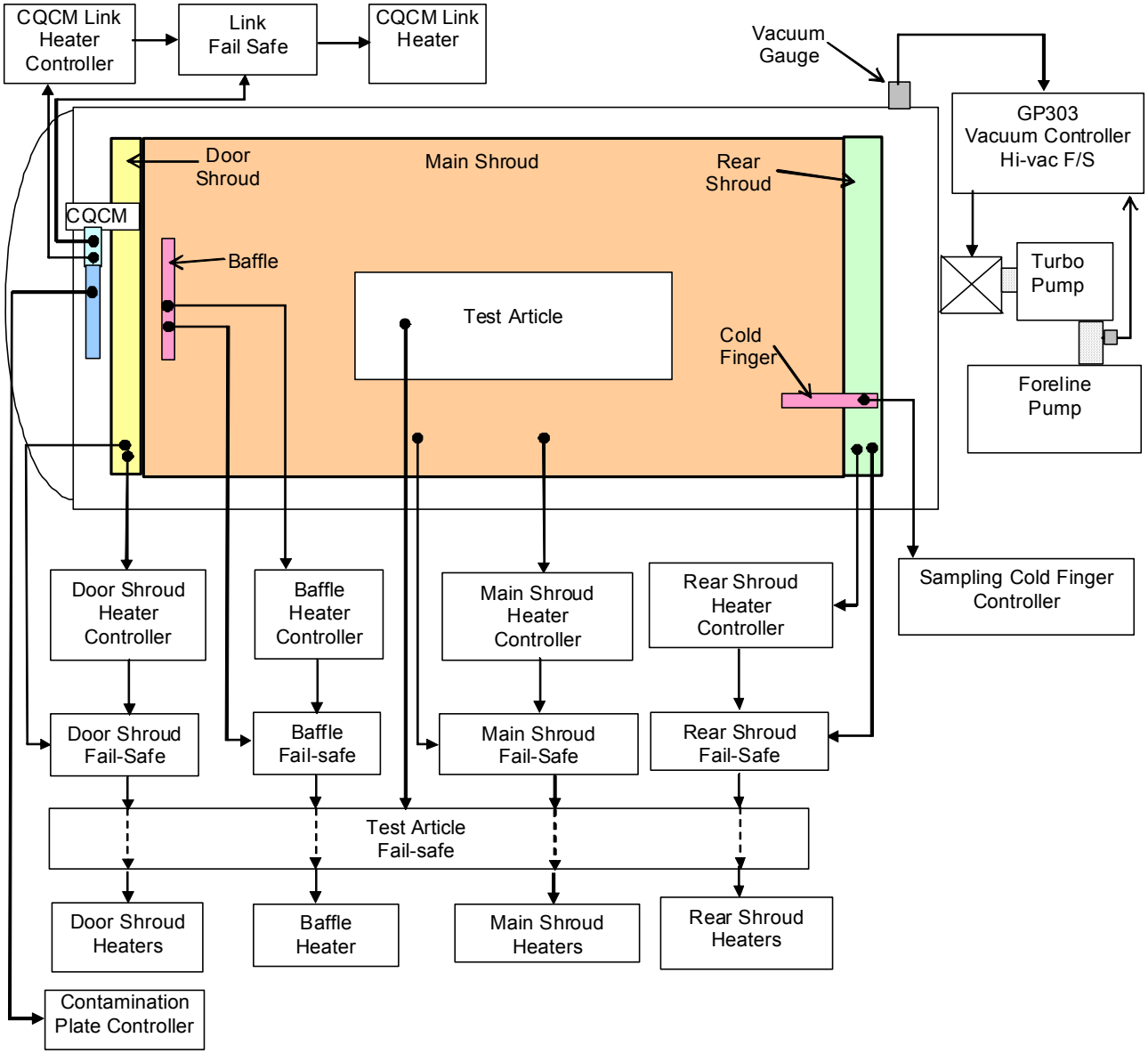


Figure 6-2 T-Vac Chamber Block Diagram

6.3 Thermal Vacuum Chamber TV-10 (B-144)

DESCRIPTION: The TV-10 thermal-vacuum (TV) chamber (Figure 6-3) is a medium-sized chamber equipped with a radiative shroud and can accommodate the installation of as many as five conductive heat exchangers typically used to test instrument radiators and sensor targets. The chamber door can accommodate a cantilevered mount platform, or the chamber vessel has rails to support a test article mounted on the chamber cart. The facility is used for thermal-vacuum testing, for thermal-balance testing, and for baking-out of hardware.

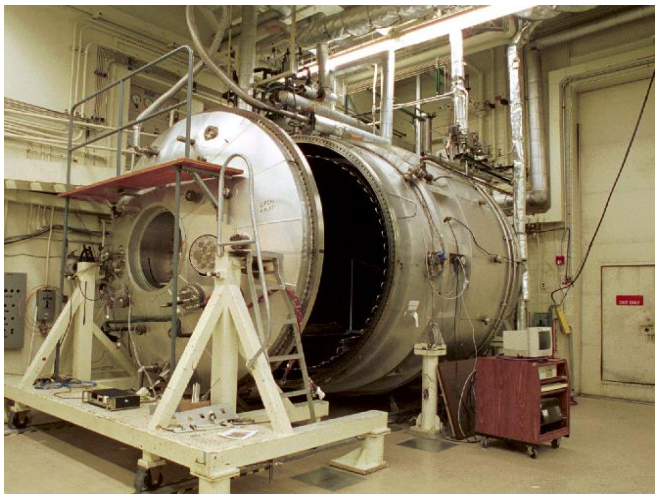
TEST PRESSURE: $< 1 \times 10^{-5}$ torr (1.3×10^{-3} Pa)

TEMPERATURE RANGE: –185°C to 125°C (–301°F to 257°F)

INSIDE WORKING DIMENSIONS: 119 in. diameter × 96 in. (3.0 m × 2.4 m) deep

AUXILIARY EQUIPMENT:

Portable thermal systems (roll-around) are available to control multiple heat exchangers required for testing. ETL carries both the CQCM and some older TQCM used to measure contamination levels. An independent temperature failsafe is used for instrument protection. More than 100 thermocouples are available for payload temperature monitoring.



(a) Outside View of 10-ft Vacuum Chamber

(b) Vacuum Chamber Control Console

Figure 6-3 Chamber TV-10 (B-144)

6.4 Chamber TV-7 (B-144)

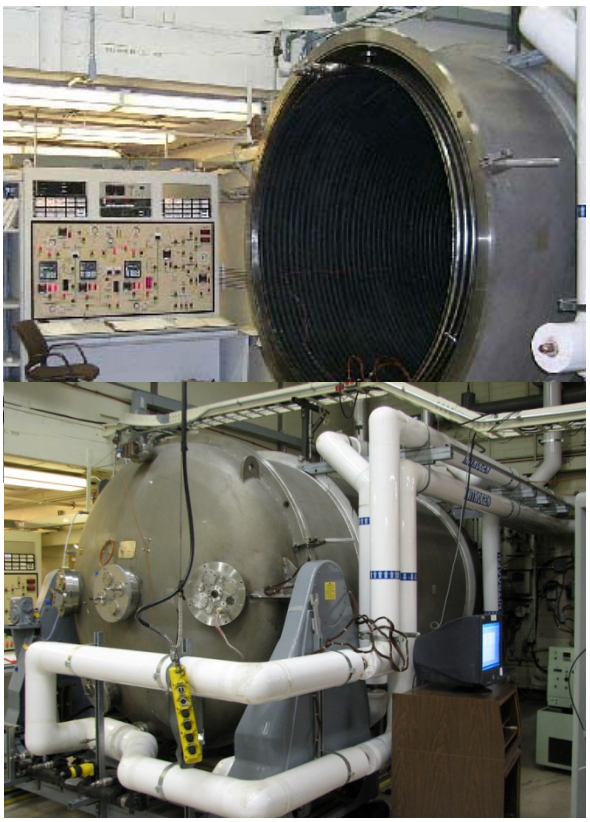
DESCRIPTION: The TV-7 medium-sized thermal-vacuum (TV) chamber (Figure 6-4) is equipped with a radiative shroud and additional conductive heat exchangers can be accommodated as required. This is a horizontal-loading thermal vacuum chamber with a cantilevered mount platform attached to the front door or a cantilevered beam can be supported from the top of the door. A monorail crane mounted above the chamber can be used to lift support hardware or test articles into position. The facility is used for thermal-vacuum and thermal-balance testing, and bakeout of test articles. An optional quartz window can be mounted in the door to enable portable solar simulation.

TEST PRESSURE: < 1×10^{-5} torr (1.3×10^{-3} Pa)

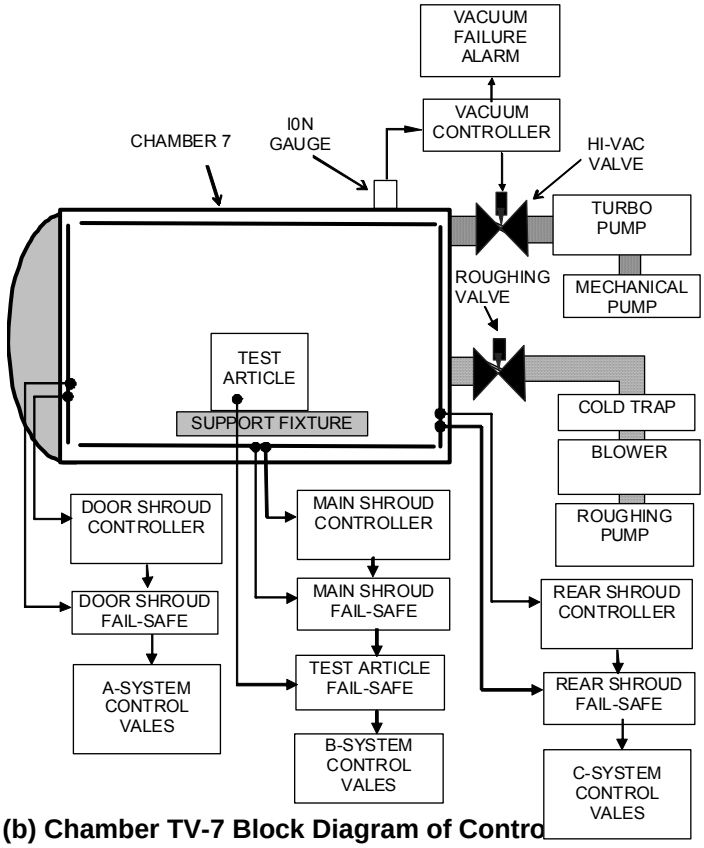
TEMPERATURE RANGE: –185°C to 125°C (–301°F to 257°F)

INSIDE WORKING DIMENSIONS: 72 in. inside diameter × 124 in. deep (1.8-m × 3.1-m)

AUXILIARY EQUIPMENT: Portable thermal systems (roll-around) are available to control multiple heat exchangers required for testing. ETL carries both the CQCM and some older TQCM) used to measure contamination levels. An independent temperature failsafe is used for instrument protection. More than 100 thermocouples are available for payload temperature monitoring.



(a) Two Views of Chamber TV-7 (7-ft): without Door (above) and With Door Closed (below)



(b) Chamber TV-7 Block Diagram of Contro System

Figure 6-4 Chamber TV-7 (B-144)

6.5 Temperature Chamber T-5 (B-144)

DESCRIPTION: The temperature chamber T-5 facility is a medium-sized temperature-controlled chamber used for thermal conditioning of small to medium components. The chamber loads through a front-opening door. The instrumented payload is installed in the chamber on a shelf, and it is connected to the ground support equipment via a feed through port. 1.01-m high × 0.81-m deep × 1.01-m wide (40 in. × 32 in. × 40 in.).

The chamber is cooled with a two-stage Freon compressor to –60°C, and then it reaches its lowest temperature of -175°C with a liquid-nitrogen (LN_2) boost. It is heated with electrical resistance elements. Nitrogen purging is available with humidity measurement of the chamber purge exhaust gas. The chamber is capable of meeting the dry-heat requirements for planetary-protection sterilization bake-outs.

TEMPERATURE RANGE: –175°C to 200°C (–283°F to 392°F)

INSIDE WORKING DIMENSIONS: Test volume: 1.01-m wide × 1.01-m high × 0.81-m deep (40 × 40 × 32 in.)

Access port size: 15-cm (6-in.) diameter (2 each).

INTEGRAL INSTRUMENTATION: Temperature is controlled by a digital programmer/controller located on the side of the chamber. An independent temperature failsafe is used for instrument protection. More than 50 thermocouples are available for payload temperature monitoring.

Figure 6-5 Ambient-Pressure Chamber T-5 (B-144)

6.6 Temperature Chamber T-4 (B-144)

DESCRIPTION: The T-4 temperature chamber is a high-temperature medium-sized temperature-controlled chamber used for thermal conditioning of small to medium components. The chamber loads through a front-opening door.

TEMPERATURE RANGE: +22°C to +593°C (+72°F to +1100°F)

INSIDE WORKING DIMENSIONS: 0.53-m wide × 0.43-m deep × 0.45-m high (21 × 17 × 18 in.)

INTEGRAL INSTRUMENTATION: Temperature and humidity are controlled by a digital programmer/controller located on the side of the chamber. More than 50 thermocouples are available for payload monitoring.

(a) Outside View

(b) Inside View

Figure 6-6 High-Temperature Chamber T–4 (B-144)

6.7 Thermal Vacuum Chamber TV-11 (B-306)

DESCRIPTION: The TV-11 is a horizontal-loading TV chamber (Figure 6-7). It has vibration-isolation capability for the payload. The facility is used for thermal-vacuum and thermal-balance testing, with customer thermal shrouds.

TEST PRESSURE: < 1×10^{-5} torr (1.3×10^{-3} Pa)

TEMPERATURE RANGE: –185°C to 125°C (–301°F to 257°F)

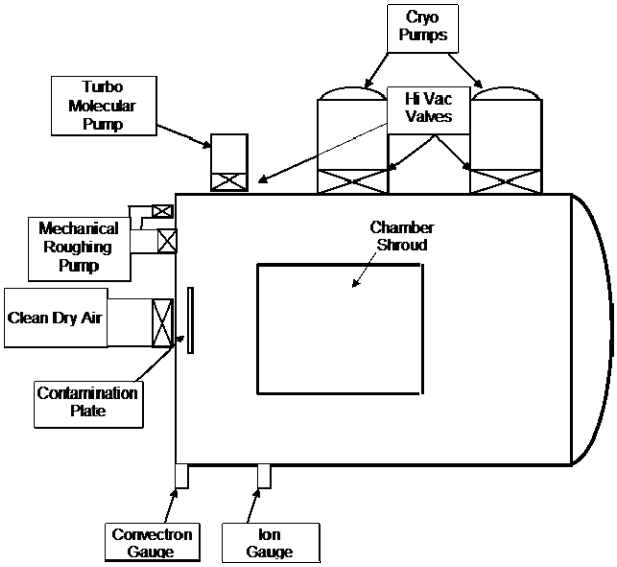
INSIDE WORKING DIMENSIONS: 3.3-m diameter × 3.3-m deep (11 × 11 ft)

Thermal Shrouds: The 3.3-m (11-ft) chamber is not equipped with built in thermal shrouds for cooling a test article. There are ports and control equipment to install custom thermal shrouds into the chamber.

AUXILIARY EQUIPMENT:

Portable thermal systems (roll-around) are available to control multiple heat exchangers required for testing. ETL carries both the CQCM and some older TQCM used to measure contamination levels. An independent temperature failsafe is used for instrument protection. More than 100 thermocouples are available for payload temperature monitoring.

(a) Chamber Door



(b) Chamber Schematic

Figure 6-7 (11-ft) T-Vac Chamber TV-11 (B-306)

6.8 Thermal Vacuum Chamber TV-24 (B-306)

DESCRIPTION: The TV-24 chamber (Figure 6-7–Figure 6-10) is equipped with removable radiative shrouds and/or conductive heat exchangers. This is a horizontal-loading TV chamber. The facility is used for thermal-vacuum and thermal-balance testing.

TEST PRESSURE: < 1 × 10^{-5} torr (1.3 × 10^{-3} Pa)

TEMPERATURE RANGE: –185°C to 125°C (–301°F to 257°F)

INSIDE WORKING DIMENSIONS: 1.2-m diameter × 1.2-m deep (4 × 4 ft)

AUXILIARY EQUIPMENT:

Portable thermal systems (roll-around) are available to control multiple heat exchangers required for testing. ETL carries both the CQCM and some older TQCM's (Temperature Quartz Crystal Microbalance) used to measure contamination levels. An independent temperature failsafe is used for instrument protection. More than 100 thermocouples are available for payload temperature monitoring.

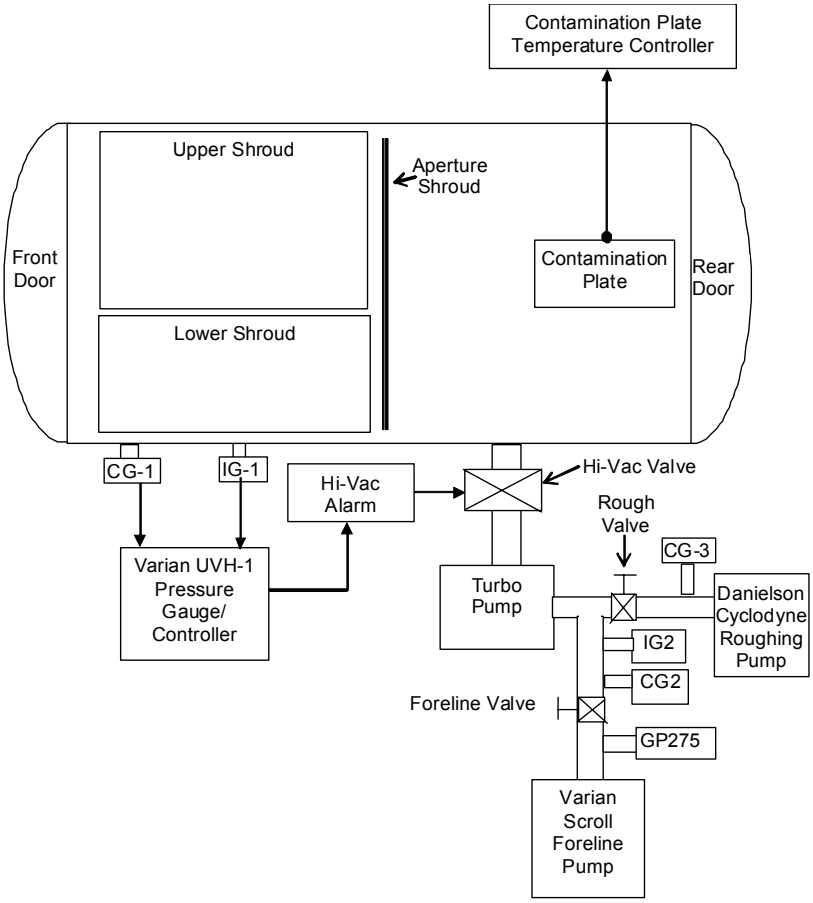


Figure 6-8 TV–24 1.2-m Turbo-Pumped Vacuum Chamber Schematic

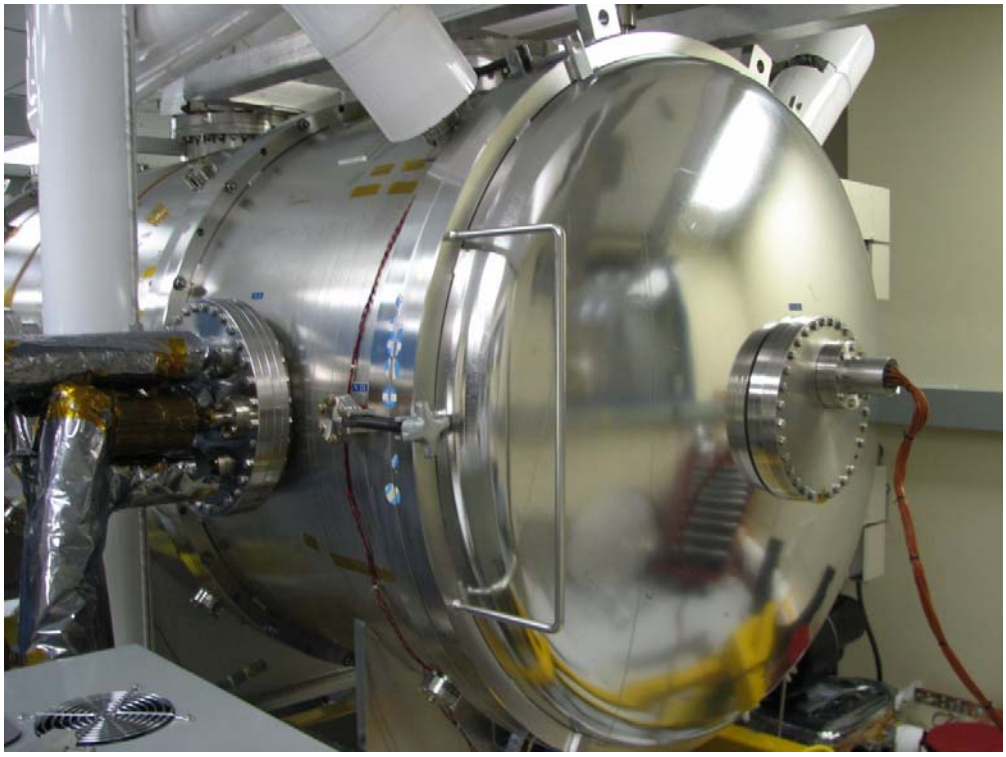


Figure 6-9 Thermal Vacuum Chamber TV-24 Outer

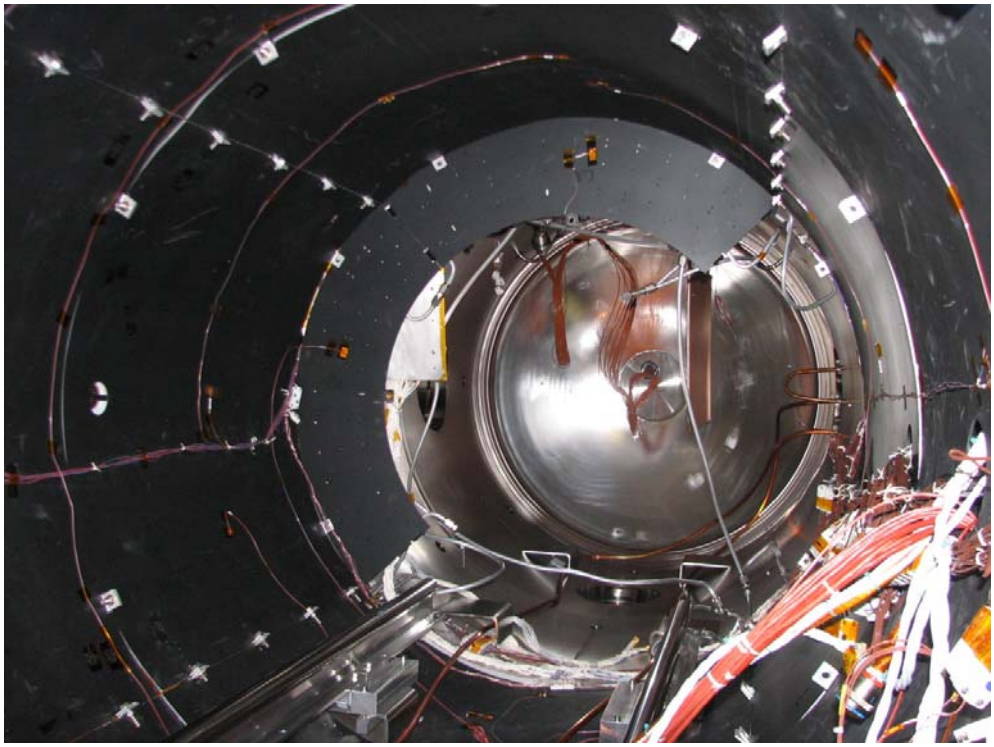


Figure 6-10 Thermal Vacuum Chamber TV-24 Inner View

6.9 Vac-Bakeout Chamber, TV-23 (B-248)

DESCRIPTION: The TV-23 vacuum bakeout chamber is a horizontal-loading chamber (Figure 6-11 and Figure 6-12). The facility is used for thermal bake out only.

TEST PRESSURE: $< 1 \times 10^{-5}$ torr (1.3×10^{-3} Pa)

TEMPERATURE RANGE: 22°C to 125°C (72°F to 257°F)

INSIDE WORKING DIMENSIONS: 0.81-m diameter × 1.65-m deep (32 × 65 in.)

AUXILIARY EQUIPMENT: A CQCM is available. Ten thermocouples are available.

Figure 6-11 TV–23 Vacuum Chamber Outer View

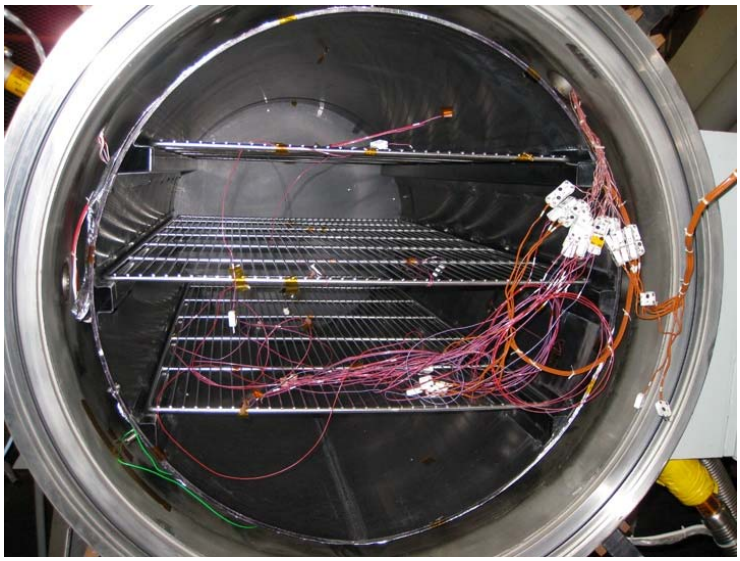


Figure 6-12 TV–23 Vacuum Chamber Inner View

6.10 Temperature Chamber, T-1 (B-248)

DESCRIPTION: The T-1 facility (Figure 6-13) is a medium-sized temperature-controlled chamber used for thermal conditioning of small to medium components. The chamber loads through a front opening door. The instrumented payload is installed in the chamber with no special handling or mounting fixtures, and it is connected to the GSE via a port.

TEMPERATURE RANGE: –50°C to 190°C (–58°F to 374°F)

INSIDE WORKING DIMENSIONS: 0.6-m wide × 0.6-m high × 0.6-m long (25 × 25 × 25 in.)

ACCESS PORT SIZE: 15 cm (6 in.) diameter (2 each).

INTEGRAL INSTRUMENTATION: Temperature is controlled by a digital programmer/controller located on the side of the chamber. An independent temperature failsafe is used for instrument protection. More than 20 thermocouples are available for payload temperature monitoring.

Figure 6-13 T–1 Temperature Chamber Inner and Outer Views

6.11 Temperature Chamber, T-6 (B-248)

DESCRIPTION: The T-6 is a medium-sized temperature-controlled chamber used for thermal conditioning of small to medium components (Figure 6-14). The chamber loads through a front-opening door. The instrumented payload is installed in the chamber on a shelf, and it is connected to the GSE via a feed through port. Physical dimensions include: 1.01-m^3 (40 in. × 40 in. × 40 in., 36 ft^3)

The chamber is cooled with a two-stage Freon compressor to –60°C, and then it reaches its lowest temperature of -175°C (–283°F)with an LN_2 boost. It is heated with electrical resistance elements. Nitrogen purging is available with measurement of the humidity of the chamber purge exhaust gas.

TEMPERATURE RANGE: –175°C to 200°C (–283°F to 392°F)

INSIDE WORKING DIMENSIONS: 1.01-m wide, high, and long (40 in.)

Access port size: 15-cm (6-in.) diameter (2 each).

INTEGRAL INSTRUMENTATION: Temperature is controlled by a digital programmer/controller located on the side of the chamber. An independent temperature failsafe is used for instrument protection. More than 50 thermocouples are available for payload temperature monitoring.

Figure 6-14 T–6 Temperature Chamber Outer and Inner Views

6.12 25 Foot Space Simulator TV-25 (B-150)

Description: The 25-ft (7.6-m) TV-25 Space Simulator (SS) in Building 150 (Figure 6-15, Table 6-1) was originally built in 1961. It has been modified since then to satisfy expanding space simulation and cleanliness requirements. Today's facility is a turbo-/cryo-pumped vacuum and space/solar simulation chamber pumped by ten cryogenic pumps and two turbo-molecular pumps. The inside walls are lined with temperature-controlled aluminum shrouds. Solar simulation is provided by an array of xenon arc lamps, capable of solar eclipses and solar irradiation levels below and above one solar constant. Physical dimensions as follows: 7.6-m diameter × 25.9-m high (25 × 85 ft).

The 25-ft (7.6-m) SS has supported many space flight programs for both NASA and private industry. The test capabilities include:

a) Test article thermal response to simulated sunlit space environments (thermal balance tests).

b) Test article contamination-controlled bake-outs.

c) Qualification and functional testing of spacecraft and instruments.

The facility is capable of supporting 24-hour operations over extended periods of time. Past test durations have exceeded one month.

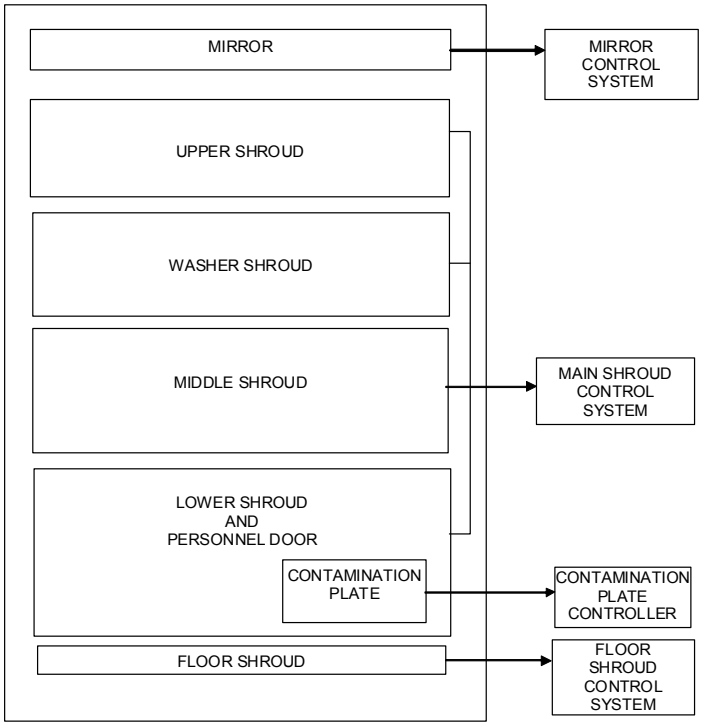
Chamber Details: The chamber is a cylinder approximately 85 ft (25.9 m) high and 27 ft (8.2 m) in diameter. The test volume is 20 ft (6.1 m) in diameter, with a ceiling at 25 ft (7.6 m) for solar operation. Otherwise, the ceiling is approximately 70 ft (21.3 m). The chamber access door is rectangular and at ground level. Door dimensions are 15-ft wide (4.6-m) × 25 ft high (7.6 m).

The high-vacuum system was upgraded in 1992/1993. It presently consists of ten 45,000-l/s (11,900 gal/s) cryogenic-pumps and two 2,200-liter/second (580 gallons/second) turbo-molecular pumps.

The chamber shrouds are aluminum panels with chevrons, and n all surfaces that face the test volume are painted black. Shroud temperatures can be controlled over a range between –185°C and +100°C (–301 and +212°F) using liquid and gaseous nitrogen.

The off-axis solar-simulation system consists of an array of 37 xenon arc lamps, (each with a maximum power of 30 kW), an integrating lens unit (which mixes the light from the lamps to form a uniform beam), a fused-quartz penetration window, and a 23-ft (7.0-m) diameter collimating mirror mounted at the top of the chamber (temperature controlled with gaseous nitrogen over a range from –75°C to +150°C [–103 to +302°F]). Four different solar beam diameter/solar intensity configurations can be achieved by using combinations of two integrating lens units and two collimating mirrors of 23 ft and 15 ft (7 m and 4.6 m). The accompanying Table 6-1 presents details of these configurations.

Structural support for a test article within the chamber can be provided in two ways. First, the floor shroud has openings that allow test article support structures to be hard-mounted to support columns in the chamber end bell. These columns rest on an isolated seismic mass below the chamber end bell. Secondly, wall-mounted attachment points, each capable of a 10,000-lb (4500-kg) vertical load, can be used to attach suspension cables or fixed hardware. Figure 6-16 shows the Mars Science Laboratory spacecraft suspended by cables inside the Space Simulator. The chamber has a variety of penetrations in the cylinder wall and end bell to provide feed-throughs for instrumentation, power, and temperature-control systems.



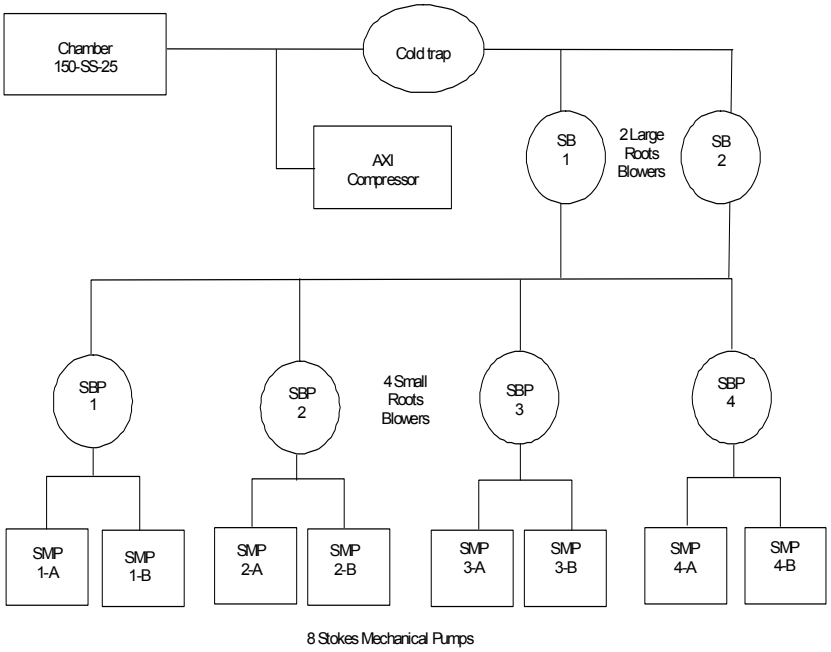


Figure 6-15 TV-25 Photo and block diagrams

Table 6-1 Integrating Lens for TV–25

	ILU 2	ILU 4
23-ft collimating mirror	SSB-15 (15-ft [4.6-m] diameter solar beam)	SSB-18.5 (18.5-ft [5.6-m] diameter solar beam
Lamps available	37	37
Maximum Solar Intensity (37 lamps at 30 kW)	2.5 solar constants (3,400 w/m^2, 316 W/ft^2]	2.0 solar constants (2,660 w/m^2, 247 W/ft^2]
Collimation half angle		1.1 degrees (96.2% of energy is within 1°)
Uniformity		+0.6% to –1.4%
15-ft [4.6-m] collimating mirror	SSC-8.5 (8.5-ft [2.6-m] diameter solar beam)	SSC-11 (11-ft [3.4-m] diameter solar beam
Lamps available	37	37
Maximum solar intensity (37 lamps at 30 kW)	11.0 solar constants (14,900 W/m^2, 1390 W/ft^2)	8 solar constants (10,600 W/m^2), 986 W/ft^2)
Collimation half angle	2 degrees	TBD
Uniformity	± 5%	TBD

Facility Power: Facility power is at the following ratings:

- 120 volts alternating current (VAC), 1 phase
- 208 VAC, 3 phase
- 480 VAC, 3 phase

In the event of a loss of utility-supplied power (from Southern California Edison), two emergency power generators are switched on to provide power to the primary chamber controls, the Data Acquisition System, and the customer's support equipment (as requested).

Customer Ground Support Equipment Area: An area for customer GSE is available inside the 25-ft (7.6-m) Space Simulator building adjacent to the control room. Power can be made available at the following ratings.

- 120 VAC, 1 phase
- 208 VAC, 3 phase
- 480 VAC, 3 phase

Notes:

1. See ETL for specific activation procedures.
2. The generators are intended to protect the Test Article and facility only until power returns, not to continue testing.

Data Acquisition System: The standard instrumentation capabilities of the DAS 25-ft Space Simulator Data Acquisition System (DAS) are listed below. Other special or additional instrumentation can be provided and/or accommodated as needed.

Test Article Instrumentation:

Thermocouples	600 channels, type E or type T
Heater Control	60 power supplies (75 W each, 100 V at 0.75 A)

Facility Data:

Thermocouples	140 channels (shrouds, mirror, etc.)
Chamber Pressure	6 ion gauges
Solar-	1 Kendall cavity radiometer
Contamination	3 quartz crystal microbalances (QCM)

Clean Room and Test Article Handling Provisions: The 25-ft (7.6-m) SS, located in building 150, contains an air lock and a class 10,000 clean room (35 ft × 30 ft × 32 ft, LWH [10.7 × 9.1 × 32 m]) that is available for test article assembly and system checkout prior to environmental testing. A 10-ton crane is available in these clean rooms.

Test article mobility within the clean room, air lock, and high bay (adjacent to the chamber), is provided by an overhead crane system. Loading test articles into the chamber can be accomplished using either the 5-T (4500 kg) monorail crane, which extends into the chamber or a (customer-provided) ramp system, which can be mounted on the lower hard points located in the chamber.

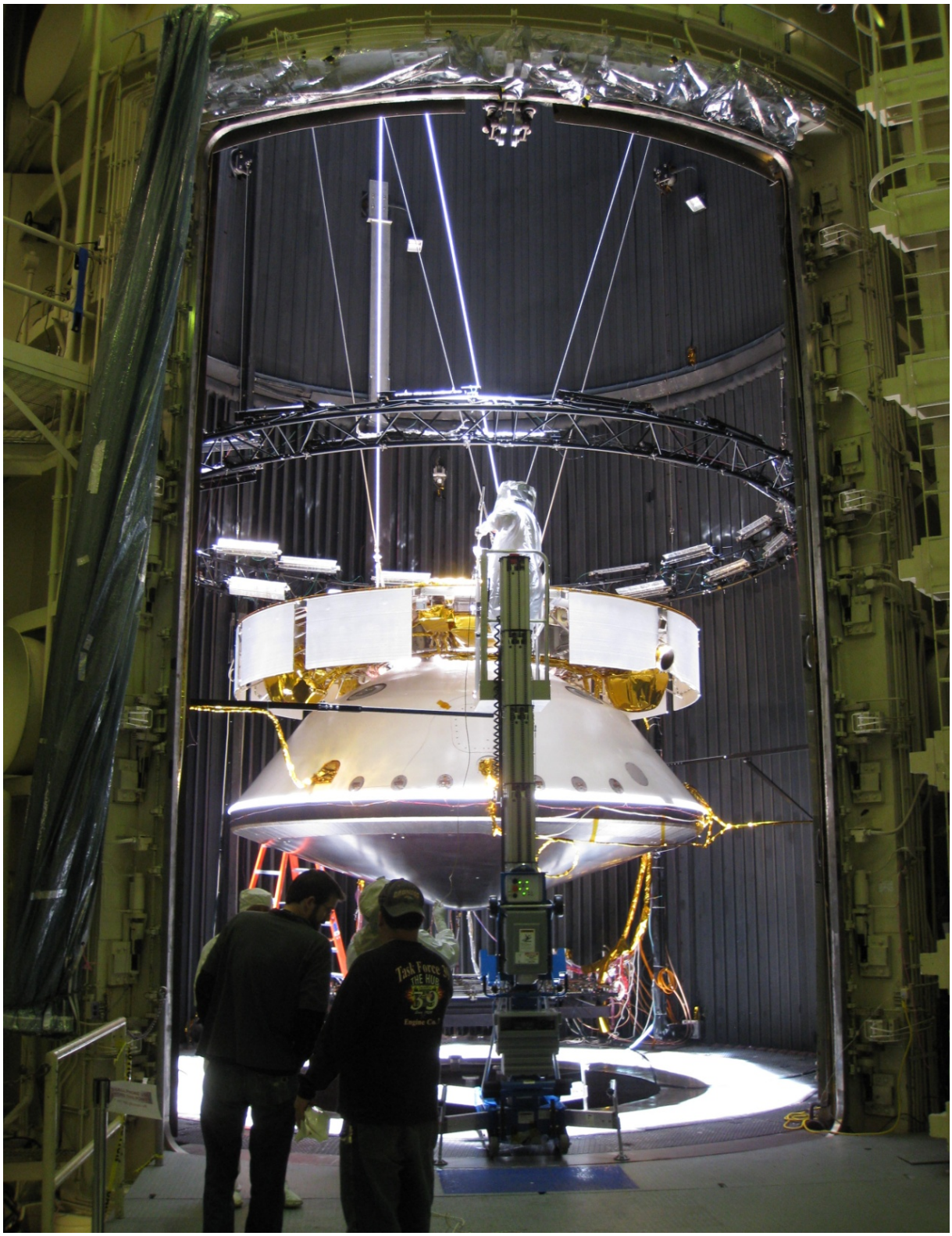


Figure 6-16 The MSL Spacecraft Suspended in JPL's B150 25-ft Space Simulator (7.6 m)

6.13 10-foot Vertical Space Simulator (B-248)

DESCRIPTION: Thermal-vacuum (TV) chamber.

The B-248 Space Simulator is a bottom-loading chamber with a side personnel door (Figure 6-17). The facility is used for thermal-vacuum and thermal-balance testing.

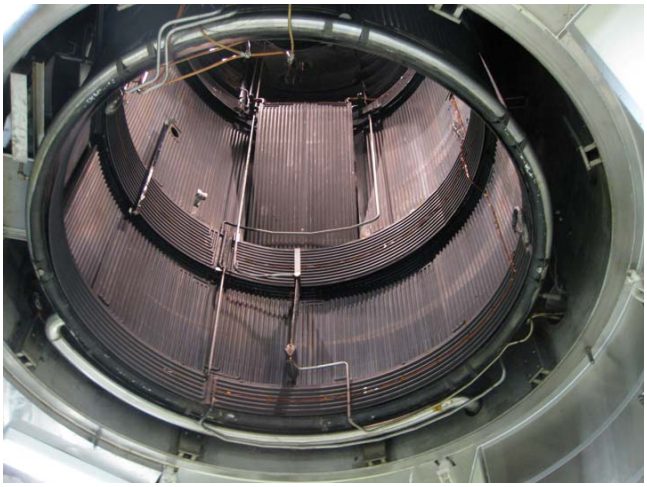
TEST PRESSURE: < 1 × 10^{-5} torr (1.3 × 10^{-3} Pa)

TEMPERATURE RANGE: –185°C to 125°C (–301°F to 257°F)

INSIDE WORKING DIMENSIONS: 0.4-m diameter × 7.6-m high (10 ft × 25 ft)

AUXILIARY EQUIPMENT: Portable thermal systems are available to control base plates and the CQCM. The end bell of this chamber is located in a class 100k cleanroom. Access to the cleanroom is through a rollup door on the west side of the facility. There is no airlock to support the entry and removal of hardware into the facility. Consequently, precautions must be taken to protect the hardware from contamination when using this facility. As many as 300 thermocouples are available for payload temperature monitoring.

(a) Outside View of Facility



(b) Chamber Shrouds (Looking up)

(c) Chamber End Bell with Test Article (MER)

Figure 6-17 Chamber Views a, b and c of Facility

APPENDIX A: ADDITIONAL INFORMATION

A.1 ETL instrumentation

Dynamics data acquisition includes: two 64-channel and one 32-channel digital data recorders. Each system can accommodate integral electronic or voltage inputs, provide sampling from 1 kHz to 100 kHz and standard analysis programs (which include; PSD, Sign Sweep, Shock Response Spectrum (SRS), 1/n Octave, and time history. Data can be provided on a memory stick and installed on one of the computers provided in the customer area for data processing or emailed to the customer's office computer.

ETL has a large selection of accelerometers, force sensors, and signal conditioners to accommodate nearly any small or large system-level test. With advanced notice, flyaway sensors can be procured, prepared, and provided to a project to install during the assembly of flight or critical systems. ETL can additionally provide instrumentation support for in situ modal or shock testing at remote locations.

The Temperature Data Acquisition System (TDAS) includes: a PC-based LabVIEW program that can sample once every other minute and plot temperatures real time on the computer monitor or on paper, and data may be provided in an Excel file for further evaluation. TDAS can monitor PRT sensors, thermocouples, and it can measure voltages from power supplies or other equipment including; QCMs), ion gages, or vacuum controllers and gages. TDAS can be setup per the customer's instructions to monitor temperatures and control heaters (via power, voltage or temperature) and set limits to provide an on-screen notification when a limit is approached or exceeded. TDAS may also be programmed to calculate computed telemetry channels (e.g., min/avg/max of group of temperature, voltage or current measurements; temperature differences across interfaces, power sums for many supplies).

Thermocouples (TCs) are custom fabricated by ETL on a special-order basis. Several different wire gages are available in custom lengths. The Environmental Test Laboratory exclusively uses Type "T" and Type "E" (Chromel-Constantan) TCs.

A.2 Roles & Responsibilities

The Quality Assurance Representative shall:

a) Be present during all testing.

b) Approve the detailed test procedure and ensure the pretest has been completed prior to testing flight hardware (as required).

c) Verify software version is the most current (as required).

d) Verify the calibration of equipment.

e) Monitor the test to ensure that the requirements of the procedure are being followed.

f) Verify that the critical steps have been completed prior to each run and stamp or initial the procedure as appropriate.

The Test Conductor shall:

a) Be present or provide a dedicated alternate during all testing.

b) Direct all test activities.

c) Achieve consensus prior to any test commencement or continuation.

d) Maintain necessary discipline in the test area to protect people, hardware, and facilities.

e) Ensure appropriate personnel are involved in resolving issues.

f) Ensure all parties are following the Detailed Test Procedure completely and as intended.

g) Declare the test completed.

The Test Article Engineer (TAE) shall:

a) Be present or provide a dedicated alternate during all testing.

b) Notify JPL Quality Assurance personnel that a test has been scheduled and arranges for a representative from QA to participate in testing.

c) Provide personnel, tools, connectors, and special materials required to connect the test hardware into the test system.

d) Install and remove the test article to and from the test equipment.

e) Notify the Test Conductor and ETL Test Operator of any hardware malfunctions requiring termination of the test.

f) Inform ETL personnel of the criticality of the test hardware per the definition in D-560.

g) Notify Test Conductor of all hardware idiosyncrasies that could affect test.

h) Monitor hardware under test and associated ground support equipment during testing.

The Test Operators shall:

a) Be present during all testing and contactable for emergencies during scheduled and unplanned break periods.

b) Verify that all applicable test equipment is in current calibration and that the monthly maintenance report is current.

c) Locate and mount transducers required to control and monitor the input environment specified in the applicable Test Plan.

d) Perform the test in accordance with the Detailed Test Procedure.

e) Maintain the Test Log Sheet to document the progress of the test operation.

f) Perform yearly certification testing on the dynamics control system; and add data from this certification test to the archival notebook.

g) Maintain familiarity with the operation of the controller system.

h) Maintain personal knowledge and training on the operating system by performing training runs on the shakers yearly and as available.

The ETL Supervisor shall:

a) Be responsible for managing the facility including ensuring that maintenance, calibration, and equipment updates are performed in a timely manner and as required.

b) Secure the facility in an anomalous situation and gather the appropriate experts to ensure resolution before allowing testing to resume.

c) Ensure personnel are provided education in dynamics testing and control system software operation.

d) Ensure ETL operator availability.

A.3 Test Process Flow

[The text below was copied from 2.0 of JPLRules33832; in case of a conflict, the most current JPL Rules document rules.]

Actor		Action
		[JPL Rules 33832, 1.0 not included here.]
Test Article Engineer (TAE) or designee	2.1	Supply the Test Laboratory a Test Plan that includes the following: • Description of test article (including name [not just an acronym], size, weight, and drawing number) • Environmental test requirements • Instrumentation and data requirements • Schedule requirements
	2.2	Access the Technical Facilities Management System to begin the process of coordinating with the Environmental Test Laboratory (ETL) for Test Laboratory support by accessing the Technical Facilities Management System website by keying TFM (http://tfm.jpl.nasa.gov/). ***Note:*** *To access the website, subcontractor personnel must either have a JPL person function as the TAE or secure a JPL badge for the desired subcontractor TAE.*
	2.3	Click on "Room Assignments + New Reservations" to input the desired test equipment, testing duration, account number, and contact information. (The web page includes contact information for getting any needed clarifications or additional information.) ***Note:*** *ETL will perform a make-or-buy decision if the appropriate equipment is not available.*
	2.4	If the Test Laboratory is outside JPL, arrange scheduling and certification of the facilities per **Standard Environmental Testing Facilities and Practices** (JPL Rules! DocID 35492).
Test Laboratory Test Engineer (TL-TE)	2.5	Prepare a cost estimate for the test activities.
	2.6	Review with the TAE as needed the required details of the following: • Test Plan • Proposed schedule

Actor	Action
	• Requirements for handling flight hardware • Test requirements • Estimated cost for the test activities
	2.7 Schedule the test.
	• For a test within JPL, verify the schedule in TFM (see 1.2) • Open a service order. • For a Test Laboratory outside JPL, use the scheduling function of that Test Laboratory and coordinate with the ETL Test Engineer. • For a Test Laboratory outside JPL, use whatever administrative function of that Test Laboratory that is analogous to a service order. • Prepare a job folder.

A.4 Prepare for Test

[The text below was copied from 3.0 of JPLRules33832; in case of a conflict, the most current JPL Rules document rules.]

Actor		Action
TAE or Designee	3.1	Generate the appropriate test fixtures or coordinate use of used fixtures (if available) from the Test Laboratory.
	3.2	Contact the Materials & Contamination Control Engineering group in Division 35 to discuss cleanliness and contamination-avoidance issues.
	3.3	Verify compatibility of the test article materials.
TL-TE	3.4	Prepare a Detailed Test Procedure (DTP).
	3.5	Obtain approval signatures on the Detailed Test Procedure as applicable to the two cases below: • If testing is by ETL: from TAE, ETL Supervisor, and Quality Assurance. Approvals from the Contamination Control Engineer and Planetary Protection Engineer may also be needed for thermal vacuum bake-outs. • If testing is by a Test Laboratory outside JPL, obtain approvals from the Test Laboratory Test Engineer (TL-TE), the TAE, and Quality Assurance.
	3.6	Review the Detailed Test Procedure with the lead technician and/or other operations personnel at the Test Laboratory.
TAE or Designee	3.7	Contact the Systems Safety engineer to schedule an Operational Safety Survey.
	3.8	Contact the Transportation Department to arrange transportation for delivery of test hardware and support equipment to the Test Laboratory if the Test Laboratory is within JPL and also coordinate with the transportation organization of any Test Laboratory outside of JPL if such a non JPL Test Laboratory is being used.
	3.9	Arrange for flight technician and Quality Assurance support as required.

Test Laboratory Instrumentation Personnel

3.10 Make pre-test preparations:

- Discuss instrumentation requirements and proper test article handling procedures with the TAE and/or TL-TE.
- Install instrumentation transducers on the test article and support equipment.
- Set up and check out the data-acquisition equipment.
- Verify that calibrations of data acquisitions equipment are current.

Test Laboratory Facility Operations Personnel

3.11 Verify Detailed Test Procedure:

- Verify that Detailed Test Procedure is approved and that the procedure is the latest revision per the Test Laboratory document custodian.
- Review Detailed Test Procedure with the TAE.

A.5 Perform Test

[The text below was copied from 4.0 of JPLRules33832; in case of a conflict, the most current JPL Rules document rules.]

Actor		Action
Test Laboratory Facility Operations Personnel	4.1	Make pre-test preparations: • Place orders for liquid nitrogen deliveries as required. • Schedule labor as required. • Verify that all equipment calibrations are current and will not expire during the test. • Verify that the monthly maintenance is current. • Verify that equipment is ready to support test operations. ***Note:*** *Any rescheduling of the test may result in the need to redo any or all of these test preparations.*
	4.2	Assist TAE with installation of test article as required.
Test Laboratory Instrumentation or Facility Operations Personnel, TAE, and QA	4.3	Make final test preparations: • Connect all instrumentation to the Test Article or other locations as specified in the Test Plan. • Verify all instrumentation is operating properly and that it meets current calibration requirements.
Test Laboratory Facility Operations Personnel, TAE, and QA	4.4	Perform test operations and collect data per the approved Detailed Test Procedure.
	4.5	Following completion of the test, assist in the removal of the test hardware as necessary.
Test Laboratory Instrumentation Personnel	4.6	Perform post-test functions: • Remove all instrumentation transducers from the test article. • Perform data reduction services as required and deliver reduced data to TAE. • Maintain all raw test data per the requirement Standard Environmental Testing Facilities and Practices (JPL Rules! DocID 35492). • A Test Laboratory outside of NASA maintains raw data per its organizational requirements. • ***Note:*** *TAEs with a potential need for the raw test data may*

		consider requesting it immediately after the test, particularly if the test was performed by a Test Laboratory outside JPL.
TAE or Designee	4.7	Call the Transportation Department to arrange transportation for the removal of test hardware and support equipment from the Test Laboratory if the Test Laboratory is within JPL and also coordinate with the transportation organization of any Test Laboratory outside of JPL if such a non-JPL Test Laboratory is being used.

A.6 Report Test Results

[The text below was copied from 5.0 of JPLRules33832; in case of a conflict, the most current JPL Rules document rules.]

Actor		Action
Test Laboratory Test Engineer	5.1	Generate a copy of all test data and pertinent documentation (e.g., Assembly and Inspection Data Sheets (AIDS), test log sheets, and completed Detailed Test Procedure).
	5.2	Deliver this original data package to the TAE.

A.7 Reviews and Approvals

Tests must follow JPL, NASA, Occupational Safety and Health Administration (OSHA), project, and facility rules and regulations and must often include involvement of appropriate Quality Assurance (QA) personnel.

Activities that may be required (partial list) include:

a) System Safety Survey

b) Facility Safety Survey

c) Electrostatic Discharge (ESD) Survey

d) Reviews such as a Test Readiness Review (TRR)

e) Structural or other Ground Support Equipment (GSE) Evaluations

f) Chamber Certification Survey

A.8 Service Process Flow

[The illustration below was copied from JPLRules78024; in case of a conflict, the most current JPL Rules document rules.]

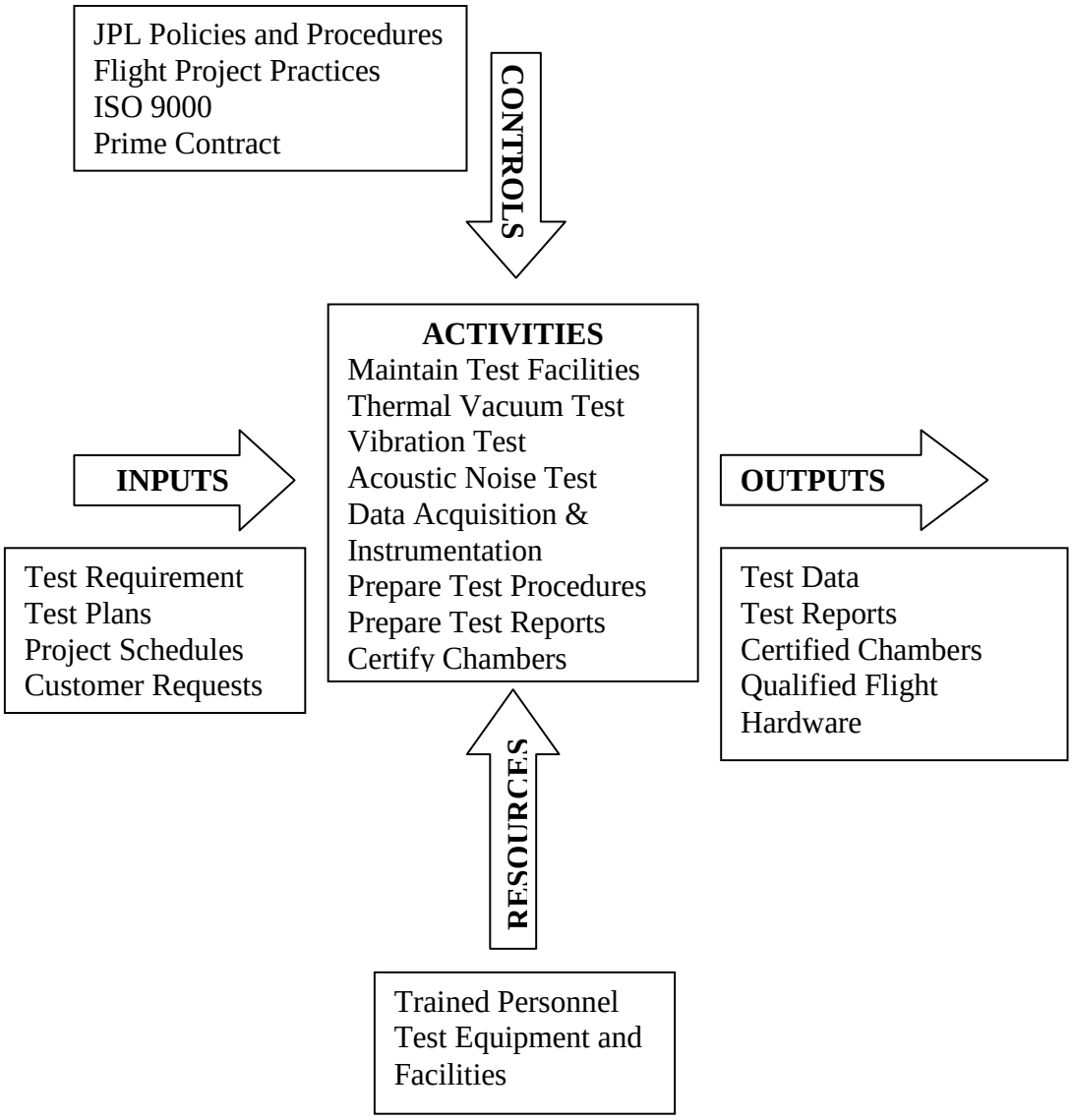
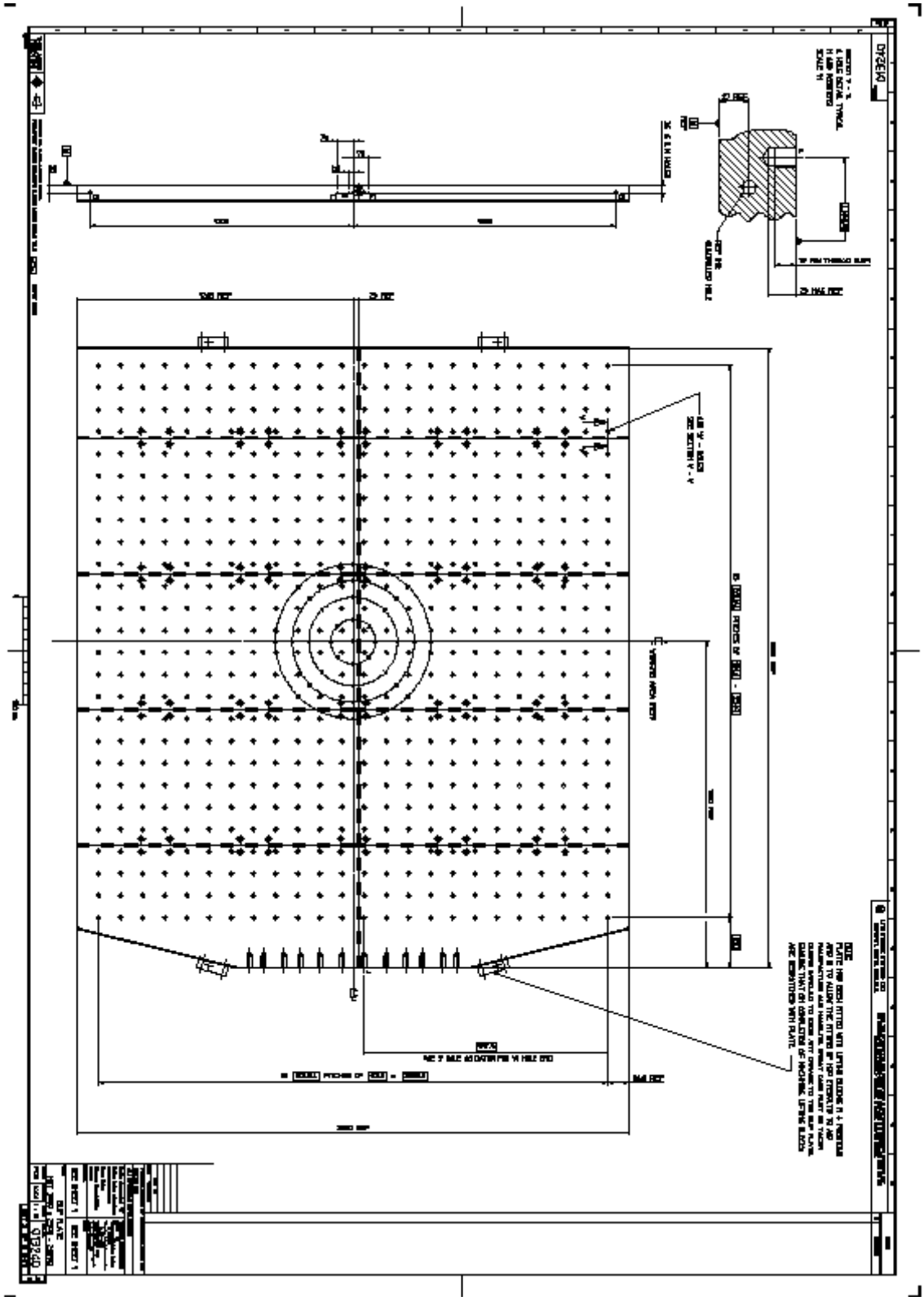


Figure 1. Environmental Test Laboratory Inputs, Controls, Outputs, and Resources (ICOR)

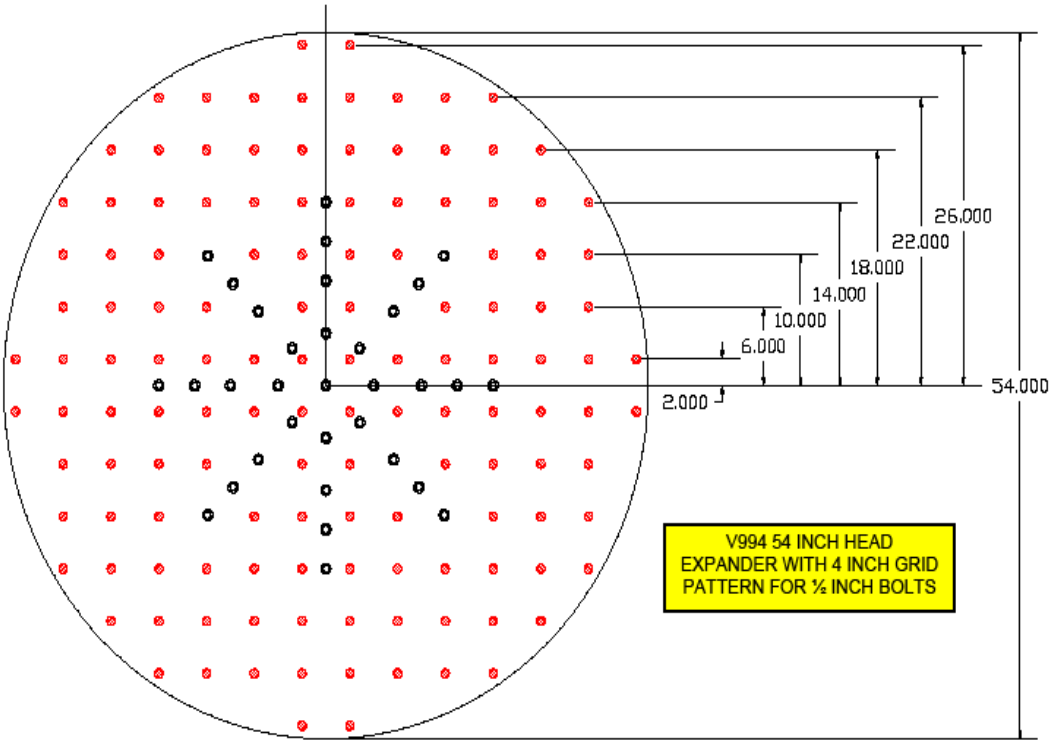
A.9 994 Slip Plate Drawing

(Used for dynamic testing)



A.10 54-in. Head Expander Pattern

(Used for dynamic testing)



A.11 Heater and IR Lamp Controller

The JPL Environmental Test Laboratory (ETL) has the capability of controlling six zones of infrared lamps or other heating elements. Five of these zones are capable of controlling a maximum of 22.5 kW of input power, and one is capable of controlling 45 kW. Custom lamp arrays can be fabricated for all ETL chambers. (Roughly 2 ft (0.6 m) in diameter by 3 ft (0.9 m) length is the minimum practical size for lamp arrays.)

When considering a recommended maximum for continuous operation of 80%, the maximum recommended power per zone becomes 18 kW and 36 kW, respectively**.**

The control system can either be used in one of three modes:

1. Manual mode, where an operator manually sets the power through the use of a potentiometer,
2. PID controlled mode, where the operator sets the desired temperature of the test article on a Fuji PID controller which controls the temperature with respect to a single thermocouple.
3. Computer controlled mode, where a computer controls the system to function with any of a number of different transducer types such as thermocouples, PRTs, calorimeters, etc. This mode can also use more complicated control strategies such as average of a number of transducers, highest transducer not to exceed or lowest transducer temperature not to go below a set temperature.

Infrared lamps have been used in the ETL for testing a variety of missions including Mars Pathfinder, Mars Excursion Rovers, and Mars Science Laboratory, as well as testing the TOPEX solar panels.

Figure A.11-1 Typical Lamp Array Fixture

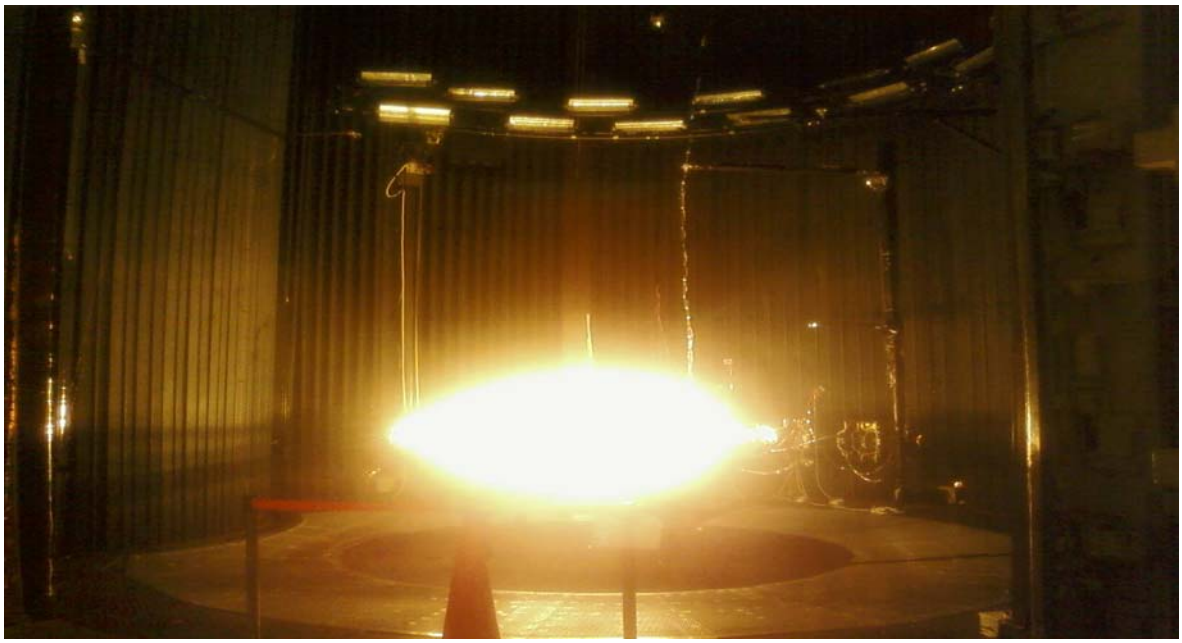


Figure A.11-2 Two-Lamp Array Testing in 25-ft (7.6 m) Chamber

Figure A.11-3 Eighteen Fixtures for Upper Lamp Array for MSL Test

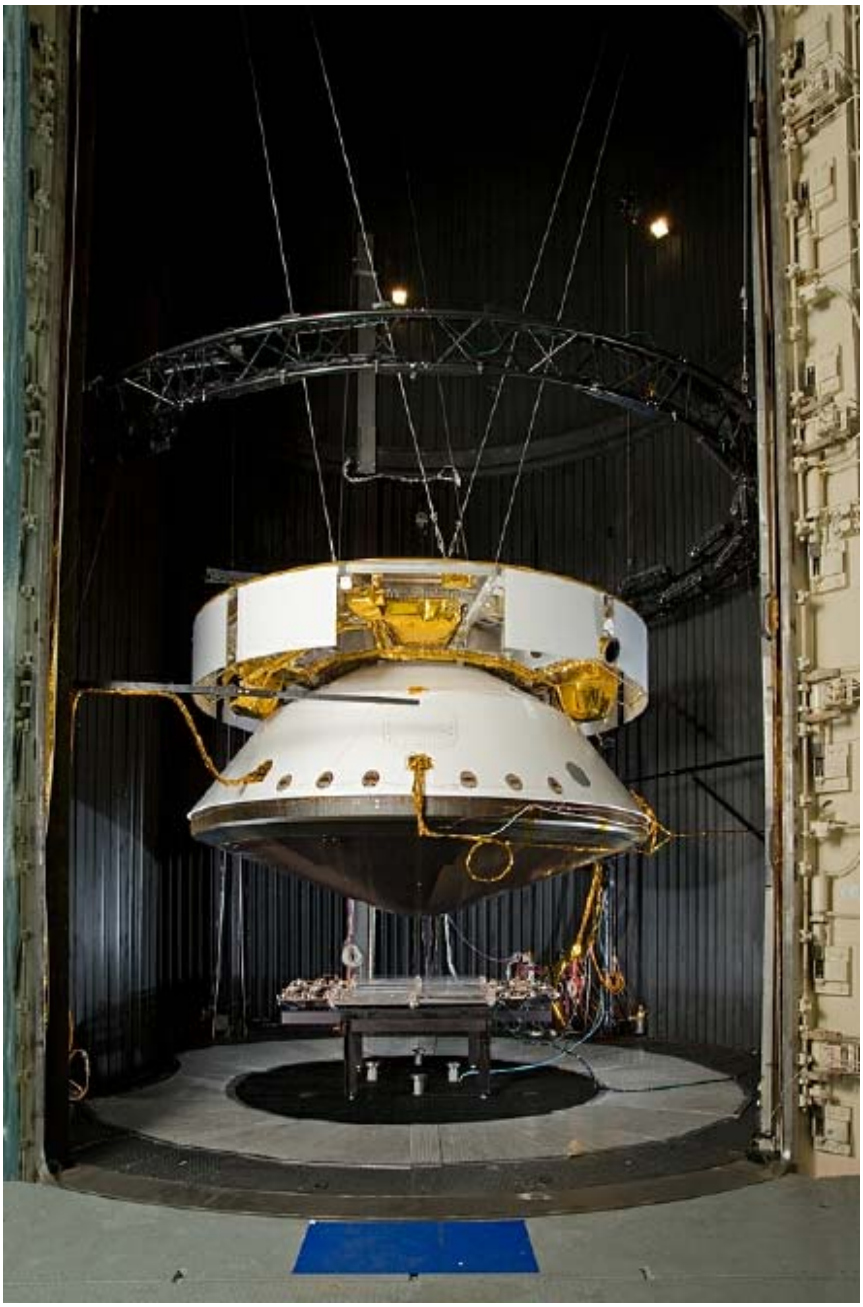


Figure A.11-4 Upper and Lower Lamp Arrays with MSL

Figure A.11-5 Lamp Controller Racks (three controllers per rack)

A.12 ETL T-Vac Informational Requirements

The following is an outline of information to be provided so that the ETL can schedule a thermal-vacuum test or a temperature test, prepare a cost estimate, open a service order, prepare a test procedure, and conduct your test.

1. Type of test
   - A. Temperature (no vacuum)
   - B Thermal vacuum bakeout
     - i. Contamination Control
       - a. Time and temperature only
       - b. Quartz Crystal Microbalance (QCM) required
     - ii. Planetary Protection bakeout – provide minimum and maximum temperature requirements. Need durations at specific temps too?
   - C. Thermal vacuum
     - i. Qualification (non-flight hardware)
     - ii. Proto-flight (flight hardware)
     - iii. Flight Acceptance (flight hardware)
   - D. Thermal balance
     - i. Thermal development or thermal characterization test (non-flight hardware)
     - ii. Instrument or spacecraft thermal balance test (flight hardware)
2. Name of project
3. Test Article description
   - A. Name (please define acronyms)
   - B. Drawing/Part Number
   - C. Size (x, y, z)
   - D. Weight (in kilograms or pounds)
   - E. Number of test articles
4. Account and task number
5. Test schedule
   - A. When will this test be started?
   - B. How long is it expected to last?
   - C. Will 24-hour coverage be required and does the project have the resources to staff the test 24 hours/day?
   - D. Timely notification to ETL of test start delays several weeks is preferred (as soon as you know) to free reserved chamber for use by other project customers and facilitate test support planning by ETL staff (i.e., specify advanced notice preferred by ETL).
6. Test Article Engineer (TAE)
   - A. Name
   - B. Badge number
   - C. Office phone number
   - D Cell Phone Number
7. Funds cognizant manager to authorize the test if the cost exceeds the signature authority of the TAE ($10K).

A. Name
B. Badge number
C. Office phone number
D Cell Phone Number

8. Test profile
   A. Temperatures
      i. Shroud and heat exchanger temperatures
      ii Test Article temperatures
         a. Minimum temperature requirements (Planetary Protection bakeouts)
         b. Do not exceed temperatures (high and low limits)
   B. Durations of soaks and functional tests
   C. Ramp rates of test article preferred/Maximum
   D. Vacuum requirements or atmosphere (GN_2 or CO_2 at 8 torr (0.15 psi, 1066 Pa))
   E. Will solar simulation be required, and if so, what intensities and beam diameters are required?
   F. Will solar mapping be required to ensure beam spatial uniformity or spot mapping to detect possible reflection/focusing issues for either a portable solar simulator for a smaller chamber or the Xe arc lamps for the 25-ft chamber?
9. Description of how test articles will be mounted in chamber
   A. Heat Exchanger(s)
   B. Support fixtures (grill, shelf, pedestal, frame, cart)
   C. Suspended
   D. Who will be installing the test hardware into the chamber?
10. ETL Instrumentation requirements
   A. Thermocouples (TC)
      i. Number required for monitoring test article and fixture temperatures
      ii. List of TC names for Thermal Data Acquisition System (TDAS)
      iii. Table of TC warning and alarm levels for TDAS
      iv. Drawing showing TC locations
      v. What type and gage TC will be required (26 ga Type E Std)?
   B. Electric heaters
      i. Number of power supplies to be provided
      ii. List of heater names for TDAS
      iii. Drawing showing heater locations
      iv. Will current limiting be required at power supply and in TDAS software to prevent heater shorting by accidental large-current inputs?
      v. Do the standard ETL power supplies (75 W, 100 V at 0.75 A) meet your heater power needs? If not, is customer bringing own power supply with expanded capability or expecting ETL to obtain (rent?) them?
   C. PRTs
      i. Number of PRTs to be monitored
      ii. List of PRT names for TDAS

iii. Drawing showing PRT locations
iv. How many wires will be required for (two or four-wire) measurement?

11. Contamination Control (CC) requirements
    A. Has Contamination Control approved the materials used in the Test Article?
    B. Is a pre-test bakeout required for GSE cables and/or fixtures?
    C. Quarts Crystal Microbalance (QCM) requirements (from Contamination Control)
        i. Test article temperature during sample
        ii. QCM temperature during sample
        iii. Pass/fail QCM Hz/hr requirement
        iv. Identify approximate QCM location will special mounting or suspension provisions be required?
    D. Is a pre-test chamber bakeout and baseline QCM sample required?
    E. What is the name of the Contamination Control engineer supporting this project?
12. Planetary Protection (PP) requirements
    A. What is the minimum temperature required?
    B. What is the do-not-exceed temperature limit?
    C. What is the soak duration requirement?
    D. What is the name of the PP engineer supporting this project?
13. Is the test article ESD sensitive?
14. How many bulkhead cable feed-through connectors will be required to support the operation of the Test Article? What size and type of connectors will be required? (The project will be required to supply their own bulkhead feed through connectors and mounting plates.)
15. Viewing options;
    A. None required
    B. Video camera & recording
    C. Window for viewing
16. Will a vacuum failure relay be required to kill high voltage to the test article to prevent corona discharge in the event that the chamber pressure rises above 5×10^{-5} torr (0.006 Pa, 9.6×10^{-7} psi)?17. Is a Test Plan available? If not, when is the planned release of the draft test plan?
18. Has an Environmental Test Authorization Summary been approved by Reliability Engineering?
19. Special requirements (for example, liquid-helium cooling or carbon-dioxide atmosphere)
20. What special plumbing requirements are there for the customer's custom shroud (e.g., a multi-faced box where each panel is operated at a different temp to properly simulate in-flight thermal loads)?
21 Any special barriers required around open chamber doors (e.g., curtains, high-efficiency particulate air [HEPA] filters) to ensure CC/PP compliance?

APPENDIX B: ABBREVIATIONS, ACRONYMS, AND SYMBOLS

Term	Definition
AIDS	Assembly and Inspection Data Sheet
ASCII	American Standard Code for Information Interchange
CC	contamination control
CG	center of gravity
CMMR	common mode rejection ratio
CQCM	cryo quartz crystal microbalance
DAQ	Data Acquisition
DAS	Data Acquisition System
DTP	Detailed Test Procedure
GSE	ground support equipment
ESD	electrostatic discharge, Engineering & Science Directorate
ETL	(JPL) Environmental Test Laboratory
GN_2	gaseous nitrogen
HEPA	high-efficiency particulate air (filters)
ICOR	inputs, controls, outputs, and resources
IR	Infrared
JCI	JPL Critical Item
KSC	Kennedy Space Center, Florida
LN_2	liquid nitrogen
M-Fab	JPL Mechanical Fabrication
MOI	moment of inertia
M+P	M+P International (manufacturer of Vibrunner controller software)
OSHA	Occupational and Safety and Health Administration

PCB	printed circuit board
PID	Proportional integral derivative (temperature controller)
PLC	Programmable Logic Controller
POI	product of inertia
PP	planetary protection
PRT	platinum resistance thermometer
QA	Quality Assurance
QCM	quartz crystal microbalance
RGA	residual gas analyzer
rms	root mean square
rpm	revolutions per minute
SRS	Shock Response Spectrum (program used for dynamics data acquisition)
SS	(25-ft) Space Simulator
STV	Solar Thermal Vacuum
SSB-15	15-ft diameter Solar Simulator beam
SSB-18.5	18.5-ft diameter Solar Simulator beam
SSC	8.5-ft diameter Solar Simulator beam
SSC-11	11-ft diameter Solar Simulator beam
TAE	Test Article Engineer; engineer with item to be tested (could be Cog Eng)
TC	Test Conductor; individual in charge of performing a test
TC	thermocouple
TDAS	Temperature Data Acquisition System (program used for dynamics data acquisition)
TFM	Technical Facilities Management (Scheduling Website)
TL-TE	Test Laboratory Test Engineer
TQCM	thermoelectric quartz crystal microbalance
TRR	Test Readiness Review
TV	thermal-vacuum (chamber)
VAC	volts alternating current, vacuum