National Aeronautics and Space Administration

GODDARD SPACE FLIGHT CENTER

ENVIRONMENTAL TEST AND INTEGRATION FACILITIES HANDBOOK

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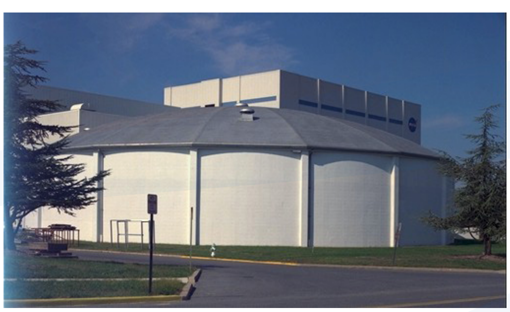


National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

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Introduction

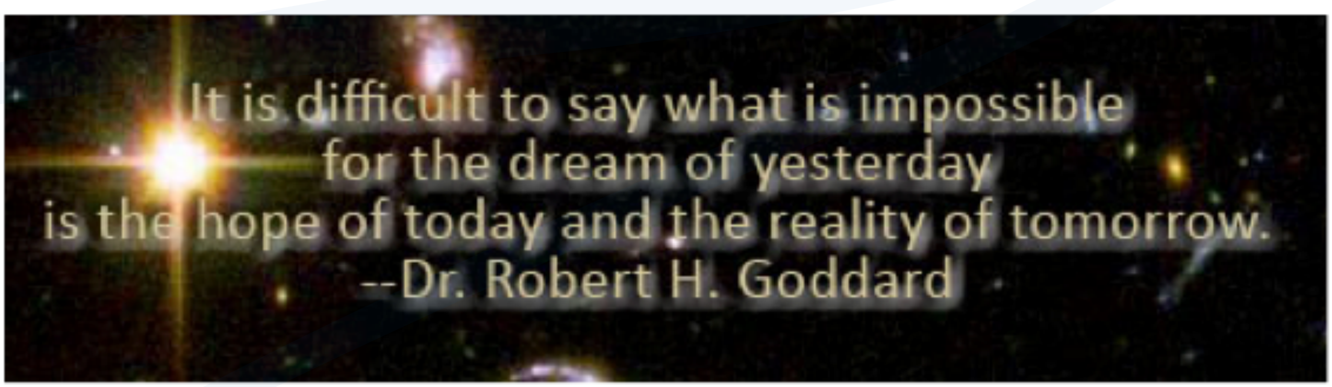
NASA's Goddard Space Flight Center (GSFC) is home to the nation's largest organization of scientists, engineers and technologists that build spacecraft and instruments to study the earth, sun, solar system, and universe. Scientific missions are carried out from concept, through design, manufacture, test, launch and operations. To support its science missions, Goddard functions as a full-spectrum, end-to-end research and development laboratory. Goddard is committed to maintaining and upgrading its core infrastructure, laboratory facilities and equipment to preserve the Center's preeminence as a national resource and Center of Excellence. The capabilities provided in Goddard's Integration and Test Complex are a key element to realizing its scientific goals.

Goddard's Integration and Test (I&T) facilities are managed by the Applied Engineering and Technology Directorate's Mechanical Systems Division. Goddard's I&T facilities provide projects with cleanrooms and test facilities for building flight hardware and ensuring it will withstand the launch, space and electromagnetic environments. The Environmental Test Engineering and Integration Branch has long-range goals of advancing state-of-the-art of environmental testing and aiding the development of improved spaceflight systems. Goddard's Integration and Test Complex is one of the most comprehensive and capable spaceflight test facilities within the United States Government.

This handbook provides a comprehensive catalog of Goddard's I&T facilities and their capabilities. These facilities are located in Buildings 7, 10, 15 and 29 as shown on the GSFC map found on the next page.

Additional information about Goddard's I&T facilities can be obtained from:

Environmental Test Engineering & Integration Branch
Code 549
Goddard Space Flight Center
Greenbelt, Maryland 20771
(301) 286-2187 or (301) 286-8747



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1.0 Environmental Test Engineering Services and Facilities

The Environmental Test Engineering and Integration Branch provides test facilities, instrumentation support, data analysis and experienced staff to perform structural dynamic, electromagnetic and space simulation testing of spaceflight hardware in an effective and safe manner. A full spectrum of test articles, including components, instruments and spacecraft can be thoroughly tested to survive the launch, electromagnetic and space environments. Testing capabilities the Environmental Test Engineering and Integration Branch provide include:

Structural Dynamics:	Acceleration Acoustic Mass Properties and Spin Balance Modal Survey Static Load Vibration / Shock
Electromagnetics:	Electromagnetic Compatibility Magnetics
Space Simulation:	Bakeout (outgassing) Solar Simulation Thermal Thermal Balance Thermal Vacuum

Details of these environmental test facilities are described in the following sections.

1.1 STRUCTURAL DYNAMIC TESTING

1.1.1 Vibration Facility

General: The Vibration Laboratory provides all necessary services and equipment to perform shock and vibration testing of spacecraft and subsystems. Digital control systems provide sinusoidal, random, and transient waveform control to four separate electro-dynamic exciters. All exciters are rigidly mounted to very large reaction masses that are isolated from the building. Digital data acquisition systems condition and record accelerometer, force, and strain gage signals. A small machine shop with drill press, milling machine, and band saw is available for simple fixture fabrication.

Control System: Two control rooms equipped with a state of the art m+p Vibration Controllers provide excitation signals to the exciters. The controllers are capable of putting out sine, random and various transient waveforms (sine burst, classical shock and SRS shock). The controllers have VXI front ends that are configured with 32 channels each. The control rooms are also equipped with digital data recorders (to record time history data), vibration limiters (to provide secondary vibration limiting protection) and response instrumentation conditioning equipment.

Data Acquisition: For smaller channel counts data acquisition is provided by the m+p controllers. For larger channel counts data acquisition is done using a modular 192 channel DataMax system (hard drive digital recorder). Continuous data acquisition rates up to 50 ksamples/sec are achievable. An extensive quantity of accelerometers from Kistler and Endevco are available for your instrumentation needs. Tri-axial force transducers from Kistler are available for force-limited vibration testing. In the event strain data is needed a 32 channel strain gage conditioning system is available. Personnel trained by Vishay/Micro-Measurements are available for any strain gage installations.

Vibration Exciters:

Facility 409 – Unholtz-Dickie T4000-2 Shaker

Usable Frequency Range	5 – 2500 Hz
Amplifier Model	2XSAI180 (360 kVA)
Maximum Force (Sine)	40,000 lbf (178 kN) pk
Maximum Force (Random)	40,000 lbf (178 kN) rms
Maximum Displacement (Continuous duty)	1.7” pk-pk
Maximum Displacement (Intermittent duty)	2.0” pk-pk
Maximum Velocity (Sine)	85 in/s (2.1 m/s)
Maximum Velocity (Shock)	165 in/s (4.2 m/s)
Shaker Internal Load Support	4,000 lb (1,818 kg)

Slip Table	Team T-Film
Dimensions	50” x 50”
Pitch Moment Capacity	3.7 x 10^6 in-lb (418 kN-m)
Roll Moment Capacity	3.7 x 10^6 in-lb (418 kN-m)
Yaw Moment Capacity	1.62 x 10^5 in-lb (18 kN-m)

Facility 410 – Unholtz-Dickie T4000-3 Shaker

Usable Frequency Range	2 – 2500 Hz
Amplifier Model	2XSAI180 (360 kVA)
Maximum Force (Sine)	40,000 lbf (178 kN) pk
Maximum Force (Random)	40,000 lbf (178 kN) rms
Maximum Displacement (Continuous duty)	2.7” pk-pk
Maximum Displacement (Intermittent duty)	3.0” pk-pk
Maximum Velocity (Sine)	85 in/s (2.1 m/s)
Maximum Velocity (Shock)	165 in/s (4.2 m/s)
Shaker Internal Load Support	4,000 lbs (1,818 kg)

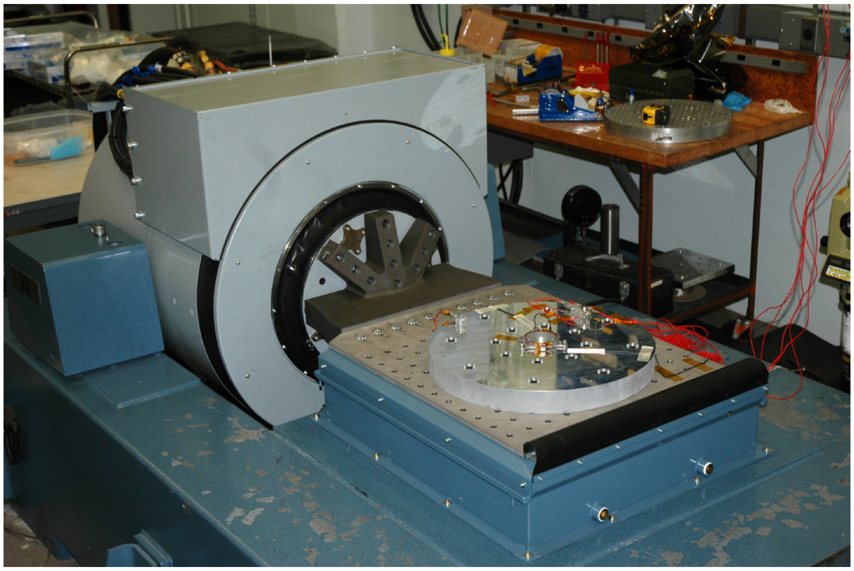
Slip Table	Team T-Film
Dimensions	74” x 74”
Pitch Moment Capacity	>7.0 x 10^6 in-lb (790 kN-m)
Roll Moment Capacity	>7.0 x 10^6 in-lb (790 kN-m)
Yaw Moment Capacity	>2.16 x 10^5 in-lb (75 kN-m)

Facility 411 – Unholtz-Dickie T2000-3 Shaker (Coming Summer 2013)

Usable Frequency Range	5 – 3000 Hz
Amplifier Model	2XSAI180 – T2000 (360 kVA)
Maximum Force (Sine)	25,000 lbf (111 kN) pk
Maximum Force (Random)	23,000 lbf (102 kN) rms
Maximum Displacement (Continuous duty)	2.7” pk-pk
Maximum Displacement (Intermittent duty)	3.0” pk-pk
Maximum Velocity (Sine)	80 in/s (2.0 m/s)
Maximum Velocity (Shock)	165 in/s (6.0 m/s)
Shaker Internal Load Support	1,500 lbs (680 kg)

Slip Table	None (Vertical testing only)

Facility 412 – Unholtz-Dickie T2000-3/CSTA Shaker



Usable Frequency Range	5 – 2500 Hz
Amplifier Model	2XSAI180 (360 kVA)
Maximum Force (Sine)	25,000 lbf (171 kN) pk
Maximum Force (Random)	23,000 lbf (102 kN) rms
Maximum Displacement (Continuous duty)	2.7” pk-pk
Maximum Displacement (Intermittent duty)	3.0” pk-pk
Maximum Velocity (Sine)	80 in/s (2.0 m/s)
Maximum Velocity (Shock)	235 in/s (6.0 m/s)
Shaker Internal Load Support	1,500 lbs (680 kg)

Slip Table	CSTA/T2000-24-24
Dimensions	24” x 24”
Pitch Moment Capacity	5.0 x 104 in-lb (790 kN-m)

1.1.2 Acoustic Test Facility

Description: The Acoustic Test Facility at the Goddard Space Flight Center tests various sized scientific satellites, subsystems, and components. The facility consists of a reverberant chamber, acoustic horns, noise generators, control console, and a data acquisition system. The chamber can be operated as a class 100,000 clean room once the payload access doors are closed and the facility is cleaned. When required, an anteroom is used for changing into clean garments before entering the facility through the personnel door.

Mode of Operation: The spectrum of the desired sound pressure level is programmed into the m+p Acoustic Control System. The payload is either suspended on the crane hook or mounted on a cart, dolly, or other fixture at the center of the chamber. Four to eight control microphones are placed around the payload a minimum of 1.0' (0.30 m) away.

Acoustic energy is generated by modulating the flow of GN_2 through the generator(s) attached to the horn(s). A fresh air, forced ventilation system stabilizes the chamber pressure during operation of the facility and purges the chamber of GN_2 for safe entry after the test.

Data Acquisition: Instrumentation data is acquired using the modular DATAMAX digital data acquisition system. A large selection of accelerometers are available for instrumenting the test item.

Acoustic Chamber

Technical Specifications	
Max SPL (Empty Chamber)	150 dB
Horns/Generator	25 Hz Exponential /Wyle WAS 3000 50 Hz Hypex/Wyle WAS 3000 (future upgrade)
Frequency range	25Hz – 10 KHz
Acoustic Media	Gaseous Nitrogen
Microphones (4 - 8)	0-175 dB

Physical Characteristics	
Interior	33’ L x 27’ W x 42’ H
Payload Access	14’ 11” W x 30’ H
Personnel Door	3’ W x 6’ 6” H
Crane Capacity	7.5 ton
Test Viewing	CCTV
Instrumentation Booms (2)	78 channels each

1.1.8 Mass Properties Measurement Facility (MPMF)

Description: The MPMF is used to measure the weight, center of gravity (CG), moment of inertia (MOI), and product of inertia (POI) of large structural assemblies. The facility can also be used to balance payloads statically and dynamically.

The MPMF is portable and can be operated in clean rooms, or remotely operated in vacuum chambers at pressures down to 1.33 KPa (10 torr).

Mode of Operation: The machine contains a spherical air bearing that supports the measuring table and the test item. The control console is remotely connected to the MPMF by flexible cables and a GN2 line. The console controls the table's motion and takes measurements of the unbalance moment, period of oscillation, and table rotational speed.

Weight Measurement: The facility is mounted on a Pennsylvania 6600 scale base platform (5.75' L x 5.75' W x 0.33' H) which gives an immediate digital readout of the weight of the test specimen, regardless of its mounting position on the facility.

CG Measurement: The static unbalance (CG offset) is determined by measuring the moment created by a CG displaced from the measurement axis of the machine.

MOI Measurement: The MOI is determined by using the facility as an inverted torsional pendulum and measuring the period of oscillation about the geometrical axis of the machine.

POI Measurement: The POI (dynamic unbalance) is determined by rotating the payload on the MPMF at several different speeds, and measuring the moment.

Parameter	Specification
Test Weight (maximum)	10,000 lbs (4,536 kg)
Table Dimensions	4' (1.22 m) diameter mounting table 10' (3.1 m) table is also available for large payloads
Moment Measurement	30,000 in-lb (3,390 Nm)
Range (maximum)	±0.06 "(0.15 cm) for payload at 3' (0.91 m) above table and displaced 1" (2.54 cm) from vertical axis ±0.12" (0.3 cm) for payload at 10' (3.1 m) above table and displaced
CG Capability	1" (2.54 cm) from vertical axis
MOI Accuracy	1% of measured MOI
POI Accuracy	5% of measured POI
MPMF Table Speed	0 to 200 RPM
Platform Scale Capacity	20,000 lb (9,072 kg)
GN_2 Flow Rate	0.17 m^3/minute (6.0 ft^3/minute) standard

1.1.9 High Capacity Centrifuge Facility

The High Capacity Centrifuge (HCC) at Goddard Space Flight Center (GSFC) is used to simulate launch and landing loads on spacecraft hardware. Test items are installed on a test platform at the end of the arm. The platform utilizes a tilt fixture that will position the payload into the desired test orientation (clocking and tilt). The device is capable of tilting a payload up to 12,000 lbs. The facility is serviced by a 7.5 ton crane. The HCC is capable of being driven by either one or two 1250 hp (0.93 Mw) DC motors operated in conjunction with a motor generator set.

High Capacity Centrifuge with GPM Structure

Technical Specifications	
Nominal Test Radius	60 feet
Maximum Test Acceleration	30 g's
Maximum weight at 30 g's	5000 lbs. (payload & fixturing)
Maximum platform moment	7.5 x 106 in-lbs.
Tilt Fixture Limit	12,000 lbs.
Maximum Arm Speed - 1 motor 2 motor	30.0 RPM 38.4 RPM
Crane Capacity	7.5 Ton
Data System Channel Count	160

1.1.10 Universal Static Test Facility

The Universal Static Test Facility is a structural steel framework designed for the application of multiple, individual static loads to large spacecraft-sized test items and payload handling assemblies.

Infinite mounting arrangements of hydraulic actuators allow simultaneous manually-controlled loading at over 20 locations.

Instrumentation including load cells, strain gages and displacement transducers can be installed, connected to and monitored by a 600-channel Vishay System 5000 Data Acquisition System.

Express Logistic Carrier

Parameter	Specification
Vertical Load	up to 26,000 lbs. (11,794 kg)
Lateral Load	up to 41,000 lbs. (18,598 kg)
Facility Modified Load	up to 80,000 lbs. (36,288 kg)
Physical Characteristics	Specification
Internal Test Envelope	22' L x 15' W x 15' H (6.7m x 4.6m x 4.6m)
Facility Weight	44,000 lbs. (19,958 kg))
Overhead Crane Capacity	70,000 lbs. (31,752 kg)

1.1.11 Small Static Test Facility

The Portable Static Test Facility is a structural test bed designed for the application of multiple, individual static loads to payload components, sub-assemblies and associated hardware.

Various mounting arrangements of hydraulic actuators allow simultaneous manually-controlled loading at multiple locations.

Instrumentation including load cells, strain gages and displacement transducers can be installed, connected to and monitored by a 600-channel Vishay System 5000 Data Acquisition System.

Parameter	Specification
Vertical Load	up to 20,000 lbs.(9,072 kg)
Lateral Load	up to 80,000 lbs. (36,288 kg)
Physical Characteristics	Specification
Internal Test Envelope	9’ L x 9’ W x 10’ H (2.74 m x 2.74 m x 3.10 m)
Facility Weight	32,000 lbs. (14,515 kg)
Overhead Crane Capacity	15,000 lbs. (6,804 kg)

1.1.12 Universal Load Testing Machines

Two Tinius Olsen universal load test machines are used for tensile and compressive testing of small specimens and sub-assemblies, and for calibrating load cell transducers.

The test article or connecting hardware is attached to the crosshead using various types of mounting hardware. Loads can be applied to the test article at controlled rates.

Instrumentation including load cells, strain gages and displacement transducers can be installed, connected to and monitored by a modular 600-channel Vishay System 5000 Data Acquisition System.

60,000 Tinius Olsen Testing Machine

Parameter	Specification
Machine #1 Capacity	0 – 120,000 lbs. (54,432 kg); + 1% accuracy
Machine #2 Capacity	0 – 60,000 lbs. (27,716 kg); + 1% accuracy
Physical Characteristics	**Specification**
Machine #1 Test Volume	48” L x 28” W x 42” H (122 cm x 71 cm x 107 cm)
Machine #2 Test Volume	48” L x 28” W x 42” H (122 cm x 71 cm x 107 cm)

1.1.13 Modal Test Facility

The Modal Test Facility at Goddard Space Flight Center (GSFC) is used to measure dynamic response characteristics of aerospace structures. Test items are mounted to the facility seismic block via a T-Slot table to simulate a fixed boundary condition. The facility is serviced by three bridge cranes that provide a convenient method of supporting up to four electro-dynamic shakers. The facility is supported by a digital data acquisition system that has the capability to simultaneously record raw data time signals while processing the data into spectrums, FRF's, and coherence functions in real time. Post-test curve fitting algorithms within the modal software extract the estimated modal parameters from the test data.

Modal Test Facility

Technical Specifications	
Max Excitation (Force)	200 lbf
Excitation Freq Range	2 to 2 kHz
Available Shakers	2 lbf, 200 lbf
Available Modal Hammers	500 lbf, 5000 lbf
Data System Channel Count	384
T-Slot Table Dimensions	12 ft x 12 ft

1.2 ELECTROMAGNETIC TESTING

1.2.1 Electromagnetic Compatibility Testing

Introduction: Two anechoic shielded testing facilities are available for performing Electromagnetic Compatibility (EMC) tests. These facilities meet electromagnetic performance requirements specified by MIL-STD-462, and support the performance of EMC tests specified by Mil-Std-461-C/E/F and the GSFC "General Environmental Verification Specification" (GEVS). Both facilities provide very low level ambient electromagnetic environments and the ability to contain internally-generated, radiated electromagnetic waves. All electrical power, communications, and other facility wiring are filtered; the facility structures are locally bonded to earth ground; and ventilation ducts and other apertures are designed as waveguide-below-cutoffs. Contamination-sensitive items are tested in the Large EMC Facility (Class 10k cleanroom), or they are bagged in non-reflective materials (Melonex) if tested in the Small EMC Facility.

Integral Instrumentation: Generated interference measurements are typically made using a Rohde and Schwarz EMI receiver system (ESU8/40 and ESIB40) for data acquisition, processing, and data reduction. Associated electric and magnetic field antennas and line conduction transducers are provided for testing in the 20 Hz to 40 GHz frequency range. The receiver system is controlled by the Rohde and Schwarz EMC32E/S measurement software package. Line conducted and radiated susceptibility tests are performed using a variety of signal generators, amplifiers, and transducers or antennas for injection and/or radiation of the test signals. Frequency range is 20 Hz to 400 MHz for signal injection; 10 kHz to 40 GHz for signal radiation. Radiated field strengths up to 200 V/m can typically be provided. Programmed swept frequency test signals, appropriately modulated, are provided over portions of the test spectrum.

Data Acquisition: The Rohde and Schwarz EMC32E/S EMC measurement software can be used for all Electromagnetic Interference (EMI) and Electromagnetic Susceptibility (EMS) measurements. The software is a modern and powerful tool for controlling and monitoring devices/equipment. Susceptibility test data relating to the susceptibility test signal can be time synchronized with the test item performance test data which is typically recorded as a function of the type of ground support equipment furnished with the test item. Failure modes are test project defined and susceptibility thresholds determined whenever the test item responds to the susceptibility test signal.

Electrical power: Test item power is normally provided by project-furnished, current and/ or voltage limited power supplies. An Elgar 5250 Switching Amplifier can be supplied for power quality tests that desire spacecraft specific power ripple tests. Each anechoic chamber is supplied with 100W of filtered power and can be modified to handle higher power applications with the proper amount of preparation.

1.2.1.1 Small EMC Facility

Description: This facility is located in Building 7, and is designed for either small satellite or sub-assembly tests. This facility consists of three contiguous electromagnetically shielded enclosures that meet or exceed shielding enclosure requirements stated in Mil-Std-285 and IEEE-299. The individually shielded enclosures include the anechoic Test Room, the EMC Control Room, and a Ground Support Equipment (GSE) Room. Inside the Test Room is a free standing faraday cage that is lined with ferrite tiles with TDK IP-090, carbon impregnated Styrofoam wedge absorbers to handle RF energy absorption up to 200 V/m (70 mW/cm^2) from 20 Hz to 40 GHz. The Control and GSE Rooms consist of standard modular shielded panels constructed of ¾" plywood paneling, sandwiched by an inner and outer layer of 10 mil galvanized steel. A cable penetration plate, located on the same wall as the test bench, separates the Test Room from the GSE Room and acts as a Single Point Ground for both the spacecraft and GSE. The standard penetration plate consists of four "Pi" filters and three 3" diameter Wave-Guide-Below cutoffs that can be used to feed cables through. When desired a penetration plate can be made to mount existing TVAC cables to reduce cable costs and to reduce common mode currents.

Mode of Operation: The test article is installed in the EMC chamber and bonded to the copper test bench that is certified to hold a 250 pound payload (5:1 tested to 1250 lbs). The test bench is bonded to the anechoic panels via a copper ground strap which maintains a 5:1 (L:W) ratio. Interconnecting cables between the test article and its ground support equipment are connected through an access panel mounted either on the cleanroom or GSE side, allowing for greater flexibility and acting as a single point ground. The test enclosure maintains relative humidity between 30% and 70% and temperature at 68°F ±5° (20°C ±2.8°).

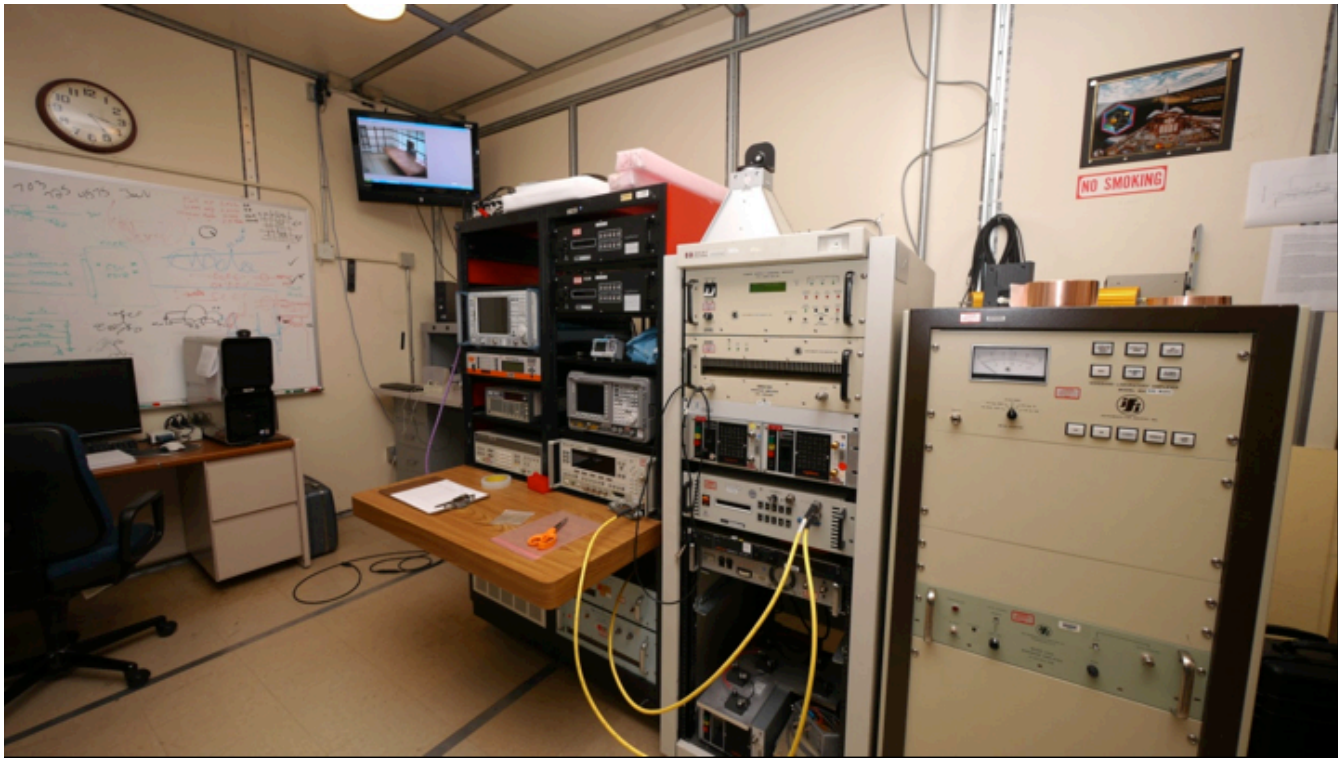
Physical Characteristics:
Experimenter's area: 4 m (L) x 2 m (W) x 3 m (H) Personnel door: 1 m (W) x 1.7 m (H)

Control room: 7.3 m (L) x 3.7 m (W) x 3 m (H) Personnel door: 1.3 m (W) x 2.1 m (H)

Test area room: 5.5 m (L) x 5 m (W) x 3 m (H) Equipment door: 2 m (W) x 2.2 m (H)

Test Area Anechoic Characteristics: Ferrite tiles and Carbon impregnated Styrofoam wedge absorbers combine to make the facility a broadband anechoic chamber capable of absorbing electromagnetic waves over the frequency range of 20 Hz to 40 GHz. Field measurement accuracy is thereby enhanced compared to shield room facilities that lack the anechoic material, and radiated susceptibility test signals are controlled with improved signal-to-noise ratios. The test facility also has web based video camera system and Fiber Optic lighting capable of withstanding 200 V/m that keeps the facility RF emissions to a minimum.

Fire Protection: Fire protection is provided in the Test Area using retractable sprinkler heads and an auto-cutoff ventilation system for toxic smoke exhaust to the outside of the building. The TDK IP-090 Carbon impregnated Styrofoam wedge absorbers release CO_2 and water vapors when ignited. Personnel safety features include a radiation hazard warning and monitoring system. The facility is also equipped with electrostatic discharge testing and prevention capabilities and a large copper test bench for mounting and earth-bonding test items.



Small EMC Control Console

Small EMC Shielded Enclosure

1.2.1.2 Large EMC Facility

Description: This facility is located in Building 7, and is designed for testing large spacecraft that require Class 10k contamination protection. This facility consists of three contiguous electromagnetically shielded enclosures that meet or exceed shielding enclosure requirements stated in Mil-Std-285 and IEEE-299. The enclosures consist of Test Room (Rm. 108A), the EMC Control Room (Rm. N115), and a Ground Support Equipment (GSE) Room (Rm. N117). Inside the enclosure is a free standing faraday cage that is lined with ferrite tiles with Panashield HYB-NF12, fibrous composite material with carbon impregnated within wedge absorbers to handle RF energy absorption up to 200 V/m (70 mW/cm_2) from 20 Hz to 40 GHz. The Control and GSE Rooms consist of standard modular shielded panels constructed of ¾" plywood paneling, sandwiched by an inner and outer layer of 10 mil galvanized steel. A cable penetration plate, located on the same wall as the test bench, separates the Test Room from the GSE Room and acts as a Single Point Ground for both the spacecraft and GSE.

Mode Of Operation: The test article is installed inside the faraday cage and bonded to the penetration plate ensuring a single point ground for project and EMI test equipment. Grounding for larger spacecraft, that can't fit onto the test bench, can connect to either an 18" or 36" wide copper strap for a better RF ground and maintaining a 5:1 (L:W) ratio. Interconnecting cables between the test article and its ground support equipment are connected through an access panel mounted either on the cleanroom or GSE side, allowing for greater flexibility and acting as a single point ground. The test enclosure maintains a relative humidity at a value between 30% and 70% and temperature at 68°F ±5° (20°C ±2.8°).

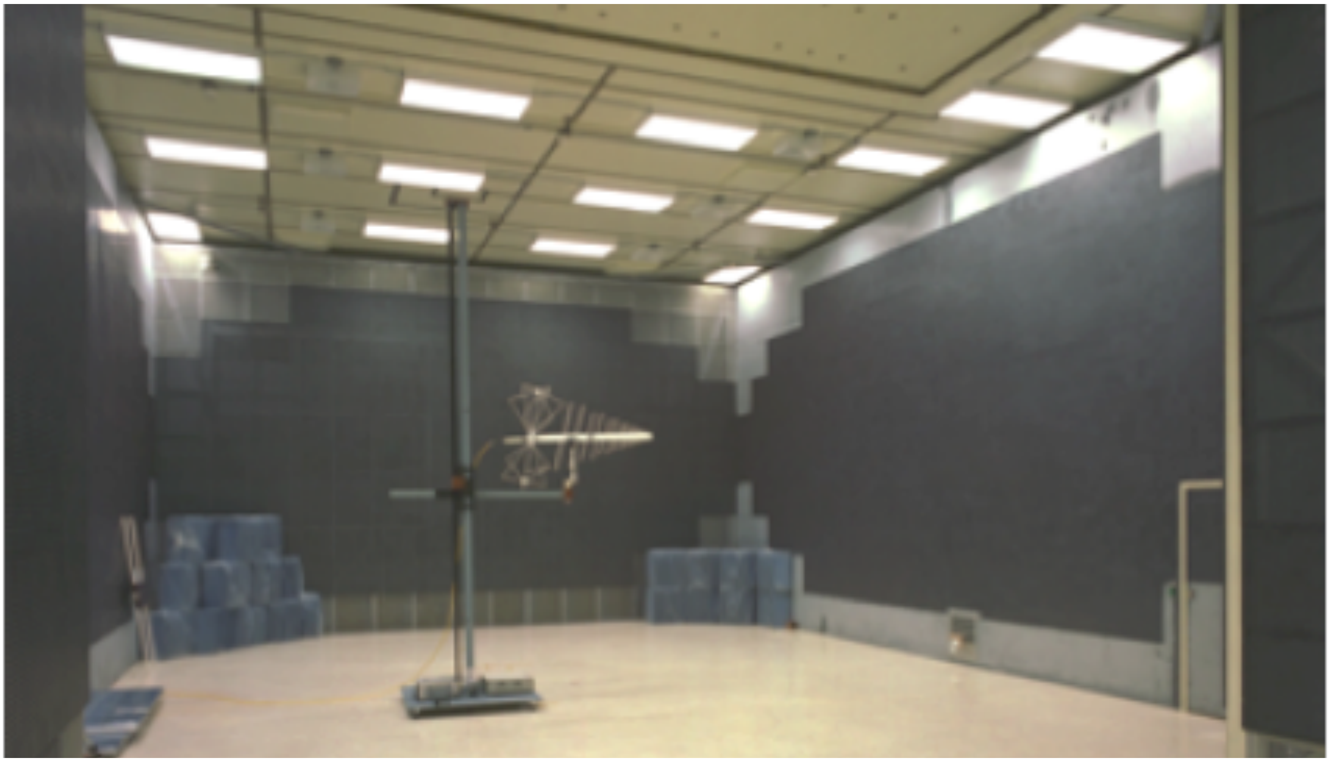
Physical Characteristics:
Test Enclosure Size: Expandable from basic 6.5 m cubed. Max Height: 6.7 m

Ferrite-Tiled Anechoic Enclosure Door Size: 6.5 m (W) x 6.2 m (H)

Ground Support Equipment Enclosure:	Room Size: 6.7 m (L) x 5.2 m (W) x 3.2 m (H
	Door Size: 2 m (W) x 2.5 m (H)

Test Area Anechoic Characteristics: Ferrite tiles with Panashield HYB-NF12, fibrous composite material with carbon impregnated within, absorbers handle RF energy absorption up to 200 V/m (70mW/cm2) from 20 Hz to 40 GHz are mounted on the interior walls of the test area combine to make the facility a broadband anechoic chamber capable of absorbing electromagnetic waves over the frequency range of 20 Hz to 40 GHz. Field measurement accuracy is thereby enhanced compared to shield room facilities that lack the anechoic material, and radiated susceptibility test signals are controlled with improved signal-to-noise ratios. The test facility also has web based video camera system capable of withstanding 200 V/m and just like the Fiber Optic lighting, keeps and facility RF emissions to a minimum.

Safety Features: The Test Enclosure is equipped with flashing warning lights at all entrance doors to warn personnel not to enter whenever electromagnetic waves are being propagated within the room. Internal humidity and temperature alarms, as well as a fire alarm and dry sprinkler system, are also features of this facility.



Large EMC Shielded Enclosure

Large EMC Control Console

1.2.2 Magnetic Testing

Introduction: The remotely located Magnetics Test Site contains two major coil systems, 6.7 m (22') and 12.8m (42'), used for magnetic testing of payloads ranging from fully-configured spacecraft down to component level assemblies; and for calibrating torque coils and magnetometers in attitude control systems. Both facilities are 3-axis Braunbek coil systems consisting of 12 coils (four coils for each of three orthogonal axes.) Each coil contains windings for Earth's field cancellation, static and dynamic field generation, diurnal variation control, temperature gradient compensation, external gradient compensation, and two sets of spare windings.

Control consoles for both coil systems are located in a separate building apart from the coils. This isolation prevents control equipment magnetic fields from degrading the specified magnetic environment established within the Braunbek coils. For both coils, static and dynamic (0-100 rad/sec) field vectors can be generated along any axis with magnitudes up to 60,000 nanotesla (nT.)

1.2.2.1 6.7M (22') Coil Magnetic Test Facility

Description: The Magnetic Field Component Test Facility (MFCTF) contains a 6.7 m (22') diameter spherical coil system. This system provides geomagnetic field cancellation within a 0.9 m (3') diameter sphere to levels described below. This coil system is used primarily for testing smaller satellites, performing instrument-level dipole moment measurements, and for calibrating magnetometers and attitude control systems.

Mode of Operation: For a typical magnetometer test, a zero field is established in the center of the coils before the test unit is installed. A reference standard proton magnetometer is then used to calibrate the system. Following this, the test magnetometer is positioned on the platform at the center of the coil and aligned to the coil axes. Finally, static and dynamic fields are generated to establish the linearity, frequency response, zero offset, and alignment characteristics of the magnetometer.

Parameters:

Static Field Capability		Dynamic Field Capability	
Magnitude (each axis):	±60,000 nanotesla	Magnitude (each axis):	± 60,000 nanotesla
Resolution:	±0.1 nanotesla	Resolution and stability:	± 2%
Stability:	±0.5 nanotesla	Frequency:	0 To 100 rad/sec
Homogeneity:	0.001% (0.91 m, 3' diaspherical volume)		

Physical Characteristics:
Coil access opening: 1.52 m W x 1.52 m H (5' x 5')

Building access opening: 3.05 m W x 3.05 m H (10' x 10')

Integral Instrumentation: The MFCTF is equipped with instrumentation for the calibration and alignment of magnetometers. This instrumentation includes fluxgate and proton magnetometers for zeroing and calibrating. A data acquisition/analysis system is available to acquire the magnetometer data, perform near field analysis, and produce a customer-ready report.

1.2.2.2 12.8M (42’) Coil Magnetic Test Facility

Description: The Spacecraft Magnetic Test Facility (SMTF) 12.8 m (42’) coil system is one of the three known spherical coil systems of this size in the world. Its geomagnetic field cancellation system is capable of cancelling the Earth’s magnetic field within a 1.83 m (6’) diameter sphere. The SMTF also has a set of 2.90 m (9’6”) diameter Helmholtz coils available for perming and deperming spacecraft, and 1.22 m (4’) and 1.83 m (6’) diameter coils for magnetically cleaning smaller test items.

Mode of Operation:
Magnetic Dipole Moment Testing: Zero-field is first established in the center of the coil. A reference standard proton magnetometer is used to calibrate the coils. For each measurement sequence, the test item and facility dolly are moved to the center of the coil. As the dolly is rotated 360 degrees, three-component magnetic field data is obtained at 10-degree increments. The data are then stored in the computer for immediate display and processing. If the test item exceeds its test limit, compensation magnets can be developed to reduce the dipole moment to acceptable levels.

Spacecraft Magnetometer Calibration: Initial setup is similar to magnetic dipole moment testing. The test item is positioned in the center of the coil and aligned with the coil axes. Static and dynamic fields are generated to establish linearity, frequency response, zero offset, and alignment characteristics of the test item. The data system can be used to collect, store, and display test parameters.

Parameters:

Static Field Capability		Dynamic Field Capability	
Magnitude (each axis):	±60,000 nanotesla	Magnitude (each axis):	± 60,000 nanotesla
Resolution:	±0.1 nanotesla	Resolution and stability:	± 2%
Stability:	±0.5 nanotesla	Frequency:	0 to 100 rad/sec
Homogeneity:	0.001% (1.83 m, 6' diaspherical volume)		

Physical Characteristics:

Coil access opening:	3.05 m W x 3.05 m H (10’ x 10’)
Building access opening:	4.27 m W x 4.57 m H (14’ x 15’)
Hoists lifting capacities (4):	4,536 Kg (5 ton), 2,722 Kg (3 ton), and two each 2,268 Kg (2.5 ton)

Integral Instrumentation: The SMTF is equipped with single and triaxial magnetometers, proton magnetometers, torque meter, and data collection instrumentation. It contains the three Helmholtz coils described above, with their associated AC and DC power supplies.

Spacecraft Magnetic Test Facility

Data Acquisition: An array of three state-of-the-art triaxial fluxgate magnetometers is used for magnetic field testing. A field mapping of the test item is performed, the resultant data is automatically provided as input into the facility's "near field analysis" software, and an equivalent dipole moment is calculated. Measurements are taken for various magnetic field conditions including: perm, deperm, induced and stray field (test item powered) measurements.

1.3 SPACE SIMULATION TESTING

Introduction: This section provides a summary of the environmental capabilities and dimensions of the test facilities controlled by the Space Simulation Test Engineering Group. The test volume measurements provided are nominal dimensions of the thermal shroud for chambers that have a shroud. Pumping speeds provided are the manufacturer's stated speeds at the pump opening.

The test facilities are operated and monitored 24-hours per day. Test setups and teardowns are performed during normal working hours unless other arrangements are made in advance. The Space Simulation Test Engineering Group Lead and Test Engineers provide customers with cost estimates, chamber availability and technical support. A Thermal Vacuum Orientation Package is also available to help customers understand documentation, operation, safety, schedule and technical requirements.

Building 7 Thermal Vacuum Chambers View

1.3.1 Capabilities Summary (English Units)

Facility	Nominal Specifications (English Units)				
Type	Number	Test Volume (ft)	Operating Pressure (psi)	Temperature Range (°F)	Unique Capabilities
Temperature	204	1.67 x 1.00 x 1.34	Ambient	-274 to 392	
Temp / Humid	232	4 x 4 x 4	Ambient	-157 to 302	Humidity <5% to 95% RH (±5%)
	233	4 x 4 x 4	Ambient	-94 to 302	Humidity <5% to 95% RH (±5%)
Thermal Vacuum	225	9 Dia x 14 L	<2x10^{-7}	-310 to 302	2 Cryopumps, Turbopump, C/F, 2 TQCMs, RGA
	237	7 Dia x 8 L	<2x10^{-7}	-310 to 257	Diffusion Pump, C/F, TQCM, RGA
	238	12 Dia x 15 H	<2x10^{-7}	-310 to 239	3 Cryopumps, Turbopump, C/F, 2 TQCMs, RGA
	239	7 Dia x 8 L	<2x10^{-7}	-310 to 257	Cryopump, C/F, 2 TQCMs, RGA
	240	3 Dia x 3 L	<2x10^{-7}	-220 to 230	Diffusion Pump, C/F, TQCM, RGA
	241	3 Dia x 3 L	<2x10^{-7}	-220 to 230	Cryopump, C/F, TQCM, RGA
	245	2 Dia x 3 L	<2x10^{-7}	75 to 302	Turbopump, C/F, TQCM, RGA
	246	3.5' Dia x 5.5' L	<1x10^{-5} torr	140 to +150	Mechanical Pump, Cryopump, C/F
	281	3 Dia x 4 L	<2x10^{-7}	-310 to 302	Cryopump, C/F, TQCM, RGA
	290	27 Dia x 40 H	<2x10^{-7}	-292 to 212	7 Cryopumps, Turbopump, He Shroud, C/F, 4 TQCMs, RGA
Rapid Pump Down	208	NA	2x10^{-4}	NA	Rough down Facilities 237 & 239 in 2 minutes
Thermal Conditioning Units	201	NA	NA	-220 to 284, LN2	GN2 transfer medium, circulating with LN2 bypass mode
	203	NA	NA	-220 to 284	GN2 transfer medium, single pass with LN2 bypass mode
	205	NA	NA	-148 to 212, LN2	GN2 transfer medium, single pass with LN2 bypass mode
	209	NA	NA	-148 to 248	GN2 transfer medium, single pass
	230	NA	NA	-238 to 302	GN2 transfer medium, circulating
Heater Racks	242	NA	NA	-148 to 212	Harrel rack
	315	NA	NA	-328 to 752*	Max temp based upon heater type
	316	NA	NA	-328 to 1112*	Max temp based upon heater type
Solar Simulator Portable	211	NA	NA	NA	61 cm dia, 1 SC
Emergency Power	253	NA	NA	NA	250 kVA, 480 V, 3-phase
	254	NA	NA	NA	350 kVA, 480 V, 3-phase
High Pressure GN2	257	NA	NA	NA	2000 psi
	258	NA	NA	NA	2000 psi

Capabilities Summary (SI Units)

Facility	Nominal Specifications (SI Units)				
Type	Number	Test Volume (m)	Operating Pressure (Torr)	Temperature Range (°C)	Unique Capabilities
Temperature	204	0.51 x 0.31 x 0.41	Ambient	-170 to 200	
Temp / Humid	232	1.22 x 1.22 x 1.22	Ambient	-105 to 150	Humidity <5% to 95% RH (±5%)
	233	1.22 x 1.22 x 1.22	Ambient	-70 to 150	Humidity <5% to 95% RH (±5%)
Thermal Vacuum	225	2.74 Dia x 4.27 L	$<1x10^{-5}$	-190 to 150	2 Cryopumps, Turbopump, C/F, 2 TQCMs, RGA
	237	2.13 Dia x 2.44 L	$<1x10^{-5}$	-190 to 125	Diffusion Pump, C/F, TQCM, RGA
	238	3.66 Dia x 4.57 H	$<1x10^{-5}$	-190 to 115	3 Cryopumps, Turbopump, C/F, 2 TQCMs, RGA
	239	2.13 Dia x 2.44 L	$<1x10^{-5}$	-190 to 125	Cryopump, C/F, 2 TQCMs, RGA
	240	0.91 Dia x 0.91 L	$<1x10^{-5}$	-140 to 110	Diffusion Pump, C/F, TQCM, RGA
	241	0.91 Dia x 0.91 L	$<1x10^{-5}$	-140 to 110	Cryopump, C/F, TQCM, RGA
	245	0.61 Dia x 0.91 L	$<1x10^{-5}$	22 to150	Turbopump, C/F, TQCM, RGA
	246	1.06 x Dia x 1.68 m L	$<2x10^{-7}$ psi	220 to +302	Mechanical Pump, Cryopump, C/F
	281	0.91 Dia x 1.22 L	$<1x10^{-5}$	-190 to 150	Cryopump, C/F, TQCM, RGA
	290	8.23 Dia x 12.2 H	$<1x10^{-5}$	-180 to 100	7 Cryopumps, Turbopump, He Shroud, C/F, 4 TQCMs, RGA
Rapid Pump Down	208	NA	$1x10^{-2}$	NA	Rough down Facilities 237 & 239 in 2 minutes
Thermal Conditioning Units	201	NA	NA	-140 to 140, LN2	GN2 transfer medium, circulating with LN2 bypass mode
	203	NA	NA	-140 to 140	GN2 transfer medium, single pass with LN2 bypass mode
	205	NA	NA	-100 to 100, LN2	GN2 transfer medium, single pass with LN2 bypass mode
	209	NA	NA	-100 to +120	GN2 transfer medium, single pass
	230	NA	NA	-150 to 150	GN2 transfer medium, circulating
Heater Racks	242	NA	NA	-100 to 100	Harrel rack
	315	NA	NA	-200 to 400*	Max temp based upon heater type
	316	NA	NA	-200 to 600*	Max temp based upon heater type
Solar Simulator Portable	211	NA	NA	NA	61 cm dia, 1 SC
Emergency Power	253	NA	NA	NA	250 kVA, 480 V, 3-phase
	254	NA	NA	NA	350 kVA, 480 V, 3-phase
High Pressure GN2	257	NA	NA	NA	13.8 MPa
	258	NA	NA	NA	13.8 MPa

1.3.2 Temperature - Humidity

1.3.2.1 Facility 204 – 0.057 m³ (2 ft³) Temperature Chamber

Description: This facility is a small temperature controlled chamber used for thermal conditioning of small components. The portable chamber loads through a front opening door that has a viewing window. The instrumented payload is installed in the chamber with no special handling or mounting fixtures, and is connected to the ground support equipment via a port.

Mode of Operation: The chamber is cooled with liquid nitrogen and heated with electrical resistance elements.

Parameters:

Temperature range:	-170°C to +180°C (-274°F to +392°F)
Heating capacity:	510 Watts
Cooling capacity:	100 Watts at -170°C (-274°F)
Accuracy:	± 5°C (± 9°F)

Physical Characteristics:

Test volume:	0.51 m W x 0.31 m H x 0.41 m L (20" x 12" x 16")
Access port size:	6.35 cm diameter (2.5")
Viewport size:	20 cm x 20 cm (8" x 8")
Power:	120 VAC, 1 phase, 20 A

Integral Instrumentation: Temperature is controlled by a digital programmer/controller located on the side of the chamber. Eighteen thermocouples are available for payload monitoring. Cooling is provided by a direct LN_2 spray system which provides a GN_2 atmosphere that minimizes humidity during cold transitions.

Temperature Chamber (Facility 204)

1.3.2.2 Facility 232 – 1.81 m³ (64 ft³) Temperature - Humidity Chamber

Description: This facility is a medium-sized chamber used for thermal and humidity cycling of medium-sized test items. A full-opening, hinged front door with a window allows for access and viewing.

Mode of Operation: The test item is installed in the chamber and connected to an external power source and data acquisition equipment via an access port. After ambient functional checks are completed, electrical heaters warm, and a cascade refrigeration system cools the air stream. A separate cooling unit provides dehumidification, and an electrically heated vapor generator provides humidification. The preferred procedure is to operate the chamber with a hot cycle before decreasing the temperature below 4°C (39°F). A dry nitrogen purge system regulates humidity in the chamber to prevent frost build-up on the test item. Five integral gloves are provided in the front door of the chamber for “glove box” type testing of mechanisms, etc.

Parameters:

Temperature range:	-105°C to +150°C (-157°F to +302°F)
Humidity range (RH):	15% to 95% (between 85°C (185°F) max and 4°C (39°F) min dewpoint); <5% with nitrogen purge
Heating capacity:	18 kW
Cooling capacity:	22 kW
Max P/L weight:	90 kg (200 lbs)

Physical Characteristics:

Test volume:	1.22 m W x 1.22 m H x 1.22 m L (4’ x 4’ x 4’)
Viewport size:	61 cm x 61 cm (24” x 24”)
Access port size:	15.2 cm inside diameter (6”)

Integral Instrumentation: Temperature and humidity are controlled by a digital programmer/controller located on the side of the chamber. Eighteen thermocouples are available for payload monitoring.

Temperature - Humidity Chamber (Facility 232)

1.3.2.3 Facility 233 – 1.81 m³ (64 ft³) Temperature - Humidity Chamber

Description: This facility is a medium-sized chamber used for thermal and humidity cycling of medium-sized test items. A full-opening, hinged front door with a window allows for access and viewing.

Mode of Operation: The test item is installed in the chamber and connected to an external power source and data acquisition equipment via an access port. After ambient functional checks are completed, electrical heaters warm, and a cascade refrigeration system cools the air stream. The preferred procedure is to operate the chamber with a hot cycle before decreasing the temperature below 4°C (39°F). A dry-air and dry nitrogen purge system regulates humidity in the chamber to prevent frost build-up on the test item. Two integral gloves are provided in the front door of the chamber for “glove box” type testing of mechanisms, etc.

Parameters:

Temperature range:	-70°C to +150°C (-94°F to +302°F)
Humidity range	(RH): 15% to 95% (between 85°C (185°F) max and 4°C (39°F) min dewpoint); <5% with nitrogen purge
Heating capacity:	18 kW
Cooling capacity:	22 kW
Max P/L weight:	90 kg (200 lbs)

Physical Characteristics:

Test volume:	1.22 m W x 1.22 m H x 1.22 m L (4’ x 4’ x 4’)
Viewport size:	61 cm x 61 cm (24” x 24”)
Access port size:	15.2 cm inside diameter (6”)

Integral Instrumentation: Temperature and humidity are controlled by a digital programmer/controller located on the side of the chamber. Eighteen thermocouples are available for payload monitoring.

Temperature - Humidity Chamber (Facility 233)

1.3.3 Thermal Vacuum

1.3.3.1 Facility 225 – 2.7 m x 4.3 m (9' x 14') Vacuum Chamber

Description: This is a horizontal loading thermal vacuum test chamber used for thermal vacuum and thermal balance testing, and baking out large test items. Electrical feedthroughs and liquid and gas penetrations are provided at locations on the sides and rear of the chamber. A clean tent covering the door opening provides a Class 10,000 clean area for integrating hardware prior to loading it into the chamber.

Mode of Operation: Test items are loaded by crane onto a load cart, which is rolled into the chamber on a rail system. Payload weight can be as high as 2,268 kg (5,000 lb). Access to the chamber is through a clean tent. The use of cleanroom procedures and the wearing of clean garments are required when working in the chamber.

Chamber evacuation is provided by two cryopumps and one turbomolecular pump. Roughing is provided by a blower and rotary piston mechanical pump. Shroud temperature conditioning is accomplished by a recirculating GN_2 thermal system, or it may be flooded with LN_2.

Parameters:

Test pressure:	$<1x10^{-5}$ Torr ($<2x10^{-7}$ psi)
Shroud temperature:	
GN_2 mode:	-140°C to +150°C (-220°F to +302°F)
LN_2 mode:	-190°C (-310°F)
Pumping speeds for N_2:	
2 Cryopumps:	60,000 l/s (127,000 cfm)
Turbomolecular pump:	1,000 l/s (2,120 cfm)

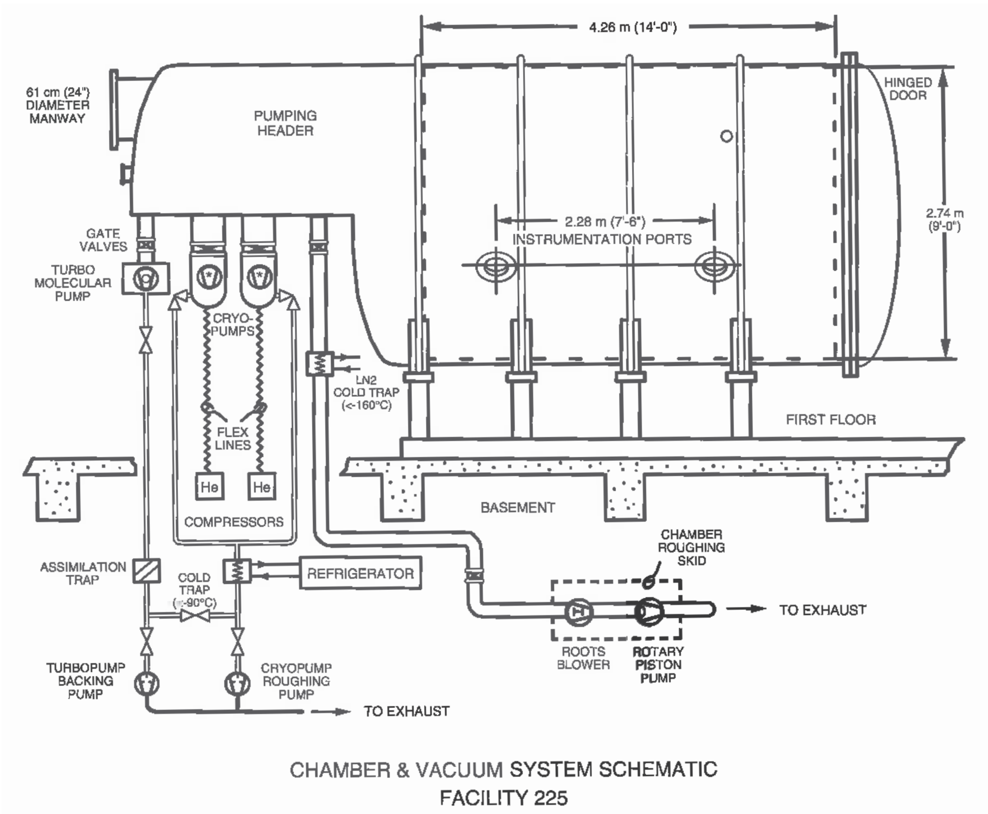
Physical Characteristics:

Test volume:	2.74m dia x 4.27m L (9' x 14')
Payload support:	76" x 144" cart - 1,361 kg (3,000 lb) capacity
Crane capacity:	4,536 kg (5 ton)
Instrumentation ports:	6 each 25.4 cm dia (10"), 6 each 12.7 cm dia (5")
Std. electrical feedthroughs:	61-pin, 37-pin, 7-pin, 4-pin, RF

Integral Instrumentation:

Pressure:	Convectron - atm to 10^{-3} Torr
	Ion gauge - 10^{-3} Torr to ultimate
Payload temperature:	320 channels
Contamination:	TQCM, scavenger plate, cold finger, residual gas analyzer

Auxiliary Equipment: Portable thermal systems are available to control baseplates, the thermoelectric quartz crystal microbalance (TQCM) and contamination control mirrors.



Chamber and Vacuum Schematic (Facility 225)

Facility 225

1.3.3.2 Facility 237 – 2.1 m x 2.4 m (7’ x 8’) Diffusion Pumped Vacuum Chamber

Description: This is a horizontal loading thermal vacuum test chamber equipped with a viewport to accommodate an external solar simulator. An overhead rail is available for mounting purposes and stainless steel tubes are available for hanging thermal blankets. The facility is used for thermal vacuum and thermal balance testing, and baking out test items.

Mode of Operation: The test item is craned or hand carried onto the payload cart positioned at the chamber door. Typically, the payload is instrumented and connected to GSE prior to rolling it into the chamber. Ground support equipment cabling is connected through the penetration plates and ambient functional checks are performed. Prior to solar testing, it is normal to perform an alignment check of the test item with the external simulator.

Chamber evacuation is provided by a rotary piston mechanical pump and an oil diffusion pump. Rapid pump down can also be performed. A sliding gate main valve allows chamber access while the pumping systems are established.

Parameters:

Test pressure:	$<1x10^{-5}$ Torr ($<2x10^{-7}$ psi)
Shroud temperature:	
GN_2 mode:	-140°C to +125°C (-220°F to +257°F)
LN_2 mode:	-190°C (-310°F)
Diffusion pump speed for N_2:	25,000 l/s (53,000 cfm)

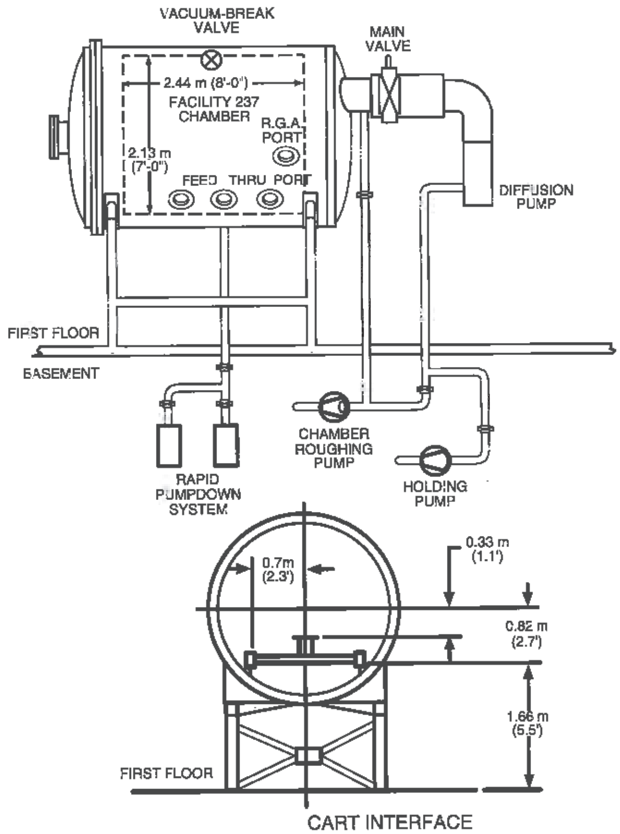
Physical Characteristics:

Test volume:	2.13 m dia x 2.44 m L (7’ x 8’)
Payload support:	44” x 76” cart – 584 kg (1288 lb) capacity
	43.5” x 80” cart – 729 kg (1607 lb) capacity
Crane capacity:	4,536 kg (5 ton)
Viewport dimensions:	31cm dia (12”) quartz window
Std. electrical feedthroughs:	61-pin, 37-pin, 7-pin, 4-pin, RF

Integral Instrumentation:

Pressure:	Convectron - atm to 10^{-3} Torr
	Ion gauge - 10^{-3} Torr to ultimate
Payload temperature:	126 channels
Contamination monitors:	TQCM, scavenger plate, cold finger, residual gas analyzer

Auxiliary Equipment: Heater racks and thermal conditioning units (TCUs) are available to control auxiliary heater panels, cryopanels and baseplates. The portable solar simulator can be used with this chamber.



Chamber and Vacuum System Schematic (Facility 237)

Facility 237

1.3.3.3 Facility 238 – 3.7 m x 4.6 m (12’ x 15’) Cryo & Turbo Vacuum Chamber

Description: This is a vertical loading thermal vacuum test chamber used for thermal vacuum and thermal balance testing, and baking out spacecraft hardware. A bracket containing stainless steel tubes is available for hanging thermal blankets. Ports for electrical feedthroughs, liquid/gas feedthroughs, and viewing are located around the perimeter of the chamber. A clean tent at the chamber entrance provides class 10,000 cleanliness conditions.

Mode of Operation: Test articles are normally loaded through the top of the chamber using the building crane; however, small payloads can be transported through the personnel entrance. In some cases, special fixtures must be designed due to the uniqueness of the test article support system. Once installed, the payload is connected to the ground support equipment via feedthroughs. Access to the chamber is through a clean tent. The use of cleanroom procedures and the wearing of clean garments are required when working in the chamber.

Initial chamber evacuation is provided by two rotary piston mechanical pumps, with three cryopumps and a turbomolecular pump for high vacuum pumping. All four pumps are isolated from the chamber by sliding gate main valves.

Parameters:

Test pressure:	$<1x10^{-5}$ Torr ($<2x10^{-7}$ psi)
Shroud temperature:	
GN_2 mode:	-120C to +115°C (-184°F to +239°F)
LN_2 mode:	-190°C (-310°F)
Pumping speeds for N_2:	
3 cryopumps	90,000 l/s (190,700 cfm)
Turbomolecular pump	2,000 l/s (4,237 cfm)

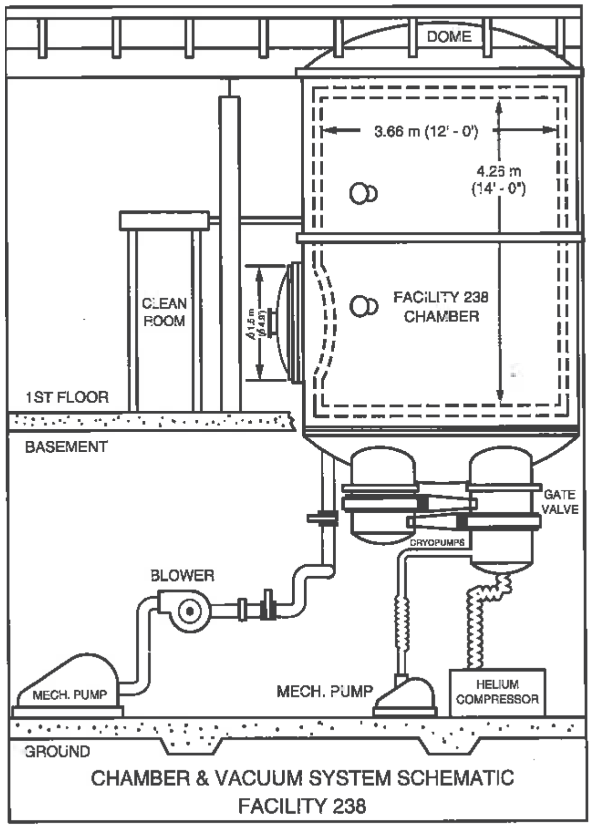
Physical Characteristics:

Test volume:	3.4 m D x 4.3 m H (11’2” x 14’2”)
Personnel door:	1.5 m (5’) diameter
Payload support:	Floor level - 1.2 m (4’) square platform – 1950 kg (4300 lb) capacity
	Side wall - hard points at 1.8 m and 3.7 m (6’ and 12’) levels
Crane capacity:	4,536 kg (5 ton)
Crane hook height:	4.06 m (13’4”) to dome stop, 4.16 m (13’8”) to top flange
Viewport dimensions:	23 cm (9”) diameter
Std. electrical feedthroughs:	61-pin, 37-pin, 7-pin, 4-pin, RF

Integral Instrumentation:

Pressure:	Convectron - Atm to 10^{-3} Torr
	Ion gauge - 10^{-3} Torr to ultimate
Payload temperature:	360 channels
Contamination monitors:	TQCM, scavenger plate, cold finger, residual gas analyzer

Auxiliary Equipment: Heater racks and thermal conditioning units (TCUs) are available to control auxiliary heater panels, cryopanels and baseplates.



Chamber and Vacuum Schematic (Facility 238)

Facility 238

1.3.3.4 Facility 239 – 2.1 m x 2.4 m (7’ x 8’) Cryopumped Vacuum Chamber

Description: This is a horizontal loading thermal vacuum test chamber equipped with a viewport to accommodate an external solar simulator. An overhead rail is available for mounting purposes and stainless steel tubes are available for hanging thermal blankets. The facility is used for thermal vacuum and thermal balance testing, and baking out test items. A clean tent at the chamber entrance provides class 10,000 cleanliness conditions.

Mode of Operation: The test item is craned or hand carried onto the payload cart positioned at the chamber door. Typically, the payload is instrumented and connected to gse prior to rolling it into the chamber. Ground support equipment cabling is connected through the penetration plates and ambient functional checks are performed. Prior to solar testing, it is normal to perform an alignment check of the test item with the external simulator. Access to the chamber is through a clean tent. The use of cleanroom procedures and the wearing of clean garments are required when working in the chamber.

Parameters:

Test pressure:	$<1 \times 10^{-5}$ Torr ($<2\times10^{-7}$ psi)
Shroud temperature:	
GN_2 mode:	-138°C to +125°C (-216°F to +257°F)
LN_2 mode:	-190°C (-310°F)
Cryopump speed for N_2:	30,000 l/s (63,560 cfm)

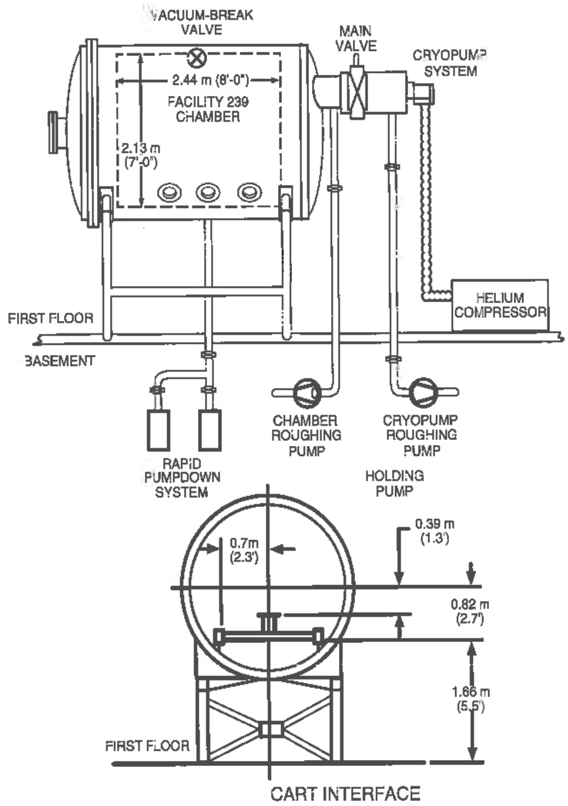
Physical Characteristics:

Test volume:	2.13 m diameter x 2.44 m L (7’ x 8’)
Payload support:	44” x 76” cart – 584 kg (1288 lb) capacity 43.5” x 80” cart – 729 kg (1607 lb) capacity
Crane Capacity:	4,536 kg (5 ton)
Viewport dimensions:	30 cm (12”) diameter quartz window
Std. electrical feedthroughs:	61-pin, 37-pin, 7-pin, 4-pin, RF

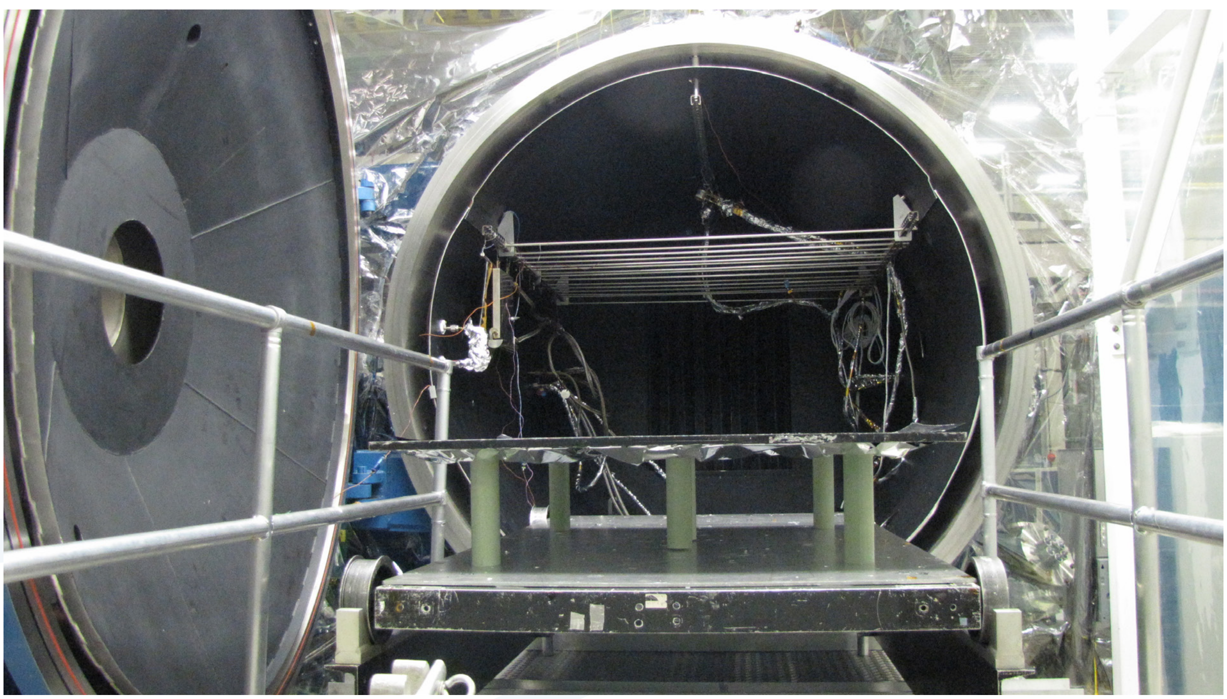
Integral Instrumentation:

Pressure:	Convectron - Atm to 0.13 Pa (10^{-3} Torr) Ion gauge - 10^{-3} Torr to ultimate
Payload temperature:	126 channels
Contamination monitors:	TQCM, cold finger, scavenger plate, residual gas analyzer

Auxiliary Equipment: Heater racks and thermal conditioning units (TCUs) are available to control auxiliary heater panels, cryopanels and baseplates. The portable solar simulator can be used with this chamber.



Chamber and Vacuum Schematic (Facility 239)



Facility 239

1.3.3.5 Facility 240 – 0.9 m x 0.9 m (3' x 3') Diffusion Pumped Vacuum Chamber

Description: : This diffusion pumped facility is a horizontal loading thermal vacuum test chamber used for thermal vacuum testing and bakeout of test articles. The payload is mounted on a plate which is supported by rails welded to the chamber wall.

Mode of Operation: After the test article is instrumented with thermocouples and placed in the chamber, ground support equipment cabling is connected through the penetration plates, and ambient functional checks are performed. Placing the test article on a baseplate or suspending it from the overhead rail is an acceptable mounting method. Chamber evacuation is provided by rotary piston mechanical pumps and an oil diffusion pump. A main valve allows test set up while the pumping system is being established.

Parameters:

Test pressure:	<1 x 10^{-5} Torr (<2x10^{-7} psi)
Shroud temperature:	-140°C to +110°C (-220°F to +230°F)
Pumping speed for N_2:	1,600 L/sec (3,400 cfm)

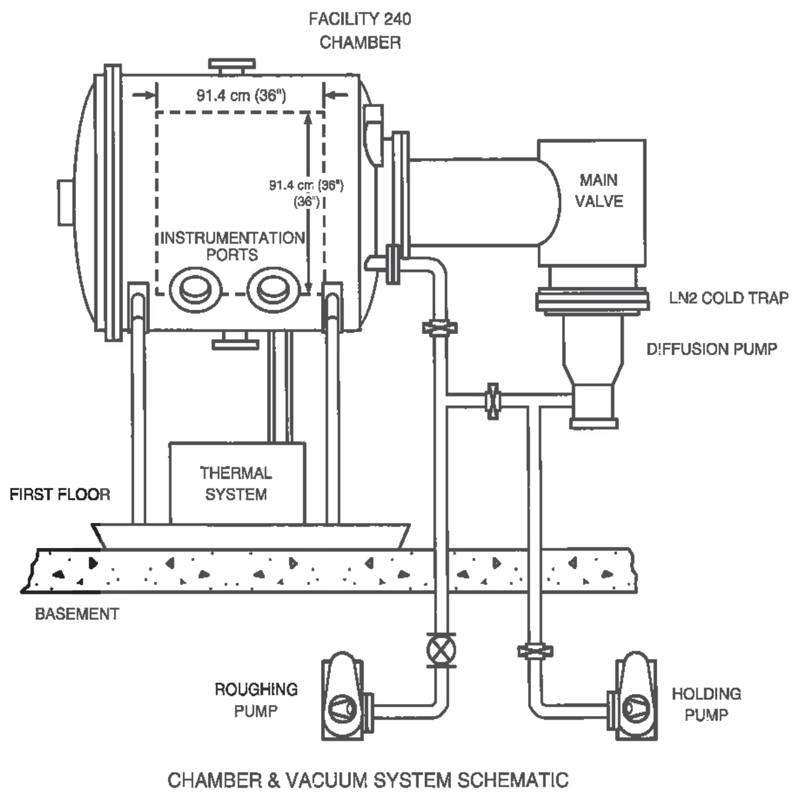
Physical Characteristics:

Test volume:	0.91 m D x 0.91 m L (3' x 3')
Std. electrical feedthroughs:	61-pin, 37-pin, 7-pin, 4-pin, RF
Max P/L weight:	840 kg (1854 lbs)

Integral Instrumentation:

Pressure:	Convectron - atm to 0.13 Pa (10^{-3} Torr)
	Ion gauge - 10^{-3} Torr to ultimate
Payload temperature:	36 channels
Contamination monitors:	TQCM, cold finger, scavenger plate

Auxiliary Equipment: Portable thermal systems are available to control baseplates, the thermoelectric quartz crystal microbalance (TQCM), and contamination control mirrors.



Chamber and Vacuum Schematic (Facility 240)

Facility 240

1.3.3.6 Facility 241 – 0.9 m x 0.9 m (3’ x 3’) Cryopumped Vacuum Chamber

Description: This cryopumped facility is a horizontal loading thermal vacuum chamber used for thermal vacuum testing and bakeout of test articles. The payload is mounted on a plate which is supported by rails welded to the chamber wall..

Mode of Operation: After the test article is instrumented with thermocouples and placed in the chamber, ground support equipment cabling is connected through the penetration plate, and ambient functional checks are performed. After roughing down the chamber with the rotary piston mechanical pump, ultimate pressure is achieved with the cryopump. A main valve allows test set up while the pumping system is being established.

Parameters:

Test pressure:	$<1 \times 10^{-5}$ Torr ($<2\times10^{-7}$ psi)
Shroud temperature:	-140°C to +110°C (-220°F to +230°F)
Pumping speed for N_2:	1,500 L/sec (3,200 cfm)

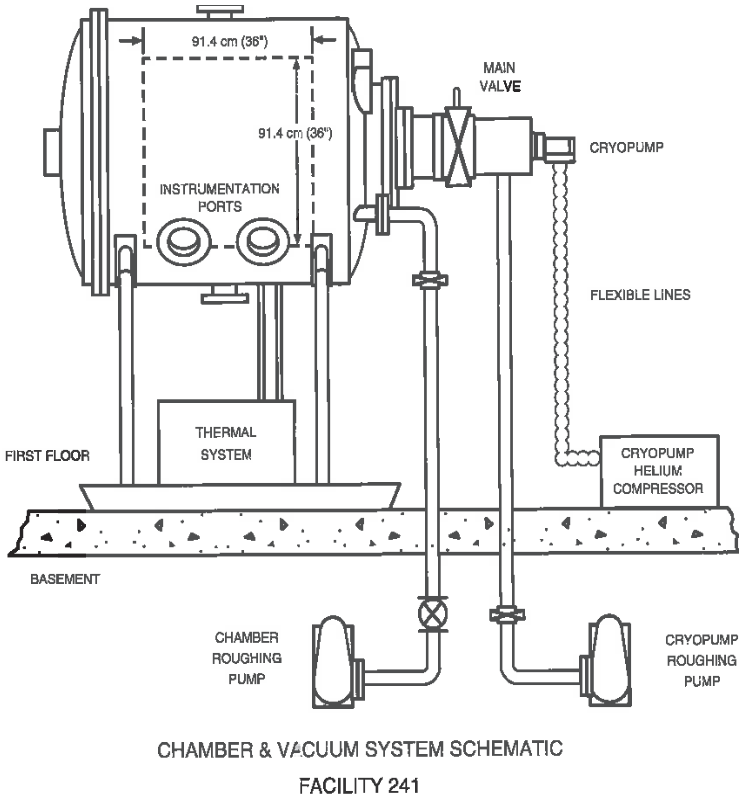
Physical Characteristics:

Test volume:	0.91 m diameter x 0.91 m L (3’ x 3’)
Std. electrical feedthroughs:	61-pin, 37-pin, 7-pin, 4-pin, RF
Max P/L weight:	840 kg (1854 lbs)

Integral Instrumentation:

Pressure:	Convectron - Atm to 0.13 Pa (10^{-3} Torr)
Ion gauge	- 10^{-3} Torr to ultimate
Payload temperature:	36 channels
Contamination monitor:	TQCM, cold finger, scavenger plate

Auxiliary Equipment: Portable thermal systems are available to control base plates, the thermoelectric quartz crystal microbalance (TQCM), and contamination mirrors.



Chamber and Vacuum Schematic (Facility 241)

Facility 241

1.3.3.7 Facility 245 – 0.6 m x 0.9 m (2' x 3') Vacuum Chamber

Description: This turbo pumped facility has a horizontal cylindrical chamber with a hinged door. The vacuum chamber is a horizontal stainless steel cylinder 2 feet in diameter by 3 feet deep. The side and rear shroud assembly rests on rails welded to the chamber walls. The door shroud is hinged to the main circular side shroud. The shrouds of this facility are made of black anodized aluminum sheet. 500 Watt metal strip heaters are mounted to the backside of the shroud and controlled by Lambda heater power supplies. The chamber does not provide a method to cool the shrouds.

Mode of Operation: After the test article is instrumented with thermocouples and placed in the chamber, ground support equipment cabling is connected through the penetration plate, and ambient functional checks are performed. After roughing down the chamber with the rotary vane mechanical pump, ultimate pressure is achieved with the turbopump. Ports for payload electrical feedthroughs and liquid/gas feedthroughs are located on the west side of the chamber. The vacuum system is comprised of one mechanical pump and a 12" diameter turbopump.

Parameters:

Test pressure:	$<1 \times 10^{-5}$ Torr ($<2\times10^{-7}$ psi)
Shroud temperature	+22°C to +150°C (+72°F to +302°F)
Pumping speed for N_2:	1,500 L/sec (3,200 cfm)

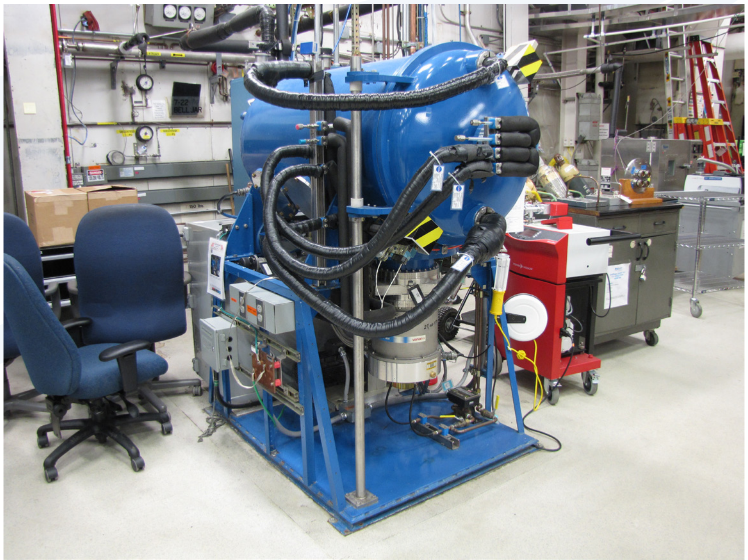
Physical Characteristics:

Test volume:	0.61 m diameter x 0.91 m L (2' x 3')
Std. electrical feedthroughs:	61-pin, 37-pin, 7-pin, 4-pin, RF
Max P/L weight:	90 kg (200 lbs)

Integral Instrumentation:

Pressure:	Convectron - Atm to 0.13 Pa (10^{-3} Torr)
	Ion gauge - 10^{-3} Torr to ultimate
Payload Temperature:	18 channels
Contamination monitor:	TQCM, cold finger

Auxiliary Equipment: Portable thermal systems are available to control base plates, thermoelectric quartz crystal microbalance (TQCM), and contamination mirrors.



Facility 245

1.3.3.8 Facility 246 – 1.2 m x 1.8 m (4' x 6') Thermal Vacuum Chamber

Description: This is a horizontal loading thermal vacuum test chamber used to simulate lunar vacuum environments. Electrical feedthroughs and liquid and gas penetrations are provided at locations on the rear section of the chamber.

Mode of Operation: Test items are loaded onto a 30'' wide x 50'' deep payload table that is capable of supporting 227 kg (500 lb). The table rolls out to improve payload accessibility. Access to the chamber is through a clean room that encloses the facility.

Chamber evacuation is provided first by a mechanical roughing pump, followed by a cryopump. Shroud temperature conditioning is accomplished by a recirculating GN_2 thermal system, or it may be flooded with LN_2.

Parameters:

Test pressure:	$<1x10^{-5}$ Torr ($<2x10^{-7}$ psi)
Shroud temperature:	
GN_2 mode:	-140°C to +150°C (-220°F to +302°F)

Physical Characteristics:

Test volume:	1.06 m dia x 1.68 m L (3.5' x 5.5')
Payload support:	227 kg (500 lb)
Instrumentation ports:	12 each 15.2 cm dia (6"), 2 each 20.3 cm dia (8"), 4 each 25.4cm dia (10''), 1 each 35.6cm dia (14'')
Std. electrical feedthroughs:	61-pin, 37-pin, 7-pin, 4-pin, RF

Integral Instrumentation:

Pressure:	Convectron - atm to 10^{-3} Torr
Ion gauge	- 10^{-3} Torr to ultimate
Contamination monitors:	Cold finger, scavenger plate

Auxiliary Equipment: Portable thermal systems are available to control baseplates and contamination control mirrors.

Facility 246

1.3.3.9 Facility 281 – 0.9 m x 1.2 m (3' x 4') Cryopumped Vacuum Chamber

Description: This cryopumped facility is a horizontal loading thermal vacuum chamber used for thermal vacuum testing and baking out test articles. The payload is mounted on a plate which is attached to rails in the chamber.

Mode of Operation: After the test article is instrumented and installed in the chamber, it is connected to the ground support equipment and data acquisition system via electrical feedthroughs. After roughing down the chamber with the mechanical pump, ultimate pressure is achieved with a cryopump. A main valve allows test set up while the pumping system is being established.

Parameters:

Test pressure:	<1 x 10^{-5} Torr (<2x10^{-7} psi)
Shroud temperature:	
GN2 mode:	-148°C to +150°C (-234°F to +302°F)
LN2 mode:	-190°C (-310°F)
Pumping speed for N_2:	1,500 L/sec (3,200 cfm)

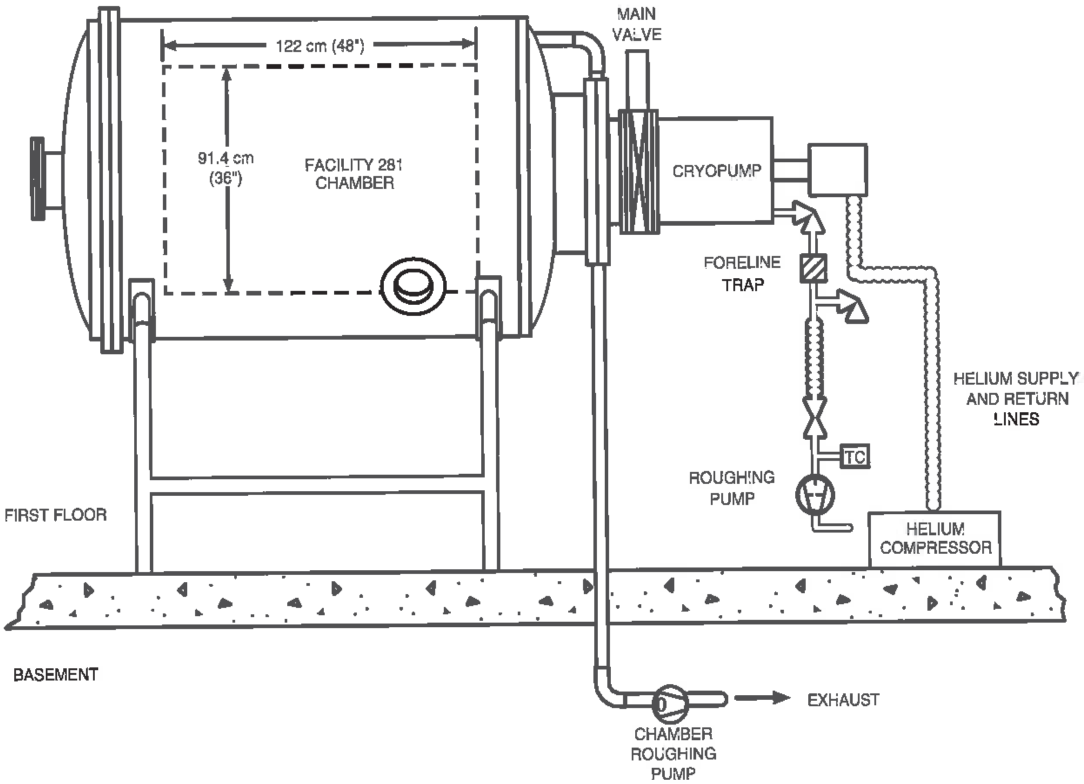
Physical Characteristics:

Test volume:	0.91m diameter x 1.22m L (3' x 4')
Payload support:	Plate on support rails
Std. electrical feedthroughs:	61-pin, 37-pin, 7-pin, 4-pin, RF

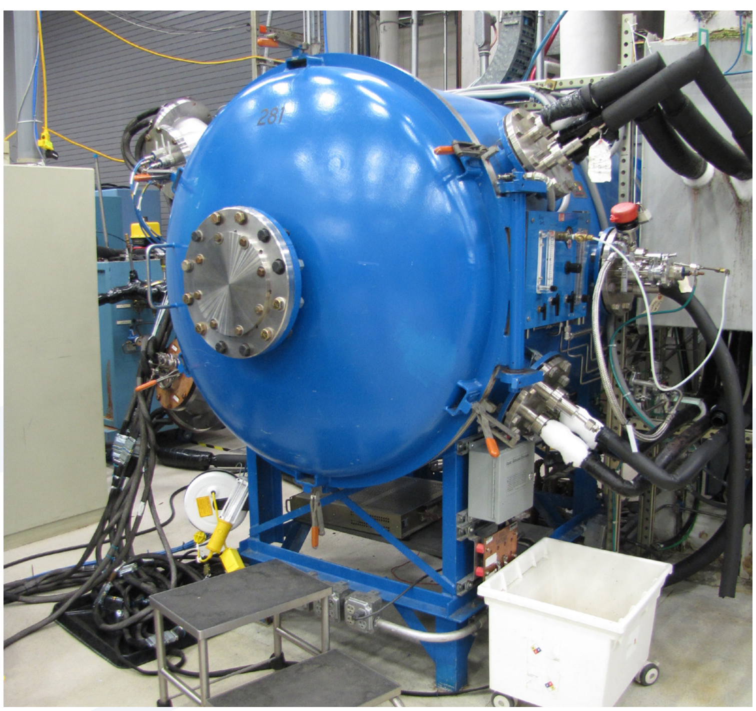
Integral Instrumentation:

Pressure:	T/C gauge - atm to 0.13 Pa (10^{-3} Torr)
	Convectron - Atm to 0.13 Pa (10^{-3} Torr)
	Ion gauge - 10^{-3} Torr to ultimate
Payload temperature:	72 channels
Contamination monitor:	TQCM, cold finger, scavenger plate

Auxiliary Equipment: Portable thermal systems are available to control base plates, the thermoelectric quartz crystal microbalance (TQCM), and contamination mirrors.



Chamber and Vacuum Schematic (Facility 281)



Facility 281

1.3.3.9 Facility 290 – 8.2 m x 12.2 m (27’ x 40’) Cryopumped Vacuum Chamber

Description: Facility 290, also known as the Space Environment Simulator (SES) is a very large vertical loading thermal vacuum chamber capable of achieving ultra-low pressure and a wide range of thermal conditions. In addition to the 27’D x 40’H nitrogen shroud, two auxiliary helium shroud configurations are available (25’D x 15’H and 25’ x 27’H). A 1 kW at 20K helium refrigerator is used to cool the helium shrouds and/or other auxiliary equipment. An integrated HEPA filtration system provides a Class 10,000 environment in the chamber and anteroom. The chamber is used for thermal vacuum and thermal balance testing, and baking out very large test articles.

Mode Of Operation: To load large test articles the chamber dome is rolled back to allow loading with the overhead crane. Small test articles and equipment are brought in through the personnel entrance located in the basement. Wearing of clean garments is required. Entry to instrument the payload, connect ground support equipment cabling, and install hardware is through a cleanroom air shower at the personnel door. Scaffolding may be erected to provide access to the payload. An area adjacent to the main facility control console is reserved for the experimenter’s ground support equipment.

Chamber evacuation is provided by eight rotary piston mechanical pumps with Roots blowers, seven cryopumps and a turbomolecular pump. Thermal control is provided by an aluminum tube-in-sheet cylindrical shroud with both liquid nitrogen and gaseous nitrogen operational modes. The dome and bottom shrouds are also connected to the thermal skid. Helium shrouds, resistance heater arrays and gaseous nitrogen panels are available for special thermal requirements. Thermoelectric quartz crystal microbalances (TQCMs) and a residual gas analyzer (RGA) provide both quantitative and qualitative monitoring of molecular contamination and gaseous constituents within the chamber. Closed circuit television coverage is available for monitoring the test article.

Helium Skid: A 1.0 kW helium refrigeration system is piped to 2.54 cm (1”) VCR fittings inside the chamber that may be connected to manifolds providing the capability of achieving 20K on those surfaces. This is enough cooling energy to cool and maintain large thermal shrouds at cryogenic temperatures.

Vibration Isolation Table: The pneumatic isolation system and payload platform (with counter weights) is designed to support and provide vibration isolation to delicate spacecraft and component payloads during testing in Facility 290. The isolation system consists of three constant-effective-area pneumatic isolators controlled by three height sensing servo valves with an adjustable deadband. The isolation system will support any load up to its maximum capacity of 6032 kg (13,300 lbs).

The isolation system is configured with heaters to maintain the system above 0°C during cold wall testing in Facility 290. The maximum operating temperature for the system is +50°C.

<u>Natural Frequencies</u>

Vertical:	0.7- 0.9 Hz
Horizontal:	0.4- 0.5 Hz
Dimensions:	43” High 120” Diameter

Parameters:

Test pressure:	13.3 µPa (10^{-7} Torr)
Shroud temperature:	
GN_2 mode:	-130°C to +80°C (-202°F to +176°F)
LN_2 mode:	-180°C (-292°F)
Chamber pumping speed:	
7 cryopumps:	2.1 x 10^5 L/sec (4.5 x 10^5 cfm) @ 133 µPa (10^{-6} Torr)
Turbomolecular pump:	6,000 L/sec (12,700 cfm) @ 133 µPa (10^{-6} Torr)

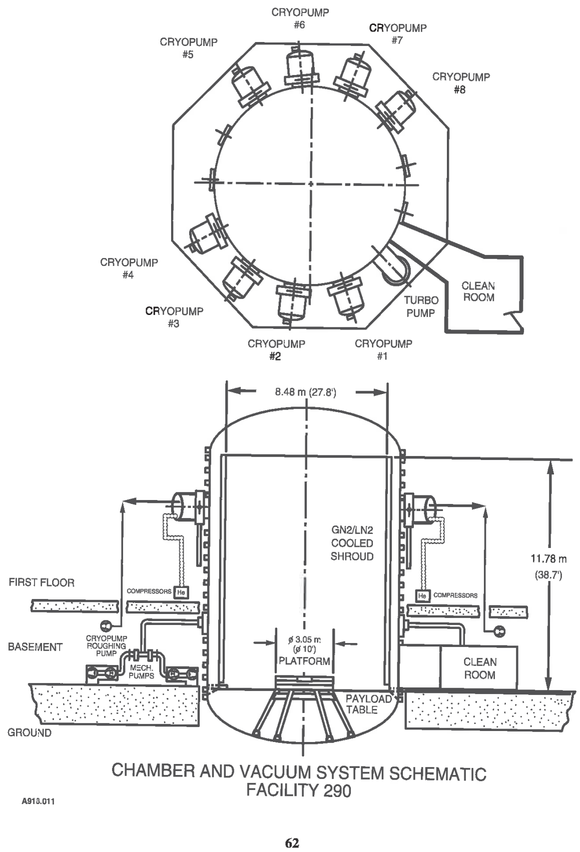
Physical Characteristics:

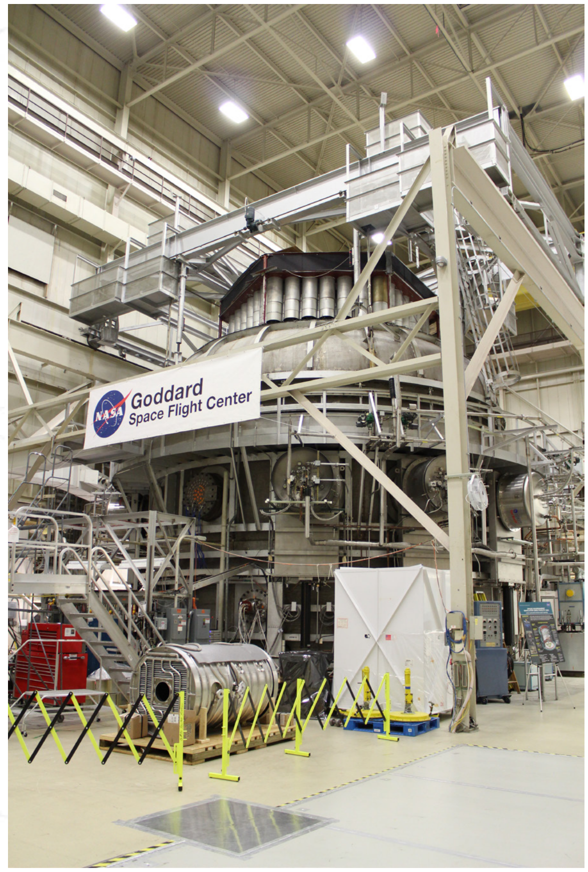
Test volume:	8.23 m diameter x 12.19 m H (27' x 40')
Payload support:	11794 kg (26000 lb)
Viewport:	30 cm (12") Standard electrical feedthroughs: 61-pin, 37-pin, 7-pin, 4-pin, RF
Personnel door:	1.8 m H x 1.5 m H (6' H x 5' W)
Crane capacity:	13,608 (15 ton)
Crane hook height:	12.8 m (42') to I-beam structure

Integral Instrumentation:

Pressure:	Convectron (2) - Atm to 0.13 Pa (10^{-3} Torr)
	Ion gauge (3) 0.13 Pa to 13.3 µPa (10^{-3} to 10^{-7} Torr)
Payload temperature:	760 channels of thermocouples
Contamination monitor:	TQCM, cold finger, scavenger plate, residual gas analyzer
TQCM frequencies:	15 MHz (4); 10 MHz (2)

Auxiliary Equipment: Portable thermal systems are available to control base plates, the thermoelectric quartz crystal microbalances (TQCMs), and contamination mirrors.





Chamber and Vacuum Schematic (Facility 290)

Facility 290

1.3.4 – Solar Simulator (Facility 211)

Description: This portable solar simulator projects a divergent beam. The unit is mounted on a castered platform to provide alignment with the windows of the medium-sized thermal vacuum chambers. The power supply and controls are incorporated in a separate castered console.

Mode of Operation: The intensity is adjusted to the desired level, and uniformity of the beam at the target plane is measured before the test article is installed in the facility. The lamp is then aligned at the quartz window at the required distance from the target plane. The lamp is ignited and the payload illuminated in accordance with the test procedure.

Parameters:

Beam size:	61 cm (24") across flats
Intensity:	90 to 270 mW/cm^2 (0.16 in^2); 0.6 to 1.0 S.C.
Target plane:	191 cm (75") from exit optics
Uniformity:	± 10% max of average intensity
Subtense angle:	7° half angle
Spectrum:	Filtered to air mass zero solar spectrum

Physical Characteristics:

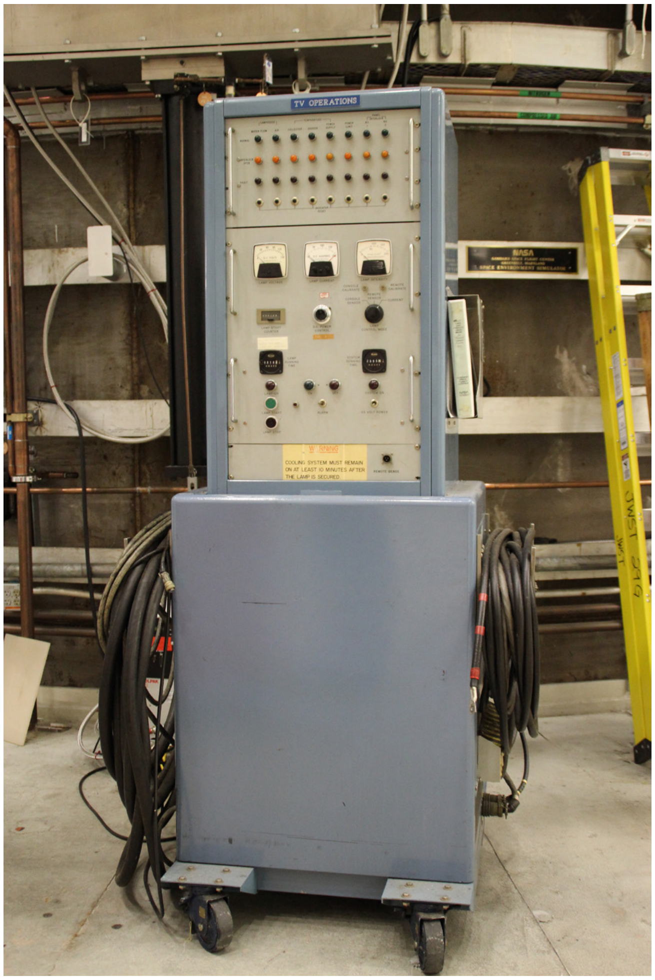
Source:	One 6.5 kW Xenon arc lamp
Lamphouse:	76 cm x 137 cm x 122 cm (30" x 54" x 48")
Control console:	76 cm x 76 cm x 183 cm (30" x 30" x 72")
Platform:	173 cm x 76 cm x 127 cm (68" x 30" x 50")
Exhaust fan:	8.5 m^3/min (300 ft^3/min)

Utility requirement:

Power:	480 V, 60 Hz, 3 phase, 35 A 110 V, 60 Hz, 1 phase, 25 A
Cooling water:	15°C to 30°C (59°F to 86°F) 11 to 19 L/min (3 to 5 gal/min)

Integral Instrumentation:

Lamp voltage: 0-150 VDC, Lamp current: 0-200 A Lamp intensity: 0-200 mW/cm^2 (0.16 in^2)
DC System alarms: Klaxon and lights



Power Supply

Source Module

1.3.5 Thermal Vacuum Data Acquisition Facility

Description: This facility is a client/server Windows network application operating over a local area network (LAN.) It is designed to measure, display, and store data such as temperature, chamber pressure, thermoelectric quartz crystal microbalance (TQCM) frequencies, voltages, and other chamber and payload data.

Mode of Operation: Data is acquired by the Supervisory Control and Data Acquisition (SCADA) computer every two minutes and recorded in the thermal vacuum Oracle database located on the server. Data stations located throughout Labs 7 and 10 can view this data through an Ethernet TCP/IP connection. The Thermal/Vacuum Data System (TVDS) graphical user interface (GUI) displays the data in tabular and graphical formats.

The number and location of payload thermocouples are determined by the experimenter/thermal engineer. Facility thermocouples are strategically placed to provide a full representation of all chamber shrouds. The different operating parameters (temperature, pressure, TQCM frequencies, and rate of TQCM change) can be viewed simultaneously in tabular format or graphical plot. All measuring devices have alarm limits that allow for facility and payload control.

All recorded data and data station configurations are stored in an Oracle. An uninterruptible power supply prevents the loss of data in case of a power outage. Data is backed up at the end of every test, and stored off-site in Building 5.

Software features: The TVDS application runs on each data station and can be customized by the operator or experimenter. Any facility that is active (under test) can be viewed on any data station.

Operators have the ability to create, start and stop tests, enable/disable measuring devices, and edit alarm limits, averages and gradients. Display options include tabular displays, graphical plot displays, multiple color schemes, scale-able plots, and copying displays from other data stations. All tabular and plot displays can be printed to a LAN printer.

Thermal Vacuum Data Acquisition Area

1.3.6 Thermal Conditioning Units

Description: The following thermal conditioning units are portable and available for use at each thermal vacuum facility as needed. They are designed to produce and maintain a wide range of temperatures. The heat transfer medium is GN_2 for all units. Typical applications for these units include independent thermal control of test articles and contamination monitoring devices such as mirrors and TQCMs. Chamber penetrations are configured to accommodate the thermal conditioning units.

Facility No.	Temp Range	Heating Cap. (Watt)	Cooling Cap. (Watt)	Size (H x W x D)	MFR
201	-140 to 140°C (-220 to 284° F)	1,400	1,000	1.8 m x 0.97 m x 1.7 m (5.9' x 3.2' x 5.6')	CVI
203	-140 to 140°C (-220 to 284° F)	500	500	0.40m x 0.55m x 0.34m (1.3' x 1.8' x 1.1')	Built in-house
205	-100 to 100°C (-148 to 212° F)	500	500	0.89 m x 0.51 m x 0.51 m (2.9' x 1.7' x 1.7')	Slack
209	-140 to +150°C	800	800	1.68m x 0.79m x 0.52m (5.5' x 2.6' x 1.7')	Slack
230	-150 to 150°C (-238 to 302° F)	12,000	10,000	2.1 m x 0.81 m x 2.1 m (6.8' x 2.7' x 6.8')	DynaVac

Note 1: Thermal capacities at nominal 10°c (18°f) gradient

Facility 201

Facility 203

Facility 205

1.3.7 Electrical Heater Controller (Facility 242, Harrel)

Description: The electrical heater controller rack is a standard 48 cm (19’’) electronic console that contains direct current power supplies, power distribution, and a microprocessor-based control panel. Heater circuits can be controlled individually at continuously variable temperatures between -100 and +100°C (-148 and +212°F). Power available for heater circuits is 5.4 kW maximum.

Mode of Operation:Each temperature control panel can control sixteen heater circuit zones. The microprocessor-based panel uses a platinum resistance temperature detector to feed-back real time temperature data. The panel uses a proportional plus integral (PI) rate characteristic to control a solid state relay. The time-proportioning control circuitry cycles the solid state relay to control the power to the heater. All adjustments are available from the front panel and can be locked against tampering. Each heater zone is alarmed.

Parameters:

Temperature:	-100°C to +100°C (-148°F to+ 212°F)
Heater zones:	16 channels
Heater power:	5.4 kW maximum

Physical Characteristics:

Portable unit:	2.08 m H x 0.61 m W x 0.61 m D (6.82’ x 2’ x 2’)

Electrical Heater Controller

1.3.8 Automated Electric Heater Controller (Facility 315)

Description: This system can control up to twelve heater circuits, each of which can be in temperature controlled or constant power mode, as desired. Four of the circuits can be in zero-Q mode. The rack contains twelve direct current power supplies, a programmable logic controller (PLC), a touch screen operator interface, and a Modbus Plus communication port. The system uses the proportional plus integral plus derivative (PID) control strategy.

Mode of Operation: The heater system can be operated at the touch screen or remotely via Modbus Plus from a desktop computer. For each circuit, the user enters the mode, set point, temperature limit, heater current limit, and the heater resistance. The PLC then controls the amount of continuous (i.e., not pulsed) current to the heater to achieve the desired temperature or power level. Temperatures and power levels (in any mode) are stored in the thermal vacuum data system.

Parameters:

Temperature:	-200°C to +100°C (-328°F to+ 212°F) with Kapton Strip Heaters, -200°C to +600°C (-328°F to +1112°F) with Calrods
Heater zones:	12 channels
Heater power:	600 Watts per channel (0-150 VDC @ 0-4 A)
Modes:	Temperature controlled, constant power, zero-Q
Temperature sensors:	Type T or K thermocouples, Platinum Resistance Thermometers (PRTs)

Physical Characteristics:

Portable unit:	2.06 m H x 0.56 m W x 0.76 m D (6.75’ x 1.8’ x 2.5’)

315 Automated Heater Controller

1.3.9 Automated Electric Heater Controller (Facility 316)

Description: This system can control up to twelve heater circuits, each of which can be in temperature controlled or constant power mode, as desired. Four of the circuits can be in zero-Q mode. The rack contains twelve direct current power supplies, a programmable logic controller (PLC), a touch screen operator interface, and a Modbus Plus communication port. The system uses the proportional plus integral plus derivative (PID) control strategy.

Mode of Operation: The heater system can be operated at the touch screen or remotely via Modbus Plus from a desktop computer. For each circuit, the user enters the mode, set point, temperature limit, heater current limit, and the heater resistance. The PLC then controls the amount of continuous (i.e., not pulsed) current to the heater to achieve the desired temperature or power level. Temperatures and power levels (in any mode) are stored in the thermal vacuum data system.

Parameters:

Temperature:	-200°C to +100°C (-328°F to+ 212°F) with Kapton Strip Heaters, -200°C to +600°C (-328°F to +1112°F) with Calrods
Heater zones:	12 channels
Heater power:	1800 Watts per channel (0-150 volts DC @ 0-12 amperes)
Modes:	Temperature controlled, constant power, zero-Q
Temperature sensors:	Type T or K thermocouples, Platinum Resistance Thermometers (PRTs)

Physical Characteristics:

Portable unit:	2.06 m H x 0.56 m W x 0.76 m D (6.75' x 1.8' x 2.5')

316 Automated Heater Controller

1.3.10 Rapid Pumpdown System (Facility 208)

Description:: This high-speed vacuum pumpdown system is comprised of two rotary piston pumps manifolded in parallel to a chamber exhaust line. Two 2.1 m x 2.4 m (7' x 8') thermal vacuum chambers (one diffusion pumped, one cryopumped) are manifolded in parallel to the exhaust line providing rapid pumpdown. There is a foreline valve at the inlet of each pump, and a shut-off valve at each chamber. The pumps and valves are located in the basement and operated from a remote console.

Mode of Operation: Each pump is started, and its ultimate pressure is verified to be less than 2.66 Pa (2 x 10^{-2} Torr). The foreline valve and the valve at the required chamber are opened. When test pressure is achieved, the chamber valve is closed. The foreline valves are closed and the pumps are secured.

Parameters:

Ultimate pressure:	1.33 Pa (10^{-2} Torr)
Pump down time:	Either chamber - atm to 2.66 Pa (2 x 10^{-2} Torr) in 5 min.
Pump speed:	22 m^3/min (780 ft^3/min) each pump

Physical Characteristics:

Foreline size:	25 cm (10") diameter
Chamber manifold:	31 cm (12") diameter

Integral Instrumentation:

Pump foreline pressure:	T/C gauge for atm to 0.13 Pa (10^{-3} Torr)

Rapid pumpdown system

1.3.11 Contamination Monitoring

1.3.11.1 Residual Gas Analyzer (RGA)

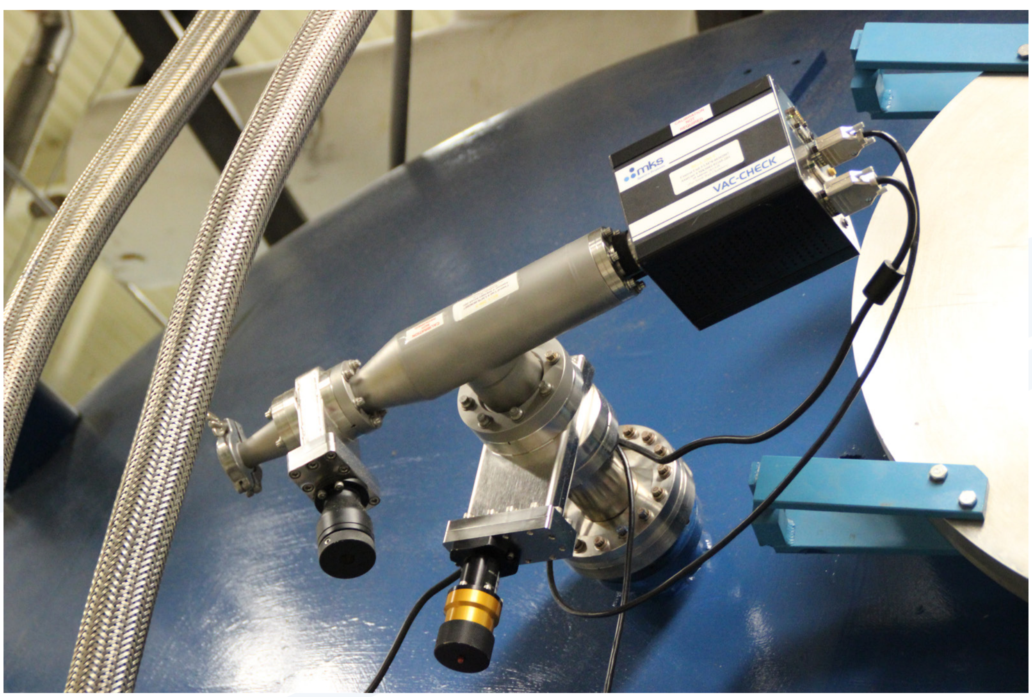
Description: The residual gas analyzer is used to measure the partial pressures of ionized molecules over a mass range of 1 to 200 atomic mass units (AMU). Using a combined RF and electrostatic field formed by two metal rods, the RGA scans the mass range and detects the partial pressures of each element or compound fraction.

Mode of Operation: The RGA probe is located in the thermal vacuum facility and is oriented to maximize the detection of the outgassing species. After the facility pressure reaches 13.3 mPa (10^{-4} Torr), the instrument may be activated. An alternate technique is to use the micro sampling valve at high chamber pressure. Monitoring and recording of the vacuum environment is via a display meter and printer.

Parameters:

Make & Model	Faraday Cup	Electron Multiplier	AMU Range	Max. Operating Pressure	Min. Detectable Partial Pressure
MKS PPT-200EM	Yes	Yes	1-200	13.3 mPa (1.0 x 10^{-4} Torr)	6.7 x 10^{-12} Pa (50 x 10^{-14} Torr)

Note: Two auxiliary RGA manifolds are available, with appropriate valves, that provide sampling of chamber gasses when chamber pressure is between 13.3 mPa (1^{0-4} Torr) and atmosphere.



RGA Installed on Chamber

1.3.11.2 Thermoelectric Quartz Crystal Microbalance

Description: The thermoelectric quartz crystal microbalance (TQCM) and M-2000 control unit system measures and records condensable masses which deposit on a piezoelectric crystal. Extreme accuracy is obtained by comparing the exposed measurement crystal to a matched encapsulated reference crystal located in the same TQCM head. A computer controlled thermoelectric pump provides a high degree of crystal temperature control, which is vital for accurate frequency measurement. Two TQCM sensing units may be used, 10 MHz or 15 MHz. All relevant data is sent from the M-2000 control unit and the PC control station to the data acquisition and reduction facility.

Mode of Operation: One or more TQCM sensing units are installed in a thermal vacuum chamber. The chamber is pumped down to a test pressure of 1.33 mPa (10^{-5} Torr) or less, at which point the TQCM is turned on and set for the appropriate operating temperature. As the payload outgasses and materials condense on the TQCM sensing crystal, the crystal frequency increases directly proportionally to the amount of payload outgassing.

Parameters:

Mass sensitivity:	4.43×10^{-9} g/cm^2-Hz (1.01×10^{-9} oz/in^2-Hz) for the 10 MHz unit
	1.97×10^{-9} g/cm^2-Hz (0.45×10^{-9} oz/in^2-Hz) for the 15 MHz unit
Crystal temperature:	-50°C to +100°C, ± 0.1°C (-58°F to +212°F, ± 0.18°F)
Sensor unit size:	5 cm (2") diameter x 25.5 cm (10") L with heat sink lines

Integral Instrumentation: The instrument consists of a TQCM sensor head unit, M-2000 multichannel control unit, SCADA station, and heat sink temperature control system.

TQCM Computer Control and Acquisition Unit

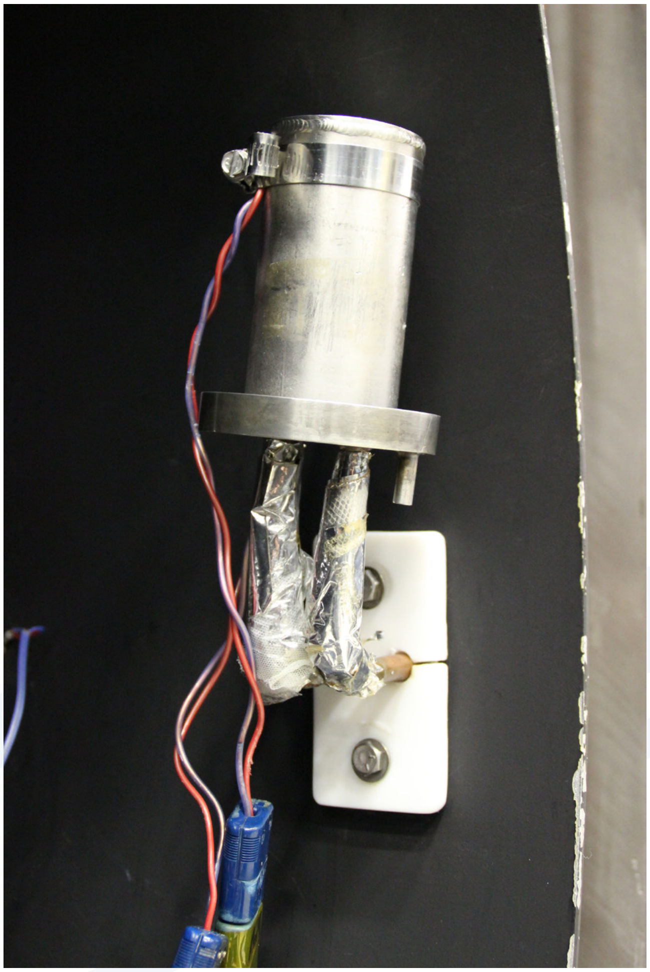
1.3.11.3 Cold Finger (C/F)

Description: Cold fingers are small stainless steel cylinders which are mounted in the test volume of each thermal vacuum chamber. Condensable vapors are collected by the cold finger and analyzed after the test. In some cases, a large cold plate is used to collect the condensable materials. The cold finger is maintained at LN_2 temperature during test and until the chamber is backfilled to 80 kPa (600 Torr).

Mode of Operation: The cold finger is thoroughly cleaned before the test. After the thermal vacuum test, the cold finger is warmed rinsed with isopropyl alcohol. The rinse sample is collected in a clean bottle and sent to the Materials Assurance Branch for quantitative and qualitative analyses.

Parameters:

Size:	5 cm (2”) diameter x 7.6 cm H (3”)
Surface area:	142 cm^2 (22 in^2) nominal
Temperature:	-196°C (-321°F)



C/F Installed Inside Chamber

1.3.11.4 Contamination Control Mirror

Description: These aluminum coated mirrors are used primarily to collect outgassed materials in the thermal vacuum chambers; however, they may be placed anywhere to collect condensable matter. To determine the quantity of material on the mirror, reflective ultraviolet measurements are made prior to test, and then compared to post-test measurements for a loss of reflectivity.

Mode of Operation: The mirror is placed in the thermal vacuum chamber (or other environment) and allowed to remain in that location for the duration of the test. In most cases, the mirror's temperature follows the thermal vacuum chamber temperature profile; however, the mirror's temperature can be controlled if desired. For large accretions (greater than 10% change in reflectivity) the mirror is sent to the Materials Assurance Branch for chemical analysis of the nonvolatile residue.

Parameters:

Temperature:	-190°C to +100°C (-310°F to +212°F)
Measurement error:	± 2%
Measurement wavelength:	1216 Å, 1608 Å, and 2000 Å
Mirror size:	5 cm x 5 cm (2" x 2"), coated on one side
Coating:	Al - 600 to 800Å thick
Over coating:	MgFl - 250Å thick

2.0 Integration Services and Facilities

The Environmental Test and Integration Branch provides trained personnel and facilities necessary to support integration of flight hardware ranging from sub-assemblies to fully-configured flight spacecraft. Integration services and facilities include mechanical integration support, electrical cable harness development, thermal blanket development, contamination control support, and cleanroom facilities.

The Environmental Test and Integration Branch's functions include the following integration disciplines:

Mechanical Integration:
Maintenance and operation of cleanrooms
Electrical and mechanical integration
Handling of spacecraft
Functional checks of spacecraft hardware
Field support at launch sites and remote facilities

Thermal Blanket Facility:
Thermal blanket template design
Thermal blanket fabrication
Thermal blanket installation
Launch site closeout and support

Electrical Cable Harness Facility:
Cable harness fabrication
Continuity and insulation resistance testing
Cable harness routing design
Cable harness installation and test

Cleanrooms and Contamination Control Support:
ISO Class 7 cleanrooms and tents
Particle and hydrocarbon monitoring
Witness plate monitoring and analysis
Cleanroom garments and supplies
Precision cleaning

2.1 MECHANICAL INTEGRATION

The Center possesses both the facilities and personnel necessary for mechanically integrating spaceflight hardware, including instruments, ground support equipment, and complete spacecraft. This integration effort is provided from the inception of the program through launch and recovery. Integration is performed either in the cleanrooms or in the general laboratories, as appropriate. Contamination-sensitive flight hardware and systems are integrated in the cleanrooms, while non-sensitive hardware is completed in the general integration facilities.

2.1.1 Handling of Spacecraft

Typical spacecraft handling tasks include preparation of procedures, use of hydrasets, crane operations, proof testing and verification of lifting devices and handling carts. The Center has extensive facilities, hardware, and trained personnel for both routine and quick reaction handling tasks. Logistics for shipping, receiving, and packaging are also provided at GSFC and other offsite locations.

2.1.2 Fabrication Support

Frequently, quick reaction machining operations need to be performed so that spacecraft integration tasks will remain on schedule. Trained personnel, using precision equipment and facilities, are available to modify or fabricate critical components and hardware as required.

2.1.3 Assembly

Both Center and project-supplied hardware is used by the integration group in the assembly of flight systems. Precision assembly tools, measuring instruments, and trained personnel are used to ensure precise alignment and installation of flight hardware. Precision optical transit squares, interferometers, surface tables, inclinometers, electronic levels, height gauges, laser trackers and helio-precision measuring tools are some of the instruments used for this effort.

2.1.4 Functional Checks of Spacecraft Mechanisms

Center personnel perform weight, moment of inertia, center of gravity, and product of inertia measurements on flight hardware. Functional checks of hinged doors, solar panel deployment mechanisms, payload ejection systems, and boom deployments are routinely conducted in accordance with the designer's and experimenter's specifications. Integration personnel also work closely with electronics personnel when installing electronic packages and routing electrical harnesses.

2.1.5 Field Support

When required, Center personnel are available for field support at contractor sites, launch sites, and other NASA installations. Typical operations performed during field support tasks are covered above.

2.1.6 Purge Systems

Spacecraft and shipping containers typically require a regulated flow of clean, dry gas to maintain a safety barrier to reduce contamination. Large and small systems can be designed to customer specifications, fabricated and certified. Existing systems can be refurbished and brought up to current NASA specifications

2.2 THERMAL SYSTEM SUPPORT FACILITY

Description: From the facilities the Thermal System Support Group provides personnel and production support for the development, design, procurements, and implementation of unique processes in layout, fabrication, and installation of mutli-layer insulation (MLI) for GSE and space flight equipment. Applications include flight spacecraft, instrumentation, optical components, mock-ups, and test fixtures. Products include thermal blanketing for space environments and adverse heat loads, attenuating Electromagnetic Interference (EMI), micrometeorite shields, and support for EVA crew tools and aids. These services are provided to all NASA centers and aerospace vendors and are not limited to the Goddard Space Flight Center facilities.

Mode of Operation: Technical support is provided to ensure thermal design, performance, fabrication, and installation requirements meet all NASA and Project instructions and guidelines, and adherence to ISO and Quality procedures possess the proper documentation. Technicians work with a variety of metalized and non-metalized thin films (ex. Mylar, GBK, Kapton, and Al FEP), fabrics (ex. Betacloth, E-glass, and Kevlar), foils (ex. titanium, stainless steel, and aluminum), tapes and adhesives, as well as a variety of buttons and fasteners. Technicians work from drawing, models, and direct from the flight hardware to produce templates for the thermal blanketing. From approved templates GSE and Flight blanketing is produced. Work is performed primarily in one of the production labs, but is also done in integration or test areas, contamination-controlled areas, and offsite locations. Technicians are trained in clean room operations, secondary bonding, Electrostatic Discharge precautions and procedures, and working on flight hardware and instrumentation. Work performed includes patterning, fabrication, modification, refurbishment, repair, and installation of thermal blanketing and EVA Tools and Aids. Technicians provide test, integration, and launch support world-wide.

Physical Characteristics:
- Production Lab 1 (Room 019) is ~ 1800 square feet.
- Production Lab 2 (Room N107) is ~396 square feet
- Production Lab 3 (coming soon)
- Maintain (2) Heavy Duty Industrial and (1) Light/Medium Sewing Machines.
- Maintain (10) Fabrication Tables (6’ X 7’).
- Maintain ~ 800 square feet bonded storage area for materials, completed MLI, templates, and project documentation.

MLI Blanket Installation

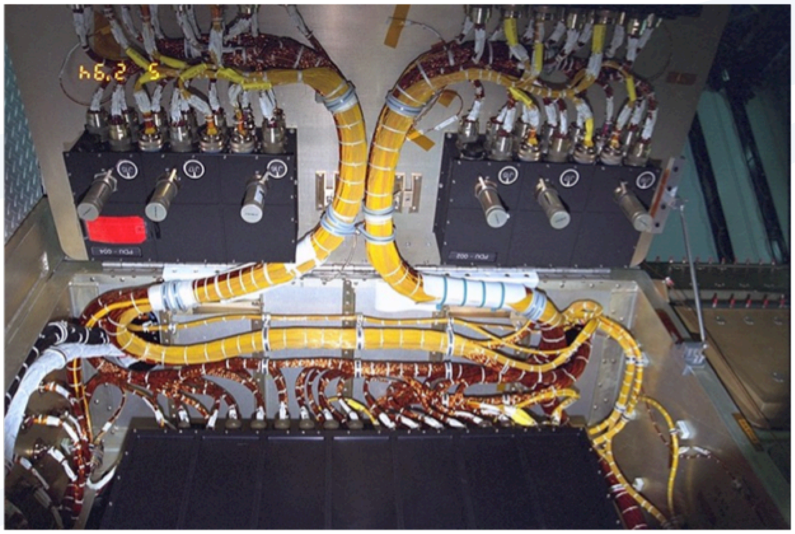
MLI Blanket Installed

2.3 CABLE/HARNESS AND ELECTRICAL SYSTEM SUPPORT FACILITY

Description: The Electrical Systems Support Group maintains the facilities and provides personnel and production support for the development, design, materials procurements, fabrication, testing, and installation of ground support and space flight electrical cabling, harnesses, circuit boards, and other electrical components and equipment. Engineering design, drawing, and procedural support is provided to project for all facets of electrical systems and wiring. Support includes design, fabrication, and installation of GSE and Flight cabling, harnesses, thermal systems support (i.e. heater, thermocouples), structural bonding, ground wire, GSE test boxes, and proof testing for all products. These services are provided to all NASA centers and aerospace vendors and are not limited to the Goddard Space Flight Center facilities.

Mode of Operation: Each cable and/or harness is built to custom specifications and in accordance with GSFC and NASA procedures and requirements. The design and testing of flight and ground support harnesses is accomplished in accordance with GSFC Design and Manufacturing Standards (GSFC-733-HARN-01) for Electrical Harnesses and 565-PG-8700.2.1. All fabrication, modification, and repair activities are performed by technicians certified to the requirements of NASA-STD-8739.1, 8739.3, 8739.4, and GFSC WM01 for staking and conformal coating, flight hand soldering, crimp/cable and harnessing, and ESD. Through these requirements and procedures we can account for design factors, fabrication methods, testing, and certifications. After fabrication and validation, harnesses can be baked out, routed, installed, and integrated to flight hardware. All fabrication benches and areas are set up to minimize electrostatic discharge potentials. If full ESD requirements are needed benches are set up and verified in clean room areas or ESD flow benches are used.

Physical characteristcs:
- Production Lab 1 (Room 104) is ~ 800 square feet.
- Production Lab 2 (Room 033) is ~ 600 square feet.
- Maintain Crimp Pull Testers, Pin retention tested, calibrated fabrication tooling, voltmeters, Hi-pot test equipment.
- Maintain ESD sensitive workbenches, (2) Flow benches, and various ESD areas/benches as required.
- Maintain 18- foot cable assembly bench.
- Maintain ~ Secured storage area for flight materials.



Harness

2.4 CLEANROOMS

Description: Cleanrooms are designed and operated to maintain a classification of air cleanliness by introducing air into the room, tent, or bench with conditioned recirculatory or direct ambient air systems through a series of high efficiency (HEPA) air filters. The filtered air is maintained at specified velocities in a unidirectional flow pattern that causes contaminants generated within the facility to be carried away in the direction of the moving air stream.

Mode of Operation: Cleanrooms are monitored on a periodic basis to verify that the classification of the facility remains within specification. Cleaning is performed on a predetermined or "as required" schedule based on classification monitoring results. Used cleanroom garments are continuously removed from the change rooms and replaced with fresh packaged garments. Project personnel are present inside the cleanrooms during test activity to insure that proper cleanroom procedures are followed.

2.4.1 Spacecraft Checkout Area (SCA)

Size	17 m L x 11 m W x 10 m H (56' x 36' x 33')
South Wall Filter Bank	5,664 m3/min (200,000 ft 3/min) - horizontal flow
Air Velocity	30m/min (100'/min), minimum
Temperature	21 ± 3° C (70 ± 5° F)
Relative Humidity	48 ± 4%
Entrance (Hardware)	Rollup door: 5.9 m W x 6.0 m H (19.4' x 19.7')
Cleanliness	Class 10,000 (M5.5)
Other Services	electrical, compressed dry nitrogen, under-floor cable tray system, telephone and intercom, outlets for central vacuum
Other Parameters	The walls and exposed steel are painted with an epoxy paint to keep particle generation to a minimum. The concrete floor has a polyurethane coating.

2.4.2 RFI Shielded Room

Size	18 m L x 11 m W x 6 m H (59' x 36' x 19.7')
West Wall Filter Bank	1,982 m^3/min (70,000 ft^3/min) - horizontal flow
Air Velocity	30 m/min (100'/min), minimum
Temperature	21 ± 3° C (70 ± 5° F)
Relative Humidity	48 ± 4%
Rf Waveguides	At entrance and exit
Entrance (Hardware)	Double door: 5.6 m W x 5.4 m H (20.0' x 19.0')
Cleanliness	Class 10,000 (M5.5)
Other Parameters	The walls and exposed steel are painted with an epoxy paint to keep particle generation to a minimum. The concrete floor has a polyurethane coating.

2.4.3 UD T4000 Vibration Test Cell

Size	8.8 m L x 8.2 m W x 15.5 m H (29' x 27' x 51')
Ceiling Filter Bank	1,416 m^3/min (50,000 ft^3/min) - vertical flow
Air Velocity	19.8 m/min (65'/min), minimum
Temperature (Nominal)	21° C (70° F)
Relative Humidity	48 ± 4%
Pass Through Window/ Door	Basement level/Bldg. 10, first floor
Personnel Entry	Basement level through NE corner
Cleanliness	Class 10,000 (M5.5)
Other Services	electrical, telephone and intercom, compressed dry nitrogen, outlets for central vacuum
Other Parameters	The walls and exposed steel are painted with an epoxy paint to keep particle generation to a minimum. The floor has a torginol seamless quartz coating.

2.4.4 Space Environment Simulator (SES)

Vacuum Chamber Size	8.2 m diameter x 12.2 m H (27' x 40')
Air Flow	283 m^3/min (10,000 ft^3/min)
Temperature (Nominal)	21° C (70° F)
Relative Humidity	below 60%
Anteroom	7.6 m L x 3.1 m W (25' x 10')
Air Flow	28.3 m^3/min (1,000 ft^3/min)
East Wall	Small parts passageway
Northwest Corner	Change room and air shower, basement level
Cleanliness	Class 10,000 (M5.5)
Other Services	electrical, compressed dry nitrogen, outlets for central vacuum
Other Notes	When the chamber door is open and the chamber clean air supply is on, air flows out of the chamber, down the length of the anteroom, and out through a louvered duct at the north end. When chamber door is closed, a small auxiliary blower/filter unit supplies filtered air into the anteroom.

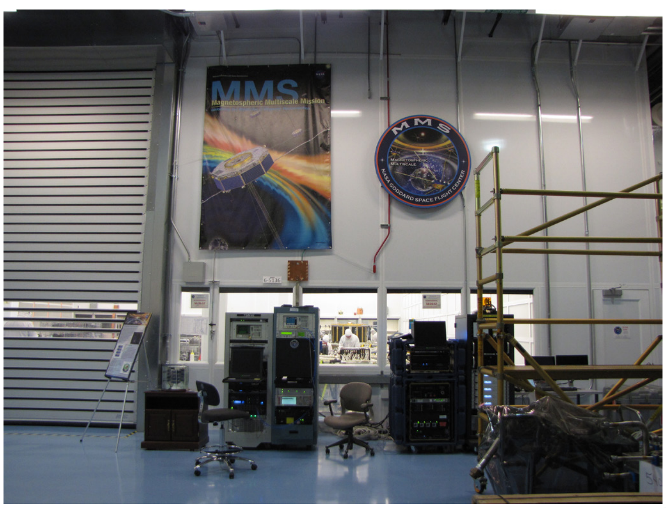
2.4.5 10/120 (Whitehouse) Cleanroom

Size	26.4 m L x 12 m W x 17.9 m H (86’6’’ x 39’2’’ x 58’10’’)
Air Velocity	Variable
Temperature	20°C (68°F) ± 1.11°C (2°F)
Relative Humidity	45 ± 5%
Entrance (Hardware)	Rollup door: 7.6 m W x 12.2 m H (25’ x 40')
Cleanliness	Class 100,000
Other Services	nitrogen, compressed air, house vacuum, fire alarm monitoring, emergency lighting, 4’’ (qty 2) diameter cable pass-throughs, power strip, copper grounds, 10-ton crane
Other Parameters	There are viewing windows on the west side of the clean room (30’8’’ W x 12’6’’ H), with the ability to cover the windows with curtains. A standard exit door has dimensions 36’’ x 92’’

White House Dressing Area

2.4.6 29/160 Cleanroom

Size	18 m L x 21 m W x 5.8 m H (59' x 69' x 19')
Air Flow	Horizontal flow
Air Velocity	60 fpm
Temperature	20° C (68° F) ± 1.11°C (2°F)
Relative Humidity	45 ± 5%
Entrance (Hardware)	High Speed Rollup door: 6.1 m W x 5.7 m H (20' x 18.6')
Cleanliness	Class 10,000 (M5.5)
Other Services	4 nitrogen, 4 compressed air, fire alarm monitoring, emergency lighting, 30"x 40" pass-through area, power strip, copper grounds, fully redundant air-handling system, modular clean-room, 14'' north and south wall touch screen displays indicating clean room environment, 5-ton crane w/ hook height of 5.6 m (18'3''), area outside of cleanroom maintained at 20±4.5° C (72±8° F)
Other Parameters	There is a gowning room that is Class 100 certified and equipped with HEPA filters (2.3 m W x 7 m L x 5.8 m H) in the ceiling. The black-out curtains are available for black light inspections. 208v, 100amp bus rails are on the outside of the clean room for EGSE.



Outside 29/160 Cleanroom

Inside 29/160 Cleanroom

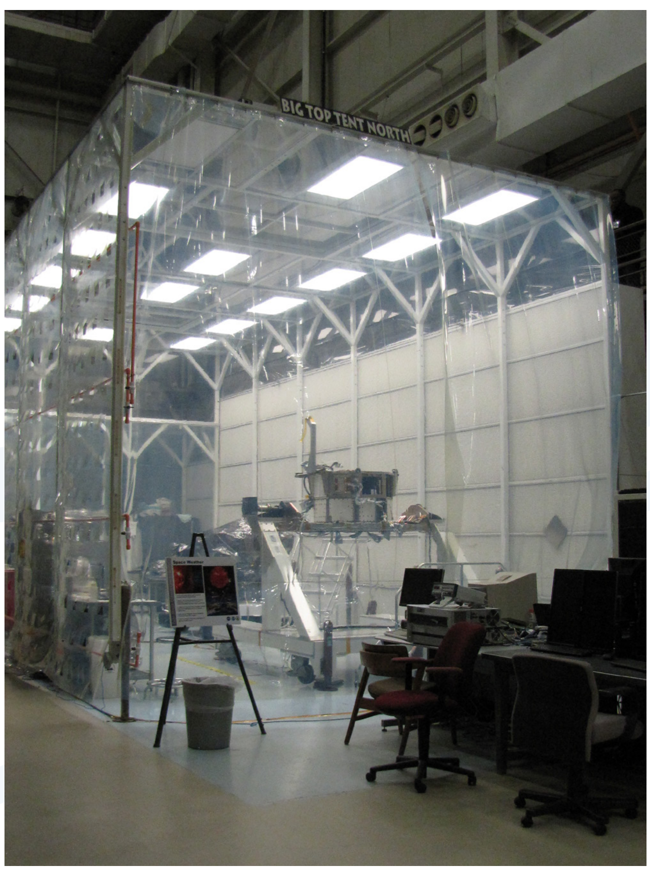
2.4.7 29/150 Cleanroom

Size	18.3 m L x 9.4 m W x 8.2 m H (59.9' x 31' x 27')
Air Flow	Horizontal flow
Air Velocity	Variable
Temperature	Variable
Relative Humidity	Variable
Entrance (Hardware)	Roll-away door: 7.6 m W x 8.1 m H (24.9' x 26.5')
Cleanliness	Class 10,000 (M5.5)
Other Services	5-ton overhead crane

2.4.8 Cleanroom Tents

Building 7 High Bay (150 Tent)	
Size	6.1 m W x 9.1 m L x 4.7 m H (20' x 30' x 15.4')
Air Flow	1,303 m^3/min (46,000 ft^3/min) - vertical flow
Cleanliness	Class 10,000 (M5.5)
Crane	227 Kg (500 lb) hoist
Air Velocity	30 m/min (100'/min)
Entrance	6.1m W x 4.7m H (20' x 15.4') roll up curtain
Tent Material	anti-static polyethylene
Temperature/Humidity	Building 7 HVAC

Building 10 High Bay (Big Top Tent)	
Size	11.3 m W x 5.5 m L x 5.3 m H (37' x 18' x 17.5')
Air Flow	1,869 m^3/min (66,000 ft^3/min) - horizontal flow
Cleanliness	Class 10,000 (M5.5)
Air Velocity	30 m/min (100'/min)
Entrance	5.5 m W x 5.3 m H (18' x 17.5') roll up curtain
Tent Material	305 micron (12 mil) PVC
Temperature/Humidity	Building 10 HVAC



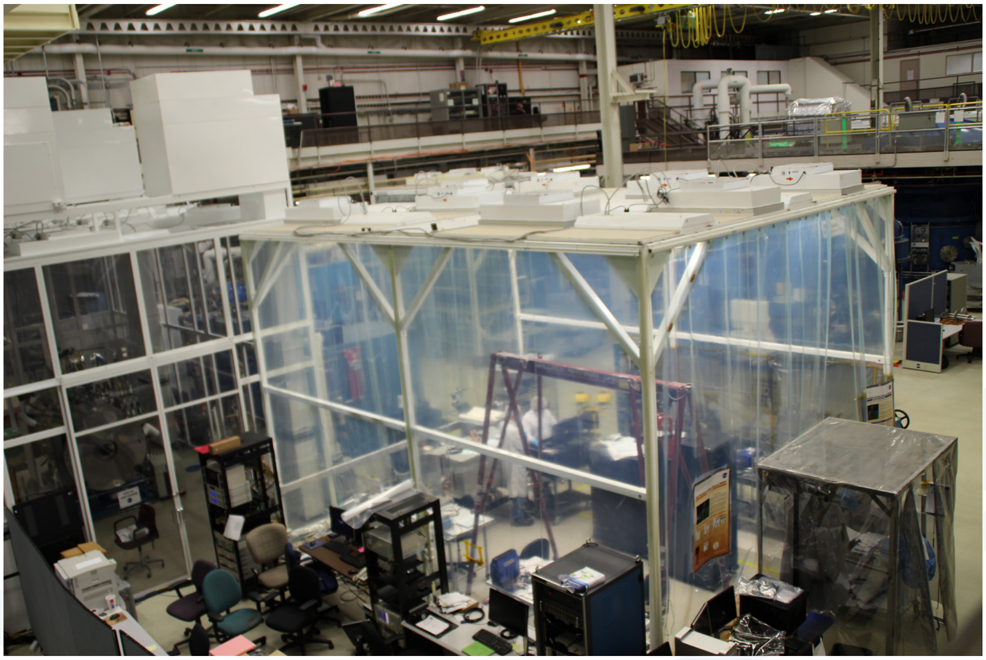
Building 10 High Bay Clean Tent

2.4.9 Special Payloads Operations and Testing (SPOT) Clean Tents

Description: There are four (4) movable SPOT tents that may be used separately, or together, to provide integration and test areas. The down-flow tents have wheels attached to their legs for easy positioning. Two of the four tents have crane access hatches in the ceiling for payload handling.

Mode of Operation: Normally, the tents are monitored each week when in use, depending on the protocol established by the user. The tents are cleaned on an "as required" basis, and cleanroom garments are supplied as required by the cleanliness specification and project activity level.

Spot Clean Tents	
Size	6.1 m L x 4.9 m W x 4.9 m H (20' x 16' x 16')
Air Velocity	27 m/min (90'/min)
Cleanliness	Class 10,000 (M5.5)
Temperature/Humidity	Not controlled (subject to building's ambient conditions)
Other Parameters	Wheels on all four legs, crane access hatch in ceiling on certain tents, static dissipative tent material



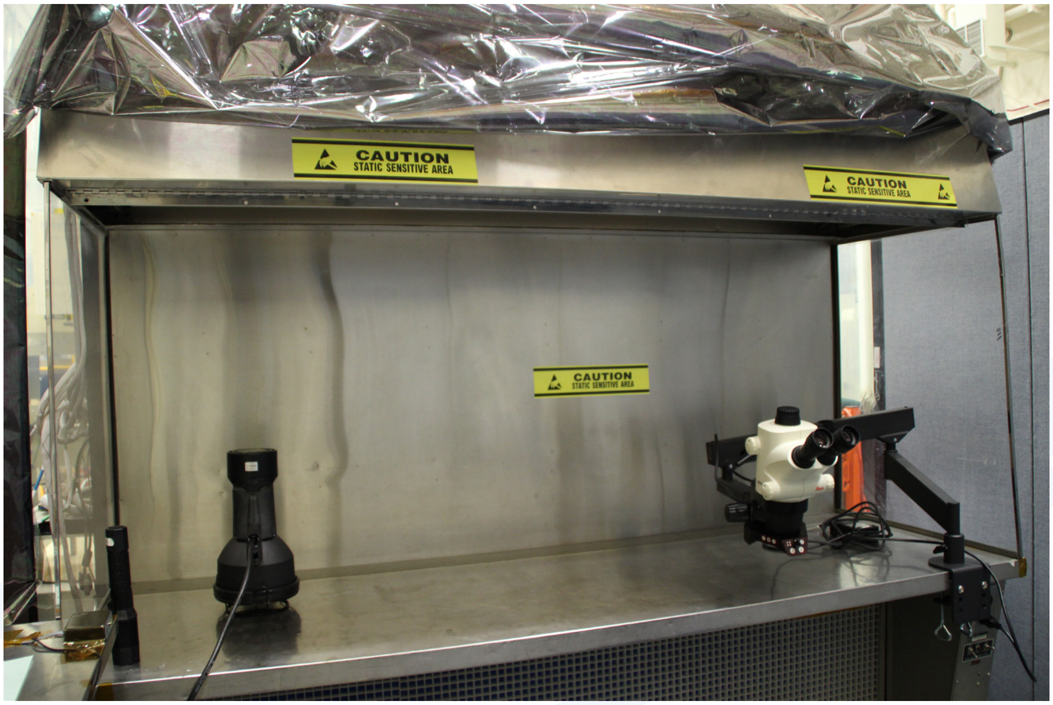
Spot Clean Tent

2.4.10 Portable Down Flow Tents

Portable Down Flow Tents	
Size	1.22 m W x 2.44 m L x 3.66 m H (4' x 8' x 12')
Cleanliness	Class 10,000 (M5.5)
Temperature/Humidity	Not controlled (subject to building's ambient conditions)
Support	Free standing (usually have wheels on all four legs)
Other Notes	Tents can be interlocked to form a 2.44m W x 2.44m L (8' x 8') module. They have side curtains of anti-static nylon, and ceiling-installed fluorescent lights. Blower units are either integral in the ceiling or stand-alone units on the floor.

2.4.11 Unidirectional Flow Clean Bench

Several unidirectional flow clean benches are available. The working areas range from 1.22 m (4') wide, 0.61 m (2') deep, and 0.61 m (2') high, to 1.52 m (5') wide, 0.91 m (3') deep, and 0.91 m (3') high.
The entire back wall of the clean bench is a high efficiency filter through which air passes at 30 m/min (100'/min). The unit has no air conditioning, but may containing lighting. These benches can be maintained at an air cleanliness classification of class 100 (M3.5).



Unidirectional Flow Clean Bench

2.4.12 Portable Particle Counters

There are four 0.028 m^3/min (1.0 ft^3/min) and two 0.0028 m^3/min (0.1 ft^3/min) portable automatic particle counters. The particle counters can be used for certifying cleanrooms and other cleanroom devices.

2.4.13 Pressure, Temperature and Humidity Monitoring

Provisions have been made to monitor room air pressure, temperature, and humidity in the CIA, SCA, RFI, and MB C220 vibration test cell. Each area is equipped with temperature and humidity chart recorders and a Magnehelic differential pressure gauge. These are direct reading instruments whose displays are monitored by viewing them near the front windows of the cleanrooms.

2.4.14 Contamination Monitoring and Analysis Lab

The Contamination Monitoring and Analysis Laboratory is located in the SSDIF Precision Cleaning Room. The lab is equipped with microscopes and an image analysis system for qualitative and quantitative analyses. A typical sample is taken to the lab in a clean container, the container is opened in the cleanroom, and the sample is placed under a microscope for a particulate count. When identification of the particles is required, the sample is studied using the image analysis system or the polarizing light microscope. Photographs may be taken and saved. After the contaminant has been identified, it can be traced to its origin, and steps can be taken to eliminate the source.

2.4.15 Spacecraft Systems Development and Integration Facility (SSDIF), Bldg 29

Description: The SSDIF is a 7,989 m^2 (86,000 ft^2) facility designed to provide support for the integration and testing of spacecraft hardware. It is unique in the fact that it contains a 36,816 m^3 (1.3 million ft^3) horizontal, unidirectional flow cleanroom. Additional features include: Automated Data Processing Area, Shipping/Receiving Area, Flight Hardware Storage Area, and Precision Cleaning facilities.

SSDIF High Bay Cleanroom

Description: The High Bay Cleanroom is a 1,161 m2 (12,500 ft2), class 10,000 (M5.5), horizontal unidirectional flow cleanroom. It has been designed to support the integration and testing of flight hardware and has the capacity to accommodate two full-sized shuttle payloads simultaneously. A cable tray provides data cable access to the Automated Data Processing Room. Access to the cleanroom is via a 7.6 m x 12.2 m (25’ x 40’) overhead roll up door. Two 31,752 Kg (35 ton) cranes, with hook heights of 21.0 m (69’) and 24.4 m (80’), provide lift and transport capabilities. Materials of construction have been selected, and procedures designed, to minimize molecular and particulate contamination levels within this facility.

Mode of Operation: A computer-based automatic control system monitors and controls environmental parameters on a 24-hour basis. Only approved personnel and materials are allowed to enter the cleanroom, and procedures are strictly enforced to maintain cleanliness of the facility. On-site contamination control personnel provide cleanroom support services such as: certification, monitoring, facility cleaning, maintenance of the change room, and precision cleaning.

Size	38 m L x 30 m W x 27 m H (125' x 100' x 89')
Cleanliness	Class 10,000 (M5.5) Automatic real time monitoring
Air Velocity	30 m/min (100'/min), minimum
Temperature	18.3 to 23.9° C (65 to 75° F)
Relative Humidity	48 ± 4%
Entrance (Hardware)	Roll up door: 7.6 m W x 12.2 m H (25' x 40')
North Wall Hepa Filter Bank	836 m^2 (9,000 ft^2) @ 25,488 m^3/min (900,000 ft^3/min) - horizontal flow
Bonded Storage	Two identical areas, one atop the other
Cranes: 2 Ea Of 31,752 Kg (35 Ton)	Hook heights of 21.0 m (69') and 24.4 m (80')
Other Services: Central Vacuum Cleaning System, Compressed Air And Nitrogen, Intercoms, Telephones, Video Monitoring	Vacuum outlets near columns C-2, C-8, D7-8, E-2, F-4, F-6 (Other services located as required)

SSDIF High Bay Cleanroom

SSDIF Precision Cleaning Room

Description: The Precision Cleaning Room is a 55 m^2 (592 ft^2), Class 1,000 (M4.5), horizontal, unidirectional flow cleanroom. It was designed to supply precision cleaning services for spacecraft hardware and ground support equipment. This area contains the necessary services, equipment, and supplies, including a Quadrex Shear Stress Precision Cleaning System.

Mode of Operation: : The facility is staffed with trained precision cleaning personnel providing a variety of cleaning services. Complete, detailed procedures govern all applications, and QA personnel provide inspection capability for all cleaned parts. Access to the facility is restricted, and operations are supported by a 46 m^2 (500 ft^2) Pre-Cleaning Room.

Size	8.5 m L x 6.4 m W x 3.0 m H (28' x 21' x 10')
Cleanliness	Class 10,000 (M5.5) Periodic monitoring
Air Velocity	30 m/min (100'/min), minimum
Temperature	18.3 to 23.9° C (65 to 75° F)
Relative Humidity	40 to 50%
Entrance (Hardware)	Two 1.83 m (6') double doors, one with airlock; also a passthrough
Hepa Filter Bank	26 m^2 (280 ft^2) @ 793 m^3/min (28,000 ft^3/min) - horizontal flow
Other Services:	Services are located as required - See facility layout drawings for details. Central vacuum cleaning system, shear stress precision cleaning system, compressed nitrogen, video monitoring, communication system

3.0 FACILITY SUPPORT SERVICES

A variety of services are needed to support the integration and test activities within the I&T Complex. Code 549 maintains and upgrades theses systems to ensure all activities within the complex occur seamlessly and safely. If utilities or capabilities are needed in a work area where they don't currently exist, they probably can be provided. Contact your Code 549 representative for more information.

3.0 FACILITY SUPPORT SERVICES

3.1 ELECTRICAL POWER

3.1.1 Normal House Power (Commercial)

Normal house power in buildings 7, 10, 15, & 29 complex consists of the following circuits:

Voltage (AC)	Hz	Phase	Current (Amp)
120/208	60	3	Up to 100
277/480	60	3	Up to 100

The primary electrical source to each bldg consist of 2-13.8 kVA feeders

- Each building has a total of 2-loadcenter
- Each Load Center is double-ended with an open tie breaker
- One Load Center is for 120/208 voltage system
- One Load Center is for 277/480 voltage system

Designated circuits in Bldgs. 7 and 10 are backed up by an emergency generator power source. It should be noted that all transformers are Y connected with the center tap grounded.

Instrument grounding plates are available throughout the complex.

3.1.2 Emergency Power Systems

Building 7 & 10 Emergency Power

Description: The emergency power systems for the test facilities in Buildings 7 and 10 consist of a 350-kVA diesel generator (Bldg-10) and a 500-kVA diesel generator (Bldg-7), respectively. The generators and their associated switchgear cabinets are permanently installed at each location.

Mode of Operation: Each generator will start and transfer automatically to the building supply when commercial power has been lost longer than 15 seconds. Due to the limited capacity of these units, normal procedure after a power failure is to initiate an orderly restart of selected facilities up to the capacity of the emergency system. For a power outage, test conditions are maintained for at least one hour by the emergency generator, or until commercial power has been restored satisfactorily.

Bldg. 10 Emergency Gen.

Building 10 Helium Skid Emergency Power

Description: The Helium Skid is equipped with a permanently installed 400 kVA uninterruptible power supply (UPS) to provide power conditioning, and protection against shutdowns resulting from either a momentary sag or complete loss of power. A portable 750 kVA generator is also available on an as-needed basis.

Mode of Operation: The UPS will provide a minimum of 5 minutes of uninterruptible power, allowing time for the generator to come on line. If commercial power is lost for more than 20 seconds (adjustable time delay), the generator will start and transfer automatically as soon as the voltage and frequency have stabilized. When commercial power is reestablished, the system will automatically transfer back to commercial power also following a preset adjustable time delay.

3.2 HIGH PRESSURE GN_2 GENERATING & STORAGE SYSTEMS (FACILITIES 258 AND 263)

Description: There are separate high pressure GN_2 generating and storage systems for Buildings 7 and 10. The Building 7 system is comprised of two liquid pressurization pumps , an ambient air heat exchanger, and a manifolded rack of forged steel gas storage bottles. The Building 7 system has a dual pump arrangement with a single ambient air heat exchanger. The Buildings 7 and 10 GN_2 storage systems are connected, and both are filled by the Building 7 GN_2 system, with the Building 10 GN_2 system serving as a hot backup.

Mode of Operation: The high pressure pump increases the liquid pressure to 13.8Mpa (2,000 psig). The liquid is evaporated in the heat exchanger and transferred to the storage bottles which are maintained at 14.1 MPa (2,045 psig) maximum. The gas is withdrawn for use in each building after a two-stage pressure reduction to 2.4 MPa (350 psig) and 0.69Mpa (100 psig), respectively.

Parameters

GN_2 generation:	227 standard m^3/hr (8,000 ft^3/hr) each pump
Storage capacities:	Bldg. 7 – 719 standard m^3 (25,400 ft^3)
Bldg. 10 – 2,322 standard m^3 (82,000 ft^3)	

Physical Characteristics

	Building 7	Building 10
Pressurizing engine pump:	1	2
LN_2 storage dewar – 1,893 lit (500 gal):	1	1
Vaporizing heat exchanger:	1	1
Storage bottles:	3	25

Bldg 10 Vaporizer

Bldg 10 GN_2 Storage Bottles

3.3 CRANE CAPACITIES

It is recommended that crane users conduct a site inspection to verify limit switch repeatability if their job requires hook heights within a few inches of the limits shown below. For example, gear-type limit switches may repeat within only a couple of inches on some cranes.

*TYPE (Except as otherwise noted, the cranes are bridge cranes.)
a - Variable hoist control;
b - Trolley crane (no bridge)
c - Hoist only (no trolley or bridge)
d- Dual trolley; e - Wooden traversing

Bldg/Crane No.	Location	*Type	Capacity Kg (Ton)	Hook Height m (ft & in)
7-4	Rm 040, Vib Lab		6,805/ (7.5)	13.5/(44'3") To Basement 7.7/(24'3") To B10 Floor
7-6	Rm 036, Vib Lab		6,805/(7.5)	13.2/(43'4") To Basement 7.1/(23'4") To B10 Floor
7-9	Rm 026, Vib Lab	b	1,814/(2)	4.4/(14'6")
7-10	Rm 026, Vib Lab	b	1,814/(2)	4.7/(15'5")
7-13	Truck lock	a	9,072/(10)	10.6/(34'8")
7-14	Rm 190A, Integration	b	1814/(2)	4.3/(14'1")
7-15	Rm 190A, Integration	b	1814/(2)	4.2/(13'11")
7-16	High Bay Lab		4,536/(5)	8.5/(28')
7-17	High Bay Lab		4,536/(5)	8.5/(28')
7-18	SCA Clean Room	a	4,536/(5)	8.3/(27'3")
7-19	CIA Clean Room	a	6,804/(7.5)	13.1/(43'1") To Basement 8.6/(28'4") To 1st Floor
7-30	Acoustic Chamber		6,804/(7.5)	8.7/(28'7")
10-1	High Bay Lab	a	13,608/(15)	20.1/(66')
10-2	White House Clean Rm	a	9,072/(10)	15.2/(50')
15-2	High Bay Lab	a	6,804/(7.5)	11.9/(39'1")
15-3	HCC Rotunda (east)	b	2,722/(3)	7.7/(25'3")
15-4	HCC Rotunda (west)	b	6,804/(7.5)	7.9/(26')
15-5	Modal Test Facility	a	907/(1)	6.7/(22')
15-6	Modal Test Facility	a	454/(0.5)	5.8/(19')
15-7	Modal Test Facility	a	454/(0.5)	4.9/(16')
29-1	SSDIF Clean Room	a	31,752/(35)	21/(69')
29-2	SSDIF Clean Room	a	31,752/(35)	24.4/(80')
29-3	Rm 140, High Bay	a	31,752/(35)	20.3/(66'9")
29-4	High Bay Blue Facility	a	31,752/(35)	20.2/(66'4")
29-5	Rm 150	a	4,536/(5)	11.6/(38)
303 30-8, Sml Coil	Central Coil Building	e	1,089/(1.2)	7.6/(25')
305 30-1, Lge Coil	Inner Truck Lock	b	2,722/(3)	4.2/(13'10")
305 30-2, Lge Coil	South Side of Building	c	2,268/(2.5)	6.7/(22')
305 30-3, Lge Coil	Coil Centerline	c	2,268/(2.5)	5.8/(19')
305 30-4, Lge Coil	Outer Truck Lock	b	2,268/(2.5)	5.8/(19')

3.4 HYDRASETS

Hydrasets are hydraulic, remotely-controlled lifting devices which are placed between the crane hook and the load. They can position a load vertically in increments of 0.025 mm (0.001”). Each is proof-tested at 200% of the rated load, and tested at 125% of payload, before lifting flight hardware. All are exercised monthly; this is in addition to other routine testing and maintenance.

Manual-Type Hydrasets

Capacity (lb)	Gage	Stroke (in)
1000	Digital	12
2000	Analog	12
5000	Digital	12
10000	Analog	12
10000	Analog	6

Manual-Type Hydraset

3.5 LIFTING AND HANDLING DEVICES

The following hardware handling and personnel lifting devices are available:

Fork Lifts

Type	Capacity (lb)	Platform Size (ft)	Lift Height (ft)
Fork Lifts			
Yale	10,000	4 x 4	10
Clark	9,500 @ <152" H		
7,500 @ >152" H	4 x 4	25	
Moto-Truc	3,000	3 x 2.6	11
EZ Lift (3 each)	1,500	2.3 x 2.1	5.4
Flat Bed Electric Truck	4,000	8 x 3	0.33
Tow Tractors			
PettiBone	3,000	N/A	N/A
Raymond (2 each)	200	N/A	N/A
Lift Tables			
Rol-Lift Pallet Jack (2 each)	5,500	4 x 2.3	0.5
Economy Lift Table (2 each)	1,000	3 x 2	1
Raymond Pallet Jack	1,000	4 x 2.3	0.5
Personnel Lifts			
Genie 3003	500	29" x 64.5"	19
Genie 3007A	500	29" x 64.5"	19
Genie 3211(LDE RECERT)	500	32" x 89"	26
Skyjack	500	31" x 87.25"	20
Upright Flying Carpet	2,000	12 x 7	36
Marklift 26	1,000	3.8 x 8.2	26
Marklift 20 (2 each)	800	2.5 8.2	20
Upright XL-24	750	5.5 x 3	18
Upright Air-Deck	500	8 x 3	24.7
JLG-45HA	500	3 x 2	45
JLG-60	500		60

3.6 DOORWAY AND OTHER CLEARANCES

These dimensions are listed to assist flight projects in their logistic planning efforts. Building modifications or staged hardware may cause these dimensions to change or otherwise obstruct movement of hardware. Prior to moving large items, passageways should be walked down and/or coordinated with the FOM. All items left in the complex must be labeled with the name, phone number and project of the person responsible for them.

Door Location	Description	Dimensions (W x H)
B7 to B10	Roll Up Door	19’2” x 19’3”
B7 Rm 008 (Small RFI) to Basement	Hinged Doors	7’ x 7’3”
B7 Rm 026 (Small Vibe Cell) to Basement	Hinged Doors	8’ x 16’8”
B7 Rm 036 (North Vibe Cell) to B10 Rm 100 (High Bay)	Hinged Doors	16’2” x 29’5”
B7 Rm 040 (South Vibe Cell) to B10 Rm 100 (High Bay)	Hinged Doors	16’2” x 29’5”
B7 Rm 108 (SCA North) to Rm 150 (High Bay)	Roll Up Door	19’6” x 19’7”
B7 Rm 108 (SCA South) to Rm 150 (High Bay)	Roll Up Door	19’6” x 19’7”
B7 Rm 108 (SCA) to Rm 108A (Large RFI)	Hinged Doors	18’6” x 17’11”
B7 Rm 108 (SCA) to Rm 108B (CIA)	Roll Up Door	12’1/2” x 11’
B7 Rm 150 (High Bay) to Rm 190 (Integration Area)	Roll Up Door	11’11” x 13’9”
B7 Truck Lock to B10	Roll Up Door	16’ x 12’11”
B7 Truck Lock to Outside	Roll Up Door	15’2” x 14’9”
B7 Truck Lock to Rm 190 (Integration Area)	Roll Up Door	11’11” x 13’9”
B10 to B15	Roll Up Door	19’6” x 19’11”
B10 to B29	Leaf Door	25’ x 40’
B10 Rm 110 (Acoustics Fac) to B10 Rm 100 (High Bay)	Hinged Doors	14’11” x 33’10”
B10 Rm 120 (White House) to B10 Rm 100 (High Bay)	Roll Up Door	25’ x 40’
B15 to HCC Rotunda	Hinged Doors	24’ x 23’6”
B15 to Outside	Roll Up Door	23’11” x 20’7”
B29 Rm 130 (SSDIF) to Rm 140 (High Bay)	Leaf Door	25’ x 40’
B29 Rm 140 (High Bay) to Outside	Roll Up Door	25’ x 25’
B29 Rm 140 (High Bay) to Rm 150	Roll Up Door	25’ x 25’
B29 Rm 140 (High Bay) to Rm 160	Roll Up Door	20’ x 19’6”
B29 Rm 160 to Outside	Roll Up Door	16’6” x 18’
B29 Rm 160 to Rm 160A (Cleanroom)	Roll Up Door	20’ x 19’6”

Other Clearances	Description	Dimensions (W x H)
B7 Bridge over B7 – B10 Corridor	Walkway	17’10” to 16’6”
B7 Duct over B7 – B10 Corridor	HVAC Duct	18’ x 19’2”
B7 Freight Elevator	Elevator	10’ x 9’7” x 7’6”
B7 Lift (Vibe Area to Basement Floor)	Elevator	5’10” x 8’5” x 8’8”
B7 Floor Hatch near Freight Elevator	Floor Hatch	12’10” x 16’10”
B10 Floor Hatch near SES Chamber	Floor Hatch	10’ x 20’
B10 Floor Hatch near Truck Lock	Floor Hatch	9’ x 10’

3.7 AIR BEARING SUPPLY STATIONS

The house air system delivers compressed air at 621Kpa (90psig) pressure with a maximum volume of 2.83m3(100ft3)/min. Connections are via a Hansen 2.54cm (1”) quick disconnect and are available at the following locations:

Building	Room	Location
B 7	High Bay	South wall (west)
B 7	High Bay	South wall (center)
B 7	High Bay	South wall by Rm 188 (east)
B 15	High Bay	West Wall
B 10	High Bay	B15 High Bay door
B 10	High Bay	B7 High Bay door
B 10	High Bay	Truck Lock door
B 29	SSDIF	Center Mezzanine Column
B 29	SSDIF	NE corner
B 29	140 (High Bay)	South Wall
B 29	140 (High Bay)	North Wall

3.8 AIR BEARINGS

Description: Air bearings and matching jacks provide both mobility and vertical height adjustment of the load. By bolting the air bearings to an object and applying air pressure, the object rides on a cushion of air and is easily moved and maneuvered. The jacks, which are attached to the air bearings, are needed to raise the load off the floor before air pressure is applied.

Quantity	Size	Capacity
4	41 cm (16”) diameter	907 Kg (2,000 lb)
4	56 cm (22”) diameter	1,814 Kg (4,000 lb)
4	71 cm (28”) diameter	2,722 Kg (6,000 lb)
4	86 cm (34”) diameter	4,536 Kg (10,000 lb)
4	30 cm L x 30cm W (12” x 12”)	907 Kg (2,000 lb)
4	69 cm L x 69cm W (27” x 27”)	5,443 Kg (12,000 lb)

3.9 GN_2 PURGE OUTLETS

Description: Gaseous nitrogen is available for purge at various locations in the cleanrooms. A GN^2 supply can be installed for special applications at any location in the Building 7/10/15/29 complex when defined by the experimenter in advance.

Location	Supply Line	Maximum Delivery Pressure	Connection
SCA Cleanroom (4 Locations)	0.95cm (3/8") Nominal	621 kPa (90 psig)	0.64cm (1/4") Swagelok fitting
CIA Cleanroom (2 Locations)	0.95cm (3/8") Nominal	621 kPa (90 psig)	0.64cm (1/4") Swagelok fitting
SSDIF Cleanroom (6 Locations)	1.3cm (1/2") Nominal	621 kPa (90 psig)	0.64cm (1/4") Swagelok fitting
SES Chamber (3 Locations)	1.3cm (1/2") Nominal	621 kPa (90 psig)	0.64cm (1/4") Swagelok fitting
Acoustic Chamber (1 Locations, column 16K)	0.95cm (3/8") Nominal	621 kPa (90 psig)	0.64cm (1/4") Swagelok fitting
Vibration Cell, Rm 36 (1 Locations)	0.95cm (3/8") Nominal	621 kPa (90 psig)	0.64cm (1/4") Swagelok fitting
Vibration Cell, Rm 40 (1 Locations)	0.95cm (3/8") Nominal	621 kPa (90 psig)	0.64cm (1/4") Swagelok fitting
Thermal Vacuum Chambers, Bldg. 7 (At each facility)	Varies	621 kPa (90 psig)	Varies (All can be adapted to 1/4" Swagelok fitting)
MMS Cleanroom (4 locations)	0.95cm (3/8") Nominal	621 kPa (90 psig)	Can be adapted to 1/4" Swagelok fitting
MMS Pre-Clean (Rm 160)(1 location)	0.95cm (3/8") Nominal	621 kPa (90 psig)	Can be adapted to 1/4" Swagelok fitting
Bldg 29 HB NW corner outside of Rm 160 (1 location)	0.95cm (3/8") Nominal	621 kPa (90 psig)	Can be adapted to 1/4" Swagelok fitting

3.10 LN_2 FILL STATIONS

Description: LN_2 stations for dewar filling are provided in the locations shown:

Location	Supply Line	Maximum Delivery Pressure	Connection
Bldg. 7 Basement near column G-6	1.3 cm (1/2”) nominal	172 kPa (25 psig)	1.3 cm (1/2”) American National fitting
West wall – Facility 255 LN_2 storage shed	1.3 cm (1/2”) nominal	172 kPa (25 psig)	1.3 cm (1/2”) American National fitting

The requirements to use the fill stations: cryogenic gloves and face shield.

3.11 LN_2 STORAGE VESSELS

Large quantities of liquid nitrogen are maintained to provide cryogenic cooling of cryopumps, cold fingers, diffusion pump cold traps and shrouds of the thermal vacuum chambers in Buildings 7 and 10, and as a supply for the high pressure gas generators. Also, small portable vessels can be filled at the Building 7 facility.

3.11.1 Building 7, 106K Liter (28K Gal) Dewar (Facility 255)

Description: This double-walled, vacuum-jacketed storage vessel is comprised of two concentric, horizontal cylinders. The outer shell, made of carbon steel, is 18.3 m (60') long by 3.7 m (12') in diameter. The inner tank, fabricated from stainless steel, has a capacity of 106 K liters (28,000 gallons) of LN_2 with a 5,299 liter (1,400 gallon) ullage volume. An ambient temperature vaporization coil maintains a tank pressure of 172 kPa (25psig). Valves are provided to control the filling and withdrawal of the cryogenic fluid.

Mode of Operation: Insulated plumbing conducts the cryogenic fluid to a distribution manifold in Building 7, where it is transferred as required to each chamber and withdrawal station through insulated or vacuum-jacketed lines.

3.11.2 Building 10, 242K Liter (64K Gal) Dewar (Facility 257)

Description: This double-walled, vacuum-jacketed LN_2 dewar is comprised of two concentric spheres supported by tubular columns. The 7.9 m (26') diameter inner vessel is constructed of welded aluminum plates and the 8.5 m (28') diameter outer casing is constructed of welded steel plate. The inner tank has a capacity of 242 K liters (64,000 gallons) with a 22.7 K liter (6,000 gallon) ullage volume. An ambient temperature vaporization coil provides a tank pressure of 172 kPa (25 psig). Valves are provided to control the supply and withdrawal of LN_2

Mode of Operation: Insulated plumbing conducts the cryogenic fluid to a distribution panel in the basement of Building 10, where it is directed as required to the cryopumps, the thermal system, and the shroud LN_2 recirculating system.

3.12 PORTABLE AIR CONDITIONING (PAC) UNITS

Introduction: There are four portable air conditioning (PAC) units available in the complex to provide cooling for spacecraft hardware. The PAC units process air by altering its temperature and humidity properties in order to produce an environment to meet the conditions favorable to the projects during hardware integration and testing. The PAC units are maintained by Code 549. Three identical units (Units #1, #2, & #3) use a refrigeration system to remove moisture from the air. The Hackley Unit is a larger unit with a desiccant wheel mechanism that provides additional capability with its refrigeration system for driving out moisture.

Parameters:

Air flow rate:	800 CFM (52 Hz on Variable Frequency Drive)	
HEPA Filter:	99.99% minimum efficiency on 0.3µ particles	
Temperature Control:	±1°F	Alarm Setting: ±2°F
Dehumidification Control:	±3% RH	Alarm Setting: ±5% RH

Note: These systems do not have the capability to add moisture to the air stream and, therefore, cannot increase the relative humidity of dry air.

PAC Units #1, #2, #3


"Hackley Unit"

APPENDIX – A: ABBREVIATIONS, ACRONYMS, & SYMBOLS

Abbreviation Symbol	Translation
“	inch
‘	foot
<	less than
>	greater than
%	percentage
µ	micro
Å	angstrom
A	ampere
AC	alternating current
A/C	air conditioning
amp	ampere
AN	American National
ANSI	American National Standards Institute
B or Bldg	building
°C	degrees Celsius
CCTV	closed circuit television
C/F	cold finger
CFM or cfm	cubic feet per minute
CG	center of gravity
CIA	Calibration-Integration-Alignment
cm	centimeter
col	column
CRT	cathode ray tube
d	diameter
dB	decibel
DC	direct current
DEC	Digital Equipment Corporation

Abbreviation Symbol	Translation
dia	diameter
dim	dimension
ea	each
EMC	electromagnetic compatibility
EMI	electromagnetic interference
°F	degrees Fahrenheit
FM	frequency modulation
fpm	feet per minute
FRF	frequency response function
ft	foot or feet
g	gram
g	unit of acceleration
gal	gallon
GN_2	gaseous nitrogen
GSFC	Goddard Space Flight Center
H	height
HCC	High Capacity Centrifuge
hdwe	hardware
HEPA	high efficiency particulate air
HgXe	Mercury xenon
hp	horsepower
HP	Hewlett-Packard
Hr or hr	hour
HST	Hubble Space Telescope
HVAC	heating, ventilation, and air conditioning
Hz	hertz (cycles per second)

Abbreviation Symbol	Translation
IIF	instrument interface flange
in	inch
ITD	Instrument Test Dewar
IVS	instrument vacuum space
JSC	Johnson Space Center
°K	degrees Kelvin
kB	kilobyte
kg	kilogram
kPa	kilopascal
KSC	Kennedy Space Center
kVA	kilovolt ampere
KW or Kw	kilowatt
L or l	liter
L	length (depth)
Lb or lb	pound
LHe	liquid helium
lit/sec	liter per second
LN_2	liquid nitrogen
LVDT	linear variable differential transformer
M or m	meter
MAP	Microwave Anisotropy Probe
max	maximum
MB	megabyte
MB C220	MB C220 vibration exciter
MicroVAX	DEC computer
MIL STD	Military Standard
min	minute
Mitoc	communications system
MLI	multi-layer insulation
mm	millimeter
MOI	moment of inertia
MPMF	Mass Property Measurement
	Facility
mV	millivolt
NA or N/A	not applicable
NASA	National Aeronautics and Space Administration

Abbreviation Symbol	Translation
NASTRAN	finite element modeling program
NIST	National Institute of Standards and Technology
nom	nominal
nT	nanotesla
OASPL	overall sound pressure level
ohm	unit of resistance
oz	ounce
pa	pascal
PC	personal computer
PCM	pulse code modulation
pH	measure of acidity
P/L	payload
PLC	programmable logic controller
POI	product of inertia
PRT	platinum resistance thermometer
PSD	power spectral density
psi	pounds per square inch
psig	pounds per square inch gauge
QCM	poly vinyl chloride
rad	quartz crystal microbalance
rad/sec	radian
RF	radians per second
RFI	radio frequency
RGA	radio frequency interference
RH	residual gas analyzer
RM or Rm	relative humidity
RMS or rms	room
RPD	root-mean-squared
RPM or rpm	revolutions per minute
RPS or rps	revolutions per second
RTV	room temperature vulcanizer
s	second
SC	solar constant

Abbreviation Symbol	Translation
SCA	Spacecraft Checkout Area
SCADA	Supervisory Control and Data Acquisition
scfm	standard cubic feet per minute
SES	Space Environment Simulator
SMTF	Spacecraft Magnetic Test Facility
SPL	sound pressure level
t	thickness
T	tesla
T/C	thermocouple
temp	temperature
torr	1/760 of a standard atmosphere
TQCM	thermoelectric quartz crystal Microbalance
TVDS	Thermal Vacuum Data System
UD	Unholtz-Dickie
UV	ultraviolet
V	volt
VA	volt ampere
Vac	vacuum
vol	volume
W or w	watt
W	width

Appendix – B: Metric/English Conversion Factors

Convert From:	To:	Multiply By:	Convert From:	To:	Multiply By:
amp/centimeter	amp/inch^2	6.45	amp/inch^2	amp/centimeter^2	0.155
amp/decimeter^2	amp/ft^2	9.09	amp/ft^2	amp/decimeter^2	0.11
Celsius	Fahrenheit	[C x (9/5)] + 32	Fahrenheit	Celsius	[F-32] x (5/9)
centimeter	inch	0.3937	inch	centimeter	2.54
centimeter^2	inch^2	0.155	inch^2	centimeter^2	6.452
centimeter^2/liter	foot^2/gallon	0.0041	foot^2/gallon	centimeter^2/liter	245
gram	ounce	0.0353	ounce	gram	28.329
gram	pound	0.0022	pound	gram	453.6
gram/centimeter^2	ounce/inch^2	0.228	ounce/inch^2	gram/centimeter^2	4.39
gram/liter	ounce/gallon	0.133	ounce/gallon	gram/liter	7.5
gram/liter	troy ounce/gallon	0.125	troy ounce/gallon	gram/liter	8
kilogram	pound	2.205	pound	kilogram	0.4536
kilogram	ton	0.0011	ton	kilogram	907.2
liter	gallon	0.2642	gallon	liter	3.785
meter	inch	39.37	inch	meter	0.0254
meter	foot	3.281	foot	meter	0.3048
meter^2	foot^2	10.76	foot^2	meter^2	0.0929
meter^3	foot^3	35.31	foot^3	meter^3	0.02832
meter^2/liter	foot^2/gallon	40.82	foot^2/gallon	meter^2/liter	0.0245
micron	microinch	39.4	microinch	micron	0.0254
micron	inch	0.0000394	inch	micron	25400
micron	mil	0.0394	mil	micron	25.4
millimeter	inch	0.0394	inch	millimeter	25.4
newton	pound (force)	0.225	pound (force)	newton	4.45
newton-meter	inch-pound (force)	8.85	inch-pound (force)	newton-meter	0.113
newton-meter	foot-pound (force)	0.7376	foot-pound (force)	newton-meter	1.356
pascal	pound/inch^2 (psi)	0.000145	pound/inch^2 (psi)	pascal	6895
pascal	Torr	0.0075	Torr	pascal	133.32
watt	horsepower	0.00134	horsepower	watt	745.7

Appendix – C: Decimal Prefixes

Prefix	Symbol	Factor
atto	a	10^{-18}
femto	f	10^{-15}
pico	p	10^{-12}
nano	n	10^{-9}
micro	µ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}

Prefix	Symbol	Factor
deka	da	10^{1}
hector	h	10^{2}
kilo	K	10^{3}
mega	M	10^{6}
giga	G	10^{9}
tera	T	10^{12}
peta	P	10^{15}
exa	E	10^{18}