NASA/TM—2013-217816

Space Power Facility—Capabilities for Space Environmental Testing Within a Single Facility

Richard N. Sorge
Glenn Research Center, Cleveland, Ohio

June 2013

NASA STI Program . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) program plays a key part in helping NASA maintain this important role.

The NASA STI Program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NASA Aeronautics and Space Database and its public interface, the NASA Technical Reports Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include creating custom thesauri, building customized databases, organizing and publishing research results.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at *http://www.sti.nasa.gov*

- E-mail your question to *help@sti.nasa.gov*

- Fax your question to the NASA STI Information Desk at 443–757–5803

- Phone the NASA STI Information Desk at 443–757–5802

- Write to:
  STI Information Desk
  NASA Center for AeroSpace Information
  7115 Standard Drive
  Hanover, MD 21076–1320

NASA/TM—2013-217816

Space Power Facility—Capabilities for Space Environmental Testing Within a Single Facility

Richard N. Sorge
Glenn Research Center, Cleveland, Ohio

Prepared for the
27th Space Simulation Conference
cosponsored by IEST, NASA, CSA, AIAA, ASTM, and JHU/APL
Annapolis, Maryland, November 5–8, 2012

National Aeronautics and
Space Administration

Glenn Research Center
Cleveland, Ohio 44135

June 2013

Level of Review: This material has been technically reviewed by technical management.

Available from

NASA Center for Aerospace Information
7115 Standard Drive
Hanover, MD 21076–1320

National Technical Information Service
5301 Shawnee Road
Alexandria, VA 22312

Available electronically at http://www.sti.nasa.gov

Space Power Facility—Capabilities for Space Environmental Testing Within a Single Facility

Richard N. Sorge
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio 44135

Abstract

The purpose of this paper is to describe the current and near-term environmental test capabilities of the NASA Glenn Research Center's Space Power Facility (SPF) located at Sandusky, Ohio. The paper will present current and near-term capabilities for conducting electromagnetic interference and compatibility testing, base-shake sinusoidal vibration testing, reverberant acoustic testing, and thermal-vacuum testing. The paper will also present modes of transportation, handling, ambient environments, and operations within the facility to conduct those tests. The SPF is in the midst of completing and activating new or refurbished capabilities which, when completed, will provide the ability to conduct most or all required full-scale end-assembly space simulation tests at a single test location. It is envisioned that the capabilities will allow a customer to perform a wide range of space simulation tests in one facility at reasonable cost.

Introduction

In 2006, early decisions were made about the required facility capabilities necessary for environmental testing of the NASA Crew Exploration Vehicle (CEV). The basic plan included typical spacecraft environmental tests in several pertinent vehicle configurations. Test needs included Thermal Vacuum, Mechanical Vibration, Acoustic, and Electro-Magnetic Interference/Electro Magnetic Compatibility (EMI/EMC). Initial requirements for facility capabilities were based on analysis of the flight phase environments from launch to earth orbit. An assessment of existing test facilities was performed and concluded that there were no existing facilities that could achieve the mechanical vibration or acoustic test requirements. At that time, the SPF only had thermal vacuum capabilities.

A concept was proposed to transform the SPF into a space environmental test facility. Thermal Vacuum (TV) and EMI/EMC testing would be conducted within the existing TV chamber. The existing west highbay would be cleared of internal structures, providing a footprint for a new large-scale mechanical vibration facility and an acoustic test chamber. Supporting equipment would be added internally and externally, and the existing control room would be completely reconstructed into a new control center. The Orion Project accepted the proposal and construction commenced in August 2007 with SAIC/Benham as the prime contractor for construction of the new test capabilities. The major construction tasks were completed in September, 2011 with some remaining open work on the mechanical vibration facility. Other facility preparatory work on thermal vacuum capabilities and EMI/EMC capabilities were completed in early 2012.

This paper documents the current facility capabilities and the near-term work towards providing a fully-capable environmental test facility. An aerial photograph of the Space Power Facility is shown in Figure 1.

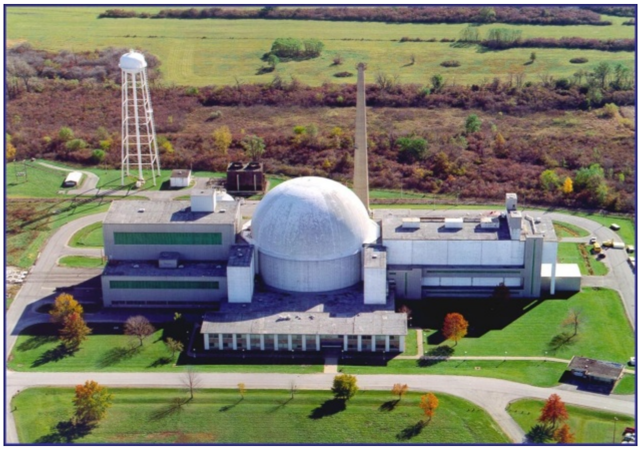

Figure 1.—Aerial photograph of the Space Power Facility.

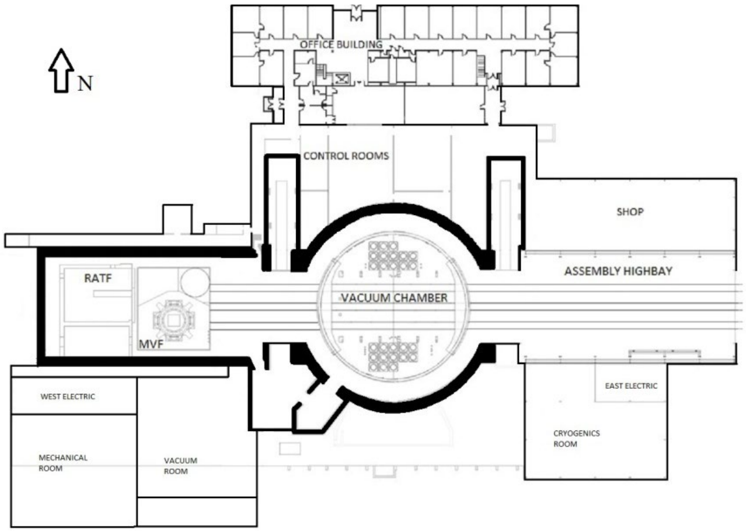

Figure 2.—Space Power Facility plan view.

Overall Layout/Configuration

The SPF was originally constructed in 1969 to perform nuclear and non-nuclear testing of large space systems needed for advanced missions beyond low-Earth-orbit. The facility was designed with excess capacity such as extremely large high-bays, doors, power systems, and supporting infrastructure to accommodate expanding test requirements well into the future of the space program. The SPF aluminum vacuum chamber surrounded by the concrete vacuum enclosure is central to the facility. The large east and west chamber doors (15 by 15 m) lead directly into large highbays. The highbay on the East side of the facility, the Assembly Highbay, is primarily used for receiving, assembling, and preparing test hardware. The highbay on the West side of the facility, the Disassembly Highbay, was originally constructed to safely disassemble nuclear components. The recent construction project converted this area into the Vibroacoustic Highbay, housing the Mechanical Vibration Facility (MVF) and the Reverberant Acoustic Test Facility (RATF). North and South of the chamber and highbays are various supporting areas. North of the chamber are the facility control rooms, signal conditioning and instrumentation areas, machine shop, and two-story office building. The office building contains 41 offices and 4 conference rooms. South of the chamber are the electric sub-stations, cryogenics room, vacuum room, and mechanical rooms. The South outdoor courtyard areas behind the SPF support the liquid and gaseous nitrogen storage bottles, vaporizers, and cooling tower. A plan view of the SPF is shown in Figure 2.

Capabilities and Description of the Test Facilities

The SPF was ideal for augmentation of environmental test capabilities to meet the demanding test requirements of the Crew Exploration Vehicle. The existing facility layout provided the ability to construct new capabilities, which allow complete space environmental testing in one location, eliminating the need for costly tear down and movement of critical space flight hardware from one facility to another. As shown in Figure 3, the new Reverberant Acoustic Test Facility and Mechanical Vibration Facility are located in the west Vibroacoustic Highbay, adjacent to the existing vacuum test chamber. The vacuum chamber has been modified to serve a dual-use purpose; thermal/vacuum test capability, and EMI/EMC test capability. The all aluminum construction of the vacuum chamber with its unique internal geometry provides an ideal self-contained environment for reverberant-mode EMI/EMC testing. A 1,024-channel high-speed Facility Data Acquisition System (FDAS) has been installed for conditioning and acquiring instrument data from the MVF and RATF facilities, and the architecture of this system has been leveraged for use with the thermal vacuum facility.

Thermal Vacuum Chamber

The Thermal Vacuum chamber has a volume of 22,653 m^3 (800,000 ft^3) and measures 30.5 m (100 ft) in diameter and 37.2 m (122 ft) high with 15.2 m (50 ft) by 15.2 m (50 ft) loading doors on each side leading to highbays. The chamber features all aluminum construction, including a removable polar crane with an 18.1 MT (20 ton) critical lift trolley and a 9.1 MT (10 ton) auxiliary hook, and a removable, reconfigurable, cryoshroud system. The chamber cryoshroud system can provide both warm and cold thermal background environment, data acquisition, and test monitoring capabilities. The vacuum chamber is surrounded by an equal-volume concrete enclosure which is typically reduced in pressure to 20 torr during chamber operations.

The vacuum chamber incorporates several electrical and instrumentation penetrations, and several blank penetrations at various locations around the chamber perimeter. Removable rail tracks in the chamber can be used in conjunction with rail dollies or the cryoshroud floor(s) to transport hardware or test articles through the facility and chamber. The facility provides a visually-clean environment. The chamber provides an empty-chamber vacuum capability of $2´ 10^{-6}$ torr using a combination of roughing pumps and high-vacuum equipment. The roughing system consists of two identical 5-stage, parallel trains of rotary-lobe blowers and rotary-piston mechanical pumps, which pump the chamber and annulus simultaneously to 20 torr, and subsequently the chamber only to 30 mtorr. High-vacuum is achieved using 5 turbomolecular pumps and 10 cryogenic pumps. The chamber can reach a vacuum level of $2´ 10^{-6}$ torr in less than 8 hr.

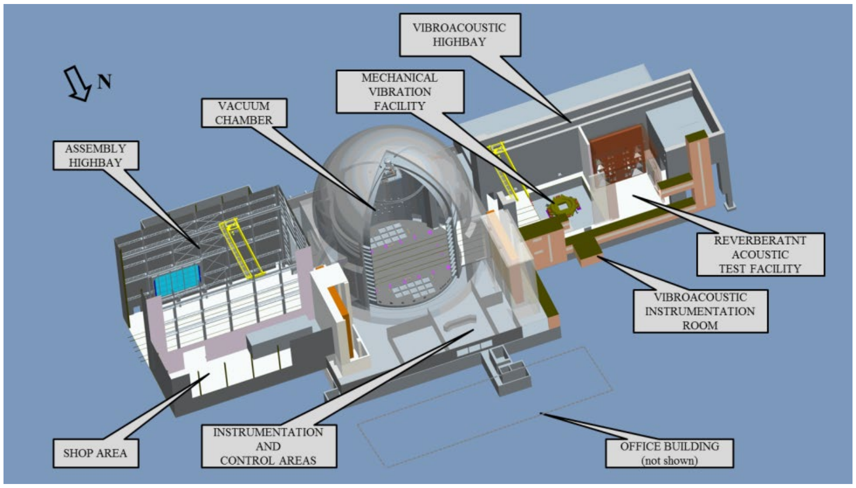

Figure 3.—SPF cut-away.

The facility uses a removable, reconfigurable, cryoshroud for background heating and cooling. The cryoshroud is warmed and cooled using a recirculating gaseous nitrogen system. The system utilizes compressor heat-of-compression to provide up to 60 °C (140 °F) wall temperatures, and a heat exchanger/liquid-nitrogen desuperheater to provide temperatures down to –160 °C (–250 °F). The facility is in the process of installing the ‘baseline’ cryoshroud configuration, a 12 m (40 ft) diameter by 12 m (40 ft) high cylinder centered in the chamber. The chamber provides in-chamber power connections and closed-loop controls for up to 33 channels of 1200 W heater power.

Data is acquired in the thermal vacuum facility via the Mobile Data Acquisition System (MDAS). Below are some approximate characteristics of the vacuum chamber.

Chamber Parameters:

Test Pressure:	<2´ 10^{-6} torr
Cryoshroud Temperature:	–160 to 60 °C (–250 to 140 °F)
Chamber Pumping Speed:	500,000 liter/sec at 10^{-6} torr

Instrument Penetrations (Varies by Test):

Type ‘T’ Thermocouple:	540
Multi-Alloy Thermocouple:	102
37-Pin Connectors:	129
BNC Coaxial Connector:	126
Ethernet:	6
Multi-Mode Fiber:	12

Physical Characteristics:

Chamber Diameter:	30.48 m (100 ft)
Chamber Height:	37.18 m (122 ft)
Chamber Volume:	22,653 m^3 (800,000 ft^3)
Blank ports:	3 each, 0.5 m dia.
Blank ports:	10 each, 0.68 m dia. (alternately used for high-power feed-through)
Blank ports:	1 each, 0.68 m dia.

Figure 4 shows an elevation cross-sectional view of the vacuum chamber/concrete enclosure.

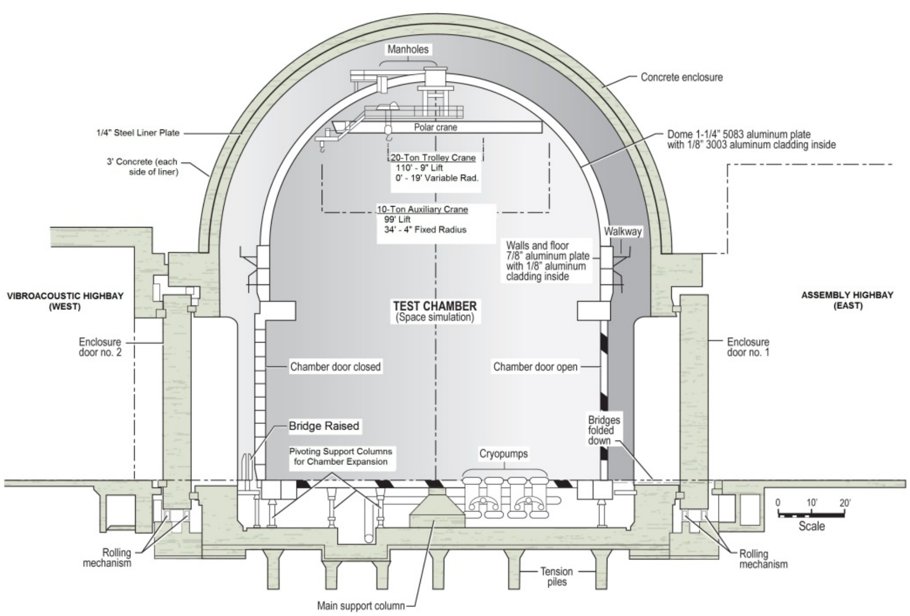

Figure 4.—SPF chamber elevation.

Reverberant Acoustic Test Facility

The RATF chamber is located within the Vibroacoustic Highbay, taking advantage of the 1.8 m (6 ft) thick surrounding concrete walls to help attenuate sound migration through the SPF. The highbay also serves as redundant protection from the RATF nitrogen atmosphere during operation. The RATF is a 2,860 m^3 (101,189 ft^3) reverberant acoustic chamber capable of achieving an empty-chamber acoustic overall sound pressure level (OASPL) of 163 dB. The facility structure is designed for a future upgrade to 166 dB OASPL, including areas in the horn room wall which have been left blank for future installation of additional modulators/horns. The RATF includes various supporting sub-systems including gaseous nitrogen generation system, horn room with acoustic modulators and horns, acoustic control system, and hydraulic supply system. Test articles are mounted onto elevated customer-provided mounting fixtures for testing. The chamber has been constructed with load-bearing wall attachments for future installation of a 5-ton interior bridge crane. The chamber can be operated as a Class 100,000 clean room once the access doors are closed and the facility is cleaned. The combinations of servo-hydraulic and electro-pneumatic noise modulators utilize gaseous nitrogen capable of producing a tailored wide-range of acoustic spectrums in the frequency range from 25 to 10,000 Hz. The RATF chamber internal dimensions are 11.4 m (37.5 ft) wide by 14.5 m (47.5 ft) deep by 17.4 m (57 ft) high.

A photograph of the RATF horn wall is shown in Figure 5, and overall chamber is shown in Figure 6.

Figure 5.—RATF horn wall.

Figure 6.—RATF reverberation chamber.

A maximum of 19 control microphones can be placed around the test article for closed-loop control using the Acoustic Control System (ACS). The ACS, control microphones, or other response instrumentation (accelerometers, microphones) may be input into the Analog Abort System (AAS) to provide automatic shutdown capability. Each of twenty-three (23) servo-hydraulic acoustic modulators is coupled with individual horns of six different cut-off frequencies. Each of thirteen (13) electro-pneumatic acoustic modulators is coupled with individual horns of one cut-off frequency. This combination of modulators and horns provides for an extremely variable and tailored acoustic spectrum. Threaded inserts are located in the floor for attachment of test article mounting fixtures.

The East side of the chamber has a large rolling door and hinged door to provide access to the chamber up to 10.5 m (34.5 ft) in width. A 5.5 m (18 ft) wide by 4.2 m (14 ft) high door is located on the West side of the chamber for loading equipment when the vacuum chamber is occupied.

The Vibroacoustic Highbay is secured and support systems (hydraulics, compressed air, liquid nitrogen, gaseous nitrogen, HVAC systems, and video systems) are setup and energized. A watchdog Facility Control System (FCS) monitors these sub-systems and ensures that all permissives and interlocks are verified. The acoustic chamber is filled with a predetermined level of gaseous nitrogen. The FCS verifies that a matching modulator selection file agrees with the ACS and subsequently provides a Run Permit to the ACS. The ACS performs a self-check and the operator initiates testing using the tailored choice of modulators/horns. The nitrogen generation system automatically vaporizes liquid nitrogen into gaseous nitrogen as required up to 1,981 standard cubic meters per minute (70,000 scfm). At the conclusion of testing, fresh air is force-ventilated into the chamber via the HVAC system to purge the chamber of nitrogen for safe entry. Temperature, humidity and oxygen monitors are located in the chamber and highbay.

Data is acquired at the RATF via the Facility Data Acquisition System (FDAS), a 1,024-channel high-speed digital system.

The RATF has been tested up to a maximum OASPL of 161 dB, and is currently undergoing characterization checkout testing in preparation for customer testing in early 2013. The following are various characteristics of the acoustic facility.

Parameters:

Team Mk VI modulators:	12
Team Mk VII modulators:	11
Wyle WAS5000 modulators:	13
Horns:	36
Max. Empty-chamber SPL:	163 dB OASPL
Frequency Range:	25 Hz to 10 KHz

Physical Characteristics:

Chamber Dimensions:	14.5 by 11.4 by 17.4 m (47.5 by 37.5 by 57 ft H)
Chamber Volume:	2,860 m^3 (101,189 ft^3)
Crane Capacity:	18,143 Kg (40,000 lb)
Floor Loading:	54,422 Kg (120,000 lb)
Blank Penetrations:	25 at 0.15 m (6 in.) dia.
2 at 0.20 m (8 in.) dia.	

Mechanical Vibration Facility

The Mechanical Vibration Facility (MVF) is a 3-axis, 6 degrees of freedom, servo-hydraulic, sinusoidal base-shake vibration system located within the same Vibroacoustic Highbay as the RATF on the West side of the vacuum chamber. The proximity to the RATF allows shared use of the hydraulic system, safety systems, high-speed data acquisition system, and surveillance system. The MVF system consists of reaction mass, four horizontal servo-hydraulic actuators, sixteen vertical servo-hydraulic actuators mounted on double spherical couplings, aluminum table, hydraulic supply system, Table Control System (TCON), Vibration Control System (VCON), and the same Facility Control System (FCS) used by the RATF.

The MVF reaction mass includes an embedded steel plate for modal testing. The 2,100,000 Kg (4,650,000 lb) reaction mass is used to resist the vibratory energy from the hydraulic actuators, table and test article, transferring the energy into the shale bedrock foundation. The reaction mass has been sized such that it has sufficient inertia mass and stiffness to react against the forces applied by the actuator/couplings during sine vibe testing. The reaction mass has been designed to accommodate future growth in vibration system and test article mass. The existing actuator and table design is for sine sweep capability of 0 to 1.25 g's (peak), from 5 to 150 Hz in the vertical axis, and 0 to 1.0 g from 5 to 150 Hz in each of the horizontal axes for a test article mass of 34,000 Kg (75,000 lb) with a center of gravity elevation of 7 m. Currently, the MVF controller is capable of sinusoidal control in three independent axis.

The MVF system is designed to use a large aluminum table approximately 6.7 m (22 ft) in diameter with a 0.61 m (2 ft) wide annular mounting surface centered about a 5.5 m (18 ft) nominal diameter. The table fabrication is not complete, so the MVF system capability has been verified using a substitute steel table called the Construction Integration Fixture (CIF). The CIF allowed verification of the MVF system load-carrying capabilities, but final verifications will occur with the actual table. Table weight is partially offloaded from the system via four inflatable airbags. An overhead photograph of the MVF system with the CIF table is shown in Figure 7, and image of the MVF system with the aluminum table is shown in Figure 8.

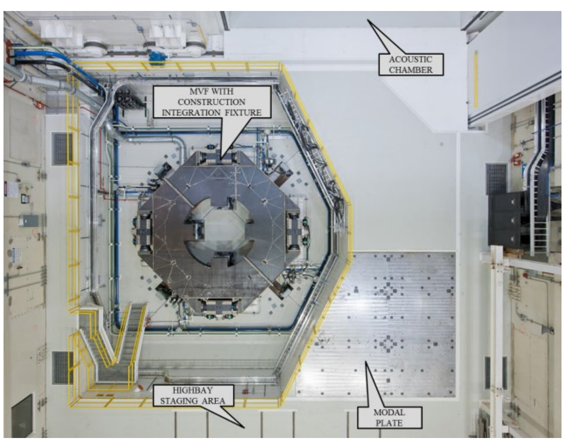

Figure 7.—MVF system (overhead photo).

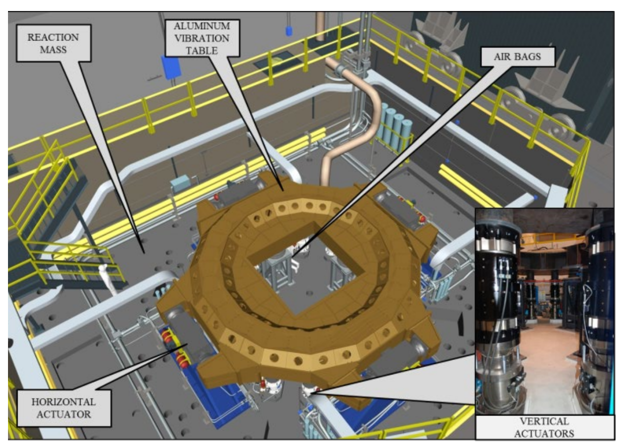

Figure 8.—MVF system w/actuators and aluminum table.

The table vertical actuation is provided by 16 hydraulic cylinder actuators attached to the reaction mass onto which 16 double-spherical couplings are attached. The vertical actuator assemblies provide the controlled vertical sine vibration, enable horizontal vibration, and provide overturning constraints during horizontal vibration. The table rests on the double-spherical couplings. The double-spherical couplings couple each vertical actuator to the table and provides high axial stiffness to deliver the vertical vibratory force during vertical excitation. Each double-spherical coupling has internal pressure sensors to enable the vibe controller to limit forces. Four horizontal actuators provide the controlled horizontal sine vibration and are comprised of two single-ended pistons which maintain outward force through hydrostatic pad-bearings to the table. The horizontal actuator assemblies provide vertical alignment during vertical actuation. The system is designed to permit testing in three independent axis without removing or lifting the test article from the table.

A customer-supplied adapter ring is necessary to attach the test article to the vibration table mounting holes. The Vibroacoustic Highbay is secured and support system (hydraulics, compressed air, life safety, video, and table mode) are setup and energized, and interlocks are verified (including vibratory mode-choice setup) using the Facility Control System (FCS). The Table Control System (TCON) and FCS communicate with the table actuator servo-valve drivers, initiate the table to a lifted, centered, ready position, and verify all servo drivers are started and ready. Operators then initiate the Vibration Control System (VCON) to generate the sine wave inputs to the servo valve controllers, establishing vibration. The VCON controller generates drive voltage waveforms for each servo valve driver to satisfy the control and limit channel constraints from the test article (outer-loop control), and each servo valve driver maintains a closed-loop control to each actuator (inner-loop control). The VCON has 64 analog input channels, which can be assigned to control channels, limit channels, or response channels, where the control and limit channels can be set to alarm and/or abort a test. Up to 44 of the analog input channels can be available for test article limit channels.

Plans are in progress to complete the aluminum vibration table and the system verifications to support Multi-Purpose Crew Vehicle (MPCV) testing, and possibly sooner if customers require the table prior to MPCV testing dates.

The following are various characteristics of the mechanical vibration facility.

Parameters:

Max. Test article Mass:	34,000 Kg (75,000 lb)
Max. Cg above Table:	7.2 m (23.6 ft)
Seismic Mass:	2,100,000 Kg (4,650,000 lb)
Max. Vertical Static Force:	3,203 K-newton (720,000 lb)
Max. Vertical Dynamic Displacement (Pk-Pk):	3.18 cm (1.25 in.)
Max. Vertical Velocity:	41.7 cm/sec (16.4 in./sec)
Max. Lateral Static Force:	1,139 K-newton (256,200 lb)
Max. Lateral Dynamic Displacement (Pk-Pk):	3.048 cm (1.2 in.)
Max. Lateral Velocity:	33.8 cm/sec (13.3 in./sec)
Frequency Range:	5 to 150 Hz
Sine Sweep Rate:	Dwell to 4 octave/min

Physical Characteristics:

Table Mounting Bolt-Circle Dia. (aluminum table):	518.16, 538.48, 558.8, and 579.12 cm
Max. Test Article Height:	23.5 m (77 ft)
Max. Test Article Height below Crane Bridge:	20.4 m (67 ft)

Data is acquired at the MVF via the Facility Data Acquisition System (FDAS), a 1,024-channel high-speed digital system.

Electromagnetic Environmental Effects Facility

Electromagnetic energy can affect the operational performance of a spacecraft. The SPF welded aluminum vacuum chamber and concrete enclosure provides an electromagnetically quiet and reverberant environment for EMI/EMC testing. Both intra- and inter- system electromagnetic environmental effects (E3) testing can be performed inside of the SPF vacuum chamber, where the inner, aluminum alloy chamber provides a complete conductive enclosure around the test article (Ref. 1). A movable RF equipment platform provides reverberant RF illumination at all vehicle surface locations. RF illumination bathes the entire vehicle from every location, at every polarization, and from every direction.

The thermal vacuum chamber is being prepared to perform Electromagnetic Compatibility compliance tests in a 'reverberation' mode. For large-scale systems, testing in a reverberation chamber can significantly reduce test sequence time. Typically Equipment Under Test (EUT) is directly illuminated by energy (with no reflections) in an anechoic chamber. In the SPF 'reverberation' chamber, the EUT is illuminated from all sides and angles, regardless of the source location. It is possible to provide a statistically better test environment than direct illumination because of the reverberant chambers ability to illuminate a EUT from random directions and with random polarizations.

To establish that the facility can be used with acceptable uncertainty, the chamber completed calibration testing in 2011 to evaluate the lowest usable frequency, field uniformity, and quality factor. To prepare for this testing, several vacuum (reverberation) chamber penetrations required additional electromagnetic shielding such as the O-ring seals on the 15.2 by 15.2 m door seals, instrumentation feed-throughs, and power penetrations. Additionally, a mode-stirring paddle was installed for testing. Otherwise, the hermetically sealed chamber and surrounding concrete enclosure provide excellent shielding. Additional calibration testing will need to be performed with the cryoshroud installed in the open configuration, and with the cryofloor in place to take full advantage of the facility for relatively quick testing.

The calibration testing was performed to verify several things: (1) controlled installation of chamber penetration shielding provides sufficient attenuation for RF radiation safety for both humans and neighboring electronic systems; (2) operation of the facility will be in compliance with the RF emissions limits required by the National Telecommunications and Information Administration (NTIA); (3) the mode-stirring paddle provides sufficient stirring of EM energy to radiate the test volume with an isotropic, randomly polarized electric field at near uniform amplitude; and (4) determine if the chamber and equipment met the requirements for a reverberant chamber in accordance with the processes and algorithms in IEC 61000-4-21, Appendix B. A photograph of the Electromagnetic Environmental Effects (E3) facility setup during calibration is shown in Figure 9.

Figure 9.—E3 calibration setup.

Parameters:
    Calibration Frequency Range: 100 MHz to 40 GHz

Physical Characteristics:
    Calibration Volume Dimensions: 20.7 by 14.9 by 22 m H (68 by 49 by 72 ft)

Electromagnetic Environmental Effects testing utilized EMC Measurement Software R&S EMC32 from Rohde & Schwarz. This software provides a common user interface for electromagnetic interference and electromagnetic susceptibility measurements. EMC32 provides data collection, evaluation, and documentation of measurement results including all statistical calculations.

Data Acquisition Systems

The SPF commissioned a new 1,024 channel high-speed Facility Data Acquisition System (FDAS) which serves both the MVF and RATF facilities. The architecture was leveraged to provide a smaller scale Mobile Data Acquisition System (MDAS) for use with the thermal vacuum chamber. The FDAS system includes test article sensor interface cabling, signal conditioners, data recording, data storage, display, and archive systems.

The FDAS system can provide a minimum of 20 kHz analog bandwidth per channel, for all 1,024 channels. Data is synchronized by an external facility IRIG-B signal. Data is stored within four, 3-Terabyte RAID arrays. The FDAS currently has 800 signal conditioners of the IEPE type for accelerometers or microphone conditioning.

After commissioning the FDAS system, the SPF constructed a close-coupled, 128-channel Mobile Data Acquisition System (MDAS) to measure the high-bandwidth thermal vacuum instrumentation signals using similar architecture to the FDAS. In addition, the thermal vacuum facility has a 512-channel digital temperature scanner system for any thermocouple type, which includes isothermal blocks, A/D conversion, and microprocessor, which outputs temperature data to the MDAS system. The MDAS system was successfully used in a recent fairing deployment test.

Facility Concept of Operations

Test articles and ground support equipment are generally received and assembled in the Assembly Highbay. The Assembly Highbay has direct access to the Plum Brook Station road system via a 15.2 m (50 ft) by 15.2 m (50 ft) overhead door. The Assembly Highbay is approximately 46 m (150 ft) long by 23 m (75 ft) wide and 22 m (72 ft) free height under the 25-ton overhead crane bridge. There is no loading dock at SPF; therefore, the bridge crane or facility forklifts are used for receiving equipment.

Once in the facility, there are several methods of transport that can be used. The facility has three sets of standard-gauge rail tracks in parallel that start in the East roadway outside the Assembly Highbay, continue West through the Assembly Highbay, the Vacuum Chamber, and into a staging area in the Vibroacoustic Highbay. The 20-ton Vibroacoustic Highbay overhead crane can lift articles from the staging area to the modal plate, MVF, or RATF chamber. The rail tracks are level with the exception of the vacuum chamber which has a 1 percent grade leading to and from the chamber North-South centerline. The facility has six rail dollies that can be assembled across all three rail tracks to provide a moving platform for transport through the facility. An electric tow tractor is used for moving the rail dollies. Customers may bring castered or wheeled carts for moving items through the facility; however, the rail track grooves must be considered in the two highbays, and the above-grade rail tracks must be considered if rolling the casters/wheels across these surfaces. The rail tracks in the vacuum chamber are removable for these purposes; however, plug caps must be installed over the rail tie-down points which must be considered. If a test article is to be used in a thermal vacuum test inside the facility cryoshroud, the test article can be mounted to the cryofloor prior to test. The cryofloor is mounted on rail dollies and can be moved throughout the facility in a similar fashion as the rail dollies. Both the cryofloor and the rail

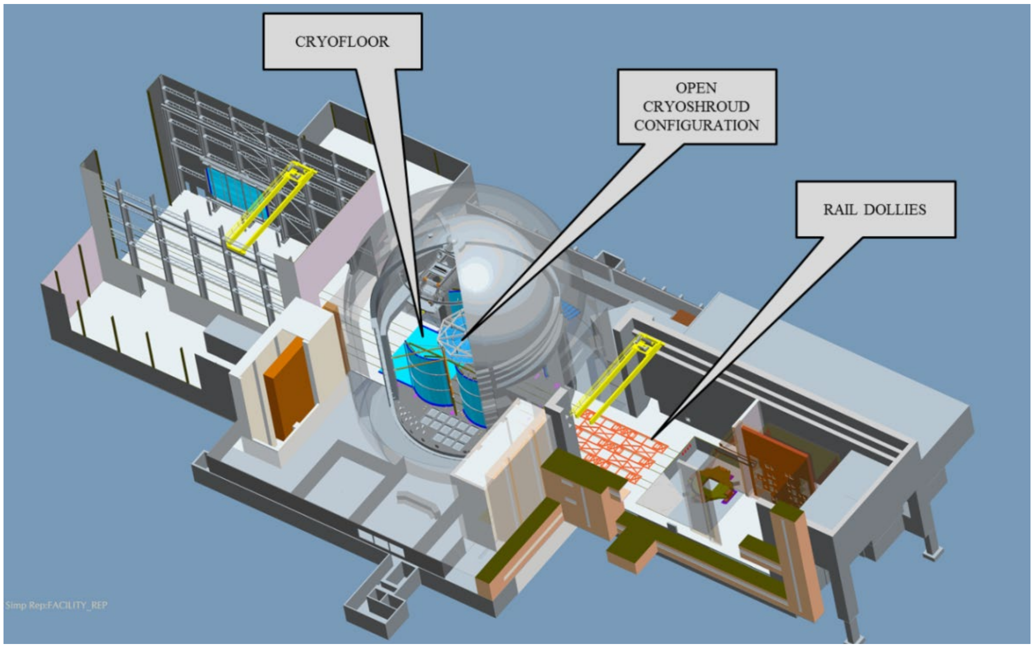

Figure 10.—Methods of transport through facility.

dollies can be moved through the cryoshroud assembly in the vacuum chamber when the cryoshroud wall panels are in the open configuration. Figure 10 shows the facility with the rail dollies, cryofloor, and cryoshroud (in the open configuration).

A concept of operations for performing a complete set of environmental tests would involve buildup of the test article on the cryofloor while the vacuum chamber is prepared for EMI/EMC testing. Transit the test article into the open cryoshroud configuration in the vacuum chamber, close the chamber and perform initial EMI/EMC testing. While this testing is being performed, the FDAS system and cabling are setup in the vibroacoustic test areas. Upon completion, we transit the test article on the cryofloor to the staging area of the Vibroacoustic Highbay, lift the test article onto the MVF vibration table using the 20-ton overhead crane, existing umbilical cabling in the MVF pit is connected to the test article instrumentation, and base-shake vibration testing is conducted. Optionally, the modal floor area can be used for multi-point random vibration testing with the use of portable shakers. While vibration testing is conducted, the vacuum chamber is prepared for thermal vacuum testing. The instrumentation umbilical's are disconnected, and the test article can then be lifted from the MVF directly into the RATF acoustic chamber. The RATF chamber has a removable roof plug to allow passage of the overhead crane hook into the slot while the crane passes over the acoustic chamber. The data system umbilical cables are quickly switched over to disconnect from MVF to connect to the RATF umbilical's using the cabling interconnect cabinet located in the Vibroacoustic Highbay. Acoustic chamber and highbay doors are closed, and acoustic testing is conducted. After acoustic testing is complete, the highbay doors are opened, the chamber doors and roof plug are opened, and the test article is lifted from the acoustic chamber back onto the cryofloor in the highbay staging area, and subsequently moved into the vacuum chamber, and then the vacuum chamber doors are closed. Instrumentation, EGSE, leak checking, and other connections are made to the test article and cryoshroud while the cryoshroud is closed. Access to the chamber is made through door #7 and #5, approximately 2.4 m doors (8 ft). Access into the cryoshroud and test article is through a nominally 2.4 m^2 (8 by 8 ft) door located in the Southwest cryowall quadrant. After all checkouts are completed, the cryoshroud personnel door is closed, aluminum chamber door #5 is closed, and concrete enclosure door #7 is closed and thermal vacuum testing commences. At the conclusion of thermal vacuum testing, potentially additional EMI/EMC testing can be conducted, or the testing is completed, and the test article and cryofloor are moved into the Assembly Highbay for disassembly and preparations for shipment.

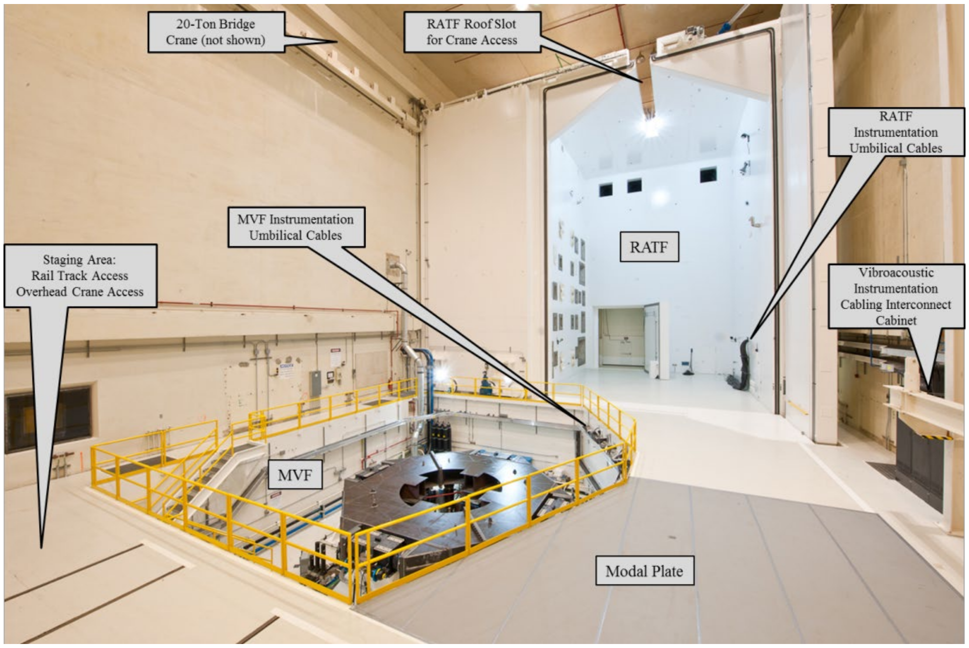

Figure 11.—Vibroacoustic highbay.

A photo of the Vibroacoustic Highbay in its current configuration is shown in Figure 11.

Near-Term Facility Enhancements

A Fiscal Year 2013 construction of facilities project is scheduled to minimally complete three projects for the facility. The facility roofs replacement project will be completed. Major doors controls rehabilitation work will be performed to replace actuators, sensors and controls. The facility HVAC system will receive a new boiler and chillers. This, in combination with new HVAC units, will provide the highbays with HEPA-filtered temperature and humidity controlled ambient environments. The Assembly Highbay will also have reconditioned floor and rail tracks, greatly improving the cleanliness. Vacuum blower motors and nitrogen compressor motors will receive all new electrical starting equipment. Facility motor control centers and electrical power panels will also be replaced. Potentially other improvements will be included, dependent on contract bids. These projects will greatly improve the ambient environment and electrical reliability of the facility.

Reference

1. Susan M. Motil, Damian R. Ludwiczak, Gerald A. Carek, Richard N. Sorge, James M. Free, Harry A. Cikanek III, “Capabilities, Design, Construction and Commissioning of New Vibration, Acoustic, And Electromagnetic Capabilities Added to the World’s Largest Thermal Vacuum Chamber at Nasa’s Space Power Facility,” *62nd International Astronautical Congress*, October 3–7, 2011, Cape Town, South Africa.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
01-06-2013

2. REPORT TYPE
Technical Memorandum

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Space Power Facility-Capabilities for Space Environmental Testing Within a Single Facility

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Sorge, Richard, N.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
WBS 359257.01.07.01

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
John H. Glenn Research Center at Lewis Field
Cleveland, Ohio 44135-3191

8. PERFORMING ORGANIZATION REPORT NUMBER
E-18559

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITOR'S ACRONYM(S)
NASA

11. SPONSORING/MONITORING REPORT NUMBER
NASA/TM-2013-217816

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified-Unlimited
Subject Category: 14
Available electronically at http://www.sti.nasa.gov
This publication is available from the NASA Center for AeroSpace Information, 443-757-5802

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The purpose of this paper is to describe the current and near-term environmental test capabilities of the NASA Glenn Research Center's Space Power Facility (SPF) located at Sandusky, Ohio. The paper will present current and near-term capabilities for conducting electromagnetic interference and compatibility testing, base-shake sinusoidal vibration testing, reverberant acoustic testing, and thermal-vacuum testing. The paper will also present modes of transportation, handling, ambient environments, and operations within the facility to conduct those tests. The SPF is in the midst of completing and activating new or refurbished capabilities which, when completed, will provide the ability to conduct most or all required full-scale end-assembly space simulation tests at a single test location. It is envisioned that the capabilities will allow a customer to perform a wide range of space simulation tests in one facility at reasonable cost.

15. SUBJECT TERMS
Space; vibration; Acoustic; Electromagnetic; Vacuum; Environmental; Thermal

16. SECURITY CLASSIFICATION OF:

a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
U	U	U	UU	20

19a. NAME OF RESPONSIBLE PERSON
STI Help Desk (email:help@sti.nasa.gov)

19b. TELEPHONE NUMBER ***(include area code)***
443-757-5802