Space Power Facility for Testing Large Space Optical Systems

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Abstract—The Space Power Facility is located at NASA's Glenn Research Center Plum Brook Station in Sandusky, Ohio. It is the world's largest space simulation test facility with a test chamber that is 30.5m (100ft) in diameter by 37.2m (122ft) high. It has been used to test a variety of large space flight hardware and space systems for NASA, other government agencies, and the private sector over the last 20 years. Most of the design features of the facility provide unique characteristics that are ideally suited to meet the requirements of large space optical system thermal/vacuum testing. This paper[1,2] describes the Space Power Facility's unique characteristics and systems and how they meet these requirements. Future large space optical systems will require a facility that can handle large, delicate hardware in a clean environment. Large high bay clean rooms will be needed for pre-test build-up and checkout activities. A large test chamber with easy access will be needed near the build-up area to minimize the risk of transporting the hardware into the chamber for thermal/vacuum testing. The Space Power Facility's unique architecture with large high bays on each side of the test chamber is ideal for handling and processing large hardware and systems. Large space optical system testing will also require a test environment that is as quiet as possible from a vibration standpoint. By nature of the construction of the Space Power Facility, the vibration environment has been found to be extremely stable. Additionally, large space optical system testing must be performed at high-vacuum (< 1x10-5 Torr) conditions and many future systems require testing at cryogenic temperatures. The facility's high-vacuum system for pumping the test chamber has recently been upgraded with cryopumps and high-vacuum isolation valves to provide a contaminant-free, clean testing environment. To ensure that the facility upgrades will meet the demands of future test programs, an integrated systems test was performed to assess the operation and performance of the chamber and the new vacuum pumping system.

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1. INTRODUCTION

NASA's vision for space exploration includes exploring and understanding the universe using very large space based telescope observatories which can image light without the blurring effects of the Earth's atmosphere. NASA has plans to launch various large space telescopes throughout the next several decades. The Department of Defense also has a need for launching large earth observing spacecraft, to meet national security objectives. It is critical that these large optical systems be successfully ground tested prior to launch. At the present time, there are limited choices in test facilities for pre-launch verification of optical system on-orbit performance. The future space telescope observatories will be larger, more sensitive, and more complex, and the limiting factor for most existing facilities is the size of the test chamber. Current and future large space telescope observatories will require a test facility with exceptional cleanliness levels, extreme vibration isolation, and cryogenic temperature capability to simulate in-space environmental conditions.

This paper describes the unique features and attributes of the Space Power Facility for large optical systems testing. The facility has been studied for possible use as an integration and test facility for large space optical systems. Although some facility modifications must be performed, many of the existing systems are ideal for meeting the demands of large optical system testing.

2. FACILITY BACKGROUND

The Space Power Facility (SPF) houses the world's largest space environment test chamber, measuring 30.5m (100ft)

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[1] U.S. Government work not protected by U.S. copyright
[2] IEEEAC paper #1001, Version 5, Updated Sept, 9 2005

in diameter by 37.2m (122ft) high. The facility was designed to test both nuclear and non-nuclear space hardware in a simulated low-Earth-orbit environment, deep space environment, and other planetary environments. The SPF is located at the NASA Glenn Research Center, Plum Brook Station, Sandusky, Ohio. Construction of the facility was started in 1966 and completed in 1969. Although the facility was designed for testing nuclear hardware, only non-nuclear tests have been performed throughout its history. The facility can sustain a high-vacuum (10^{-6} torr), simulate solar radiation via a 4-MW quartz heat lamp array, solar spectrum by a 400-kW arc lamp, and cold environments down to -196°C (-320°F) with a variable geometry cryogenic shroud. Some of the test programs that have been completed at the facility include high-energy experiments, rocket payload fairing separation tests, Mars lander system tests, and International Space Station hardware tests. An aerial photo of the facility is shown in figure 1 and a cutaway depiction is shown in figure 2.

Figure 1 – Space Power Facility Aerial View

The Space Power Facility is divided into four major areas:

(1) Assembly and Shop Area

(2) Test Chamber

(3) Disassembly Area

(4) Office and Control Area

Three parallel sets of standard-gage railroad tracks which connect externally to the SPF from the Plum Brook rail network run through the assembly area, into the test chamber, and then through the disassembly area. The layout of the facility makes it ideal for performing multiple test programs. The facility was originally designed for test build-up in the assembly area, followed by installation into the chamber for testing, and post-test tear-down of radioactive hardware in the disassembly area. Without the restriction of radioactive hardware, test build-up and tear-down can occur in either the assembly area or the disassembly area. Access to the test chamber from either area is unrestricted through the large chamber doors. The advantage of having both areas available allows two major test programs to be prepared at the facility at the same time. Build-up activities for one program can occur in the assembly area while testing of another program is being performed inside the vacuum chamber.

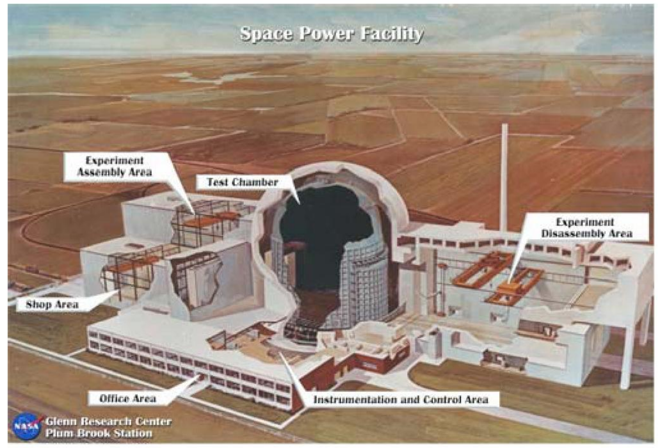

Figure 2 – Facility Cutaway Depiction

3. TEST CHAMBER SYSTEM

The test chamber is made of aluminum and is surrounded by a vacuum-tight heavy concrete enclosure. This unique configuration is essentially an aluminum vacuum chamber enclosed within a larger concrete vacuum chamber and is shown in figure 3. The concrete chamber was designed to serve as a radiological shield and is the primary structural vacuum barrier from atmospheric pressure.

Aluminum Test Chamber

The test chamber is a vacuum-tight aluminum plate vessel 30.5m (100ft) in diameter by 37.2m (122ft) tall. The aluminum vessel is designed for an external pressure of 17.2 KPa (2.5 psig) and an internal pressure of 34.4 Kpa (5.0 psig). The chamber is constructed of Type 5083 aluminum, which is clad on the interior surface with 3mm (1/8in) thick type 3003 aluminum for corrosion resistance. This material was selected principally because of its low neutron absorption cross-section, permitting personnel to enter the chamber in minimum time following a nuclear test. The floor plate and vertical shell are 25mm (1in) thick, while the dome shell is 35mm (1 3/8in) thick. Circumferential aluminum structural T-section members are welded to the exterior surfaces for rigidity.

The doors on the aluminum test chamber are curved to fit the cylindrical shape of the chamber. The two entrances are 15.2m x 15.2m (50ft x 50ft) and are located at opposite sides of the chamber. One door faces the assembly high bay and the other faces the disassembly high bay. Double o-ring door seals are used for a high-vacuum seal between the doors and the chamber. The chamber also has a small door 2.5m x 2.5m (8ft x 8ft) which can be used for smaller equipment and personnel entry once the large doors have been closed.

The chamber floor is designed to withstand a total load of 300 Tons. The chamber is supported by 88 one-foot diameter columns with urethane isolation pads mounted to a five-foot thick concrete foundation and tension piles that run 30 feet down to bedrock. This unique configuration provides extraordinary vibration stability to the test chamber. The chamber floor has three sets of removable standard-gage stainless steel rails which can be used for transport of large hardware. The high-vacuum pumps are located beneath the chamber floor and are sealed to the floor with flanges and o-rings. A 20-ton capacity vacuum-compatible aluminum overhead polar crane is mounted at the top of the chamber. If necessary, this crane can be removed prior to testing.

There is a full complement of service penetrations in the chamber including electrical power, data acquisition, and high-pressure liquids and gases.

The inner surface of the aluminum test chamber must be exceptionally clean to meet the needs of space optics testing. Organic compounds, silicon oils, and other potential contaminants must be removed from this surface. While much of the chamber has been recently chemically cleaned using detergents followed by isopropyl alcohol wipe down, two unique methods of cleaning can be performed while the test chamber is under vacuum conditions and would require no physical scrubbing of surfaces. All areas such as small crevices that could contain contamination will be cleaned using these two techniques. The first method, atomic oxygen cleaning, is performed in a vacuum environment of approximately 10 millitorr where a radio frequency generator disassociates oxygen molecules from air to atomic oxygen. The atomic oxygen then readily combines with organics to form carbon monoxide, carbon dioxide, and water, which is then swept from the vacuum chamber by the roughing pump system. Existing silicon oils would be converted to silica which is inert and would not be a source of contamination. The second method, plasma cleaning, involves generating a plasma field that is at higher potential than the chamber. Chamber inner surface materials are sputtered off by the flow of ions. Using various plasma gases can enhance this process. Plasma cleaning has been used on smaller test chambers and is very popular in the vacuum deposition industry.

Build-up and checkout activities inside the test chamber for large optical systems could take a significant amount of time. During these pre-test operations, a clean air environment will be needed inside the chamber. A preliminary engineering study to create a clean room environment inside the aluminum test chamber has recently been completed. A unique configuration of flow ducts with removable supply lines can be used to create clean horizontal air flow inside the chamber which meets ISO 14644-1,-1,-4 class 7 requirements.

Concrete Chamber Enclosure

The concrete chamber enclosure is designed to withstand atmospheric pressure externally while having vacuum conditions on the inside. The enclosure has a 39.6m (130ft) inside diameter and a 40.2m (132ft) inside height.

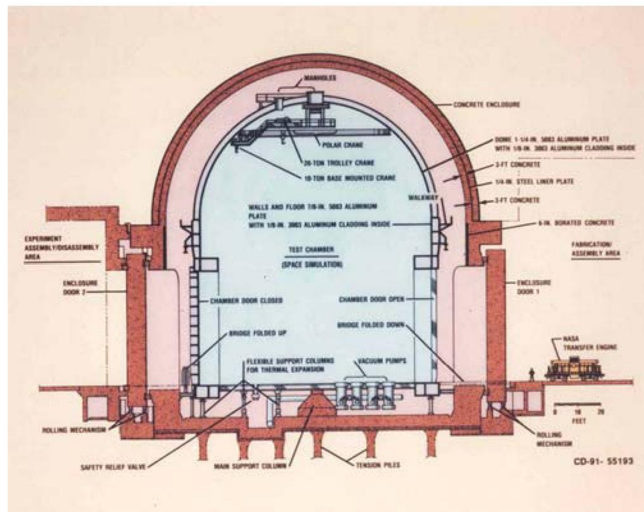

Figure 3 – Vacuum Chamber System

The concrete thickness varies from 1.8m to 2.1m (6 to 7 feet) and contains a leak-tight 6.3 mm (¼ in) steel containment barrier embedded within. Like the aluminum test chamber, the concrete chamber has two 15.2m by 15.2m (50ft by 50ft) doors. Inflatable seals are used to seal these doors to the enclosure. There is an air-lock in the concrete enclosure with two 2.5m x 2.5m (8ft x 8ft) doors.

The space between the concrete enclosure and the aluminum test chamber, called the annulus, is pumped down to a pressure of 20 torr during vacuum testing while the aluminum test chamber is pumped to high-vacuum levels. This unique system of chambers has several advantages for testing optical systems. The annulus space can be pumped down and backfilled with an inert gas which then creates a controlled atmosphere around the test chamber. All vacuum chambers have some amount of leakage through penetrations and door seals. Having an inert gas leak into the chamber, rather than air and water vapor, would reduce the possibility of optical system contamination particularly on cryogenic cooled surfaces. The low-pressure annulus environment around the test chamber also provides an acoustic buffer to help minimize vibrations. Acoustic wave energy from external sources will be significantly attenuated through the low-pressure region to minimize the impact on the aluminum test chamber surface. External noise energy in and around the facility will not be transmitted to the test article.

Penetrations in the concrete chamber enclosure exist for services such as electrical power, data acquisition, control wiring, cooling water, and vacuum systems. Wiring penetrations utilize leak-tight multipin connectors. Two series-connected isolation valves are present for all penetrating piping systems.

Chamber Vibration Characteristics

Large space optical system testing will require a test environment that is as quiet as possible from a vibration standpoint. By nature of the construction of the Space Power Facility, the vibration environment is found to be extremely stable. Vibration measurements of the facility were recently taken using the Space Acceleration Measurement System (SAMS), an ultra-sensitive vibration measurement system used aboard the International Space Station and the Space Shuttle to characterize the on-orbit microgravity environment. Measurements were taken with and without facility equipment operating and the vibration characteristics of the facility were found to be extremely quiet throughout a spectrum from zero to 400 hz. Vibration levels at very low frequencies (below 10 Hz) were particularly favorable for minimizing the effects on large structures with low resonant frequencies. The Power Spectral Density was measured at levels below 10^{-12} g^2/Hz from zero to 40 Hz. Average accelerations from zero to 100 Hz (g_{RMS}) were measured at 56 µg. A sample of the measurements taken for the facility is shown in figure 4. Although additional vibration isolation may be needed for some large optical systems, the low vibration environment of the facility will simplify the design of the isolation system.

Ambient Access to Metrology

Certain optical system tests may require the ability to service metrology such as an interferometer while the test hardware is in a vacuum environment. The Space Power Facility has the capability for installing windows or ambient pressure access tubes through both the concrete enclosure as well as the aluminum test chamber. The facility was built with a number of blank penetrations (35cm to 60cm diameter) in the concrete enclosure for future use. An existing ambient access tube is used for direct access to the test chamber environment for pressure and gas sample analysis. An engineering study performed by the Ralph M. Parsons Company determined that very large (~3.5m diameter) ambient access penetrations can be installed by cutting the concrete enclosure and sealing a tube and bellows from the aluminum chamber to the steel liner vessel within the concrete. Specific applications for test chamber windows or ambient access penetrations will require further engineering examination, however, based on the previous studies it certainly appears feasible.

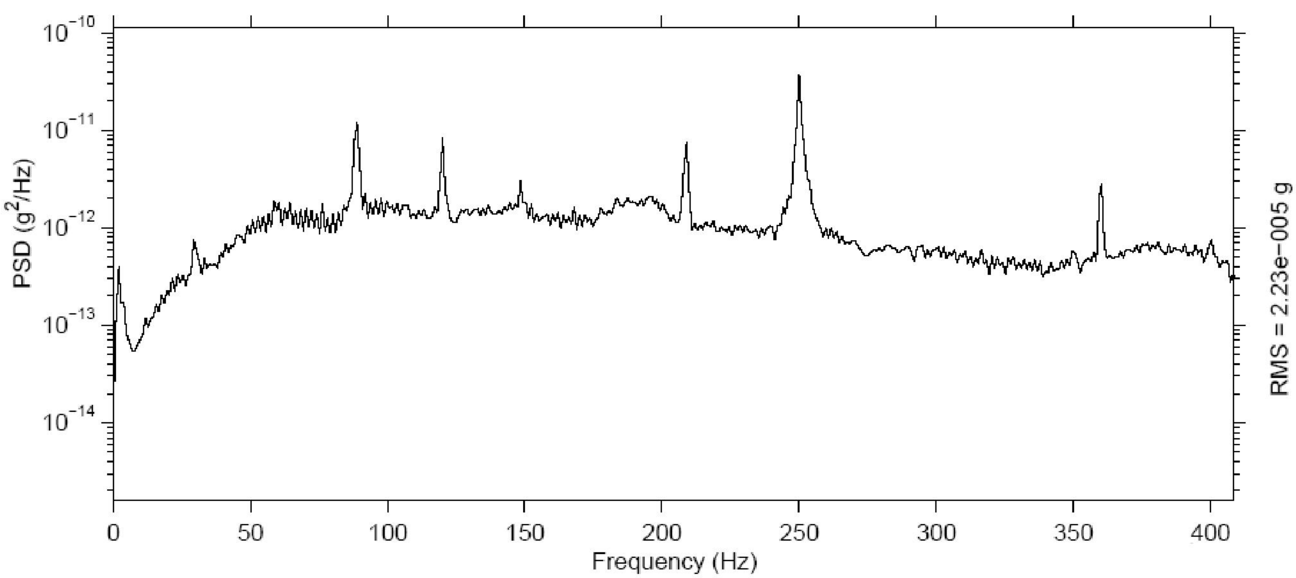

Figure 4 – Facility Vibration Data

4. Test Hardware Logistics

The facility was designed to handle very large test articles in a unique flow-through fashion by using two sets of chamber access doors 180° apart. The large high bays are located at each end of the test chamber for pre and post test hardware processing. Test preparation and integration of large optical systems can easily be performed in these high bays. Three sets of standard-gage rail tracks start from outside the facility, run through the assembly area high bay, into the test chamber, and then through the disassembly area high bay. Special carts can be used to transport large, heavy hardware on the rail system from the high bays into the test chamber. The 20-ton capacity aluminum polar crane inside the test chamber has a hook height of 32.9m (108ft) and can be used to position and build-up hardware within the chamber. Preliminary engineering studies to upgrade the high bays to clean rooms have been completed. One or both high bays can be upgraded to meet clean room requirements per ISO 14644-1,-2,-4 class 7 or class 8.

Assembly Area High Bay

The assembly area is located on the east side of the test chamber and is 22.9m (75ft) wide by 45.7m (150ft) long with a steal frame superstructure and a clear height of 24.4m (80ft). It has a 25-ton capacity overhead bridge crane with a hook height of 22.9m (75ft) and a 5-ton capacity auxiliary crane. The crane will service an area 18.3m x 39.6m (60ft x 130ft). The outside door to the assembly area is 15.2m x 15.2m (50ft x 50ft).

Disassembly Area High Bay

The disassembly area is 21.3m (70ft) wide by 45.7m (150ft) long with a clear height of 23.2m (76ft) and was designed for remote disassembly, cut-up and packaging of nuclear test articles. The structure is concrete with walls 1.8m (6ft) thick to provide shielding from gamma radiation. The area is provided with a remotely controlled 20-ton overhead capacity bridge crane with a hook height of 19.2m (63ft) and a 5-ton capacity auxiliary crane. The crane will service an area 18.3m x 42.7m (60ft x 140ft). The internal surface of the disassembly area is smooth wall and epoxy coated. The external door is 4.3m wide by 5.5m high (14ft x 18ft).

Shop Area

The shop area is adjacent to the assembly area. It is 12m (40 ft) wide x 46m (150 ft) long x 10m (34 ft) high and has a 10-ton bridge crane. This area is equipped for metal fabrication, machining, welding, grinding, cutting, and tube bending. The exterior door is 6.1m (20 ft) wide x 6.7m (22 ft) high

5. VACUUM PUMPING SYSTEM

The vacuum system consists of both a rough-vacuum system and a high-vacuum system. The rough-vacuum system is initially started during a chamber pumpdown and operated to remove most of the air from the chamber. Once the chamber pressure is at a level of about 10 x 10^{-3} torr, the rough-vacuum system is shut down and the high-vacuum system is started to continue removing air from the chamber.

Rough Pumping System

The mechanical roughing pump system consists of two systems with five stages each having a total capacity 61,000 liters/sec (130,000 cfm). The rough pumping system was designed to quickly remove most of the air from the test chamber and has redundant capability by the use of a series of bypass valves.

Stage 1: Four 500-hp Roots blowers, 28800 l/s (61000 cfm)

Stage 2: Two 500-hp Roots blowers, 17280 l/s (36600 cfm)

Stage 3: Two 300-hp Roots blowers, 9340 l/s (19800 cfm)

Stage 4: Two 200-hp Roots blowers, 4460 l/s (9440 cfm)

Stage 5: Six Beach-Russ rotary piston type vacuum pumps, 2040 l/s (4320 cfm)

The rough-vacuum system pumps air from both the test chamber and the volume between the test chamber and the concrete chamber enclosure. The rough pump lines to the chamber have liquid nitrogen cooled cold traps to ensure that rough pump oil does not migrate upstream and contaminate the test chamber.

High-vacuum Pumping System

The high-vacuum system for the facility has been recently upgraded by removing 16 of the 32 existing oil diffusion pumps and replacing them with ten state-of-the-art 132 cm (52 in.) diameter cryopumps. The remaining 16 oil diffusion pumps have been drained of oil, cleaned, and sealed from the test chamber with welded aluminum plates. Five liquid nitrogen scavenger panels were added inside the chamber to assist with pumping water vapor and to collect potential off-gassing contamination. The new cryopumps were installed with high-vacuum isolation gate valves. Space optics testing will require long duration test periods where a cryopump could become saturated with condensed materials. By using the high-vacuum isolation gate valves, these cryopumps can be selectively isolated from the chamber and regenerated as needed while maintaining vacuum and continuing the test operations.

6. CRYOGENIC SYSTEM

The cryogenic system at the facility is capable of removing up to 14 MW of heat from the test chamber. There are two liquid nitrogen storage vessels on site. One has an 821,000 liters (217,000 gallon) capacity and the other 106,000 liters (28,000 gallon). A variable-temperature closed-loop cold-gas nitrogen system exists at the facility. This system uses two 5190 l/s (11,000 cfm) nitrogen compressors to circulate gaseous nitrogen through a cryogenic shroud system. The maximum mass flow capacity of each compressor is 28 kg/s (3811 lb/min). Liquid nitrogen is injected into the cooling loop via a desuperheater to control the desired shroud temperature.

Cryogenic Shrouds

The facility has an existing large removable cryogenic shroud which is used to simulate the cold background temperatures experienced in space. The cryogenic shroud is made up of several aluminum panels and can be reconfigured in different geometries. The shroud system is currently configured as shown in figure 5 and has an internal volume of 12.8m (42ft) wide by 24.4m (80ft) long with a ceiling height of 6.7m (22ft). The existing configuration is separated into 10 zones with individual temperature control for each zone. Temperature control experience in past test programs has shown a temperature uniformity of +/- 1° C throughout the shroud system.

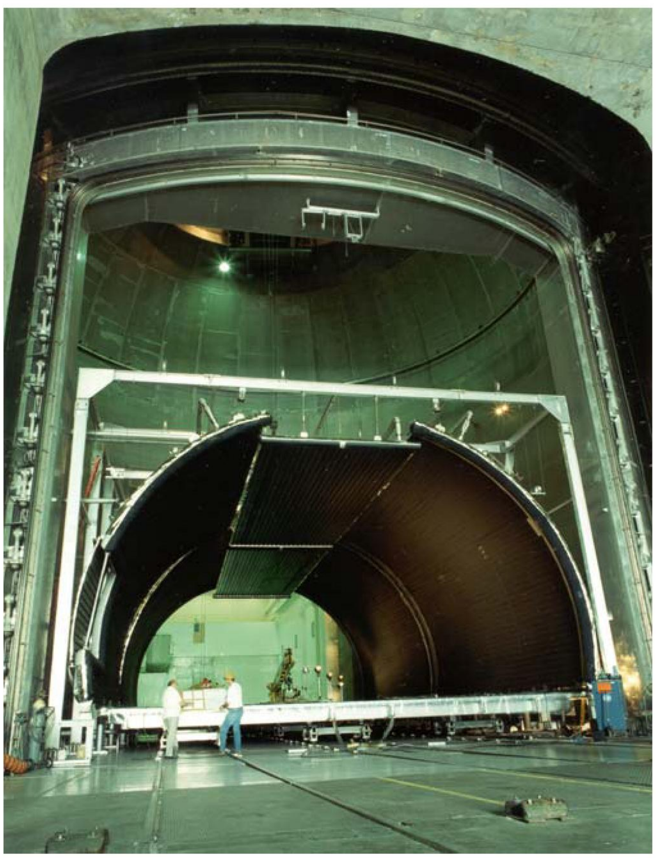

Figure 5 – Existing Cryogenic Shrouds

The shroud floor section is mounted on trolleys that ride on the rail tracks that go through the facility. It can be removed from the test chamber for test hardware build-up in the adjacent high bay. The floor is designed to withstand a uniform load of 244kg/m2 (50 lb/ft2) and there are hard attachment points at various locations to mount test hardware.

7. Control Room and Data Systems

The Space Power Facility has two test control areas. One is the 77m^2 (828 ft^2) Facility Control Room, and the other is the 238 m^2 (2556 ft^2) Test Control Room. The Facility Control Room has all the necessary control panels for operation of the facility. The Test Control Room has various consoles used for specialized test operations. Special test equipment and consoles can be brought into this area and interfaced to the test chamber.

The facility data and control system is used to control and monitor the new high-vacuum pumping system, the cryogenic systems and cryogenic shroud systems. Critical facility operational parameters such as temperatures, pressures, speeds, etc. are monitored and recorded for various facility subsystems. This system uses a Modicon architecture with two Quantum programmable logic controller processors, which may be operated in redundant mode, with one processor as the primary and the second in "hot stand-by" which monitors the primary and will automatically switch to the back-up in the case of a failure. The graphical user interface system uses Factory Suite software from InTouch Corporation loaded on conventional Pentium workstations to provide the monitoring and control interface from the controller to the operator. The operator can monitor system operation, control key field devices, view alarms, change system setpoints, all from the Facility Control Room. Automatic data and event logging operates in the background on dual computers providing automatic redundancy of all data collection.

The instrumentation system at the Space Power Facility starts with the hard-lines that run from the test chamber to the instrument room in the basement of the data and test control rooms. The flooring of the data and test control rooms is computer-type flooring and can be lifted out in small square sections to expose the instrument cables in the basement. This feature allows the placement of test consoles, data processing, data recording and data reduction equipment anywhere in the test control area. The cabling can be dropped to the basement and routed to the appropriate interface. The penetrations to the chamber are located on the basement level.

8. Support Infrastructure

The facility has an extensive infrastructure which was designed for long-duration, critical testing of large hardware. Most systems were designed for excess and redundant capacity.

Water Systems

The facility has a variety of water systems to support normal building operations and test operations.

Cooling Tower Water—This system consists of a large wood cooling tower located to the south side of the facility and is used to dissipate waste heat produced by such devices as the GN2 compressors and the vacuum pumps. The system includes re-circulating pumps, a water treatment plant, control valves and a water supply. The tower is constructed of standard redwood and includes a fire protection water deluge system. The cooling tower water system has three vertical turbine re-circulating pumps. The cooling tower water is chemically treated to reduce corrosion and contamination.

Domestic and Fire Water—This system has a 568,000 liter (150,000 gal) water tower which is located on the south side of the facility and is connected to the domestic water system. The tower has a standpipe in the domestic water outflow line, which limits the withdrawal of domestic water and leaves 340,000 liters (90,000 gal) of water in the tower. The bottom of the tank is connected to the fire water system so that, in an emergency, 340,000 liters of water is available.

Demineralized Water—This system was designed for cooling the diffusion pumps and for cooling very large cold walls that were never installed in the facility. The system consists of a demineralizer, a storage tank, chillers and piping. The system can be useful for future cooling applications on systems that may be sensitive to potable water systems.

Instrument and Service Air System

The facility has a packaged 118 l/s (251 cfm) compressor discharging into a common header containing a receiver tank with a condensate drain. There are two backup compressors; a 307 l/s (650 cfm) and 80 l/s (170 cfm) units. The discharge of the receiver tank branches into two separate systems. The first system is designated "plant or service air" and it receives no additional drying and is distributed throughout the facility. This air is used for pneumatic tools and other equipment requiring compressed air. The second system, designated "instrument air" goes through two parallel "refrigifilters" and then through an absorption "LectroDryer" unit which is followed by a second receiver tank. The instrument air is then distributed around the facility to valve operators, solenoids and other moisture sensitive devices.

Gas Systems

Gaseous nitrogen is available from a bottle located at the south side of the facility. The capacity for the bottle is 150,000 scf @ 2750 psig. This system is augmented with a trailer station of 70,000 scf @ 2400 psig. Both systems are usually charged by vaporization of liquid nitrogen from the supply tank.

Helium is also available at the facility via a trailer station with a capacity of 220,000 scf @ 2800 psig.

Other gaseous systems, including oxygen and hydrogen are available at Plum Brook Station and for use to the facility.

Electrical Power Systems

The total utility power available to the Space Power Facility is 14 MW at the substation located at west end of the facility. The electrical power supplied to the facility systems is available from three sources; utility service, backup power, and uninterruptable power.

Electrical Utility Service—Electric power is supplied to Plum Brook Station over two separate 138 kV transmission lines from two separate utility company substations. Each 138 kV line is stepped down to 34.5 kV at substation A and distributed in a ring network to substation located at the facility. This system provides redundant power supply to the facility from the utility company.

Backup Power System—The facility has a 1.25 MW diesel generator available for backup power. This is sufficient power to safely operate the facility in its nominal mode once the chamber is at vacuum. This is an important feature of the facility for cryogenic testing of large hardware. The backup power provides for safe warm-up of the hardware in the event of a power failure.

Uninterruptable Power—There is an online uninterruptable power system (UPS) which consists of a battery bank and a 15 kVa dc to ac inverter. The system supplies power to critical instrumentation and critical control systems. The system has a 15-minute capacity at full load.

Electrical Building Ground—The electrical grounding system consists of a buried copper cable that encircles the facility. The ground grid runs approximately 1 meter from the base of the building and is interconnected to every other column in the facility. This ground is also used for the instrumentation system.

General Lighting—The facility has a sufficient level of lighting in all assembly and shop areas similar to an industrial environment. Portable lighting can be used for special situations if needed. There is also an emergency lighting system throughout the facility.

9. Integrated Systems Test

An integrated systems test was performed on the facility in March 2005, to characterize the performance of the new vacuum system. The objectives of this test were to demonstrate the operational capability of the new pumping system, pump the chamber to best achievable vacuum levels, and to verify the chamber integrity with respect to leakage. Prior to the test, the chamber penetration seals and door seals were replaced and leak-checked. The analysis of the new pumping system predicted that a chamber pressure in the 5×10^{-5} torr range should be achievable.

The mechanical rough-pump system was able to pump the chamber down to 15×10^{-3} torr in about six hours. At this time, the liquid nitrogen scavenger panels were started and one slave cryopump was opened to the chamber. Within 30 minutes, the chamber was at 10×10^{-3} torr and the remaining nine cryopumps were opened to the chamber. The chamber pressure then quickly dropped to a level of 1×10^{-5} torr. The pumpdown curve from the integrated system test is shown in figure 6. After several hours passed to allow for initial off-gassing within the chamber, an ultimate chamber pressure of 8×10^{-6} torr was achieved. The integrated systems test was a complete success and proved that the new high-vacuum system was able to attain chamber pressures equivalent to the original oil diffusion pump system.

10. SUMMARY

The Space Power Facility has unique inherent features that make it ideal for testing large space optical systems. Large test hardware and ground support equipment can easily be handled with its large chamber size and large high-bays. The existing facility high bays and test chamber can be upgraded to provide ISO Class 7 or Class 8 clean environments which will be required by most optics hardware. By nature of the robust construction of the facility which was needed to meet the needs of testing large nuclear systems, the vibration characteristics of the facility are in the micro-g range and provide a stable environment to meet optical system requirements. The cryogenic cooling capacity of the facility is capable of removing 14 MW of heat from the test chamber, which should easily meet the cooling requirements for most test articles down to 80° K. Specialized helium refrigeration systems can be installed in the facility to provide cooling down to even lower temperatures. The vacuum pumping system has recently been upgraded with state-of-the-art cryopumps and has been verified to provide a clean high-vacuum environment within the test chamber. The facility also has an extensive supporting infrastructure with high capabilities to meet expanding program requirements.

Although some facility upgrades will be needed to meet all of the test requirements for future optical system testing, the cost of these modifications will be far less than the cost of designing and building a new facility for the same purpose.

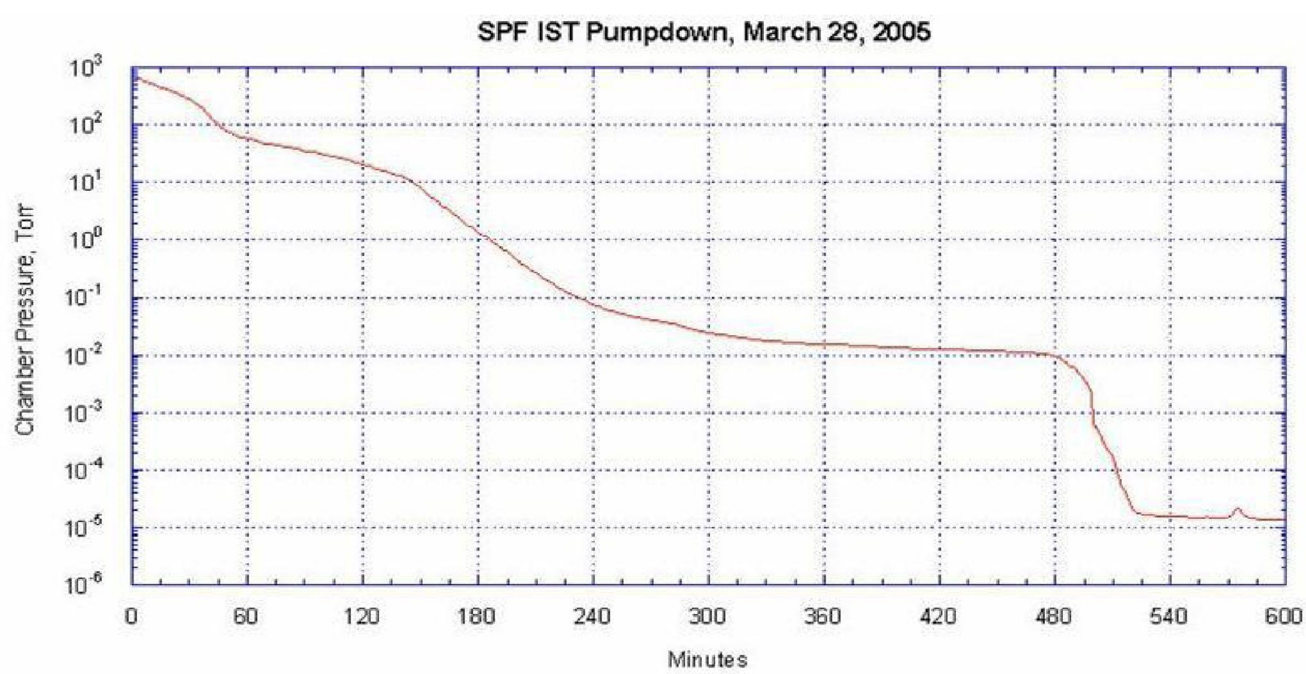

Figure 6 – Integrated Systems Test Pumpdown Curve

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BIOGRAPHY

Jerry Carek *is the Space Power Facility Manager at the NASA Plum Brook Station in Sandusky Ohio. He has been with NASA for 23 years. He worked in NASA's Propulsion Systems Division at the Glenn Research Center in Cleveland where he designed and managed the building of a variety of research test facilities to support the aerospace technology programs at the center. In 1996 he transferred to Plum Brook Station as the Space Power Facility Manager where he manages many mission-critical test programs for NASA. He directed tests for the International Space Station, the US fleet of launch vehicles, NASA's Mars Missions, and NASA's space exploration missions. He is a member of the American Institute of Aeronautics and Astronautics and serves on the Working Group for Space Simulation. He has a Master of Science Degree from the University of Toledo and is a licensed registered professional engineer in the State of Ohio.*