AEROSPACE TEST OPERATIONS AND MAINTENANCE SERVICES

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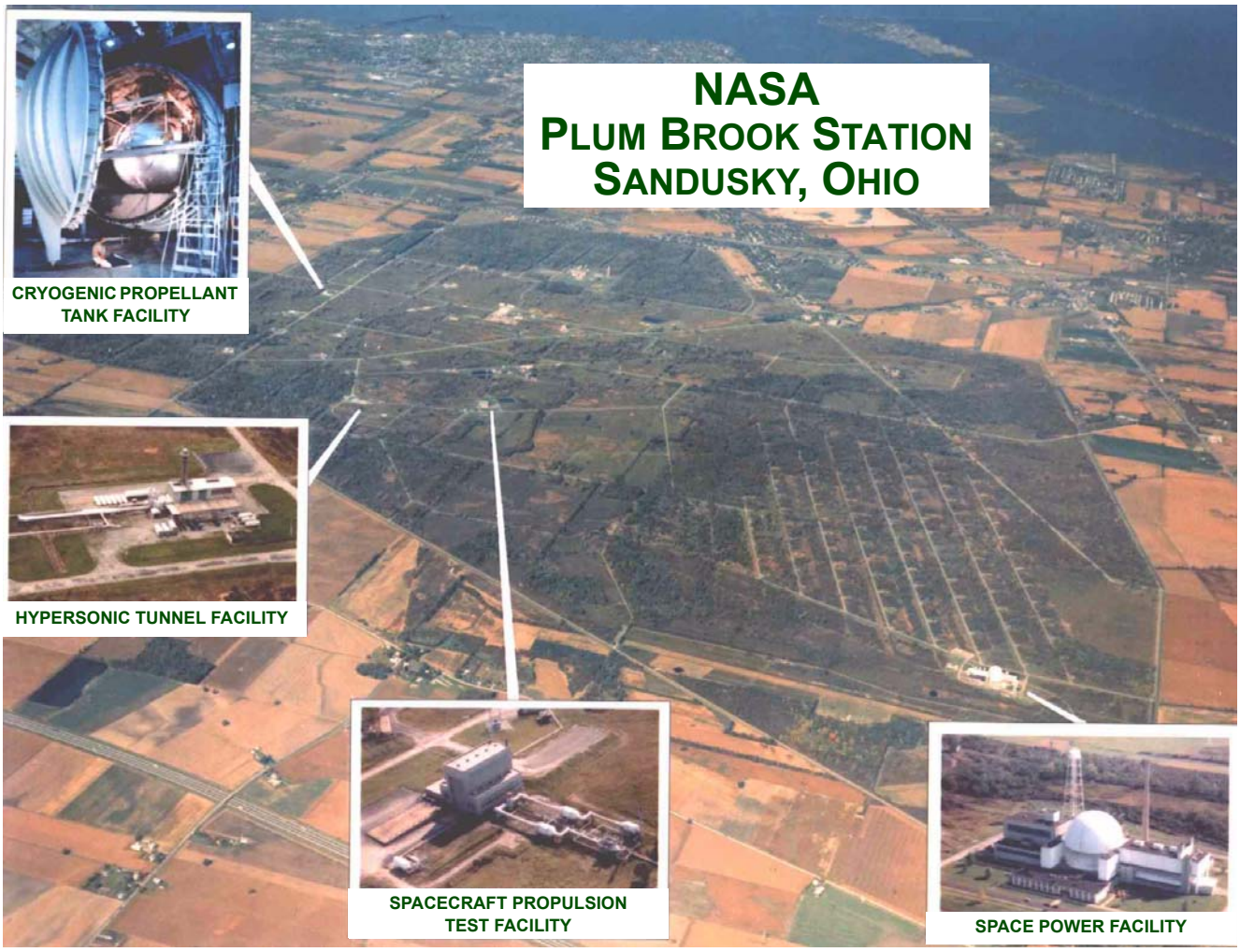

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NARRATIVE/PICTORIAL DESCRIPTION

CHI and its joint-venture team provide Plum Brook-wide infrastructure and institutional support services, as well as Station Test Facilities operations and maintenance services

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Aerospace Test Operations and Maintenance Services

CHI, a key member of a joint-venture team under contract to NASA at their Plum Brook Station, Sandusky, OH, provides the full range of operations and maintenance technical support services for the Station's four "world-class" aerospace research test facilities that support the testing of advanced space hardware for NASA, as well as other U.S. and international space hardware system developers.

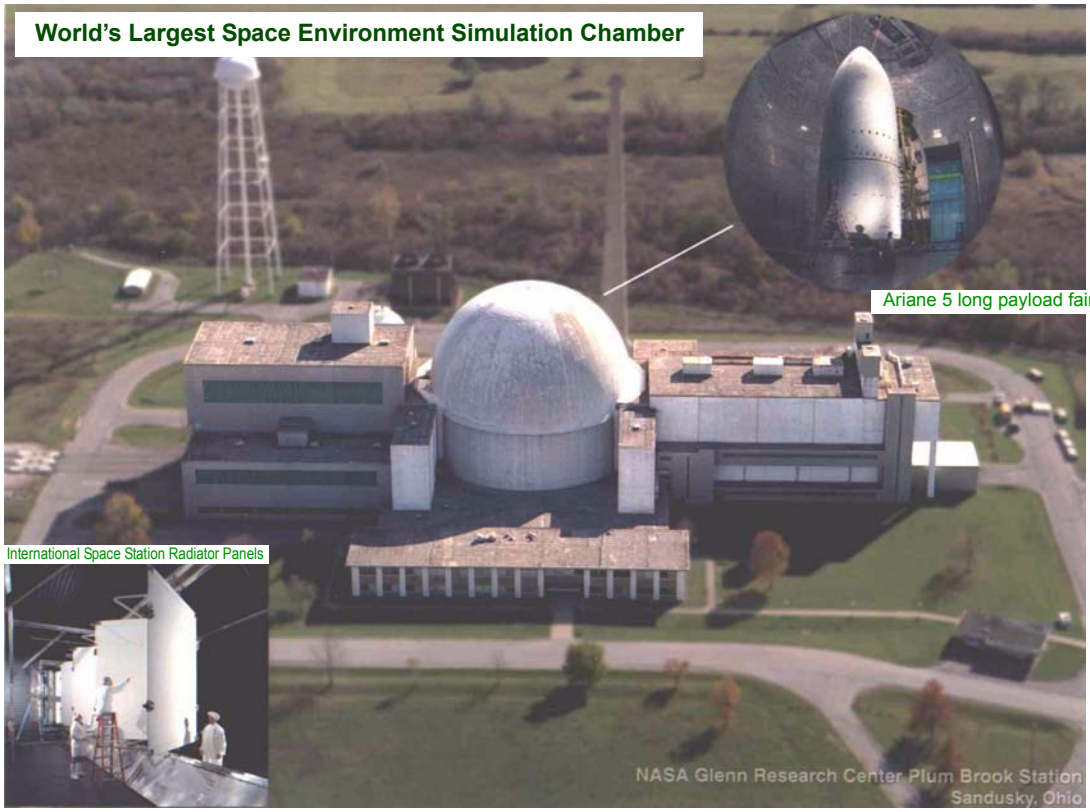
One of the four test facilities is the **Space Power Facility (SPF)** show below. The SPF is the world's largest space environment simulation chamber (100' diameter and 120' length) in which large space-bound hardware can be ground-tested in a severe environment similar to that encountered in space. The chamber air is removed to simulate the vacuum conditions of space at an altitude of 145 statute miles; charged argon gas is added to the chamber to simulate a space plasma environment of low earth orbit. Additionally, very cold and hot temperatures of space can be simulated using a cryogenic cold wall and quartz lamp heaters.

On the following page, the gigantic size of the SPF is demonstrated in photo-views of the open experiment assembly area and a test article in-place prior to testing.

CHI's joint-venture team expertise:

- Test Program Management
- Test Engineering & Planning
- Test Operations Engineering
- Test Instrumentation Engineering
- Test Control Engineering
- Facility Engineering & Maintenance
- Safety Engineering
- Quality Engineering
- Technicians & Mechanics
  - Cryogenics
  - Test Structures
  - Pneumatics
  - Hydraulics
  - Control Devices
  - Data Acquisition
  - Electronic Systems

World's Largest Space Environment Simulation Chamber



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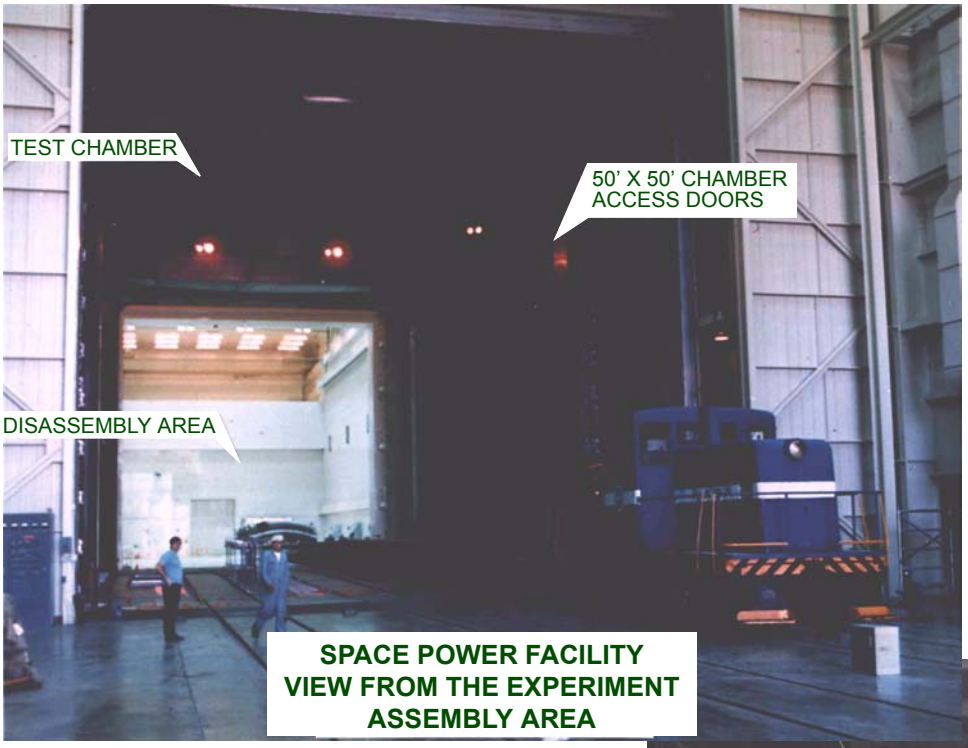

SPACE POWER FACILITY VIEW FROM THE EXPERIMENT ASSEMBLY AREA

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One of the four test facilities is the **Cryogenic Propellant Tank Facility (K-Site)** shown below. This 25' diameter chamber is used to develop the technology for generating and utilizing densified liquid hydrogen and oxygen in space. These fuels have the potential to significantly reduce the cost of access to space by reducing the size and weight of the launch vehicle fuel tanks without lowering performance, a high-priority objective of our Space program.

On the next page, the open 20' diameter door to the K-Site test facility provide a view into this impressive chamber; and one of the pre-VentureStar tanks is being readied for **K-Site** testing.

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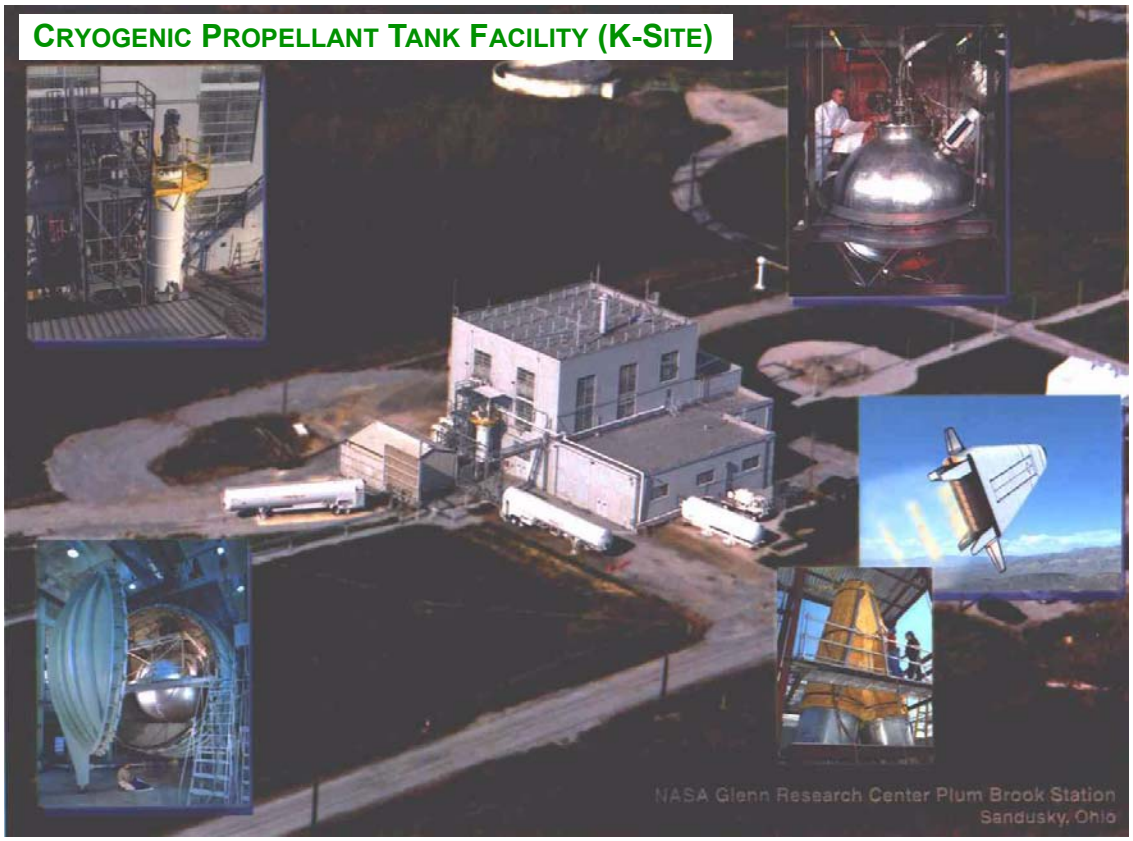
  - Hydraulics
  - Control Devices
  - Data Acquisition
  - Electronic Systems

Cryogenic Propellant Tank Facility (K-Site)



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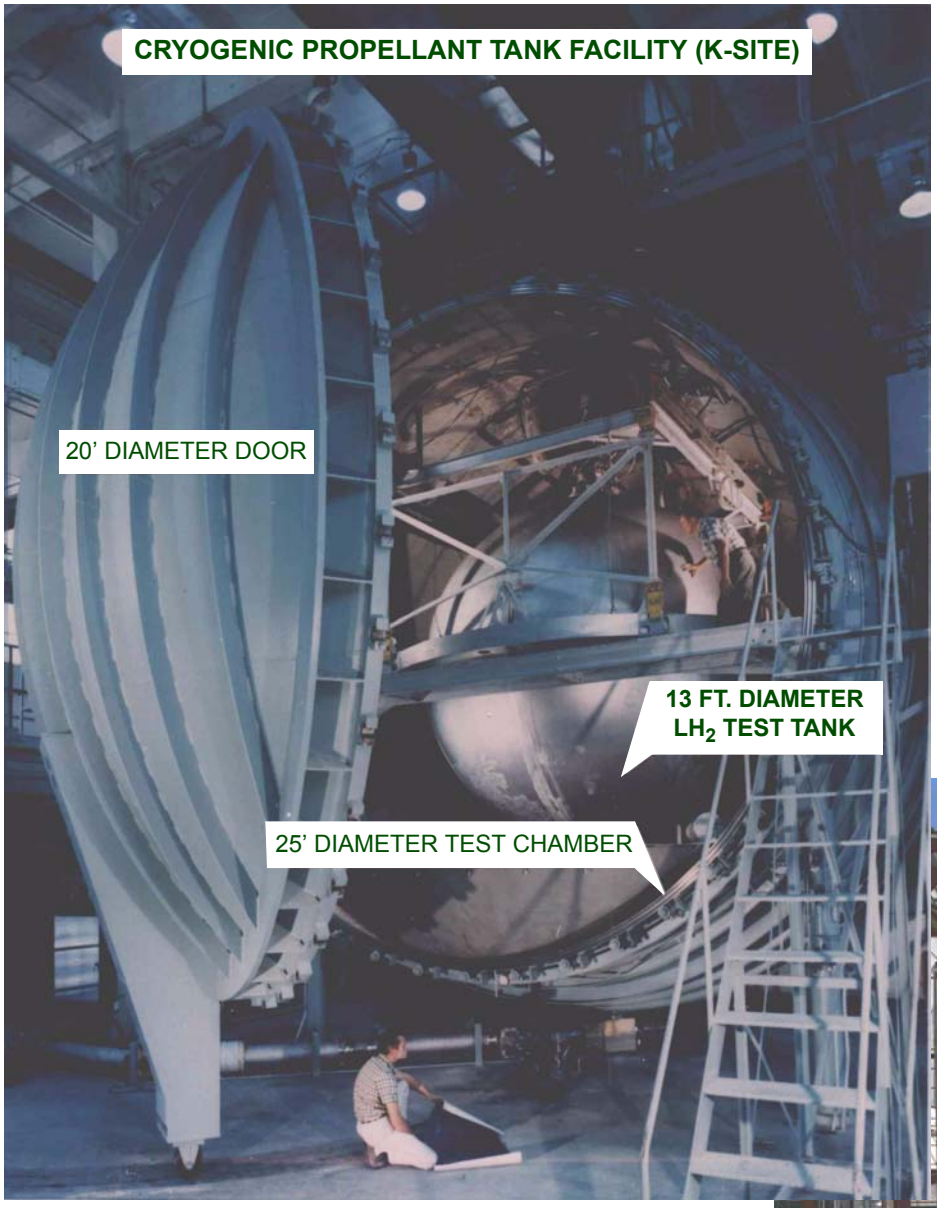

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One of the four test facilities is the **Spacecraft Propulsion Research Facility (B-2)** shown below. Large upper-stage space launch vehicles can undergo complete integrated systems testing, including engine firing, in the simulated space environment that the **B-2** provides. A full-sized launch vehicle, up to 400,000 pound thrust capability can be loaded into the 38' diameter by 55' high stainless steel vacuum chamber which can simulate pressure that would be experienced at 115 statute miles of altitude. Very high and low temperatures can be duplicated with a cryogenic cold wall and quartz lamp heaters.

The following page shows a cutaway view of the **B-2** and a photo of the Centaur rocket vehicle inside the **B-2** test chamber.

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  - Data Acquisition
  - Electronic Systems

Spacecraft Propulsion Research Facility (B-2)

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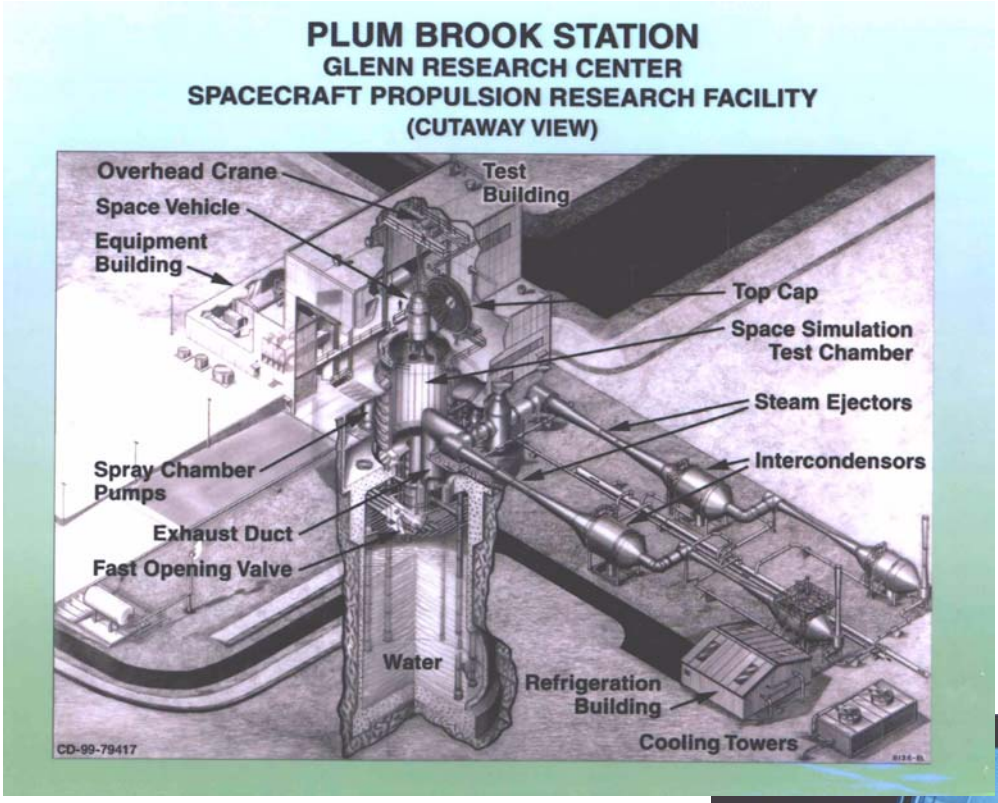
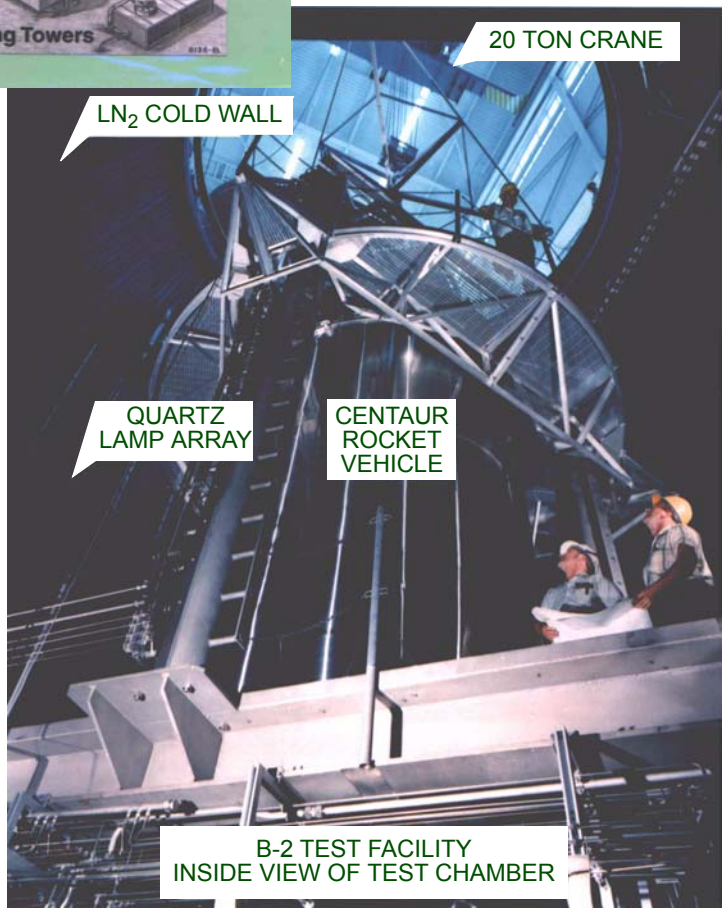
Aerospace Test Operations and Maintenance Services





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One of the four test facilities is the **Hypersonic Tunnel Facility (HTF)** shown below. This wind tunnel is capable of performing flow tests at Mach 5, 6, or 7. High-pressure Nitrogen gas flows through a 3-megawatt electrical heater that raises its temperature to nearly 2500 degrees Kelvan. Oxygen is added to the hot nitrogen to produce an air composition that is flowed through a 42-inch diameter hypersonic flow nozzle and past the test model. A large steam ejector pulls a vacuum on the test chamber to help establish the flow pattern and to simulate high altitude conditioning.

The following pages show a cutaway of the **HTF** that provides insight to the facility and its operational altitude corridor; and a photo of an engine setup for Mach 7 HTF testing.

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  - Pneumatics
  - Hydraulics
  - Control Devices
  - Data Acquisition

Hypersonic Tunnel Facility (HTF)

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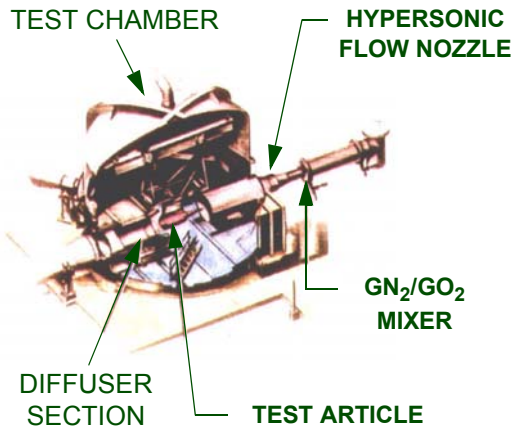
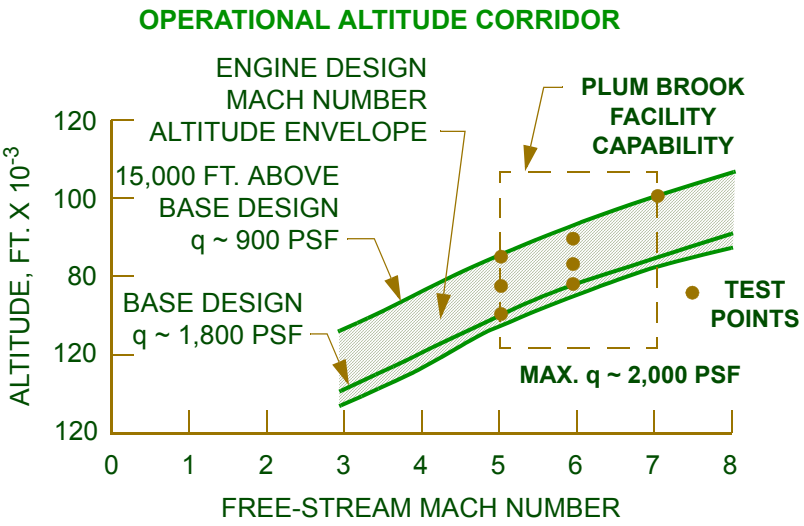
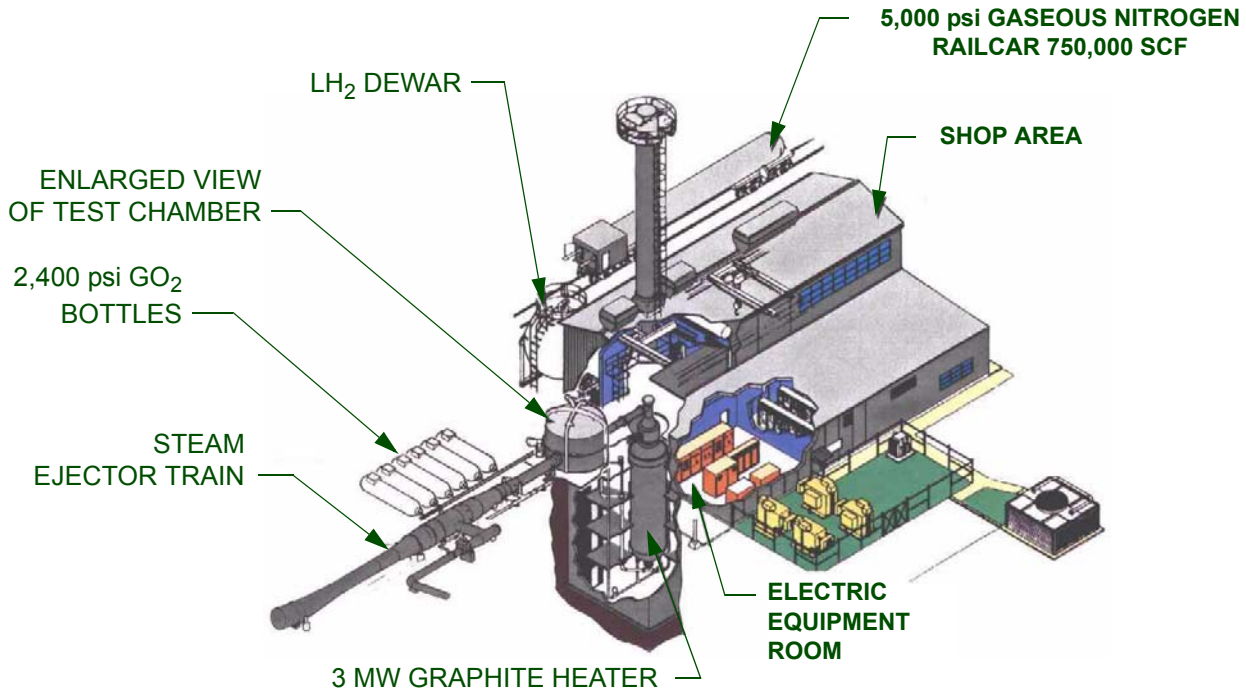
HYPERSONIC TUNNEL FACILITY (HTF) CUT-AWAY VIEW







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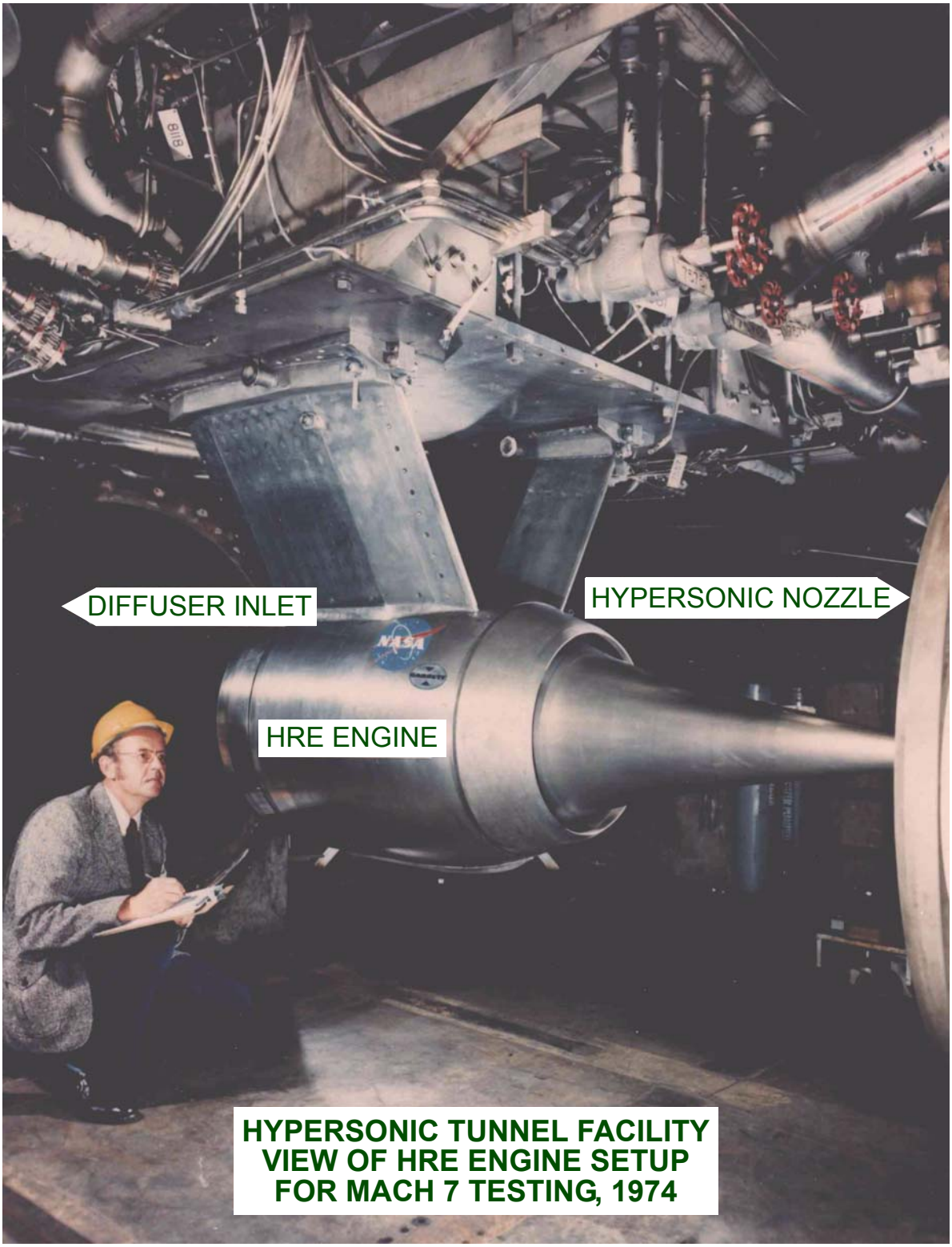

**HYPERSONIC TUNNEL FACILITY
VIEW OF HRE ENGINE SETUP
FOR MACH 7 TESTING, 1974**

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GOVERNMENT - INDUSTRY PARTNERSHIPS

In order to remain competitive, American aerospace companies are developing improved rocket vehicles which *will lower the cost of launching satellites into Space.*

These new vehicles must be thoroughly tested on the ground, before they are launched, to reduce the risk of failure during actual flights. Under a government-industry partnership, the Boeing Company's Delta 3 upper stage rocket was tested in the Spacecraft Propulsion Research Facility (B-2) at Plum Brook in March of 1998.

Delta 3 upper stage being loaded into the B-2 Facility at Plum Brook for test firing under simulated space conditions. B-2 is the world's only test facility where a full sized upper stage rocket vehicle can be tested, under conditions simulating actual flight in space.

With its joint-venture team, CHI operates and maintains this NASA Spacecraft Propulsion Research Facility at Plum Brook Station

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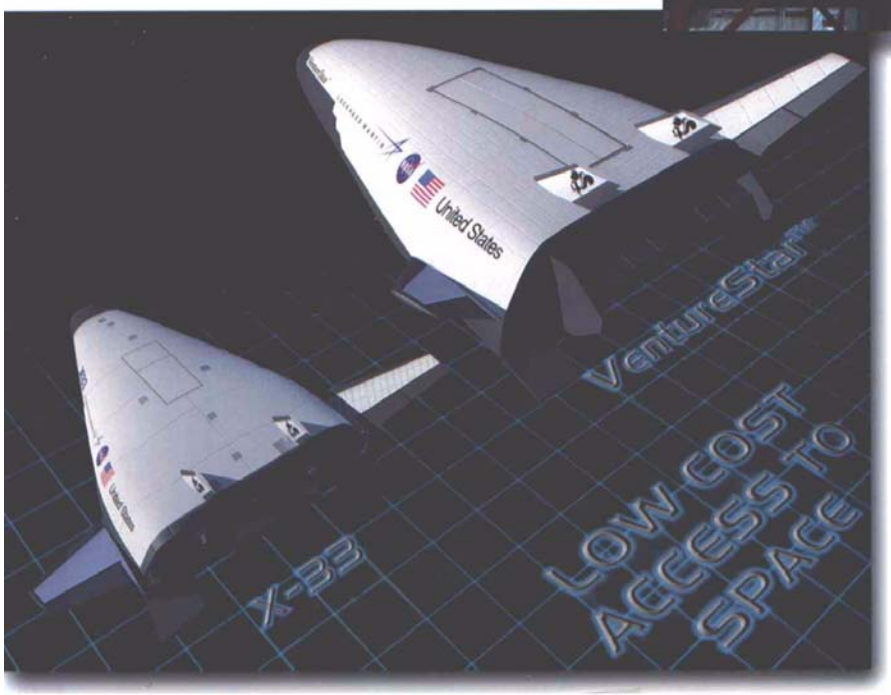
CUTTING EDGE TECHNOLOGY

NASA and industry are developing the X-33 flight vehicle to test new technologies that will be used to *reduce the cost of getting out into Space.*

One of these technologies involves making fuel more dense so that it will contain more energy per unit of volume.

Most of the country's research on densified hydrogen fuel was conducted at Plum Brook, since about 1990. During 1998, a scale model of the X-33 fuel tank was tested here using both normal and densified liquid hydrogen.



A scale model of an X-33 fuel tank is prepared for testing with densified hydrogen at the Cryogenic Propellant Tank Facility (K-Site)

CHI and its joint-venture team operate and maintain the Plum Brook Cryogenic Propellant Tank Facility for NASA

Lowering Access to Space Cost

NASA is developing new technologies to lower the cost of going out into Space.

During 1996 and 1997, in partnership with industry and the Air Force, NASA developed new engine chilldown methods for upper stage rocket engines.

These new methods reduce the amount of liquid hydrogen and oxygen needed to chill critical engine parts prior to starting the engine in space; they are expected to save about $500,000 per flight for typical high altitude satellite launches.

Technicians inspect an upper stage rocket engine involved in chilldown development tests prior to test firing in the Spacecraft Propulsion Research Facility (B-2).

CHI and its joint venture team operate and maintain this Plum Brook-based Spacecraft Propulsion Research Facility for NASA

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INTERNATIONAL SPACE STATION

The United States, with help from other countries, is building a large space station platform that will orbit the earth at about 200 miles altitude. This platform will permit men and women to live and work in space, in a protected environment, for long periods of time. Sections of this space station must be thoroughly tested on the ground, under simulated space conditions of vacuum (no air), cold (-250° F), and heat (+300° F) to verify they will perform properly when launched into Space.

September 1997: One of the radiator panels, which will remove waste heat from the International Space Station, is prepared for testing in the Space Power Facility (SPF) at Plum Brook. SPF is the world's largest space environment simulation chamber.

With its joint-venture team, CHI operates and maintains this NASA Space Power Facility located at Plum Brook Station

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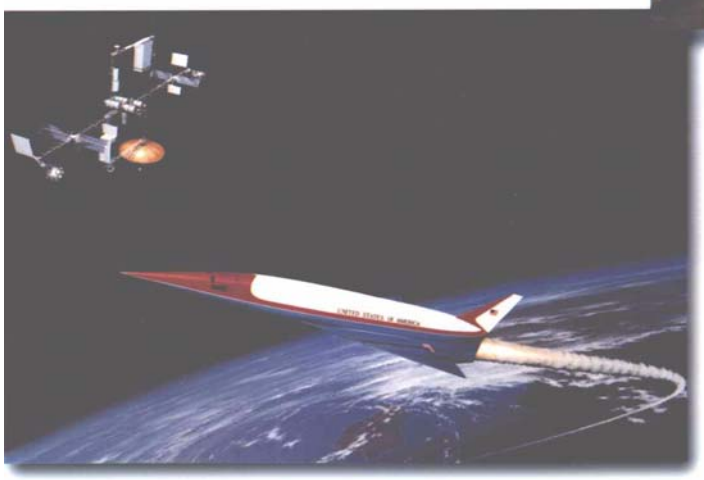
Rocket Based Combined Cycle

Future space vehicles will have more efficient combined cycle engines. These engines will use oxygen in the air we breathe to burn their fuel when they are in the earth's atmosphere; at higher altitudes, when air is no longer available, they will use oxygen from their own tanks to provide combustion. These revolutionary engines will significantly reduce the cost of getting out into space. Development of Rocket Based Combined Cycle (RBCC) engines required special test facilities that can simulate air speeds exceeding 5,000 mph.



July 1996: Rocket Based Combined Cycle (RBCC) engine set up for testing at Mach 7 conditions (7 times the speed of sound) in NASA's Hypersonic Tunnel Facility (HTF) at Plum Brook. HTF is the United States' only large scale, "clean air" Hypersonic Wind Tunnel.

This Hypersonic Tunnel Facility is one of four test facilities at Plum Brook Station that CHI and its joint venture team operate and maintain for NASA

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