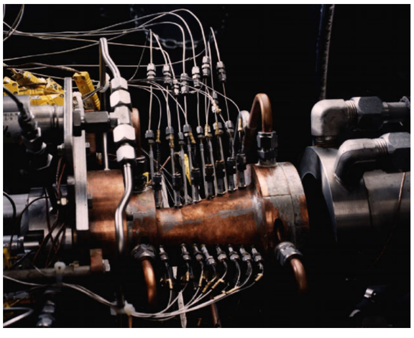
Space Combustion Facilities

Aerospace propulsion technology development is supported in the Research Combustion Laboratory (RCL). Four separate test stands can be used to test propulsion components and materials (with or without active cooling) in sub-scale combustion environments, ranging from 25 to 2000 lbf thrust. Each of the 4 separate test cells have unique characteristics providing a highly flexible matrix of test conditions that can be quickly tailored to meet research goals. Propellant capabilities vary between each of the test cells, however the most common are gaseous hydrogen and oxygen, liquid hydrogen and oxygen, and hydrocarbon fuels. Flow rates range from 0.1 lb/sec up to a maximum of 7 lb/sec. Altitude capabilities up to 90,000 ft. exist in two of the test cells. The capability to store and deliver these reactants facilitates the testing of a wide variety of test articles including rocket and air-breathing propulsion engines and components, fuel cells, and other power system components. Current and future programs supported include the Advanced Space Transportation Program (ASTP), Reusable Launch Vehicle (RLV), X-33, Bantam, Shuttle Fuel Cell Upgrade, Spaceliner 100, and Trailblazer (GRC Aero Base R&T). The facilities cross-cutting support capabilities have also made it a logical candidate for the testing of the regenerative fuel cell for the Helios aircraft, Shuttle Upgrade, and the Thrust Cell engine for the RLV program. Each of the individual test cells are discussed below.

RCL-11

Cell 11 is an altitude facility for conducting small chemical propulsion research. Performance and life tests can be conducted, as well as research-oriented work using instrumented or optically-accessible hardware. The facility is highly flexible, requires minimal staffing, and provides for quick-turnarounds. **Features:**

- **Gaseous Oxygen/Gaseous Hydrogen Propellants**
- **Altitude Simulation (137,000 ft, 10 torr)**
- **Continuous Mass Flowrates up to 0.20 lbm/sec**
- **Steady-State and Pulse Testing**
- **Digital Data Acquisition w/ Real Time Data Reduction**
- **Thrust Measurements from 2 to 35 lbf**
- **Two-Color Pyrometry for High Temperature Measurements**
- **Laser-Based Diagnostics (Rayleigh, Raman, LIF, Color Schlieren)**



RCL-11 Instrumented Chamber for 25-lbf Nozzle Study

RCL-21

Cell 21 is a low thrust (50 lbf maximum) combustion facility with altitude simulation capability up to approximately 90,000 ft. Cell 21 is used frequently to test rocket engine igniters and other sub-scale rocket engine components. Propellant capabilities include gaseous hydrogen up to 0.1 lb/sec, and gaseous oxygen up to 0.2 lb/sec. Other propellants included liquid hydrogen, liquid oxygen, and various hydrocarbon fuels.

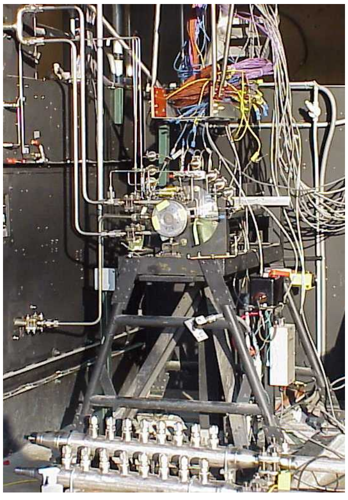
RCL-22

Cell 22 is a sea-level test stand, typically used as a high temperature thermal shock rig to test advanced rocket engine materials. The test stand is capable of thrust capabilities up to 2000 lbf and includes active cooling using a de-ionized water system. Propellants include both gaseous and liquid hydrogen, gaseous oxygen, and various hydrocarbon fuels.

RCL-24C

Cell 24C is currently being upgraded to provide testing of Regenerative Fuel Cells. Gaseous hydrogen up to 0.0045 lb/sec, and gaseous oxygen up to 0.0023 lb/sec can be supplied to the fuel cells. De-ionized water is supplied at a flow rate up to 2 gpm at 100 degree Centigrade. The test cell is rated Class I, Division II for NEC hazardous atmospheres. Electrical input of 10vdc at 200 amps is provided to the electrolyzer units, and electronic power dissipation can dissipate up to 20 Kw produced by the fuel cells.

RCL-32



RCL-32 Test Stand

Cell 32 is the newest space combustion test stand. Thrust measurements up to 2000 lbf are possible. Propellants include both gaseous and liquid hydrogen up to 1.0 lb/sec, and both gaseous and liquid oxygen at up to 7.0 lb/sec. Other propellants such as Hydrocarbon fuels are also available. Cooling for the test article can be provided using water, liquid hydrogen, or gaseous hydrogen. Cell 32 is designed for the extensive use of laser based diagnostic techniques for fluid and droplet velocity, species, and temperature measurements. A laser diagnostic equipment room is located between the test cells and the main control room, providing space for optical benches and associated control and measurement electronics. Several ports for optical access are located in the main blast wall, which separates the test cells from the laser room.

Space Cryogenic Facilities

The Small Multipurpose Research Facility (SmiRF) was designed to evaluate the performance of thermal protection systems required to provide long-term storage (up to 10 years) of cryogenic propellants in space.

More recently the facility has been used to test a wide variety of hardware. SMiRF provides the ability to simulate space, high altitudes and launch pressure environments; conduct calorimetry tests on prototype insulation systems and safely handle gaseous and cryogenic propellant. SMiRF specializes as a low cost small scale screening facility for concept and component testing. Programs recently completed with LH2 as the test fluid include: insulation performance tests for the X-33 vehicle, demonstration of rapid chill and fill of a subscale propellant tank for the High Energy Upper Stage program, and demonstration of a zero boil-off long term cryogenic storage concept for the Mars Exploration program.

Test Facility

The SMiRF vacuum chamber can accommodate test articles as large as 71 inches in diameter by 90 inches high. A programmable thermal shroud system can be used inside the SMiRF chamber to control background temperatures over a temperature range of 200 to 650 R. Test article size is limited to 44 inches in diameter by 65 inches high when the shroud is installed. The SMiRF chamber can maintain a vacuum environment of $5x10^{-5}$ torr. The chamber can be evacuated along the Space Shuttle Pressure Ascent profile (760 torr to 10-2 torr in 2 minutes)

Various purge gases are available on-site (GHe and GN2). The facility has also handled GH2 and G02 tests. Up to 512 channels of data at can be collected at a nominal rate of 1/sec. Data is collected and processed by a dedicated workstation computer and is archived on Glenn’s central computer.

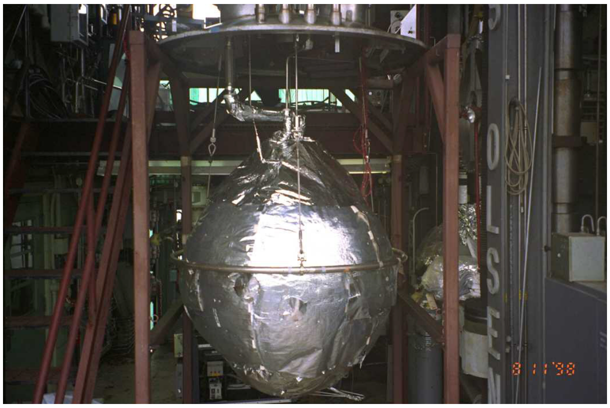
Test building

The steel frame building consists of a control room, shop, and test area. The shop is separated from the test area by an 8-inch thick concrete block wall. The shop is separated from the control room by a 1'-3" thick concrete wall. Entry doors are located on the east and west sides of the control room, and on the East Side of the shop. A pressurization system exists that is used to pressurize the shop and control room during testing.

The high bay test area is 31 feet high. The building walls consist of thirteen (13) 10'x12' panel lift doors. All lift doors are open during hydrogen testing. LH2, and LN2, are supplied to the test article located in the vacuum chamber from roadable dewars located north of the test area inside the mounded area. A crane with a 4000 lb. capacity and 20 feet lift is located in the high bay.

Vacuum Chamber

A 261 ft^3 vacuum chamber is located on the ground level of the building. The stainless steel vacuum chamber is a cylinder with a vertical main axis and dished heads at the top and bottom. It is 98.25 inches high by 71.25 inches in diameter. Test articles are placed inside the vacuum chamber and suspended from the lid. All electrical and fluid connections pass through the lid of the vacuum chamber. The test article is removed by lifting the vacuum chamber lid/research article assembly.



Test Article Supported from Vacuum Chamber Lid

A mezzanine level allows access to the vacuum chamber lid.

The vacuum system is capable of providing rapid pump down of the SMiRF vacuum chamber. Rapid pump down is defined as being able to follow the STS launch pressure profile. The STS launch pressure profile, from atmospheric pressure to 0.05 torr, is achieved by using several mechanical roughing pumps. The space vacuum environment is achieved by using three 1500 liter per second diffusion pumps backed by a mechanical roughing pump.

Thermal Shroud

The shroud is located inside the vacuum chamber between the vacuum chamber wall and the research article. The thermal control system provides a known radiative background temperature for the research article and can simulate a lunar day temperature profile. The shroud is made of aluminum finned tubes that are attached to an upper and lower manifold. The emissivity of its inner and outer surfaces is less than 0.1. The shroud can be controlled between 200^o R and 650^o R. Temperature ramping capabilities are at least 0.30 R per minute over the entire range. Shroud temperature top to bottom can be controlled within $\pm$5.0 R over the entire operating range.

Electrical Systems

Electrical power for Building 204 is supplied by a 480 volt, 400 Amp panel located in the building. All electrical components in the test area are rated for Class I, Division 2, Group B service or enclosed in nitrogen purged cabinets per the NEC.

Safety critical and automatic control functions are controlled via a Modicon Programmable Logic Controller

Vent systems

Vent gases evolved from the test hardware can either be dumped to an atmospheric vent or routed through a backpressure control system. The backpressure control system is used primarily for measuring boil-off from the test article. It consists of five control valves located in parallel, sized to provide control over a flow range 0.02 to 3200 SCFH. Mass flow meters are located downstream of the control valves. Backpressures can be maintained within $\pm$ 0.02 psia at steady state conditions.