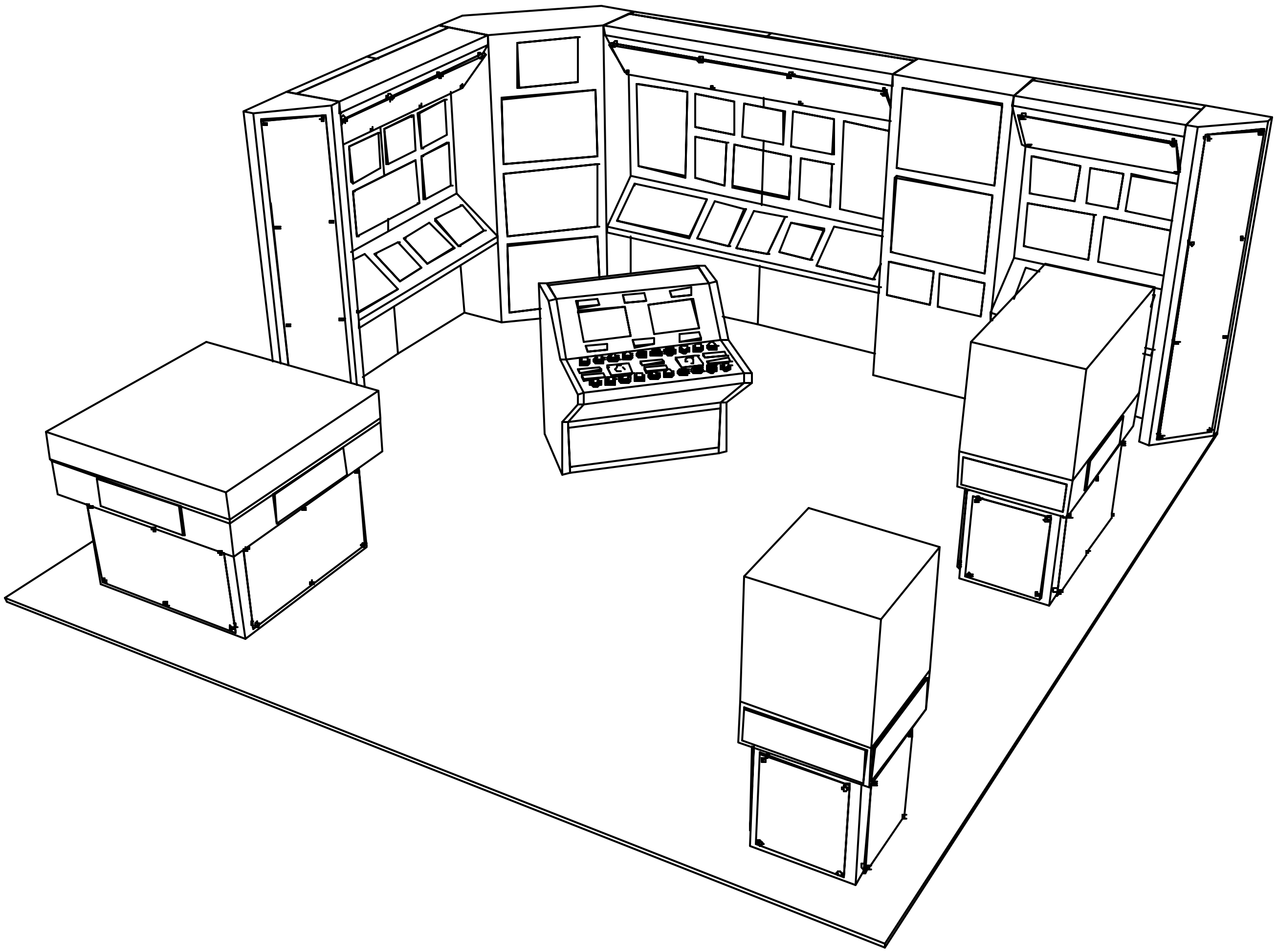

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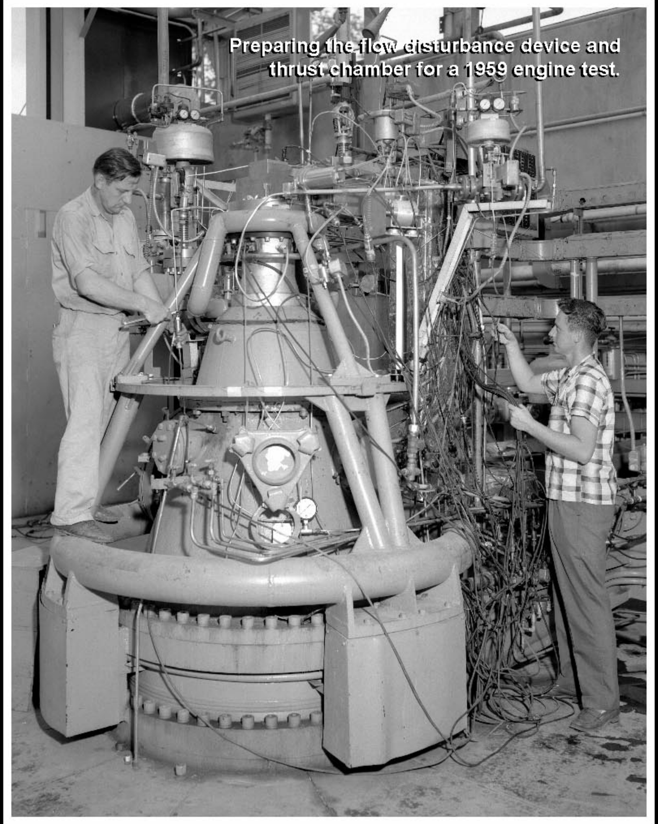
Rocket Engine
Test Facility
RETF
RETF HISTORY
A BRIEF HISTORY OF RETF
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio
RETF CONTR
LPLHTKSP
LPLHTKP
LH2TKPV SET PT.
LPLHTLiP
HPLOXTP
HPLOXTK SET PT.
DPM
POWER
HPLOXLiP
HPLOXLiP-1
HPLHTKP SET PT.
HPCLOXLiP



Preparing the flow disturbance device and thrust chamber for a 1959 engine test.

Engineer examining a data printout.

A 1964 reamable injector developed by engineers at RETF.

5,000 pound rocket engine being studied for low-cycle thermal fatigue in 1975.

SIGNIFICANT RETF CONTRIBUTIONS

Proved that liquid hydrogen could safely be used as a rocket fuel
Solved engine design problems so liquid hydrogen could be used
Tested components of the J-2 engine

LIQUID HYDROGEN AS A PROPELLANT

The Russian scientist Konstantin Tsiolkovsky proposed liquid hydrogen as a fuel as early as 1903, but only after World War II was liquid hydrogen fully developed as a propellant. After witnessing the German V-2 rocket-powered missiles, the U.S. military was prompted to develop American rocket-powered missiles as a way to help maintain national security. Although kerosene was the standard rocket fuel in the U.S. at this time, it produced significantly lower energy than liquid hydrogen could produce. More research on high-energy liquid and solid propellants was begun throughout the country at various Air Force, Navy, and NASA locations, including Lewis Research Center. Liquid hydrogen once again came into the spotlight.

Lewis Research Center took the lead in the research and testing of a variety of high-energy fuels, including the extremely cold and volatile liquid hydrogen, as they tried to find the one that would provide the most power. They examined oxidizers such as liquid fluorine and liquid oxygen, and after hundreds of tests, scientists at RETF determined that a combination of liquid hydrogen and liquid oxygen provided the greatest propulsion. Using much skill and ingenuity, they found ways to successfully and safely use the combination as fuel for a rocket engine.

Liquid hydrogen is an ideal fuel source for several reasons:

- It results in the highest exhaust velocity of all the chemical fuels. A high exhaust velocity makes the rocket more powerful, and it then can send heavier payloads into space.
- It has a high reaction rate with the oxidizer. Liquid hydrogen combines quickly with the oxidizer and therefore is better than other fuels for injection into the combustion chamber.
- As an extremely cold liquid at -400 ºF, liquid hydrogen can help cool the engine as it flows through. RETF engineers developed this ingenious idea because an engine using liquid hydrogen burns much hotter than an engine using kerosene, and they could use their cold propellant to cool the metal of the engine so that it would not melt or deform.

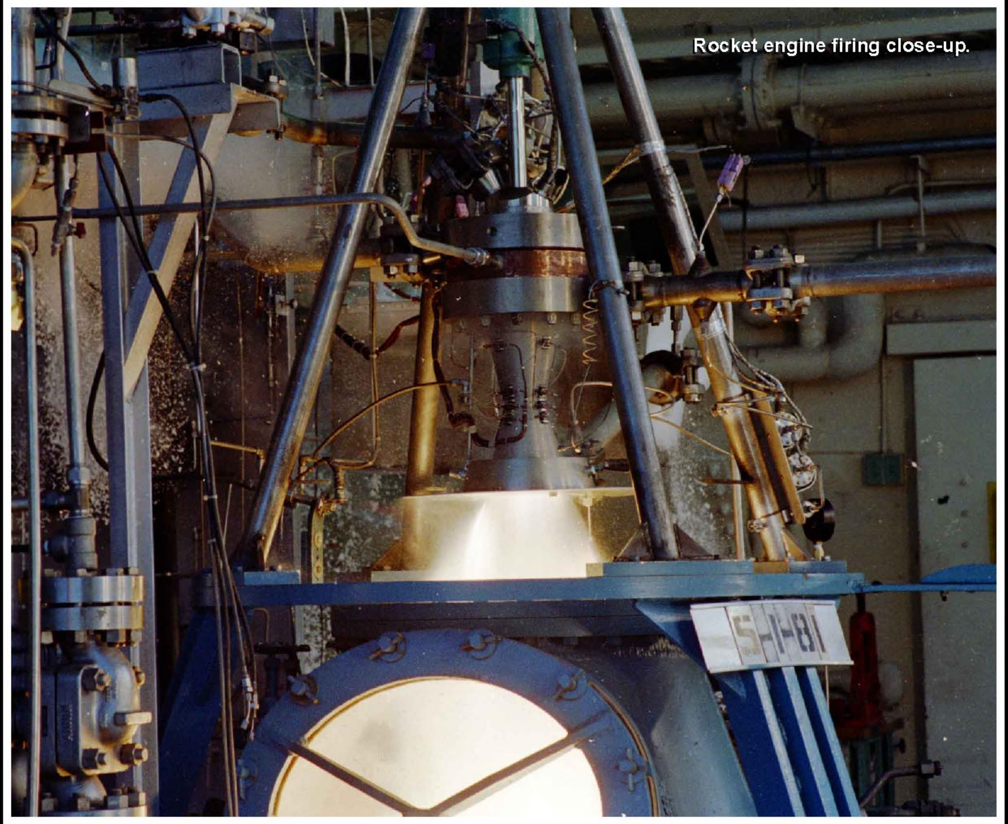
However, despite its many valuable qualities, the use of liquid hydrogen had some early drawbacks:

- It has a low fuel density, which means that less quantity of liquid hydrogen can be stored in a standard fuel tank than other types of fuel. Therefore larger and heavier tanks are needed on the spacecraft.
- Since there was little market for liquid hydrogen prior to these developments, it was not readily available from suppliers during the late 1940s and early 1950s.

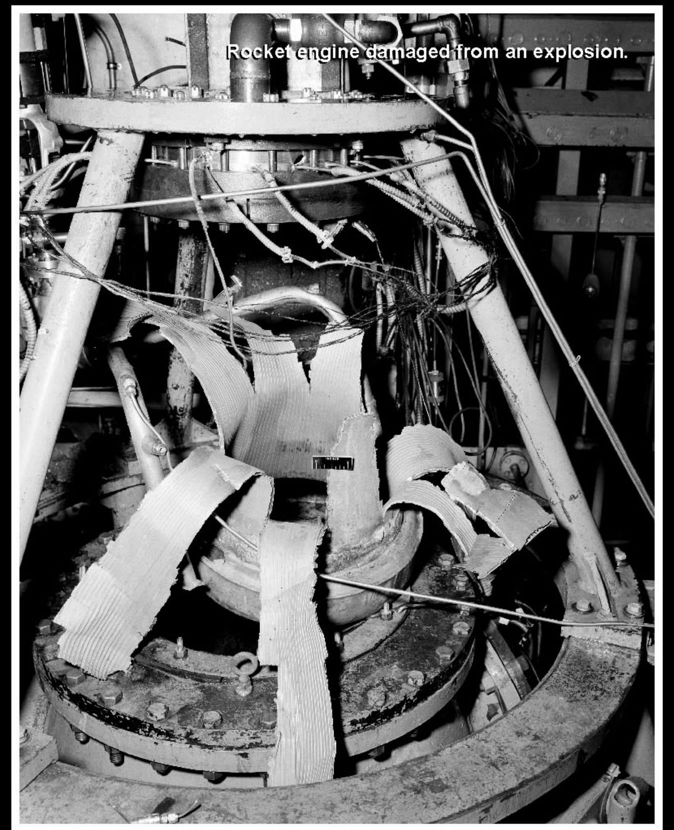
Many of the design problems of liquid-hydrogen fuels were solved at RETF. RETF engineers persisted with hundreds of tests until they solved the problems inherent in burning the potent fuel. They discovered how to cool the combustion chamber and nozzle by using the cold liquid hydrogen. They experimented with many designs for the injectors and combustion chambers until they achieved an efficient, smooth-burning, high-energy engine. By 1958, they were testing a fully cooled, liquid-hydrogen-liquid-oxygen combustion chamber at 20,000 pounds thrust.

Rocket scientists soon realized that the high energy of liquid hydrogen was useful for the upper-stage of rocket launching. It provided tremendous thrust and the extra weight of the larger fuel tanks was not as detrimental because of the lessened effect of gravity during the upper stage of flight.

The development of liquid hydrogen and liquid oxygen at RETF has contributed greatly to the exploration of space.



Rocket engine firing close-up.



Rocket engine damaged from an explosion.

Engineers pressure checking the fuel impinging qualities of a 20,000 pound rocket injector in 1959.

Preparations to test a 1000 to 1 area ratio rocket engine in Test Stand B.

HOW ROCKETS WORK

A rocket is made up of many parts, including the engine, the propellants, and the payload, which is the cargo for the trip, such as a satellite. Propellants power the rocket and can be in the form of a solid, liquid, gas, or gel, depending on the rocket. In rockets propelled by liquid fuel, separate containers hold the fuel and the oxidizer. The oxidizer is a substance that must be present for the fuel to burn. (In the RL-10 and J-2 engines, the oxidizer was liquid oxygen.) Just before the engine is ignited, the fuel and oxidizer are sprayed from the injector into the combustion chamber where they mix for combustion. The injector and combustion chamber are the two main components that make up the core of the rocket engine. When the propellants are ignited and burn, the temperatures and pressures build up in the combustion chamber, and the hot gases escape backward through the nozzle, propelling the rocket forward.

ROCKET PARTS

The key components of a liquid propelled rocket are listed below:

Payload: The cargo that is launched into orbit.

Fuel: The chemical burned in the engine. Kerosene is a common rocket fuel. RETF tested liquid hydrogen, a higher-energy fuel.

Oxidizer: A chemical that enables the fuel to burn. Liquid oxygen was an oxidizer at RETF.

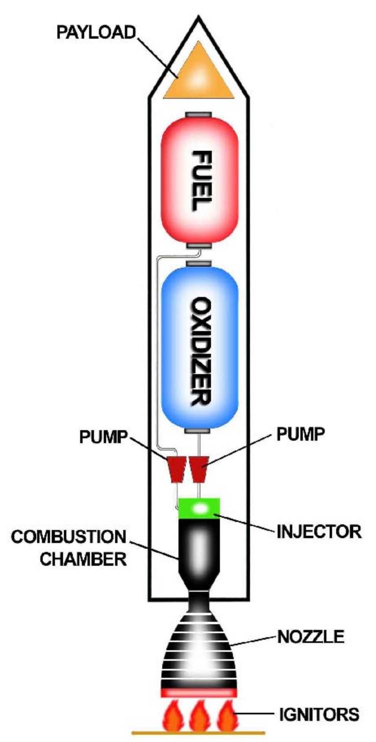
Pumps: A turbine, or rotary engine, that forces the fuel and oxidizer into the injectors and combustion chamber.

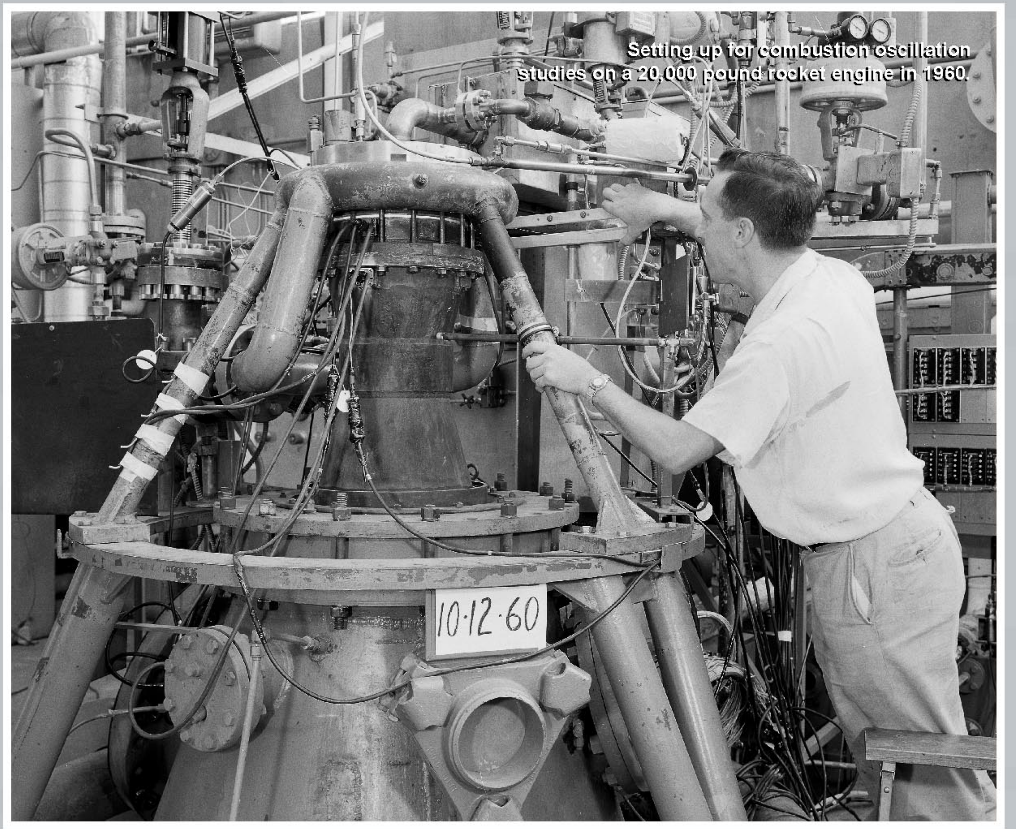
Injectors: Engine part that controls fuel and oxidizer and sprays these propellants mixture into the combustion chamber where they are mixed. A good injector controls the mix consistently so that the engine burns smoothly and powerfully.

Combustion chamber: The engine container where the propellant mixture is ignited and burns. The hot gases that result will expand and push the rocket forward.

Nozzle: An opening at the lower end of the rocket that allows the hot gases to escape.

Igniter: Device that lights the propellant.





Setting up for combustion oscillation studies on a 20,000 pound rocket engine in 1960.

Photo of workstation in Building 206A.

ARTIFACT
206A-1

MONITOR

THE RL-10 ENGINE

The first liquid-hydrogen-liquid-oxygen engine produced in the United States was the RL-10, which was tested at the Lewis Propulsion Systems Laboratory. RETF was the site of many tests for the engine's components. During the late 1950s, Pratt & Whitney, the designers of the RL-10, encountered problems with their rocket's injector. Because of Lewis's work with liquid hydrogen, Pratt & Whitney visited the RETF many times and began to focus on a concentric ring injector that was developed at Lewis. Pratt & Whitney subsequently selected the concentric ring injector as the RL-10 injector. Today, the concentric ring injector is the standard design for almost all liquid-hydrogen rocket engines, including the main engine for the Shuttle.

The RL-10 engine can produce 16,500 pounds of thrust. A combination of two RL-10 engines allows NASA to have payloads as large as 8,500 pounds. The RL-10 was the forerunner to today's class of liquid-hydrogen-liquid-oxygen rockets.

Today, two RL-10 engines power the Centaur launch vehicle, which was the United States' first high-energy, upper-stage launch vehicle. First launched on November 27, 1963, the Atlas/Centaur was the very first flight to use liquid-hydrogen-liquid-oxygen in its engine. In May of 1966, the Atlas/Centaur launched Surveyor I, which was NASA's first soft landing on the moon, and in the 1970s, the Centaur was combined with the Atlas and Titan boosters to serve as the upper-stage launch vehicle for flights to the planets Mercury, Venus, Mars, Jupiter, Saturn, Uranus, and Neptune. The Centaur also has launched a number of observatories and communication satellites into orbit and most recently helped launch the Cassini mission to Saturn. Centaur rockets, with their RL-10 engines, have been launched over a hundred times since 1963.

THE J-2 ENGINE

The RETF contributed its knowledge and testing of liquid-hydrogen engine components to assist in the development of the J-2 engine. The J-2 tests at the RETF focused on combustion instability problems and included the design, construction, and testing of multiple injectors, combustion-chamber shapes, and acoustical linings.

The J-2 was designed by North American Aviation's Rocketdyne Division in 1960 and can produce a maximum thrust of 225,000 pounds. The J-2 was selected to power the second and third stages of the Saturn V rocket that powered each of the Apollo missions. NASA's selection of the J-2 liquid hydrogen engine gave the United States a decisive advantage in the space race during the 1960s. The Saturn V's last mission, powered by J-2's in the second and third stages, lifted NASA's Skylab space station into orbit on May 14, 1973.

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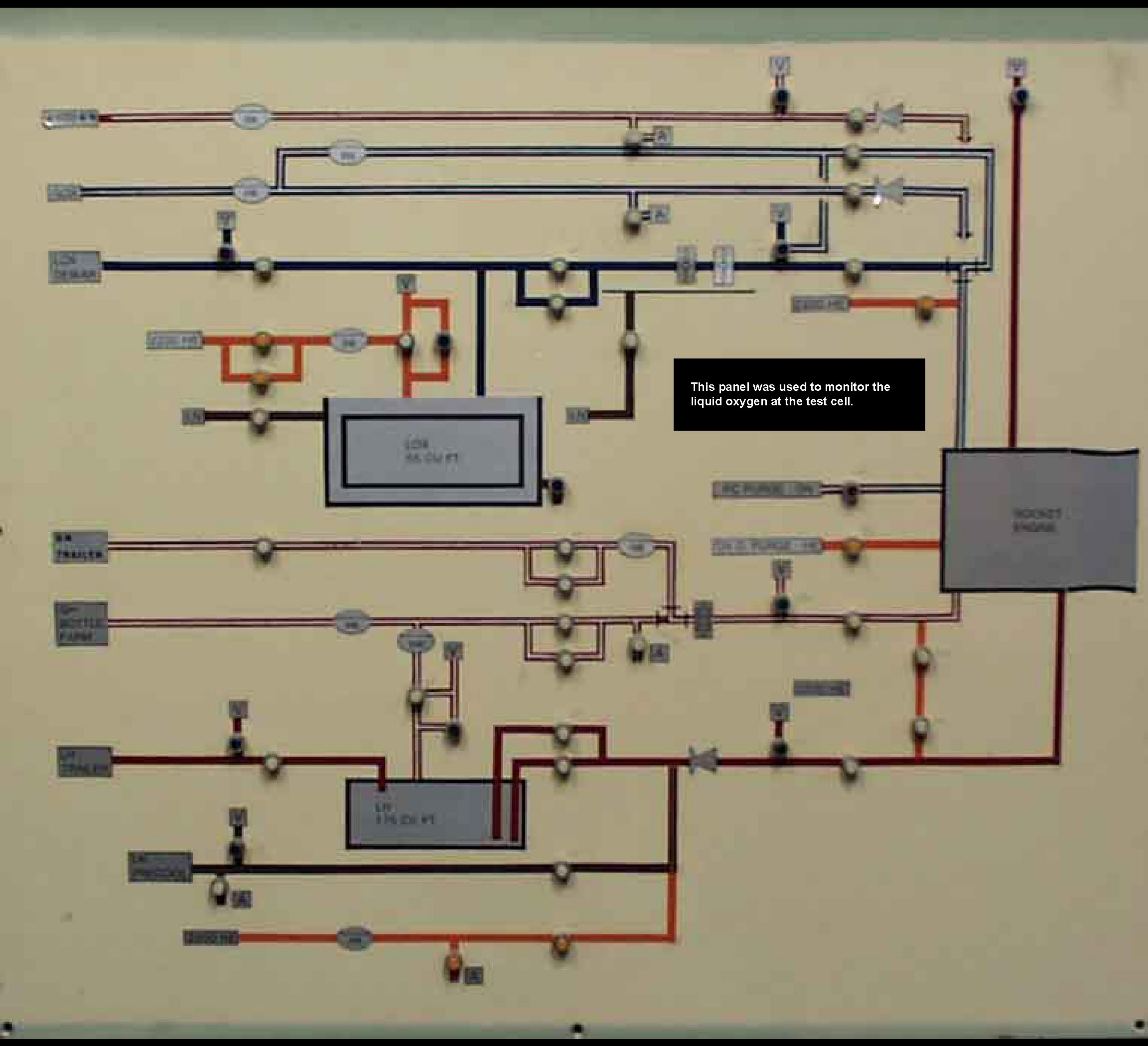
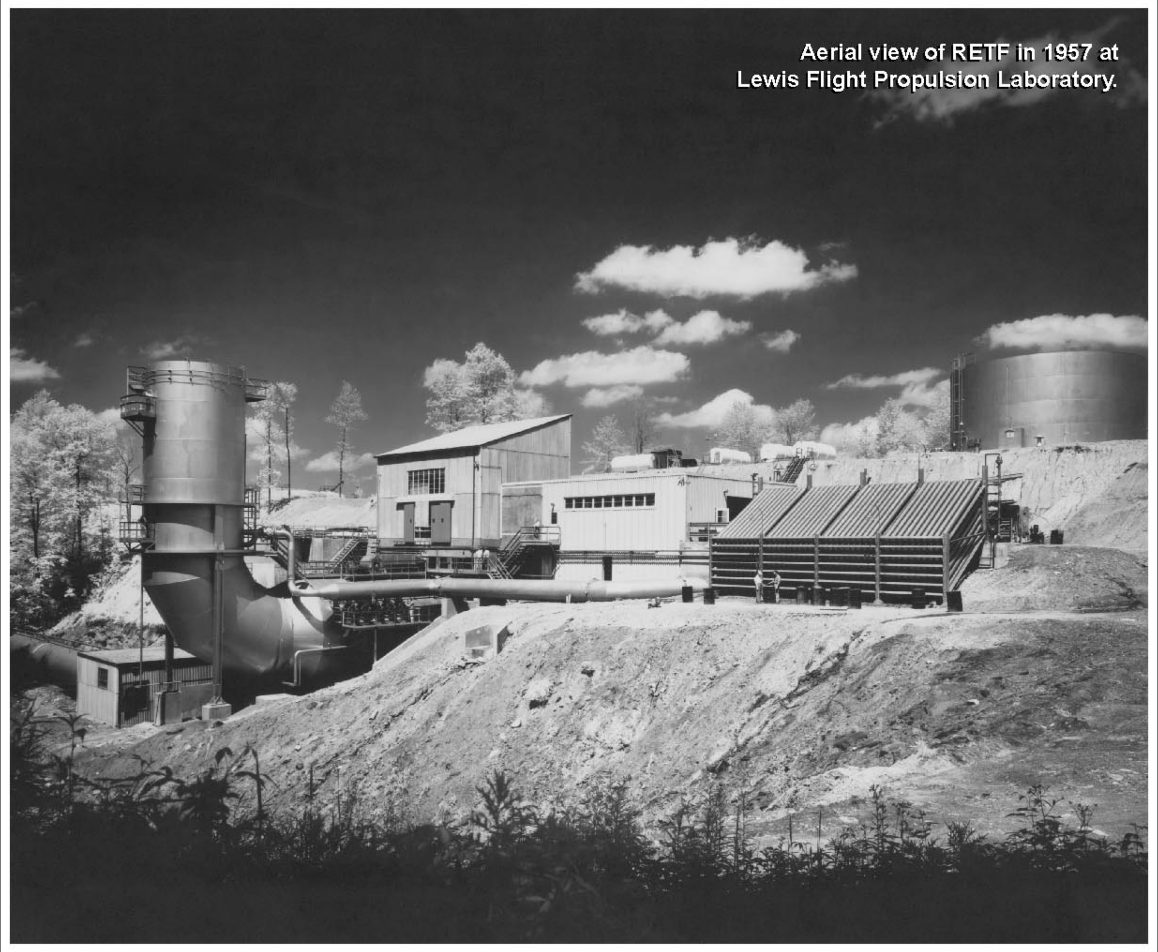


This panel was used to monitor the liquid oxygen at the test cell.

This panel and electronic equipment controlled the speed at which the valves were opened to allow the fuel and oxidizers into the test cell.

This is a ramp generator panel. According to former RETF Engineer Doug Bewley, "These ramp-generators were used to provide reference electrical signals to the controllers who then positioned the valves that provided the liquid oxygen and liquid hydrogen to the rocket engine being tested."



Aerial view of RETF in 1957 at Lewis Flight Propulsion Laboratory.

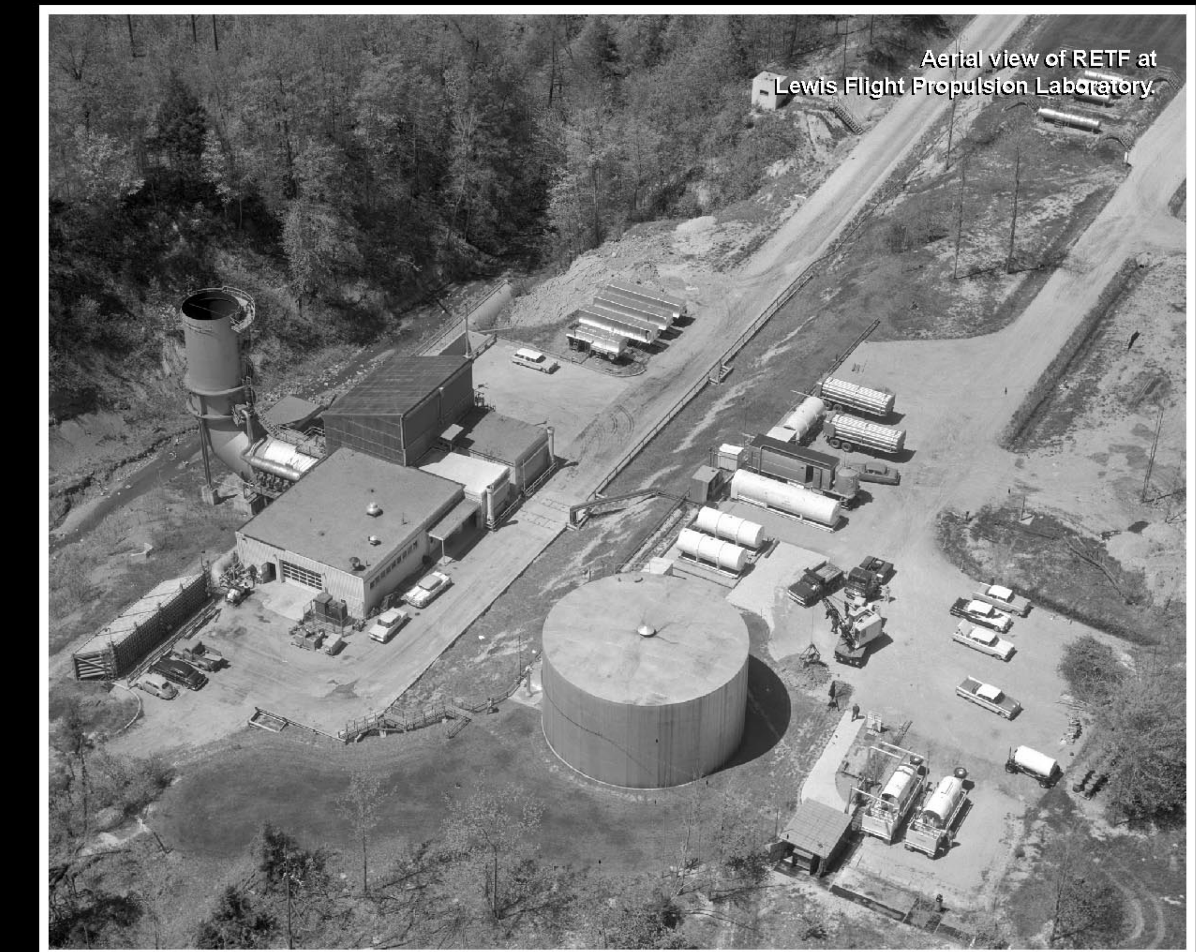
A BRIEF HISTORY OF RETF

The Rocket Engine Test Facility (RETF) was built in 1955-1957 at the Lewis Flight Propulsion Laboratory, a research facility for the National Advisory Committee for Aeronautics (NACA), located in Cleveland, Ohio. The RETF was constructed as part of a United States' mission to develop rockets. This mission was motivated largely as a response to the German advancement of rocket technology during the war and to the Russian success in launching Sputnik. Because the U.S. needed a rocket that was powerful enough to propel payloads into space, the U.S. dedicated facilities like the RETF to the research and testing of rocket engines. Scientists here focused on testing new engine designs with various combinations of high-energy liquid fuels. Although kerosene was the standard rocket fuel used by others, researchers at the RETF took the greater risk to work with the volatile liquid hydrogen, a fuel that promised much more power if they could safely harness it.

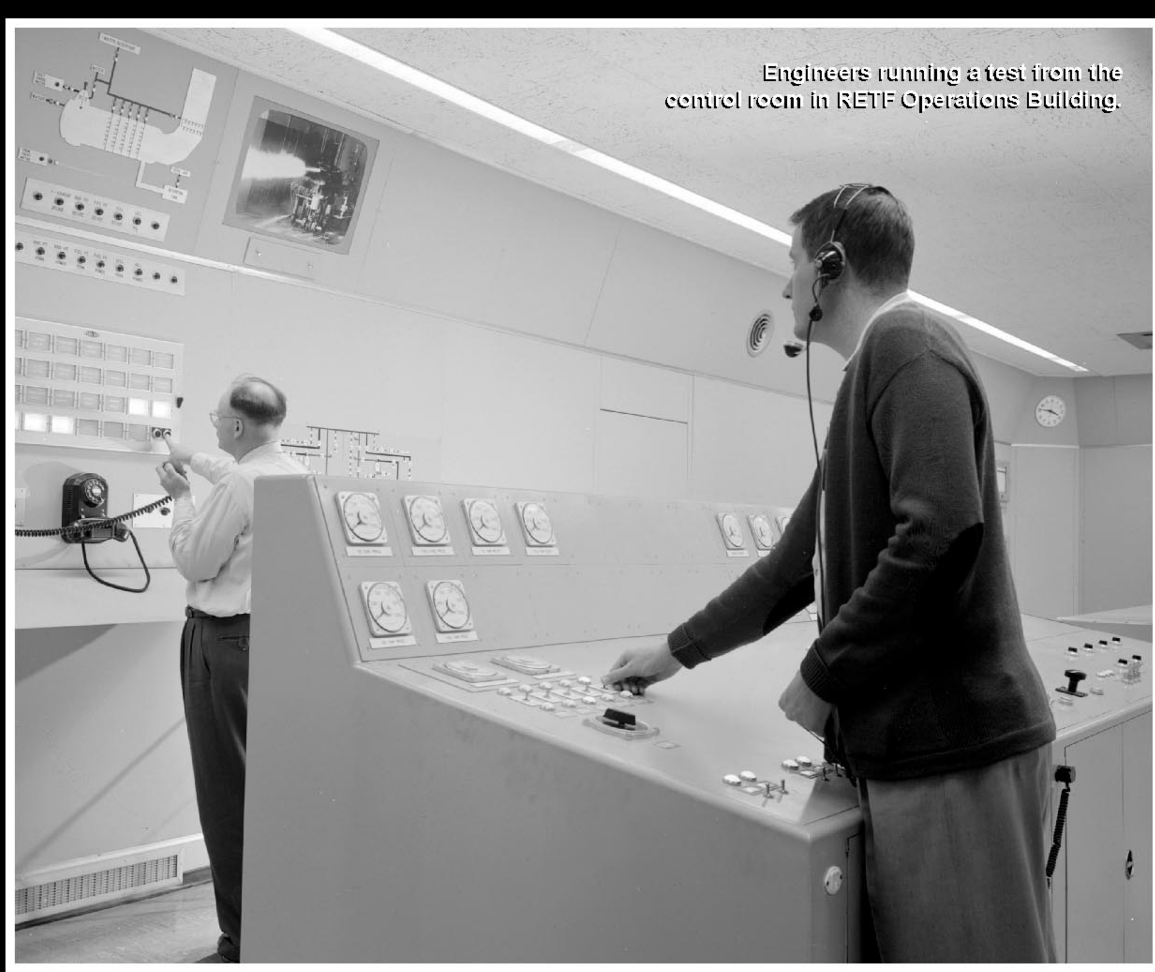
At the RETF, engineers returned to the basic components of rocket engineering and proceeded to design, build, and test hundreds of different engines. Their challenges were to make an engine body that would endure the high temperatures of their new fuels and to design an injector that would consistently mix the fuel and the oxidizer in the combustion chamber so their engine would burn smoothly. No one had successfully used liquid hydrogen as a rocket fuel before. The RETF scientists knew liquid hydrogen had tremendous potential, and they devoted themselves to finding a way to make it work.

One of the most outstanding achievements at the RETF during the 1950s and 1960s was the development of liquid hydrogen as rocket fuel. The knowledge gained at RETF on how to use liquid hydrogen was an essential contribution to the Pratt and Whitney RL-10 engine that was used in the Centaur rocket. The Centaur rocket's first mission was as an upper-stage launch vehicle for the unmanned Surveyor spacecraft that went to the Moon. The Centaur rocket has more recently served as the upper stage for probes and fly-by missions to other planets, notably Mercury, Venus, Mars, Jupiter, Uranus, Neptune, and the Cassini mission to Saturn.

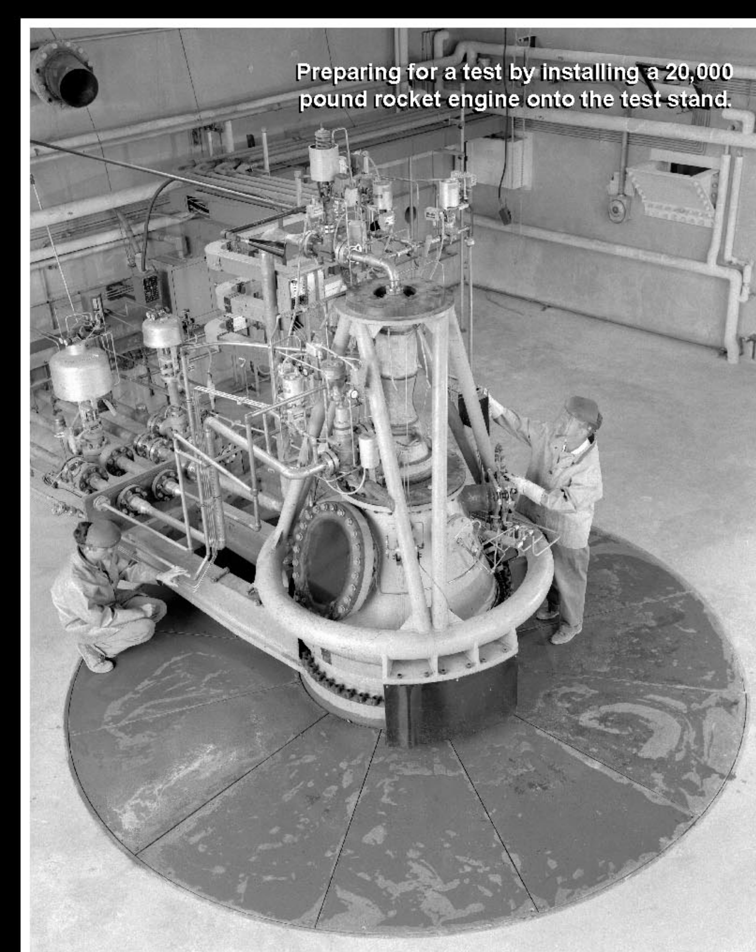
The RETF tested and also contributed to the development of the J-2 engine that was used for the second and third stages of the Saturn V rocket that powered the Apollo program to the moon. It is widely accepted that the use of the Rocketdyne J-2 liquid hydrogen engine in the upper stages of the Saturn Rocket gave the United States a decisive advantage in the race to complete a human mission to the moon.



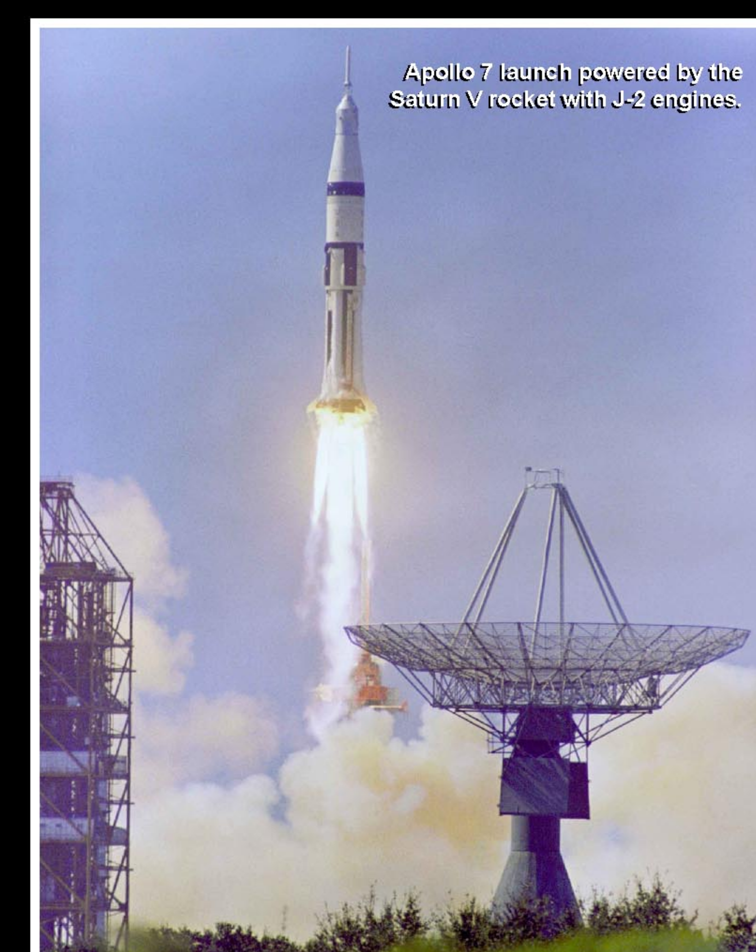
Aerial view of RETF at Lewis Flight Propulsion Laboratory.



Engineers running a test from the control room in RETF Operations Building.



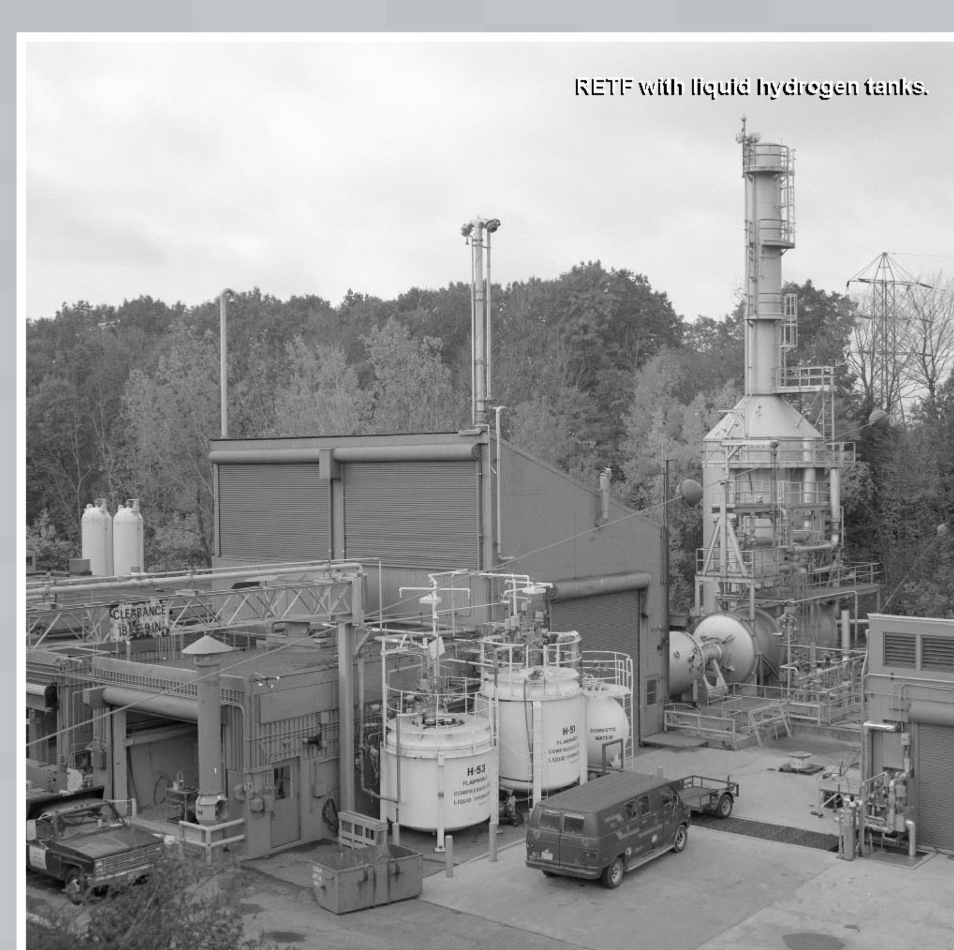
Preparing for a test by installing a 20,000 pound rocket engine onto the test stand.



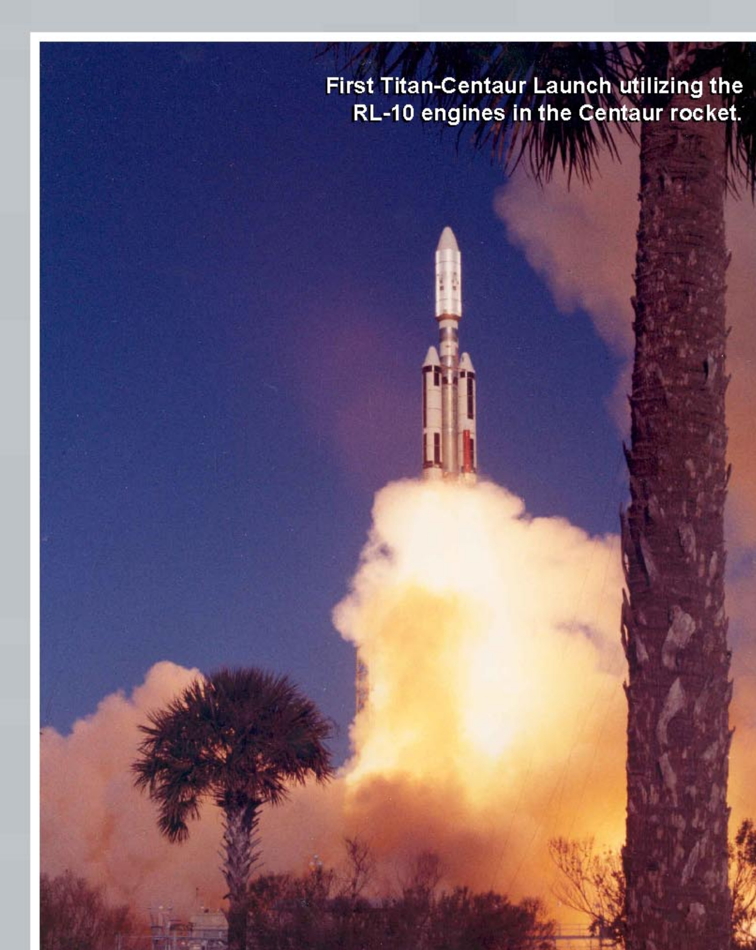
Apollo 7 launch powered by the Saturn V rocket with J-2 engines.

Building a 20,000 pound rocket engine in RETF shop.

MONITOR



RETF with liquid hydrogen tanks.

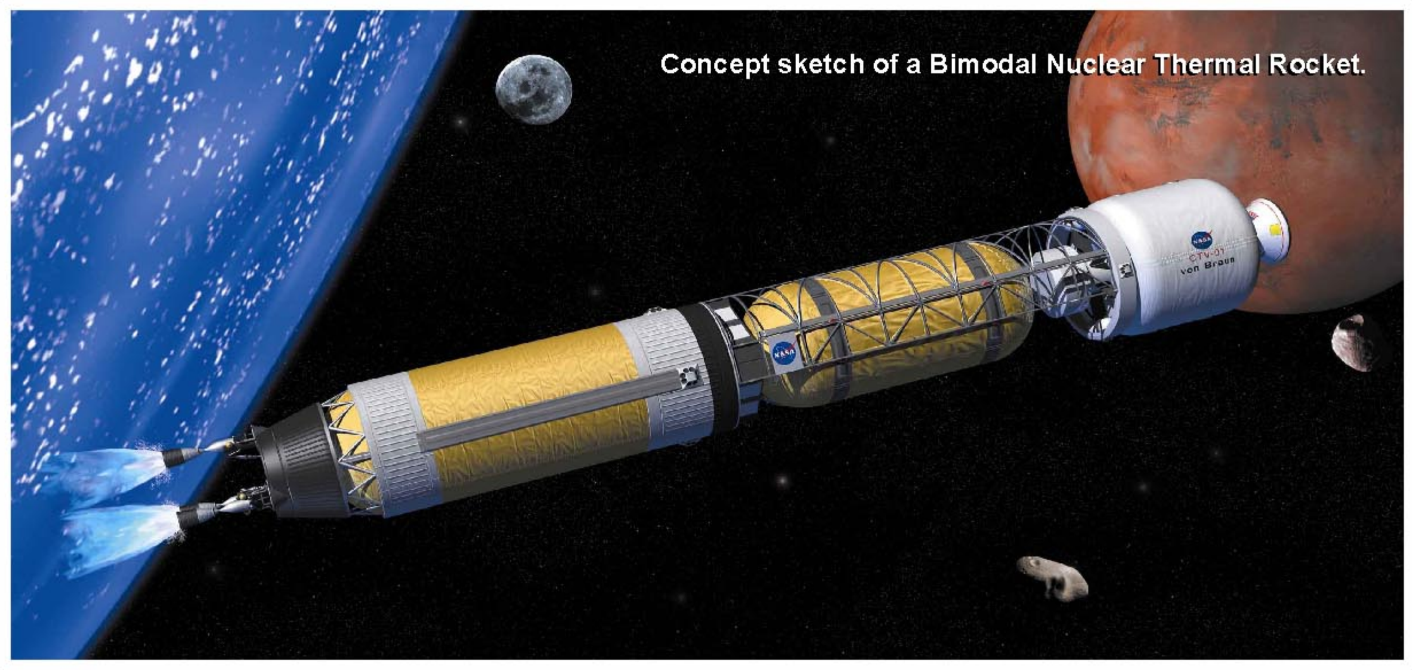


First Titan-Centaur Launch utilizing the RL-10 engines in the Centaur rocket.

Workbench with engine components.

THE FUTURE OF ROCKET ENGINES

Chemical rocket engines like those tested in the RETF have been the workhorses of the "space age" of the twentieth century. Missions from Apollo to the Space Shuttle have all relied on chemical combustion. While these engines will remain the main method of getting from Earth into space, new rocket engines are emerging to provide safe, reliable, and affordable trips for travel beyond Earth's orbit.



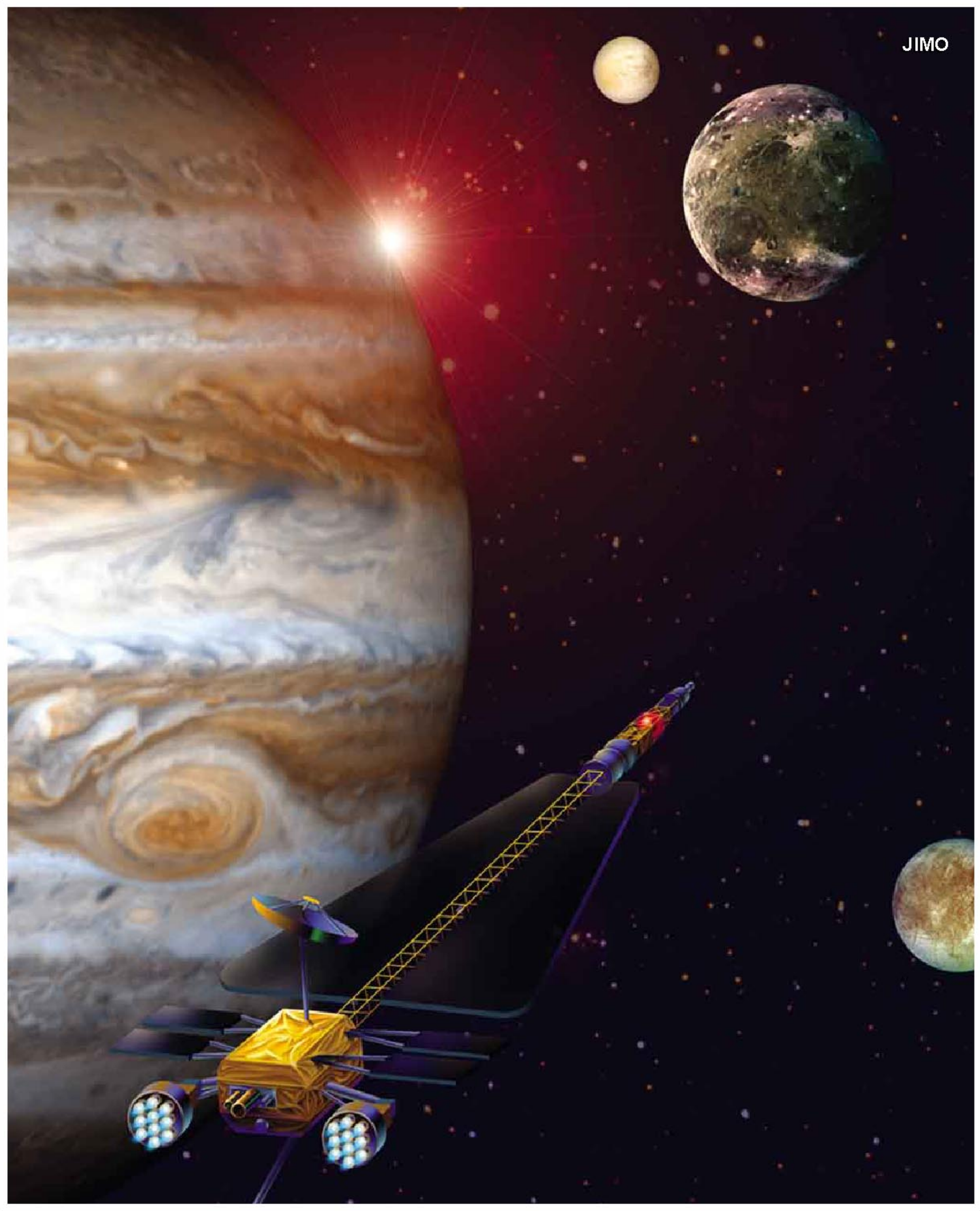
Concept sketch of a Bimodal Nuclear Thermal Rocket.

ADVANCED CHEMICAL PROPULSION

Researchers at NASA Glenn are continuing research into the advanced fuels and rocket-engine technologies that will improve the performance of chemical rockets. One technology uses a high-energy, gelled propellant with a higher-density aluminum additive mixed into the fuel. (The above image shows a rocket engine with this propellant firing in Glenn's Research Combustion Lab). The gelled propellant makes the fuel safer if it is accidentally spilled, and adding metal to the fuel makes the fuel denser and more compact, allowing the fuel to be stored in a more compact space. Other advances that researchers are investigating include safer fuels, such as ones that can be handled without special protective suits, and high-performance atomic chemical fuels that hold atoms of boron, carbon, or hydrogen in solid-hydrogen particles. These atomic chemical fuels could one day be the highest performing fuels ever created.

NUCLEAR THERMAL ROCKETS

Bimodal Nuclear Thermal Rockets conduct nuclear-fission reactions similar to those that are safely employed today at nuclear power plants, including submarines. In these rockets, the energy from the nuclear power plant is used to heat the liquid-hydrogen propellant. Advocates of nuclear powered spacecraft point out that at the time of launch, the nuclear reactors release almost no radiation. These nuclear-thermal rockets are used to generate power during the trip, not to lift off from the Earth, and they offer great performance advantages compared to chemical propulsion systems, such as faster speed or the ability to carry more payload. Nuclear power sources can also be used to provide the spacecraft with electrical power for operations and scientific instrumentation.



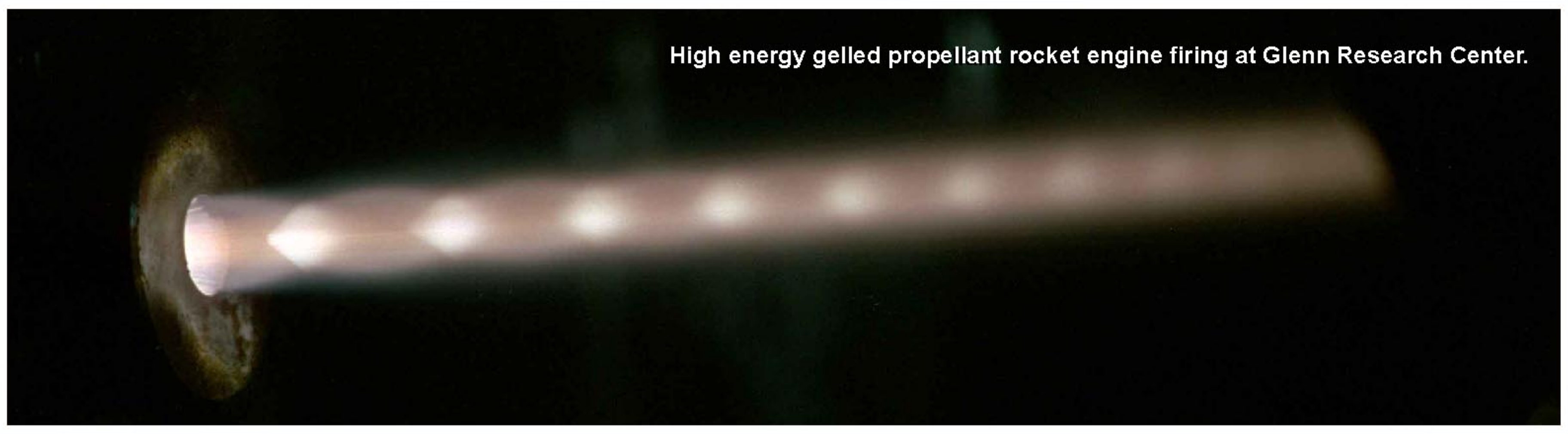
JIMO

ELECTRIC PROPULSION

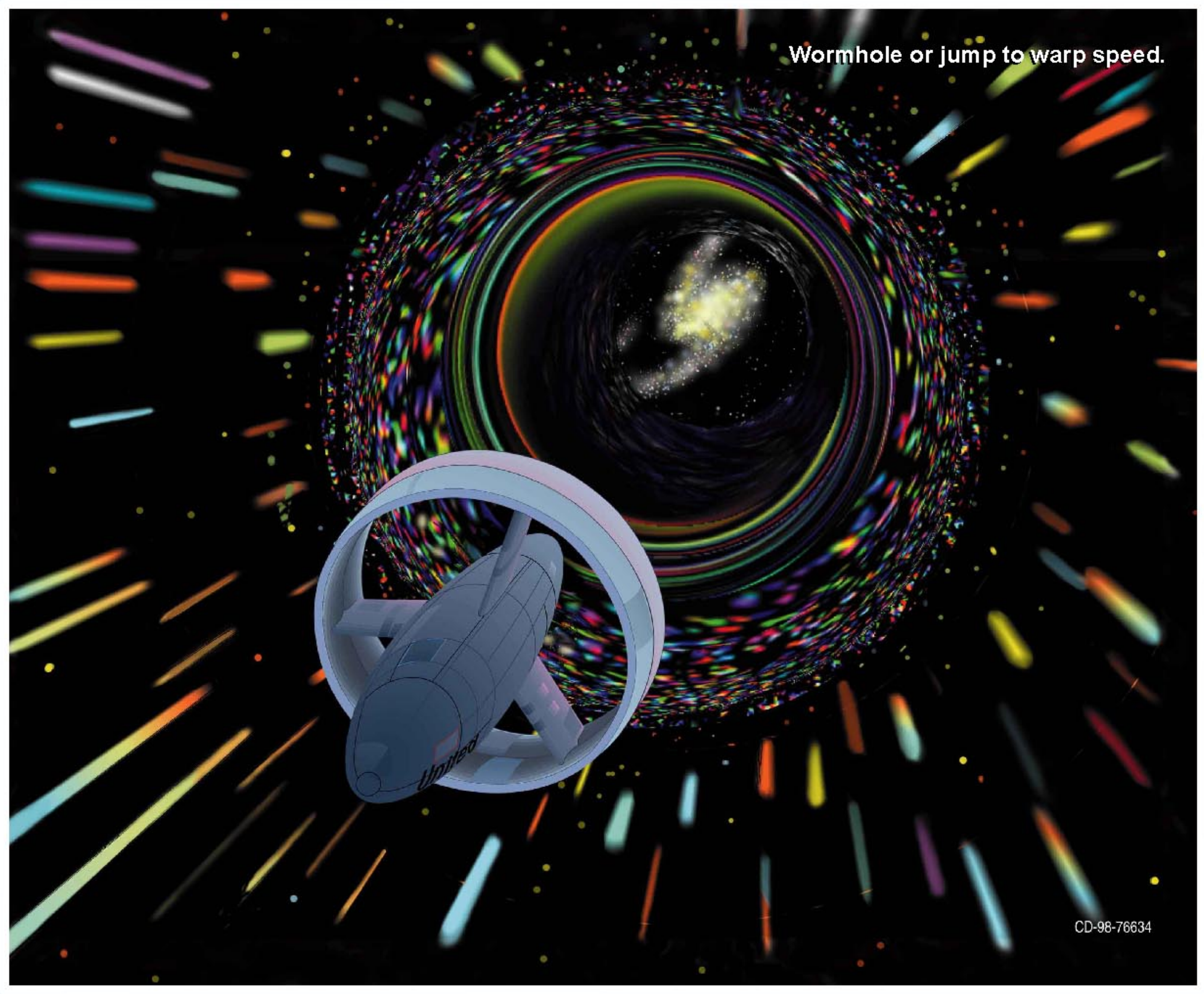
Towards the end of the twentieth century, electric propulsion emerged as a method for controlling the position of the spacecraft and as the primary system for propelling the spacecraft while it is in space. Electric propulsion systems use an electrical field to ionize a gas, typically xenon, and then electrostatically discharge the ion stream to generate a low level of thrust. Although the thrust of electric propulsion systems is significantly smaller than that of chemical rocket engines, it can operate nearly continuously, unlike the brief high-powered thrust of chemical rocket engines. This operation provides a nearly continuous ability that can be used to steer the spacecraft or even to change target destinations. When coupled with a nuclear power source, larger and more powerful electric propulsion systems can be developed. Future missions could include the Jupiter Icy Moons Orbiter (shown right).

PROPULSION BREAKTHROUGHS

While our current understanding of physics doesn't allow for travel beyond the speed of light, researchers at NASA continue to monitor and investigate near-term, credible technologies for space travel. They have made measurable progress in these areas, paving the way for the breakthrough technologies that would revolutionize space travel and enable interstellar voyages. One such technology is a hypothetical spacecraft with a "negative energy" induction ring. Inspired by recent theories that describe how space could be warped with a negative energy, this spacecraft would be a hyperfast transport able to reach distant star systems.

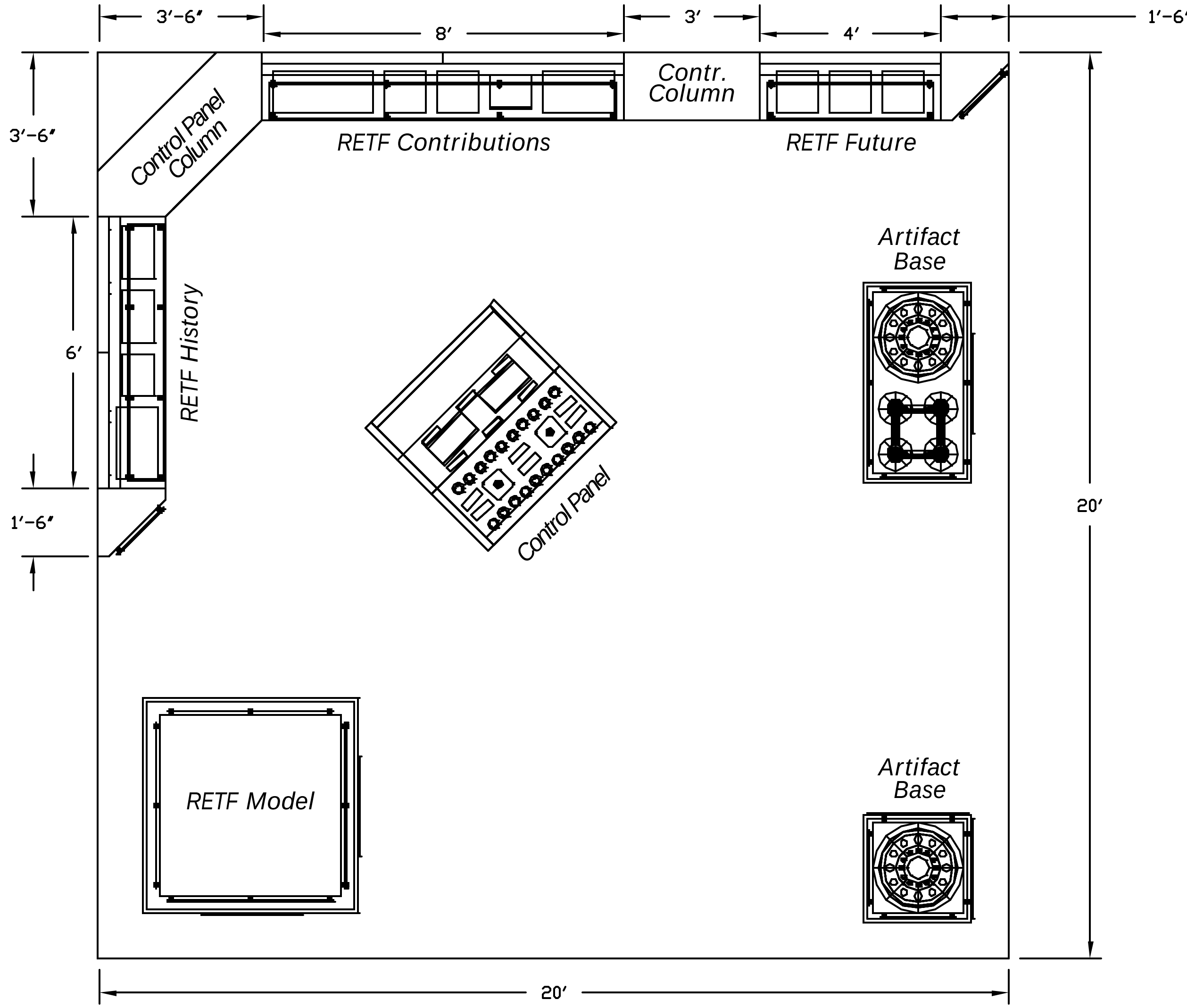


High energy gelled propellant rocket engine firing at Glenn Research Center.



Wormhole or jump to warp speed.

RETF Museum Display



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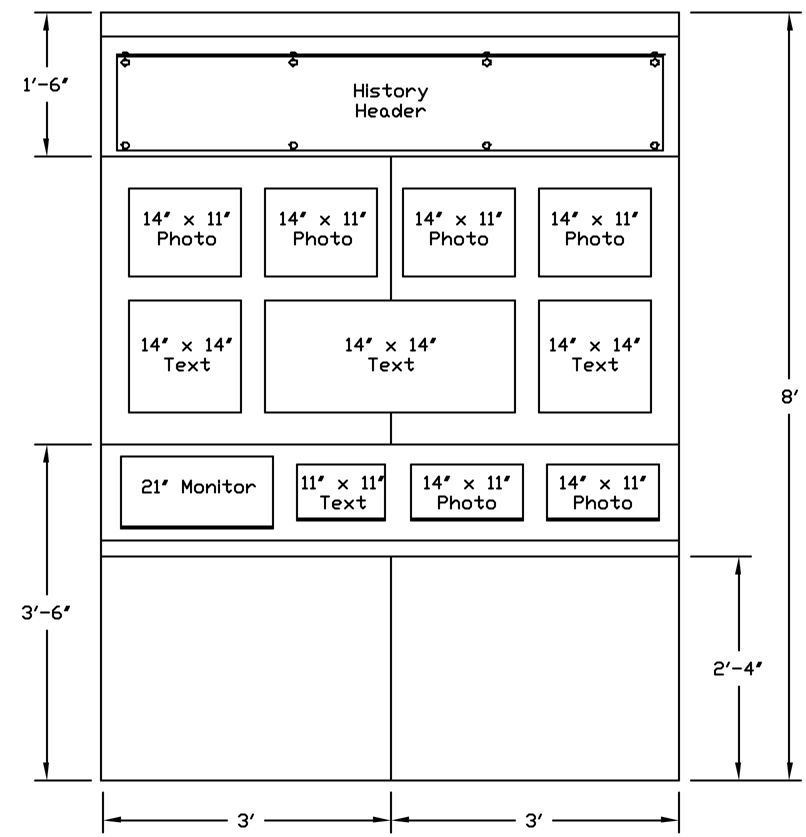

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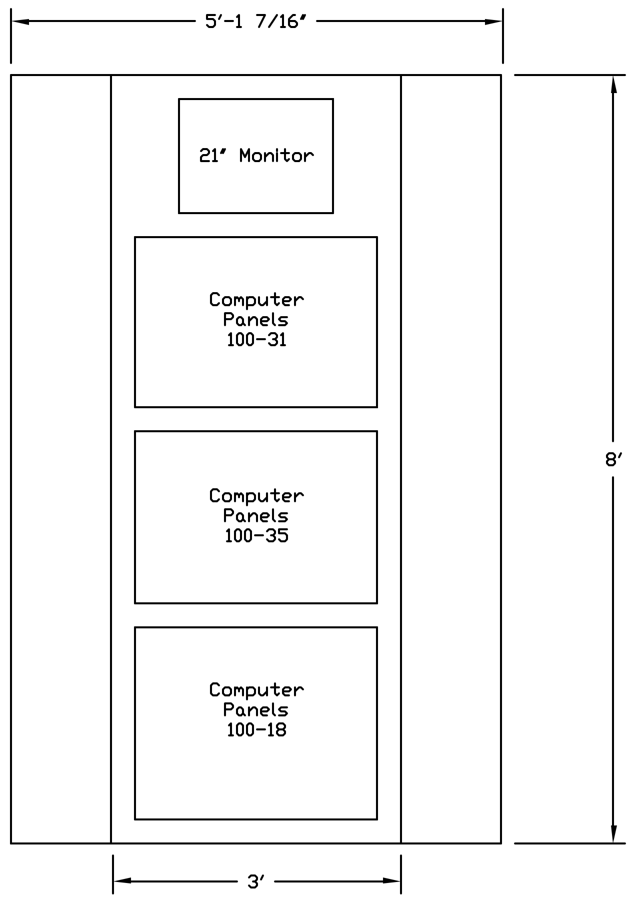

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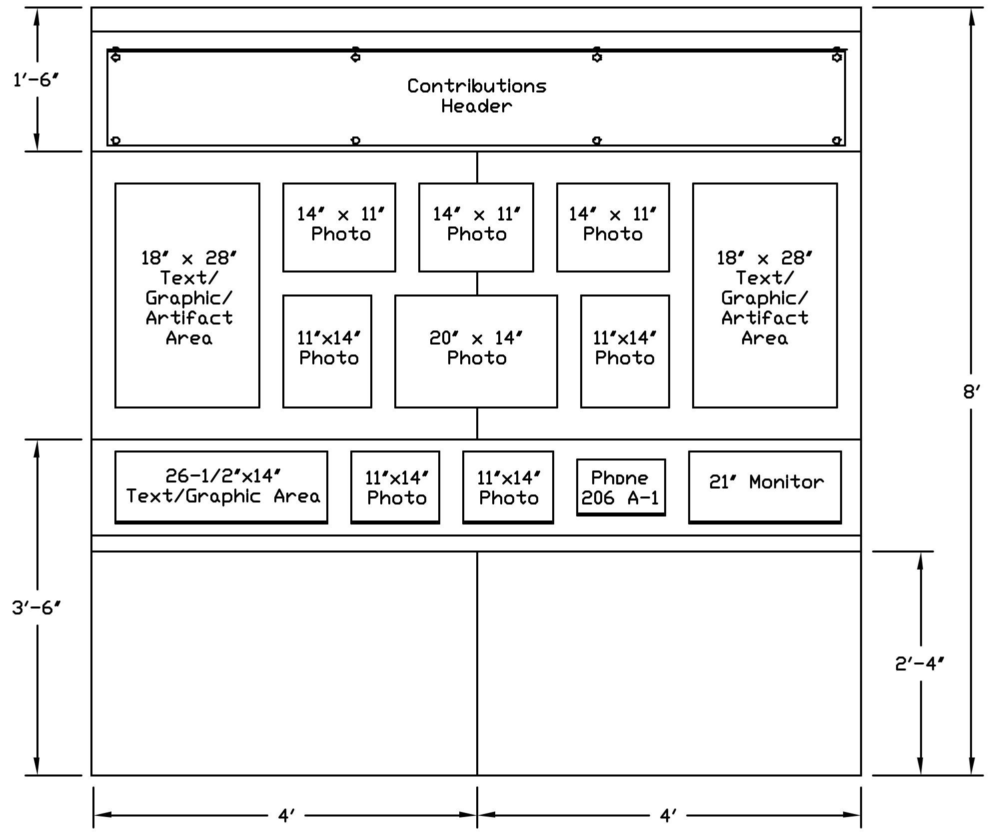

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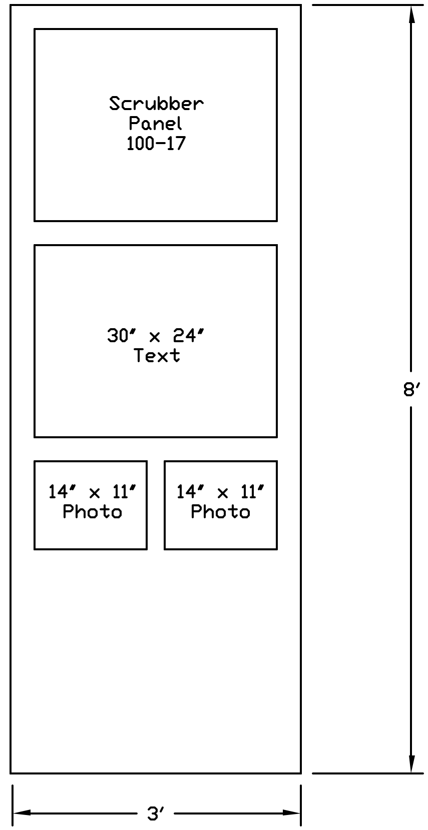

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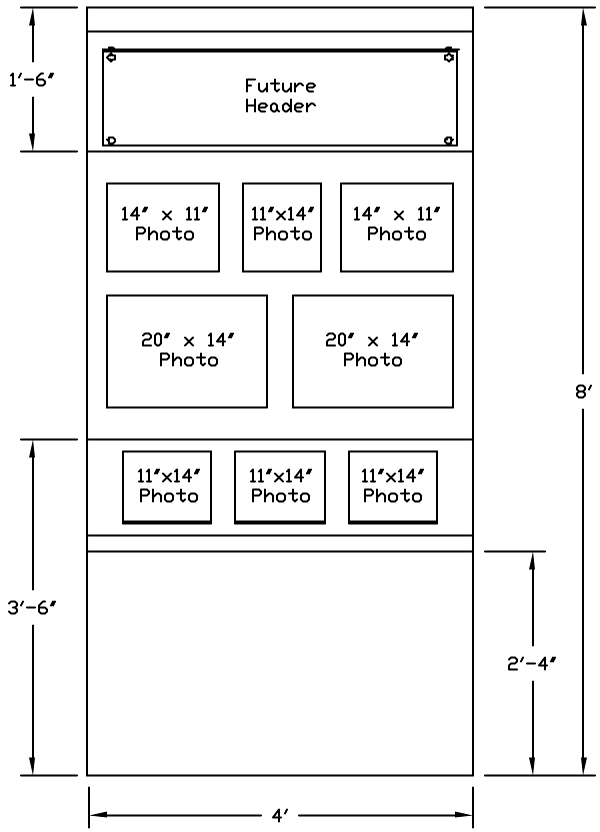

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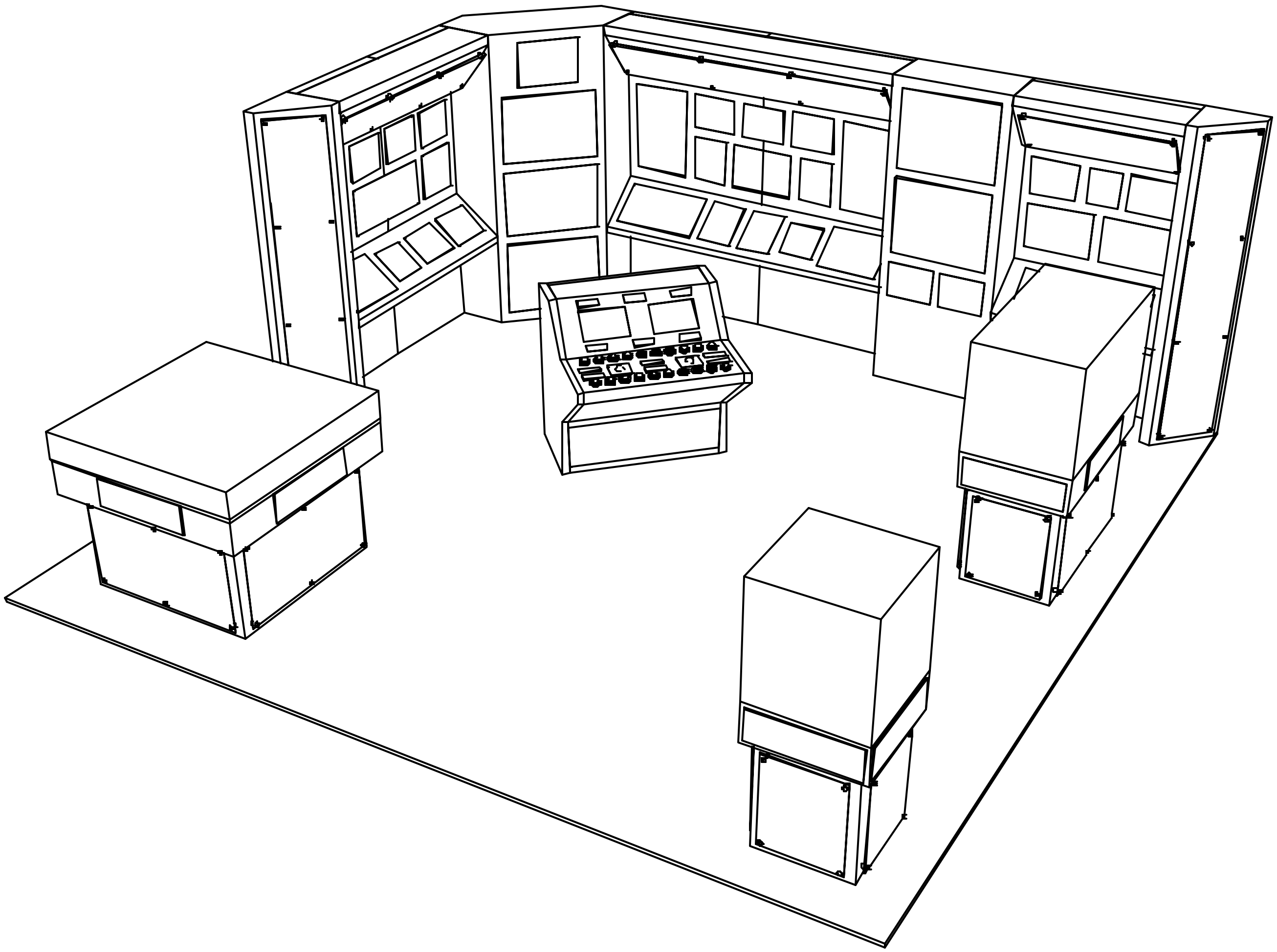

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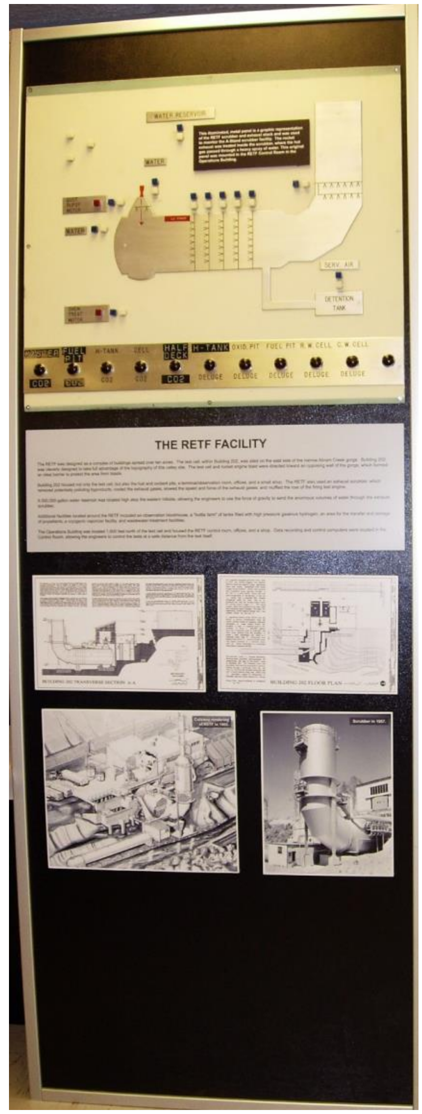
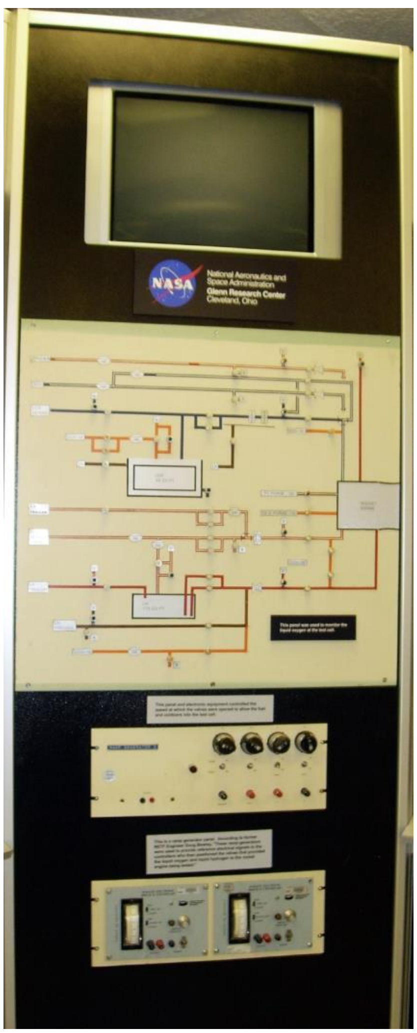
Design Column

This illuminated, metal panel is a graphic representation of the RETF scrubber and exhaust stack and was used to monitor the A-Stand scrubber facility. The rocket exhaust was treated inside the scrubber, where the hot gas passed through a heavy spray of water. This original panel was mounted in the RETF Control Room in the Operations Building.





Corner Column

This panel and electronic equipment controlled the speed at which the valves were opened to allow the fuel and oxidizers into the test cell. This is a ramp generator panel. According to former RETF Engineer Doug Bewley, these ramp-generators were used to provide reference electrical signals to the controllers who when positioned the valves that provided the liquid oxygen and liquid hydrogen to the rocket engine being tested. This panel was used to monitor the liquid oxygen at the test cell.

CUTAWAY OF PLUG ENGINE ASSEMBLY

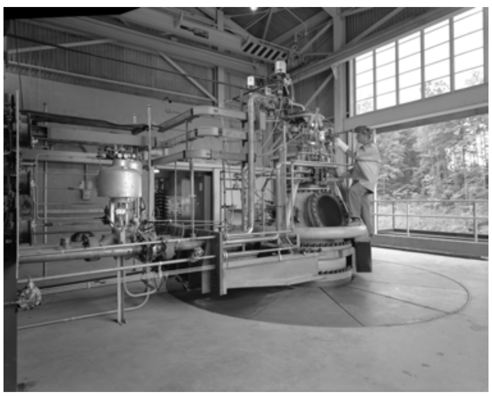
This artifact is a cutaway or a Plug Engine design and consists or a stainless steel injector, a copper spool piece, and a ceramic-coaled copper plug. George Repas, retired RETF engineer, describes this engine as a unique one that was tested at the RETF from 1972 through the 1980s: “The engine has a liquid oxygen-gaseous hydrogen injector with a hole down the center. Into this hole was mounted an hourglass-shaped cooled plug. The plug was ceramic-coated lo provide more cooling margin. Bolted lo this injector/plug combination was a cylindrical liquid hydrogen-cooled copper engine, which we called the spool piece. We would run liquid hydrogen through the spool piece and fire the engine, shut it off, fire it again, in a cyclic fashion, often doing 85 firings before the liquid hydrogen lank was starting to get empty."

The piece was tested until it began to leak, and Repas indicated that the number of cycles the spool piece could take before it leaked was used “to gauge the low cycle fatigue characteristics of the spool-piece material.” Some spool pieces were fired as many as 300 cycles. He also indicated that he built a total of 135 spool pieces, and that many different copper alloys were used for the spool pieces, including one piece with a silver liner. They also experimented with differing cooling passage configurations and ceramic coatings. Their successful design was a very unique, simple, and cost effective.

Selected Photographs for Museum Display.
January 9, 2004

VERTICAL HISTORY BOARD

A.  RETF in 1957 (Large photo)

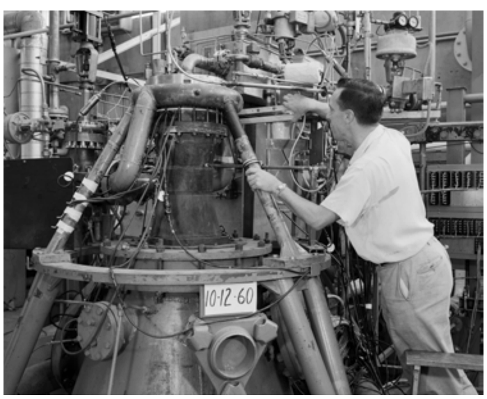
B.  Test Cell in 1957 (Large photo)

C  Person in RETF Control Room (small photo)

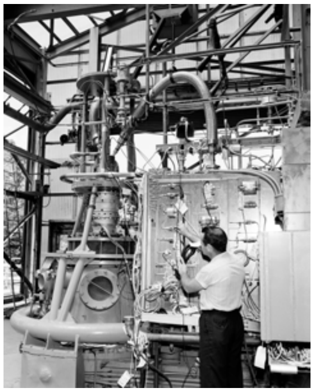
D  Building 100 Control Room (small photo)

SIGNIFICANT RETF CONTRIBUTIONS

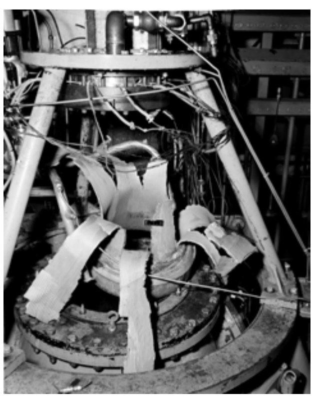
E.  Engineers assembling 20,000 pound thrust rocket engine. (Large photo)

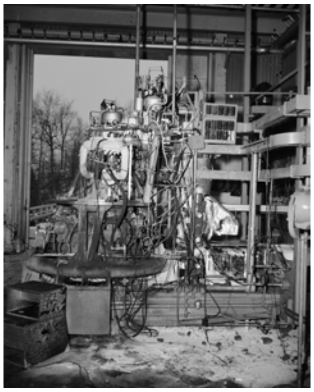
F. 

20,000 lb engine being tested in relation with combustion oscillation studies. (Large photo)

G.  Setting up the test (Large photo)

H.  Engine firing in 1975 (Large photo)

I.  Damage to 20,000 pound thrust rocket engine. (Small photo)

J.  Damage to test cell from failure and explosion of rocket (Small photo)

SCRUBBER COLUMN

K.  Scrubber (Small photo)

L.  RETF in 1965, note addition to scrubber (Small photo)

Future Panel

M.  Future Illustration (Large of small photo)

***Need additional future photographs from NASA.*