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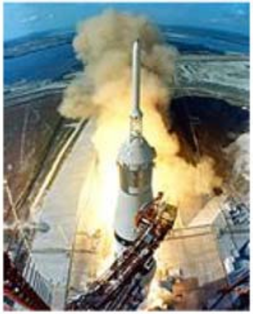
A Brief Historical Background of RETF



The Rocket Engine Test Facility (RETF) made a number of significant contributions to the U.S. aerospace industry in the area of rocket-engine propulsion, primarily with their development of the technology required to use high-energy liquid propellants, such as liquid hydrogen, as rocket-engine fuel. The results of their testing proved invaluable to the manned Apollo program and the unmanned programs for exploring the solar system, in particular to the RL-10 engine for the Centaur rocket and the Rocketdyne F-1 and J-2 engines for the Saturn rockets.

In general, the RETF was designed to be a research facility in which innovative solutions were developed in a field of study with many unknown factors. Scientists tested new designs and concepts, analyzed both successful and failed designs, and then used the results to develop better designs. For testing, they often used model and sub-scale engines, which minimized the use of expensive fuels and oxidizers. Designs that proved to be viable were then transferred to other research facilities for scale-up and possible production. During its lifetime, the RETF helped greatly to advance U.S. knowledge of rocket engines with both theoretical developments and practical applications.

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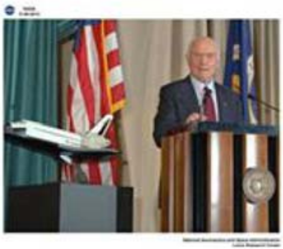
The Development of Lewis Lab

The RETF was located on the southern portion of the Lewis Laboratory, which itself came into being during World War II. Although government laboratories in England and Germany had been conducting research into advanced aircraft-engine design by the late 1930s, the U.S. government and American corporations had hesitated to commit major funding to similar types of engine development. This situation changed with World War II and the increased awareness of the critical role that aircraft play in warfare.

In 1940, the National Advisory Committee on Aeronautics (NACA) opted to build a new laboratory devoted to engine research. Several American pioneers of aeronautical engineering, including George W. Lewis, had successfully lobbied for federal funding to establish a national laboratory dedicated to engine research and military applications for World War II. Cleveland, Ohio, was selected as the site, in part because it was not located on the more strategically vulnerable coasts. The facility was built on 200 acres of land next to the municipal airport near Lake Erie and was named the Aircraft Engine Research Laboratory.



This name, however, would change over the years, either to reflect a shift in focus for the laboratory or to honor significant leaders in the aeronautical industry. In April of 1947, the name changed to the Flight Propulsion Research Laboratory to more accurately reflect the role the lab was playing in propulsion research. In 1948, the facility was renamed as the Lewis Flight Propulsion Laboratory, or the Lewis Laboratory, in honor of George Lewis, the former Director of Aeronautical Research at NACA. In 1958, when NACA was formed into the National Aeronautics and Space Administration (NASA), the name changed to Lewis Research Center. And finally, in March of 1999, the center was given its current name, the NASA John H. Glenn Research Center at Lewis Field, to honor both George Lewis and the astronaut John Glenn.

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Liquid hydrogen as rocket fuel

The American military establishment witnessed the performance of the German medium-range, V-2 rocket-powered missile against Britain during World War II.. After German documents and hardware were captured, the U.S. military became convinced that for the sake of national security, they needed to more vigorously pursue advanced rocket research. After the end of World War II, during the late 1940s and early 1950s, the U.S. military aggressively pursued research in rocket propulsion. In 1951, the U.S. government had formally appropriated funding for rocket research, possibly in response to intelligence reports of Soviet advances in rocket technology, and during this time, the Lewis Laboratory conducted intensive research on rocket fuels. Their research was circulated to such organizations as the Navy Bureau of Aeronautics and the Air Force at Wright Field. At that time, the Lewis Laboratory facility consisted of a series of cinder-block, World War II-era cells used for rocket testing, plus four larger cells that were built later using funds from laboratory operations.

Liquid hydrogen was sought out for use as a fuel because it had a high exhaust velocity, excellent cooling characteristics, and a high reaction rate. The use of liquid hydrogen as a fuel had been presented before—the Russian scientist Konstantin Tsiolkovsky proposed it as early as 1903, and researchers at The Ohio State University experimented with liquid hydrogen as a potential rocket fuel from 1945 to 1950. Aerojet General Corporation and the Jet Propulsion Laboratory also had run similar tests in the late 1940s. There were problems, however, with this type of research. Just after World War II, the U.S. had no laboratories or plants available that were capable of leading serious research with hydrogen-fueled rocket engines, and there was no steady supply of liquid hydrogen during these years. In the early to mid-1950s, even the U.S. Army was still using relatively unsophisticated or interim test stands for its research on rocket-fired missiles and atomic warheads.

In addition, testing hydrogen-fired rocket engines was a potentially dangerous activity that required special facilities. A static test stand was needed to test rocket engines, and the stand had to be securely anchored while the engine performance was measured and evaluated. The test stand also had to be housed in an appropriately secure facility with an infrastructure built to deliver reactants to the stand, as well as support the instruments that monitored the rocket's performance. The reactants

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The Rocket Engine Test Facility

In 1952, NACA authorized the scientists at Lewis Lab to build a test facility to evaluate high-energy propellants and rocket-engine designs. In the early 1950s, scientists there had acquired a hydrogen liquefier and had tested hydrogen/fluorine engines in a cell equipped with a scrubber to control toxic emissions. As they continued their research, they began to plan a rocket-engine test-complex better suited to their testing needs. Although the initial plan was to locate this facility on a remote site in the western United States, they instead decided to develop a smaller test facility at Lewis Laboratory.

Drawings for the facility were produced in 1955 and 1956, and it was built from 1955 to 1957 on a 10-acre site at the southern end of Lewis Laboratory. Called the Rocket Engine Test Facility (RETF), the complex was unique in that it was an integrated laboratory developed for highly focused research into the functions of individual rocket engines. At that time, the existing propulsion laboratories were geared toward more general missile development.

Construction of the RETF cost $2.5 million and originally included two major components: a control center in Building 100, and a test cell in Building 202. The test engine was mounted vertically in the test cell, and exhaust was channeled into a duct system. Environmental precautions were essential because the facility was located in a densely populated urban area—the facility used an innovative exhaust scrubber that removed toxic byproducts from the exhaust and muffled the roar of the firing test engine. Wastewater from the scrubber was piped into a reservoir where it was treated with chemicals, and the inert calcium fluoride residue was transported off-site.

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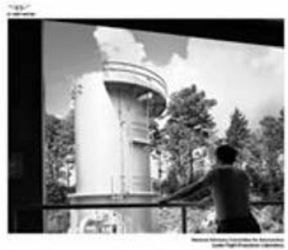

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The initial plans for the center also included an observation blockhouse that protected the researchers while they observed the tests. Support structures were added later. Building 205, a propellant transfer and storage facility, was built circa 1962-1965, and Building 206, a structure to house a cryogenic vaporizer and compressor, was built in 1968. When the facility was completed in 1957, it was the largest high-energy test facility in the United States that was capable of handling liquid hydrogen and other liquid fuels.

Most engines tested at the RETF had 4.8" chambers with 2.62" throats, or 10" chambers with 7.6" throats. In spite of the small engine size, the use of high-pressure reactants allowed some of these small engines to produce thrusts of 75 kilonewtons (17,000 pounds). The test facility was eventually able to accommodate up to three minutes of engine operation at a thrust of 89 kilonewtons (20,000 pounds). On rare occasions, tests were run at 178 kilonewtons (40,000 pounds) of thrust.

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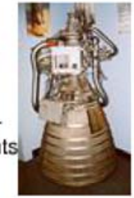
Notable RETF projects

In the early years, research at Lewis Laboratory had focused largely on military applications, but in October 1957, just after the construction of the RETF, the Soviet launch of Sputnik spurred new U.S. efforts in rocket-engine research for space exploration. Some of their most significant projects included:



•**RL-10 engine:** In the late 1950s, Pratt & Whitney developed the RL-10 engine but were having serious trouble with their injector. Pratt & Whitney visited RETF to learn about a new injector developed at Lewis, the concentric tube injector. This injector was subsequently adopted for the RL-10 engine. The RL-10 engine was the world's first liquid-hydrogen rocket engine and was used to fire the Centaur rocket. The Centaur was first used in the second stage of the Atlas rocket that carried a robotic probe to the moon. In October 1962, the management of the Centaur program was transferred to Lewis Research Center from the Marshall Space Flight Center in Hunts Alabama. Lewis continued to manage the Centaur program for the next thirty years.

•**J-2 engine:** Research completed at the RETF also influenced the decision to use a liquid-hydrogen engine for the upper stage of the Saturn launch vehicle for the Apollo Program. It is now widely accepted that 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 manned mission to the moon.

•**F-1 engine:** Between 1962 and the early 1970s, the RETF investigated the problem of combustion instability, also sometimes referred to as "screech." This instability was caused by pressure changes in the engine-combustion chamber during firing, and it could lead to the deformation of the chamber wall and, ultimately, engine failure. The F-1 engine used for the first stage of the Saturn launch vehicle experienced serious problems with combustion instability, and research completed at the RETF may have contributed to a 1965 redesign of the F-1 engine's injector.

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- **M-1 engine:** From 1962 to 1966, research at the RETF focused on combustion instability in the M-1 engine. The M-1 was an upper-stage hydrogen engine for the Nova rocket, a launch vehicle that would be more powerful than that for the Saturn rocket, and which was planned as a launch vehicle for sending a manned mission to the moon,. However, the decision to use a lunar-orbit-rendezvous approach for the moon rather than a direct-ascent approach meant that the more powerful Nova would not be needed for the moon project, and the M-1 program was cancelled in 1966. However, the Nova rocket was kept on the drawing board for future missions beyond the moon.

After the end of research for the Apollo Program, scientists at the RETF undertook a number of research programs in the 1970s and 1980s that greatly contributed to the development of propulsion systems for the space shuttle and other important NASA programs:

- In 1975, RETF engineer Richard Quentenmeyer developed a water-cooled "plug-nozzle" rocket thrust chamber that could test the problem of low-cycle thermal fatigue in reusuable rocket engines.

- RETF also undertook a program to reduce the wall temperatures of rocket engine liners. By studying and developing high-aspect ratio cooling channels, RETF was able to demonstrate that they could reduce wall temperatures from 1000˚F to between 400˚F and 600˚F.

- In the late 1970s and 1980s, engineers at the RETF tested the first liquid-oxygen-cooled engines built by NASA and explored the problems of using this unique cooling concept.

- During the early 1990s, RETF worked with TRW to demonstate the feasibility of operating a Coaxial Pintle Injector Rocket Engine using liquid oxygen and liquid hydrogen as propellants. The purpose of this effort was to demonstrate technology that would significantly reduce the cost of launching payloads into space.

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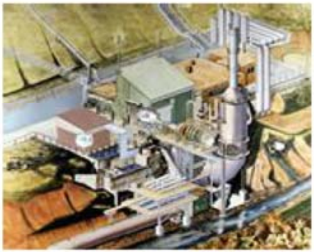
Upgrades to the RETF

The buildings and equipment at the RETF were upgraded numerous times over the years to keep pace with the demands of their research. During the 1960s, the original gas bottles were upgraded to test more powerful engines. Building 205 was constructed circa 1962-1965 as a hydrogen vaporizer and liquid oxygen storage area, and Building 206, the liquid hydrogen vaporizer building, was constructed in 1968. Mobile "dewars," or tanks, could transport liquids to these facilities, where vaporizers converted the liquids into high-pressure gases.

The exhaust scrubber stack at Building 202 was also extended in the late 1960s to guarantee thorough removal of toxic exhaust and to muffle the sound of the firing engines. The test facility control room in Building 100 was repeatedly upgraded during this period to keep current with advances in instrumentation and computer technologies. By 1972, the gas bottles had been upgraded from 2,200 psi to 6,000 psi for helium and nitrogen, and 5,000 psi for liquid oxygen. The higher pressures allowed the facility to test sub-scale engines with thrusts equivalent to full-size or larger model engines.



During the 1980s, the RETF was significantly upgraded. In 1982, Building 206A, a liquid hydrogen vaporizer facility, was added to the facility. A second test stand was added to Building 202 in the 1980s, and a third test stand was built in 1991. The RETF continued to play an important role in propulsion technology development during the 1980s and the first half of the 1990s, including tests on hydrogen-oxygen engines used in the space shuttle and tests in 1991 to 1995 on a low-cost rocket engine developed by the TRW Space and Technology Group.

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The Closing of the RETF

Although NASA developed plans in the 1990s for an extensive rehabilitation of the RETF, the City of Cleveland had their sights set on the land that RETF occupied. The City announced plans to expand Cleveland Hopkins International Airport and construct an extended runway that would require demolition of the RETF. NASA management reassessed the situation and decided against further investment in the RETF. The Space Propulsion Technology Division at NASA did not have programs that exclusively required the RETF at that point in time, and no future program funds were anticipated that could offset operational costs at the facility. NASA subsequently canceled their plans to rehabilitate the facility, and announced that the RETF would close permanently. The last tests were completed at the facility during the first half of 1995, and the official shutdown date was July 1, 1995. The entire RETF site was demolished in 2003.

To record its significance for U.S. aerospace history, the RETF was listed on the National Register of Historic Places in 1984-1985. The RETF was noteworthy for its role in the development of lightweight, regeneratively cooled hydrogen engines and for its role in facilitating the overall progress of propulsion technology used in NASA missions and programs. The National Park Service also designated the facility as a National Historic Landmark.

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