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DIVISION OF UNITED AIRCRAFT CORPORATION

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RL10

INFORMATION ABOUT

PRATT & WHITNEY AIRCRAFT

FLORIDA RESEARCH AND DEVELOPMENT CENTER

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I. THE FLORIDA RESEARCH AND DEVELOPMENT CENTER

United Aircraft Corporation's Pratt & Whitney Aircraft Division established the Florida Research and Development Center in 1956 primarily to test highly advanced jet engines. Work was started that year and the main buildings were completed in 1958. Soon afterward, the Research Center was expanded to include rocket engine research. The Research Center is located on an isolated 6, 750-acre tract on the edge of Florida's Everglades in Palm Beach County.

Two highly advanced engines have been developed at the Research Center, the RL10 rocket engine (see page two) and the J58 turbojet engine which powers the Air Force's supersonic YF-12A interceptor and SR-71 reconnaissance aircraft. The YF-12A is the first aircraft to fly at sustained speeds of more than 2, 000 miles per hour at altitudes in excess of 70, 000 feet. On May 1, 1965, the YF-12A cracked nine world records, including those for speed over a straight course (2, 062 mph) and sustained altitude in horizontal flight (80, 000 feet). Most J58 performance details are still classified.

Pratt & Whitney Aircraft's engine for the proposed U. S. Supersonic Transport is also being developed at the Research Center. This engine, designated JTF17A-20, will be capable of powering the SST at speeds of Mach 2. 7.

The Research Center's rocket test area includes horizontal and vertical engine firing stands and complete component test facilities. All engine firing stands are equipped to simulate conditions the engines will encounter in space. One vertical test stand is used to check out dual engine vehicle propulsion systems.

A multi-million-dollar addition to the Research Center's rocket engine test complex is now in operation. The addition gives Pratt & Whitney Aircraft the nation's most advanced liquid rocket propellant research capability. With the new facility, the Research Center can handle safely all known combinations of liquid propellants, including high-energy types such as fluorine, hydrazine, diborane, and hydrogen.

Looking to the future, the Research Center has an extensive department of applied research. Areas of study for this department include mission analysis, engine and controls analysis, systems engineering, combustion, heat transfer, turbomachinery, and fluid flow.

Over the years, Pratt & Whitney Aircraft has conducted a comprehensive study to define the propulsion requirements for the next generation of launch vehicles. A major development in this study was achieved at the Research Center in 1963 with the successful test firing of a cooled high-pressure hydrogen rocket chamber.

Pratt & Whitney Aircraft's Florida Research and Development Center employs about 5, 500 and has an annual payroll of more than $40 million. In 1964, the company spent more than $12 million in purchasing from or subcontracting with 632 Florida businesses, of which 425 were classified by Government standards as small Florida businesses.

II. THE RL10 LIQUID HYDROGEN ROCKET ENGINE

The RL10, powerplant for the National Aeronautics and Space Administration's Centaur and Saturn S-IV space vehicles, is the nation's first flight-proven rocket engine burning high-energy liquid hydrogen fuel. On November 27, 1963, a pair of RL10s successfully boosted a Centaur space vehicle into orbit around the Earth in the first flight demonstration of this outer space powerplant. Two months later, on January 29, 1964, a six-engine cluster of RL10s, generating a total of 90,000 pounds of thrust, propelled a 37,700-pound payload into orbit to culminate the first test flight of the Saturn S-IV stage, which pioneered hydrogen technology on the towering Saturn I booster. RL10s have an important role in the U. S. lunar exploration program with the assignment of boosting the Surveyor spacecraft to the Moon to gather information prior to landings by astronauts. The 15,000-pound-thrust RL10 was designed and developed for NASA's Marshall Space Flight Center at Pratt & Whitney Aircraft's Florida Research and Development Center.

Less than seven months after the starting date of the contract in mid-October 1958, the first RL10 thrust chamber was tested. The official Preliminary Flight Rating Test was completed successfully in the record time of three years after beginning initial engine design. In the continuing development program, the RL10 has completed more than 6,600 firings for an accumulated firing time of more than 260 hours. Individual engines have been fired more than 70 times without maintenance -- equivalent to 10 round trips to the Moon.

While the RL10 resembles other rocket engines outwardly, internally it contains many advances in the state-of-the-art design, among them the method by which it obtains multiple utilization from its fuel. The liquid hydrogen at -423° F plays two roles before it is burned. In its first role, the hydrogen serves as a coolant by passing through the series of tubes which form the thrust chamber. In its second role, the hydrogen, which has picked up heat energy as a result of its cooling the chamber, is expanded through a turbine to provide power to pump both propellants into the system.

The engine was designed to provide a capability of multiple restarts in space, with long coasting periods between firings. The problems of maintaining a conventional lubrication system under conditions of coasting made it desirable to eliminate oil lubrication in the gearbox. The gears and bearings in the RL10 turbopump were developed to operate dry and to be cooled with hydrogen gas.

The RL10 has a nozzle expansion ratio of 40 to 1 and operates at a nominal chamber pressure of 300 pounds per square inch.

An advanced RL10 engine is currently being developed at the Research Center. Under a two-year NASA contract, the RL10's specific impulse will be increased to give the engine greater payload capability.

III. RL10 MILESTONES

October 1958	Design Begins
July 1959	First Engine Fired
November 1961	RL10A-1 Engine Passes Preliminary Flight Rating Test (PFRT)
March 1962	First Centaur Test Vehicle Static Fired
June 1962	Advanced Engine (RL10A-3) Passes Preliminary Flight Rating Test
August 1962	First Six-Engine Saturn S-IV Stage Static Fired
September 1962	Full-Scale Engine Throttleability Demonstrated
May 1963	Hypergolic Ignition Demonstrated
June 1963	Instant Start Feasibility Demonstrated
October 1963	Low Idle Operation (Pressurized Mode) for Settling Propellant Demonstrated
November 1963	RL10s Power First Centaur Vehicle into Orbit
January 1964	RL10s Power First Saturn S-IV Vehicle into Orbit
September 1964	Advanced Engine (RL10A-3-1) Passes Preliminary Flight Rating Test
August 1965	Forty-Four Consecutive RL10s Have Worked Successfully in Space with Centaur AC-6 Launching

III. RL10 LAUNCH RECORD

May 8, 1962	First Atlas-Centaur (F-1) was destroyed in flight due to a structural failure in the Centaur before stage separation. RL10s were never supplied with propellants.
November 27, 1963....	The Centaur AC-2 vehicle was launched successfully with a 380-second firing of the RL10s which placed the stage in its planned orbit.
January 29, 1964......	The world's first liquid hydrogen six-engine cluster was fired in flight on the successful launch of SA-5. The six RL10s on the Saturn S-IV stage burned for the programmed 470 seconds.
May 28, 1964	RL10s performed as programmed on the S-IV stage of the SA-6 launching.
June 30, 1964.........	Centaur AC-3 was launched and a failure occurred in the vehicle hydraulic system after 254 seconds of a planned 377-second duration firing. RL10 engine operation was normal before loss of propellants.
September 18, 1964 ...	All engine and vehicle systems performed perfectly throughout the flight of the Saturn S-IV in the SA-7 launching.
December 11, 1964....	Centaur AC-4 was launched on a planned "two-burn" mission, with a 25 minute coast period between firings of the RL10 engines. The engine operation was normal for the first firing of 339 seconds, but vented hydrogen apparently caused the vehicle to tumble during the coast period preventing propellants from reaching the engines for the second firing. However, on the second burn, ignition occurred on scheduled command and engine operation was maintained at a low thrust level.
February 16, 1965	All aspects of the Saturn S-IV stage were satisfactory in the SA-9 flight,which placed the Pegasus satellite in Earth orbit.

III. RL10 LAUNCH RECORD

March 2, 1965 .... The Centaur AC-5 vehicle was destroyed when loss of thrust on the Atlas booster occurred on liftoff. No attempt was made to start the RL10 engines.

May 25, 1965 .... Six RL10s again performed flawlessly in the SA-8 flight which placed another Pegasus in orbit.

July 30, 1965 .... All engines on the Saturn S-IV operated satisfactorily in the sixth and final flight of that vehicle in the SA-10 launching which placed the third Pegasus micrometeoroid detection satellite in Earth orbit.

August 11, 1965....... Centaur AC-6 vehicle powered by two RL10 engines successfully boosted a Surveyor dynamic model into a simulated lunar transfer trajectory.

IV. RL10 STATISTICS

Rated Thrust	15, 000 Pounds
Height	69 Inches
Width	40 Inches
Weight	292 Pounds
Fuel	Liquid Hydrogen
Oxidizer	Liquid Oxygen
Specific Impulse	431 Seconds
Chamber Pressure	300 psia
Type Cooling	Regenerative
Total Firing Time	260 Hours through August 1965
Total Firings	6, 650 through August 1965

V. THE DEVELOPMENT OF LIQUID HYDROGEN

The successful development of Pratt & Whitney Aircraft's RL10 rocket engine was based upon the mastery of a powerful fuel -- hydrogen. At the advent of the space age, hydrogen held out the prospect of greatly increased thrust per pound over hydrocarbon fuels such as kerosene. When burned with liquid oxygen (LOX), liquid hydrogen delivers 35 per cent more thrust per pound of propellant than conventional fuels. Engineers knew that if hydrogen could be leashed as a fuel for rocket engines it would make possible substantial payload increases.

An entire new technology had to be established before hydrogen could become a practical fuel. Techniques for handling hydrogen as a fuel were unknown. Because of its low boiling point (-423° F), it is difficult to keep in liquid form. It will vaporize immediately if exposed to heat. Liquid hydrogen is colorless, odorless, and of very light weight.

Pratt & Whitney Aircraft's experience has proved that liquid hydrogen can be transported and stored practicably and that, in many ways if handled properly, the frosty liquid is safer than gasoline. Liquid hydrogen is chemically inert in the presence of all common materials around a test stand, including air, oil, and oxygen. It is nontoxic, nonirritating, and noncorrosive. It does not deteriorate or decompose from long time storage. Today, it is possible to keep liquid hydrogen just as "ready" as liquid oxygen. The fuel is stored in dewar tanks, which are double-walled containers with a vacuum between the walls, similar to a thermos bottle. Portable dewar tanks follow the same pattern of construction.

Large scale testing of liquid hydrogen fuel became possible in 1958 with the opening of the Pratt & Whitney Aircraft Florida Research and Development Center in West Palm Beach, Florida. Adjacent to the plant, the Air Force built the first tonnage production facility for liquid hydrogen. The facility takes natural gas, breaks it down into hydrogen gas, carbon dioxide, and other products, then refrigerates and purifies the hydrogen. The purity of the liquid hydrogen produced there is about 99.9999 per cent, among the purest materials produced in quantity by man.

By late 1965, Pratt & Whitney Aircraft at its Florida Center had handled about 55 million gallons of liquid hydrogen in the development program for its hydrogen fueled rocket engines.

VI. THE PRATT & WHITNEY AIRCRAFT DIVISION

The Florida Research and Development Center is a part of Pratt & Whitney Aircraft, the major division of United Aircraft Corporation. Pratt & Whitney Aircraft was organized in Connecticut in 1925 to design and build aircraft engines. Its first engine, revolutionary for its time, was the radial, air-cooled Wasp. It was followed by the Hornet, the Twin Wasp, and the Double Wasp. These famous engines ultimately provided half the aircraft power used by the Allied air forces during World War II. With the advent of the jet age, the skills and technology developed by Pratt & Whitney Aircraft during the piston-engine era helped the division to move to the forefront in manufacture of jet engines. Pratt & Whitney Aircraft engines today power many of the nation's most advanced military and commercial aircraft. In addition to the work being carried out at its Florida Research and Development Center, Pratt & Whitney Aircraft is developing other space-age power systems. Among them are fuel cells -- devices which convert chemical energy directly to electricity -- for space and industrial use.

Modified aircraft jet engines manufactured by the division are being used in ground installations to generate electricity and operate compressors which pump gas through long pipe lines. Other units are being developed to power ships and hydrofoils. The division employs about 46, 000 persons and has its headquarters in East Hartford, Connecticut.

United Aircraft Corporation, Pratt & Whitney Aircraft's parent corporation, also has six other operating divisions. Hamilton Standard designs and manufactures aircraft propellers and environmental controls for aircraft and space use. Sikorsky Aircraft is the world's leading designer and builder of helicopters. The Norden division produces many electronic products for defense and aerospace. United Aircraft Corporate Systems Center carries out research, development, and study in a number of areas of space technology. United Technology Center is developing solid propellant rocket engines, principally the first-stage boosters of the Titan III-C space launch vehicle. The Vector division designs and manufactures electronic telemetering systems and equipment for aircraft, missiles, space probes, and manned aircraft.

In addition to these divisions, there are the United Aircraft Research Laboratories and two subsidiaries, United Aircraft International, Inc., and United Aircraft of Canada Limited. The corporation employs about 68, 000 persons. Sales in 1964 were $1, 235, 918, 321.