News
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CLEVELAND, Ohio, July 14 -- The Apollo program has been described at various times by astronauts, engineers, space agency officials and newspaper editorials as a magnificent "team effort." Indeed, the team which is accomplishing this complex program to explore the Moon comprises hundreds of thousands of government and contractor employees throughout the nation.

One member of the National Aeronautics and Space Administration team, the Lewis Research Center, provided important early research as well as subsequent direct technical support to the Apollo program.

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The Center's contributions included:

-- Pioneer research in rocket tests with liquid hydrogen and liquid oxygen systems;

-- Engineering studies of tanks, lines, and liquifiers for liquid hydrogen;

-- Wind tunnel tests of Saturn vehicles and of the Launch Escape Subsystem;

-- Studies in the Zero Gravity Research Facility for settling propellants in fuel tanks;

-- Technical consultation and advice in such areas as safety, fuel cell performance, rocket engine combustion, propellant pump design, and thrust chamber fabrication.

Among the shapers of history in the early years of the space program was Lewis' present Director, Dr. Abe Silverstein. In 1958, when he was Associate Director of Lewis, Dr. Silverstein was called to Washington to help organize NASA, which was, as the successor of National Advisory Committee for Aeronautics (NACA), to be the nation's civilian agency for meeting the challenge of space.

Within the new agency, Dr. Silverstein was appointed the Headquarters Director of Space Flight Programs with responsibility for developing and initiating all space missions. Many of those missions are going on today, others such as Ranger and Mercury have ended.

Among the many missions conceived at that time was a manned journey to the Moon and back. Dr. Silverstein himself named it "Apollo" after one of the most versatile of the Greek gods. Dr. Silverstein recalls he chose the name after perusing a book of mythology at home one evening, early in 1960. He thought that the image of "Apollo riding his chariot across the Sun was appropriate to the grand scale of the proposed program."

When did the program originate? The idea of a lunar mission was first officially introduced at a meeting of NASA program planners in Nov. 1959 at Wallops Island, Va. However, between that time and President John F. Kennedy's historic space commitment of 1961, much of the basic mission remained to be worked out. During this time Dr. Silverstein chaired the committee that determined the characteristics of the Saturn family of launch vehicles, including the use of liquid hydrogen-oxygen propellants.

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Long before Apollo was ever planned or named, the Lewis Center in Cleveland was advancing the propulsion technology which would help make the mission possible.

As early as the later part of the 1940's Lewis had begun research on high energy liquid rocket propellants under the direction of Dr. Walter T. Olson, now an Assistant Director of Lewis, and by 1952 this work included studies of liquid hydrogen-liquid oxygen.

Initial Lewis investigations used very small thrust chambers in the range of 100 to 1000-lbs. thrust. Over the course of the next decade, rocket engineers and scientists experimented with a variety of thrust chamber designs to achieve high combustion efficiency and smooth burning; and they measured heat transfer rates within the thrust chamber and demonstrated how to cool the chamber and nozzle with liquid hydrogen. Since hydrogen, the lightest of the elements, in its liquid state boils at -423° F., and the oxidizer, liquid oxygen, is stored at -297° F., another major concern was how to handle the cryogenic propellants themselves.

By 1958, as the United States entered the space business, the Lewis Center had tested a fully cooled, liquid hydrogen-liquid oxygen thrust chamber at the, then, large scale of 20,000 lbs. thrust.

The experience Lewis propulsion experts gained in the field of high energy propellants later led to the development of the 15,000 lb. liquid hydrogen-liquid oxygen engine designated RL-10. Two of these engines power the upper stage of the Atlas-Centaur launch vehicle that has been under Lewis management since 1962. (Atlas-Centaur launched the Surveyor spacecraft that landed on the moon, and the Mariner spacecraft that will fly by Mars on July 31 and Aug. 5.

Much of the same technology developed by Lewis for Centaur was particularly applicable to the J-2 liquid hydrogen-oxygen engines of the Saturn second stage (S-II).

Consequently a number of Lewis staff members -- men by then well experienced in high energy propulsion systems -- were called upon by NASA Headquarters to serve on the technical assessment teams which recommended the contractor to build the F-1 and J-2 engines. Dr. Silverstein chaired the Source Board which made the final selection of the F-1 contractor. Work began on the F-1 engine, the nation's largest, in 1958 and on the J-2 in 1960.

During the course of development of these engines, Lewis continued its technical support in the form of consultation with NASA's Marshall Space Flight Center, Huntsville, Ala. Melvin Hartmann and Ambrose Ginsburg, Lewis fluid systems engineers, served on a Marshall committee to review problems being experienced by the F-1 turbopump.

These and other specialists served as consultants on a J-2 review committee. Among the topics discussed and of particular interest to the Lewis men was the inducer, that component which draws the boiling cold hydrogen into the pumps. Previous research conducted on this component at Lewis' Plum Brook Station near Sandusky, O., helped verify data of the Marshall Center that showed the inducers would permit a desired low pressure in the fuel tank.

Lewis also assisted a Marshall task group in achieving combustion stability in the F-1 engine. Dr. Richard Priem, experienced in advanced rocket combustion, was one of this group studying the "rocket screaming", a phenomenon caused by strong resonant pressure waves and which can destroy a rocket engine in seconds.

One other area of consultation with Marshall during the F-1 development was on fabrication of the thrust chamber. Walter Russell, a fabrication specialist served on the committee to review the materials and processes for the fabrication of the furnace-brazed thrust chamber and its jacket.

Staff members also lent their technical knowledge to other areas of the Apollo propulsion systems. Early studies were conducted at Lewis on the type of storable propellants to be carried on the upper stage of the Saturn V vehicle and on the spacecraft.

The Center's unique Zero-Gravity Facility was called upon to do two jobs for the Apollo program. In mid-1960, engineers used this facility to help solve the problem of re-starting the Service Module's propulsion system in space. Using surface tension phenomena observed during these studies, Lewis engineers assisted in designing a retainer for the propellant in the fuel tank. This retainer would keep enough propellant at the bottom of the tank to ensure that propellant would enter the pump and re-start the engine.

The Zero-Gravity Facility was used to help solve a similar problem in the SIVB third stage of the Saturn V for the Marshall Center. In flight when the SIVB engine shuts down, auxiliary hydrogen-peroxide thrusters are turned on to settle the sloshing propellants. During the coast phase the propellants are maintained in the bottom of the fuel tank by the thrust obtained when boiled off hydrogen gas is ducted through a small thruster system. Studies in the Zero-G Facility were able to determine the proper size of these various thrusters.

One of the astronaut's concerns about how weightlessness in space might affect fuel cell performance drew helpful information from Lewis too. Fuel cells are carried aboard the Service Module to provide electric power to spacecraft systems. Consequently, Lewis researchers investigated this area and made known to the Manned Spacecraft Center that the condenser of the fuel cell did not depend on gravity to operate properly. Lewis also was asked by MSC to determine the heat transfer characteristics of the condenser; this information was used in a computer simulation of the spacecraft's electrical power subsystem.

During 1967 Lewis engineers were consulting on the overall combustion and system stability of the Lunar Module ascent engine, the critical propulsion system for the Ascent Stage which returns the astronauts from the moon to lunar orbit. John Wanhainen, a chemical rocket expert, was part of a task group to overcome the high frequency combustion instability noted in the engine. Two other engineers, Robert Dorsch and Leon Wenzel, ran analog computer analyses of low frequency combustion instability characteristics.

The Center's 8 x 6-foot transonic and 10 x 10-foot supersonic wind tunnels were used in extensive tests on models of Saturn booster stages. The first such tests were made in the late 1950's when engineers studied base flow and heating tests on the SIB booster, the eight-engine first stage of the Saturn I. The 1/45th scale model had real, working rocket engines of 250 lbs. thrust each. Data were taken over a range of speeds from takeoff to Mach 3.5 and of altitudes from sea level to 150,000 feet. This simulation of actual flight conditions provided valuable information on the pressure and heat loads experienced on the base and engines' compartment of the SI vehicle. By varying the size and location of flow deflectors and shroud air scoops--devices to channel the air to best advantage--engineers were able to minimize the pressure and heating loads. Another study on the SI helped optimize vehicle flight stability and air pressure distribution.

In the 1964-1966 period base flow and heating also were studied in both wind tunnels for the SI C first stage of the Saturn V. Also, the force required to move the engine nozzles for directional control had to be measured. These measurements helped determine the size of the actuators required to gimbal the engines.

In all manned missions, safety of the public, the astronauts, and the operating crew, is a major concern to the NASA. In case a mission must be terminated early, one of the first options the astronauts have is to employ the Launch Escape Vehicle and Tower which stands atop the Command Module. This escape system propels the Command Module out and away from the Saturn V. During 1964 tests were made on the system in the Lewis Research Center's 8 x 6 tunnel at the request of the Manned Spacecraft Center. In the tunnel, a model of the escape system attached to the Command Module was released at various angles to determine its stability under simulated flight conditions.

Safety was the subject that brought I. Irving Pinkel, now Lewis' Assistant Director for Aerospace Safety, to serve as a consultant to the Apollo 204 Review Board. In that capacity and as a member of the team which investigated the causes of the spacecraft fire which took the lives of three astronauts early in 1967, Pinkel helped to recommend changes in the capsule to prevent a future tragedy.

Through extensive consulting on fracture mechanics, Lewis professionals have assisted in improving both the more than 140 pressure vessels of the Saturn V, and the SII fuel tank. Particular contributions by Lewis materials scientists to the construction of pressure vessels included improved test methods, and methods of design and analyses based on new concepts in fracture mechanics technology. Other materials scientists and engineers provided fracture research data on the critical weldments of the SII fuel and on the tank material itself; they also recommenced cryogenic proof tests, and suggested flight conditions to reduce wind loads on the vehicle.

Thus, Lewis scientists and engineers, like thousands of others who have served the Apollo team, have their hopes riding high with Apollo 11.

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