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Space Shuttle

The Space Shuttle Enterprise *travels slowly past the main headquarters building at Marshall Space Flight Center in March 1978. The* Enterprise *was scheduled to undergo vibration testing in Marshall's Dynamic Test Stand.*

The Space Shuttle represented an entirely new generation of space vehicle: the world's first reusable spacecraft. Unlike earlier expendable rockets, the Shuttle was designed to be launched over and over again, and would serve as a system for ferrying payloads and personnel to and from Earth orbit.

The Marshall Center was involved in preliminary studies on the Space Shuttle as early as 1970, 2 years before President Nixon endorsed plans for the new space vehicle on January 5, 1972. The Space Shuttle would "change the nature of what man could be in space," then NASA Administrator James Fletcher said.

Crucially involved with the Space Shuttle program virtually from its inception, Marshall played a leading role in the design, development, testing, and fabrication of many major Shuttle propulsion components. Marshall was assigned responsibility for developing the Shuttle orbiter's high-performance main engines—the most complex rocket engines ever built. Marshall was also responsible for developing the Shuttle's massive External Tank and the Solid Rocket Motors and boosters.

The Space Shuttle Main Engine is considered by many to be the world's most sophisticated reusable rocket engine. Three liquid-fueled main engines produce nearly 1 million pounds of thrust—equivalent to the energy of 23 Hoover Dams. Unlike the Saturn engines, the Space Shuttle Main Engines were designed to be throttled over a range from 65 percent to 109 percent of their rated power. Thus the engine could be adjusted to meet different mission needs. From the outset, it was recognized that the engines required the greatest technological advances of any element in the Shuttle program. The greatest problem was to develop the combustion devices and complex turbomachinery—the pumps, turbines, seals, and bearings—that could contain and deliver propellants to the engines at pressures several times greater than in the Saturn engines. Assembly of the first engine, Space Shuttle Main Engine 0001, was completed in May of 1975. This first engine, known as the integrated subsystem test-bed engine, was used in the first ignition test in June 1975.

The first engine firing at 100-percent power level was conducted early in 1977 and was followed by other tests, not all of which were successful. Problems were discovered in the high-pressure oxidizer turbopump during tests in March and September, but by the end of the year the anomalies appeared to have been resolved. Extensive engine testing continued to focus attention on certain components. The first flight engines were installed in orbiter *Columbia* in August 1980.

The External Tank provides liquid hydrogen and liquid oxygen to the main engines during the first 8 1/2 minutes of Shuttle flight. To develop the tank, engineers had to overcome a number of technical challenges. At 154 feet long and more than 27 feet in diameter, the External Tank is the largest component of the Space Shuttle and the structural backbone of the entire Shuttle system. By the end of 1975, fixtures were nearing completion at Marshall's Michoud Assembly near New Orleans for manufacturing the External Tanks. Several of the fixtures at the assembly site were more than half the length of a football field and several stories high. 1977 was one of the busiest years in the history of developing the External Tank. Fabrication of the first flight External Tank started in July. The first flight tank was delivered to Kennedy Space Center in July 1979.

The Shuttle's Solid Rocket Motors and boosters are the largest ever built and the first designed for refurbishment and reuse. Standing nearly 150 feet high, the twin boosters provide the majority of thrust for the first 2 minutes of flight— about 5.8 million pounds. That's equivalent to 44 million horsepower, or the combined power of 400,000 subcompact cars. The major design drivers for the Solid Rocket Motors were high thrust and reuse. The desired thrust was achieved by using state-of-the-art solid propellant and by using a long cylindrical motor with a specific core design that allows the propellant to burn in a carefully controlled manner. The test plan included modifications to an existing Saturn test stand to accommodate structural testing of the Solid Rocket Motors and boosters. Testing began in 1977 at Marshall and other facilities in the United States. Thrust vector control system testing was completed at Marshall. Parachute recovery testing was conducted in California.

1978 was perhaps the busiest year for Marshall's Shuttle test program. Throngs of NASA employees and local citizens turned out to greet the arrival of the Space Shuttle orbiter prototype *Enterprise* at the Marshall Center. The orbiter was test-mated with the External Tank and Solid Rocket Boosters to undergo a series of vibration/stress tests in Marshall's Dynamic Test Stand.

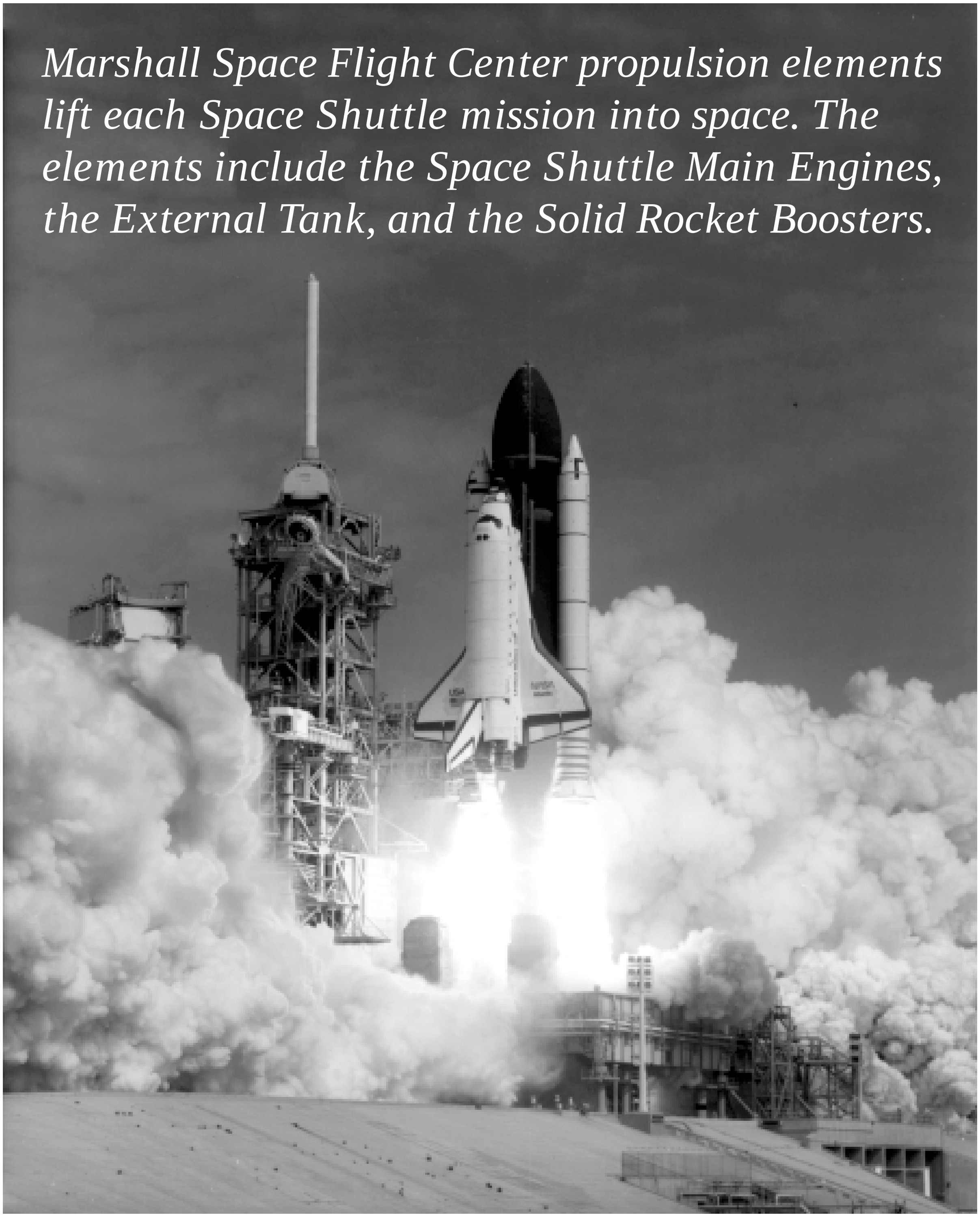
The excitement surrounding the first Space Shuttle launch drew the biggest tourist crowd to Cape Canaveral since the launch of Apollo 11. The crowd had to wait, however, because a computer problem delayed *Columbia's* launch for 2 days.

Columbia began its voyage with a flawless launch at 7 a.m. (EST) on April 12, 1981, with Commander John W. Young and Pilot Robert L. Crippen guiding the vehicle into orbit. The historic flight was concluded 2 days later when *Columbia* landed at Edwards Air Force Base, California.

In a period of less than 5 years after the first Space Shuttle flight there had been 24 launches and 24 successful missions. Then on January 28, 1986, at 73 seconds into the flight of the 25th mission, orbiter *Challenger* broke up under severe aerodynamic loads. The flames from a leaking right-hand Solid Rocket Motor caused a severe rupture of the External Tank, destroying it. The crew and the vehicle were lost.

The months that followed brought unparalleled changes in NASA's institutional management and in its technical operations. On March 24, 1986, NASA directed the Marshall Center to form a Solid Rocket Motor redesign team to re-qualify the motor of the Space Shuttle's Solid Rocket Booster. In addition to Marshall personnel, the team included personnel from other NASA Centers, industry, and academia.

The President directed NASA to implement the recommendations of the Presidential Commission on the Space Shuttle Challenger Accident. As part of satisfying those recommendations, NASA developed a plan to provide a redesigned Solid Rocket Motor.



Marshall Space Flight Center propulsion elements lift each Space Shuttle mission into space. The elements include the Space Shuttle Main Engines, the External Tank, and the Solid Rocket Boosters.

In mid-August 1986 the redesign team presented a design for the Space Shuttle booster that, among other improvements, would include tighter fitting joints, which incorporated a so-called "capture feature" designed to increase safety and performance. The new design would eliminate the weaknesses that led to the *Challenger* accident and incorporate a number of other improvements. Laboratory, component, and subscale tests would follow as well as simulator tests, using full-size, flight-type segments in order to verify the joint design under flight loads, pressure, and temperature. Full-scale tests would be used to verify analytical models, determine hardware assembly characteristics, identify joint deflection characteristics, and obtain additional technical data concerning the redesigned hardware.

After a nearly error-free countdown, *Discovery* and the STS–26 crew lifted off from pad 39B on September 29, 1988, at the Kennedy Space Center marking the first Space Shuttle flight in 32 months.

Marshall's Shuttle responsibilities did not end with the development of the operational propulsion elements. Instead, the Center has continued ongoing technology advancements to improve the Shuttle propulsion system at reduced costs. In particular, Marshall played a key role in the upgrading of the Space Shuttle Main Engines, which were successfully test-fired in 1988 using a modified Space Shuttle Main Engine in Marshall's Technology Test-Bed, actually a reconfigured Saturn V first stage test stand. Improvements also included the development of silicon nitride (ceramic) bearings for the Space Shuttle Main Engine. The Center also developed a new liquid oxygen pump using the latest technology of investment casting (versus welded components). Space Shuttle mission STS–89 in January 1998 marked the first flight of redesigned Space Shuttle Main Engines designed to increase the reliability and safety of Shuttle flights.

In 1994, the Center embarked on development of a new super lightweight Space Shuttle External Tank. The tank made its premier as part of the STS–91 mission in 1998. The new tank featured aluminum lithium—a lighter stronger material than the alloy used to manufacture previous External Tanks. The new tank was essential for launching Space Station components designed to be assembled in a more demanding orbit than previously planned. The new design resulted in a payload weight savings in excess of 7,000 pounds. Structural and modal testing for the tank was completed at Marshall. The Center also developed weld schedules and materials characterizations for the new tank. All of the work on the new tank was achieved successfully on a tight schedule of about 3 1/2 years.