(NASA-TM-84865) COLUMBIA'S SECOND MISSION. STS-2, THE FIRST FLIGHT OF A USED SPACECRAFT (National Aeronautics and Space Administration) 4 p HC A02/MF A01 CSCL 22A
G3/16
N83-10104
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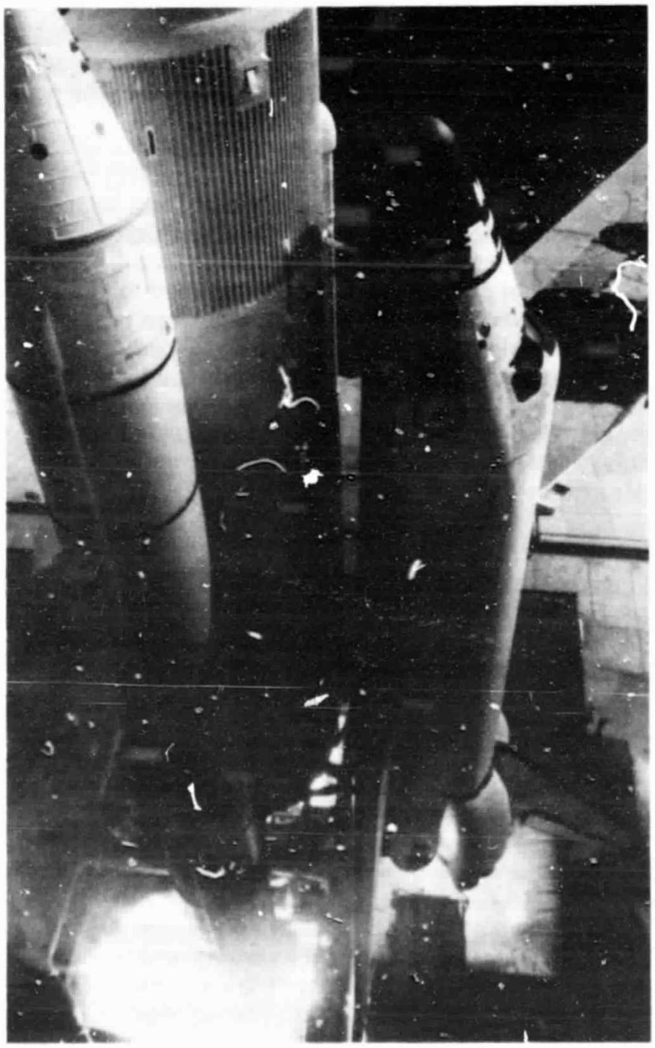
NASA
National Aeronautics and Space Administration

Mission Report

MR-002

Columbia's Second Mission—STS-2, the First Flight of a "Used" Spacecraft



Close-up of STS-2 at ignition. Right to left: The orbiter *Columbia*, the external propellant tank, and one of the two solid-propellant boosters.

A new epoch in space travel—the era of reusable space vehicles—opened with the launch of NASA's Space Shuttle from Kennedy Space Center, Florida, at 10:10 a.m. EST, November 12, 1981. The manned Space Shuttle orbiter *Columbia* flew into space again, making it the first space vehicle to be used more than once—another step toward certifying Space Shuttle as an operational spacecraft.

Columbia is the first of four planned orbiters, the part of the Space Shuttle that carries people and cargo into space. Other major Shuttle parts are the solid rocket boosters that, like the orbiter, are designed to be recovered and reused, and the external propellant tank which is jettisoned on each flight into orbit and not recovered.

The Space Shuttle is the primary launch vehicle of NASA's Space Transportation System (STS). This mission, called STS-2, is the second of four orbital flight tests designed to improve and ready STS for operational use.

Fuel Cell Problem Shortens Mission

The flight test was planned to last for more than five days. However, early on the first day, trouble developed in one of *Columbia's* fuel cells that convert hydrogen and oxygen into electrical power for the spacecraft and drinking water for the crew. With one of three fuel cells malfunctioning, mission safety rules called for STS-2 to be reduced to a minimal mission lasting 54 hours (36 orbits of Earth). After some deliberation, test managers decided to go by the book. As a result, the crew—NASA astronauts Joe H. Engle, commander, and Richard H. Truly, pilot—reluctantly cut short their space mission, landing *Columbia* at 4:23 p.m. EST, November 14, at Edwards Air Force Base, California. Their total flight time was 2 days, 6 hours, 13 minutes and 12 seconds.

Most of Goals Achieved

Although their time in space was reduced by more than half, Engle and Truly crammed extra work into

President Chats With Orbiting Crew

About 7 p.m., November 13, President Reagan visited the Mission Control Center at the Johnson Space Center, Houston, Texas. He chatted with Engle and Truly in the orbiting *Columbia*, jokingly asking to hitch a ride with them to California. On a serious note, he told them that the whole nation and the world were watching them with great pride.

the available time, providing abundant good data for orbital flight test engineers and other experimenters. They achieved more than 90 percent of the objectives set for STS–2.

Robot Arm Tested

Among their major goals was the first test in space of a Canadian-built remote manipulator system. The system is comprised of a huge mechanical arm, operating from *Columbia's* cavernous payload bay and guided by controls on *Columbia's* control deck. The system is designed to deploy payloads into orbit and retrieve them, as well as for other freight-handling activities in space. The arm can even be used to reach around and inspect various external parts of *Columbia*. It has its own lighting system and closed-circuit television so that the crews operating it have a close-up view of what they are doing.

The mechanical arm is jointed like a human arm at the shoulder, elbow, and wrist. Fully extended, it is 15.3 meters (50 feet) long. It is 38 centimeters (15 inches) in diameter. Despite its size, it is made of sturdy, lightweight materials giving it a weight on Earth of only 408 kilograms (900 pounds). The human analogy ends with the wrist. Its "hand," called an "end effector," consists of a snare wire device that can be tightened around grapples attached to the payloads.

Engle and Truly operated the arm in all of its modes, ranging from fully automatic, in which it is programmed in advance by computer to perform a series of operations, to fully manual, in which it is operated directly from a control panel that bypasses the computer.

Engle and Truly did not move loads with the arm, as this test was not planned. They did let the arm's camera picture them holding a sign saying "Hi, Mom"! A vital part of their test was swinging the arm back onto its cradle pedestals along the left side of *Columbia's* payload bay and latching it there. They accomplished this critical task expeditiously and expertly.

Good Data Obtained

As in STS–1, the first Space Shuttle orbital flight test, *Columbia* carried a complement of instruments to record the performance characteristics of its various systems. Valuable engineering data were accumulated by a flight information recorder. In STS–1, the recorder malfunctioned, losing the data. This loss was serious because the orbital flight tests are designed primarily to find and remedy defects in the Shuttle system and qualify it for routine operation.

Earth Surveys Performed

In addition to gathering engineering data, *Columbia* in STS–2 conducted experiments that would contribute to such fields as prospecting for oil, gas, coal, and minerals, locating promising ocean fishing grounds, understanding how gravity affects plant growth, forecasting thunderstorms and other severe weather, and measuring air pollution. Goals for the experiments included: determining whether *Columbia* could provide a stable platform for conducting Earth surveys, testing advanced techniques and instruments to survey Earth from space, and gathering data about Earth's resources and environment. STS–2 met these objectives despite the shortened mission although it did not provide all of the data about Earth's environment and resources that were originally called for.

For the most part, the instruments worked automatically. Engle and Truly were also scheduled to take many photographs of lightning bolts as part of one of the experiments.

Most of the instruments for these experiments were carried in an engineering model of the Spacelab pallet installed in *Columbia's* payload bay. The Spacelab pallet not only provided a structure on to which to mount experiments but also such support as electrical power. The pallet is designed for experiments requiring a broad field of view or direct exposure to the space environment.

The Earth survey experiments needed an unobstructed and broad view of Earth, making the Spacelab pallet a welcome advantage. Data from these experiments were accumulated on *Columbia* rather than radioed to Earth so that *Columbia's* data transmission capabilities could be devoted to flight test information. The experiment data were provided to the experimenters after *Columbia* landed.

As in any flight test program, the orbital flight tests are designed to identify and resolve unanticipated problems. Some of these problems result in launch delays. The test program, among other things, is designed to shorten turnaround time.

Fuel Spill Damages Tiles

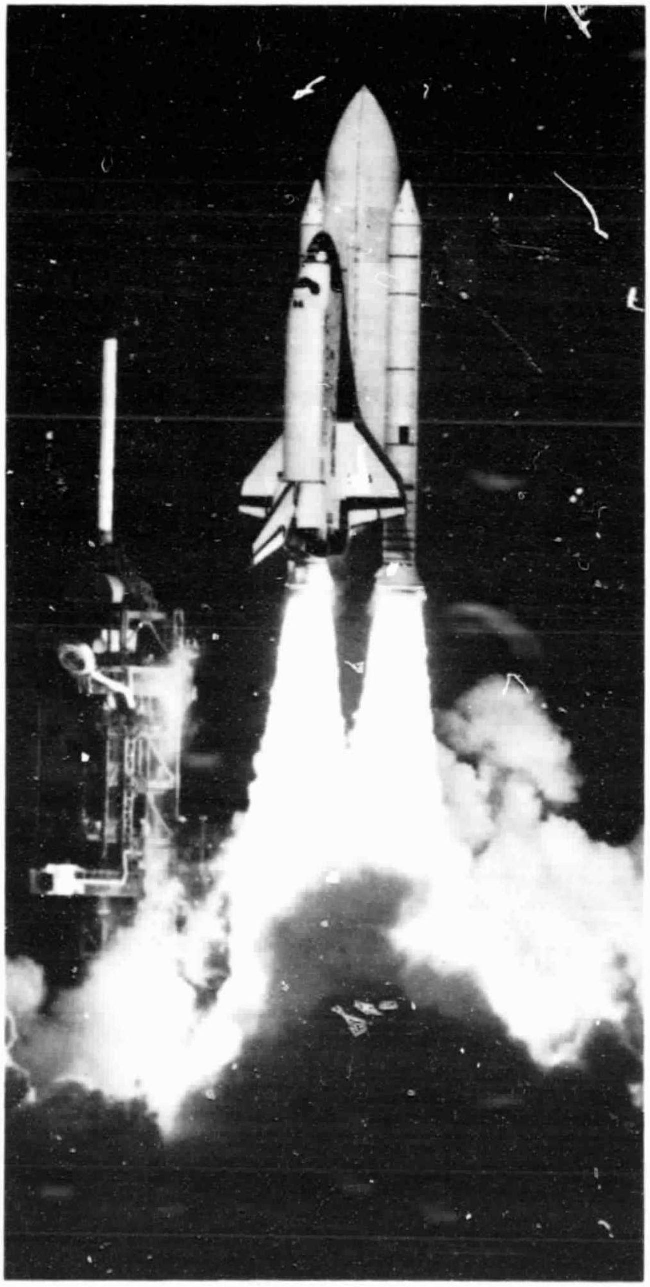
In September, launch of the Shuttle was significantly set back when nitrogen tetroxide oxidizer being pumped into *Columbia's* attitude control rocket tanks spilled onto the heat-shielding tiles. The oxidizer acted like a solvent, dissolving the cement beneath the tiles. A total of about 380 tiles had to be carefully cemented back onto the Shuttle.

Just before the launch on November 4, the countdown computer called for a hold in the countdown. During the hold, high oil pressures were discovered in two of *Columbia's* three auxiliary power units (APUs) that operate the craft's hydraulic system. The hydraulic system swivels *Columbia's* rocket engines during launch and operates its aerodynamic controls and landing gear after atmosphere entry when the spacecraft becomes an aircraft. The oil filters in two of the APUs were found to be clogged and were replaced. This set the launch back to November 12 at 7:30 a.m. EST.

However, unexplained problems arose with *Columbia's* multiplexer-demultiplexer which processes and displays data on the craft's condition for both *Columbia's* crew and the Mission Control Center, Johnson Space Center, Houston, Texas. New ones were removed from another orbiter (*Challenger*), which is under construction in California, and flown to Kennedy. This delayed the 7:30 launch to 10 a.m. Another ten minutes were added to give the launch team time to make "double sure" every thing was all right.

Shock Waves Reduced

STS–2 lift-off was a model of perfection. The problem of the shock waves from the rocket blast that had bent several of *Columbia's* fuel tank supports in STS–1 was solved by a newly-developed water-deluge system installed at the bottom of the launch pad.



STS–2 roars upward on pillar of fire.

Some 300,000 gallons of water sprayed into the rocket exhaust damped the shock wave by more than 75 percent, preventing damage to *Columbia*.

The booster rockets and the external propellant tank detached and fell to ocean areas as planned. The booster casings were recovered, but some two days after parachuting into the Atlantic Ocean. Recovery was hampered by high winds and waves.

Opening and closing of the payload bay doors were successful. The craft was turned belly upward so that its instruments could look down on Earth.

Despite the smoothness of the flight, the failed fuel cell proved too worrisome to warrant attempting the planned 83(+) orbit mission. Among considerations was that, if another fuel cell failed, *Columbia* would not have enough electric power to both bring itself in and acquire vital data such as heating on the craft during atmosphere entry. Such data were lost on STS–1. Engineers estimated that some 50 percent of the data they needed was on atmosphere entry. The judgment of flight test managers was that the risks of a longer flight far outweighed possible gains.

Fuel cells have a long record of reliable use on manned spacecraft since the 1960s and were considered among the least likely components to go wrong. The only other fuel cell problems—those on Gemini 5 and Apollo 13—were due to the fuel tank or fuel line and not to the cell itself. The nature of the fuel cell breakdown in STS–2 is under study.

Crew Achieves Smooth Landing

Engle and Truly followed the same course in returning from orbit as did Crippen and Young in STS–1: retrofire over the Indian Ocean, atmosphere entry over the western Pacific Ocean, transition to aerodynamic controls in the atmosphere to land as an aircraft.

This time *Columbia* was guided to its landing site by a microwave scanning beam landing system on the site. This time, also, Engle put the craft through rolls

Underside of *Columbia* as it came in for landing on November 14. Photograph was taken by chase plane to show condition of thermal tiles on underside. Note also trailing vortices from *Columbia's* wingtips.

and other maneuvers to test how it handled under stress. However, most of the descent was in the automatic mode until flare (leveling off) when Engle took the controls. Plans for a crosswind landing were dropped because of winds gusting to 25 knots, too high for safety. Engle made a perfect touchdown despite extensive cloud cover that made the Edwards Air Force Base site marginal for landing. As in STS-1, Engle and Truly landed on Runway 23, Edwards Air Force Base, California. The runway is a dry lake bed in the Mojave Desert. Touchdown was at 4:23 p.m. EST, November 14.

Shortly after *Columbia* landed, it was surrounded by vehicles and technicians who took measures to remove dangerous concentrations of explosive or poisonous gases from *Columbia's* payload bay and along its surface. They also ventilated *Columbia*. After *Columbia's* vicinity was determined to be safe, Engle and Truly left the spacecraft and stepped down their landing ladder. The time was 5:05 p.m. EST.

Tiles Survive Mission Well

Preliminary inspection of *Columbia* indicated that it came through STS-2 with much less wear and tear than it did in STS-1. In STS-1, all or part of 16 heat-shielding tiles were lost and 148 others were damaged. In STS-2 no tiles were lost and only about a dozen were damaged and will need to be replaced.

The improvement is attributed to changes in launch procedures, including the shock-absorbing water spray system on the launching pad, and to toughening of tiles in particularly vulnerable areas. *Columbia's* exterior is covered by nearly 31,000 heat-resistant tiles that protect the craft. More than 2,200-degree heating was generated on exterior surfaces by the entry into the atmosphere on return to Earth.

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