Columbia Exceeds Flight Goals

Kennedy Space Center, Fla.—Space shuttle Columbia's successful launch, orbital operation and reentry to a smooth landing at Edwards AFB, Calif., met or exceeded all flight test goals, carrying winged flight into uncharted territory.

Successful launch of the shuttle Apr. 12, after a launch scrub two days earlier, affirmed the integrity of the vehicle's propulsion, avionics and structural systems through the most challenging ascent profile ever flown by a space vehicle, and cleared the way for an aggressive shuttle flight test program.

Liftoff of Columbia, piloted by astronauts John W. Young and Navy Capt. Robert L. Crippen, at 3:00 a.m. EST Apr. 12, took the crew and Johnson Space Center mission controllers through the most dynamic, fast-paced series of launch events ever undertaken by the U.S. manned spaceflight program.

Highlights of the first space shuttle launch are:

- Decision at T-90 sec. to bypass a countdown hold—Kennedy Space Center's S-band Mission Support Facility became unavailable for vehicle tracking because of a procedural error at about T-90 sec. This forced Kennedy and Johnson Space Center management into a time-critical decision to launch without the important tracking capability or hold the countdown. Kennedy received a go from Silver Team ascent flight director Neil Hutchinson and flight dynamics offi-
Jay Greene to proceed with the launch despite the S-band loss—a decision that modified mission rules in real time and allowed the 7 a.m. liftoff.

- **Excess vehicle lofting**—During climbout on nearly 7.5 million lb of thrust, the shuttle vehicle began to fly a roughly 5% steeper climb profile than programmed. This could have affected adversely the crew’s abort options, such as lengthening the amount of time the vehicle would have to fly before reaching the preferred forward abort capabilities. An abort early in the launch sequence would involve a difficult return to launch site maneuver. At this stage of the flight, the extra loft was draining energy that should have been used for downrange velocity.

- **Superior propulsion performance**—Rocketdyne space shuttle main engines and Thiokol/McDonnell Douglas solid rocket boosters performed better than envisioned, giving Columbia extra thrust that canceled out the downrange energy loss resulting from the lofted trajectory. The excess performance was radiated to Young and Crippen at about 2 min. 50 sec., or shortly after solid rocket booster separation. “Columbia, you are looking a little hot, all your calls will be a little early,” spacecraft communicator astronaut Daniel C. Brandenstein said. Actually most of the later calls occurred on time because of the benefit the extra thrust provided in canceling out the excess lofting.

Hadding that extra lofting was not present, Hutchinsen believes the forward abort options could have been reached 10-15 sec. earlier in the flight. Initial comments by the crew were that the ride provided by the solid boosters was about as expected—rough but no more so than that experienced by flight in the space shuttle mission simulator (AVAST 29, 1980, p. 48). Solid rocket booster separation caused no adverse vehicle attitudes because of asymmetrical thrust tailoff, a concern with using such a propulsion system.

- **Propulsion performance targets**—Avionsics and propulsion system capability to fly this new spacecraft was demonstrated clearly by the orbital targets achieved versus those desired. Brandenstein radioed the crew to expect main engine cutoff at 8 min. 34 sec., which is when it occurred. At main engine cutoff the inertial velocity achieved was 25,670 fps, only 2 fps higher than targeted months before. Altitude rate of climb, or H-dot, of 220 fps was exactly the number desired.

The shuttle flies a diving trajectory from about 73 to 63 naut. mi. for engine cutoff to achieve proper tank separation but pulls up with a positive rate of climb at the end of the dive (AVAST Apr. 6, p. 40). The positive climb rate of 220 fps, established months ago, was achieved precisely at main engine shutdown.

Orbital maneuvering system burns by the two Aerojet engines were equally precise. Target for the first OMS burn after external tank separation was for a 165-fps, velocity vector (Delta-V) to achieve a 130 x 57 naut. mi. orbit. What the OMS burn provided was 164.7 fps of Delta-V and a 132 x 57 naut. mi. orbit. The second OMS burn 44 min. into the flight—to reach a 130 x 130 naut. mi. orbit—was equally precise.

Aside from the lofted trajectory, there was only one malfunction during ascent. Shortly after the OMS-1 burn, an electrical short developed in a line to an orbiter

Space shuttle orbiter Columbia roars away from Launch Complex 39A Apr. 12 (left) riding a combined thrust of 7.5 million lb, generated by its three main engines and two solid rocket boosters. At mission’s end Apr. 14 (below), Columbia touches down at Edwards AFB, Calif.
signal conditioner that supports significant orbiter instrumentation, such as that involving reaction control jet activity. Two main bus power supplies to the particular signal conditioner were affected. When the short occurred, it popped a circuit breaker in the cockpit and also identified itself as a malfunction. There was no damage to the signal conditioner because the circuit breaker performed its job and there was no degradation in capability since the redundant power supply kept functioning.

Young and Crippen placed a yellow indicator over the circuit breaker, and the reentry checklists were updated, keeping the breaker out during the reentry phase.

Two other unusual incidents occurred during launch. Both came shortly after main engine shutdown and tank separation as the engines were being gimbaled to a parked position.

Young commented on a noticeable orbiter vibration at about the time the engines were being gimbaled. Flight con-

Quick Fix

Kennedy Space Center, Fla.—The computer “time skew” that forced the scrub of the Apr. 10 shuttle orbiter launch was quickly diagnosed in about 6 hr. and produced a work-around operating solution later the same night.

Accuracy of the troubleshooting effort, which involved more than 50 specialists from Johnson Space Center, IBM and Rockwell International, was reflected in the faultless performance of the onboard computer complex throughout the successful mission that began Apr. 12.

Although they know how to prevent a reappearance of the problem, which disrupted communications channels that link the four primary guidance, navigation and control computers that operate as a cooperative redundant set to the lone independent backup computer, data processing experts are continuing efforts to pinpoint precisely how the 40-millisecond timing error occurred.

The problem appeared at T–20 min. in the countdown Apr. 10, when the primary computers were scheduled to switch from prelaunch to launch configuration, designated OPS 101. Until this time, the backup computer remained idle, but at this point in the countdown it was “awakened” and programmed to request data from the primary system.

Because of the 40-millisecond time skew, however, the backup computer did not receive its answer within the proper time frame, and was therefore programmed to reject the data. When the backup system again polled the network signal processor, the answer was still out of phase, causing the backup system to produce error messages onboard the orbiter and at ground facilities at both Kennedy and Houston.
trollers last week believed that the crew felt the engines hitting the stops at the end of their gimbal profile. Prior to reentry the engines were regimballed to assure they were in a proper position for best entry aerodynamics, and engineers assessed the outcome of this exercise in relation to the vibrations Young reported.

Almost simultaneously with the onset of the vibrations, the main propulsion system dumped the several thousand pounds of liquid oxygen and hydrogen remaining in the main engines against open legs. This insured that the excess propellants would pose no hazards.

The venting occurred at the OMS-1 burn, with the liquid oxygen going out the engine nozzles and the liquid hydrogen dumped out side vents. The oxygen dump had been removal and so added was con-


Shuttle Coverage
First space shuttle launch was covered by an AVIATION WEEK & SPACE TECHNOLOGY editorial team, headed by editor-in-chief William H. Gregory, at Kennedy Space Center, Fla., Johnson Space Center, Tex., and Edwards AFB, Calif. At Kenne-

dy were Gregory, Herbert J. Coleman, managing editor-bureaus; Craig Ciovault, space technology editor; and Kenneth J. Stein, avionics editor. After launch, Cov-


ault joined Dallas bureau chief Erwin J. Buban at Johnson, while Gregory joined Robert R. Ropelewski, Los Angeles bureau chief; and Bruce Smith, engineer-


ing editor, at Edwards.


than projected, and its debris landed 2,100 nau-


m. down range from Kennedy, with-


in about 10 nau. mi. of the targeted aim point.


immediately after tank separation, Young used control stick steering to


Leads to Faultless Performance


according to Neil B. Hutchinson, NASA flight
director at Johnson Space Center.


Although astronaut Robert L. Crippen hit an input/output reset button on board the orbiter, the systems again failed to commu-
nicate.


The primary and backup systems are pro-


grammed independently by IBM and Rockwell Interna-
tional to prevent a common design flaw. This generic software problems that would wipe


out all four primary machines—that would take them all out at once," Hutchinson


said.


Initially it was believed that the problem arose from the backup system software, and computer removal and exchange was con-
templated. This would have required about 2 hr., according to Brock R. Stone of NASA's data processing system engineering.


The countdown was recycled while back-


up computer software was dumped and


examined at Houston. The count was recy-


caled to T-23 min. and held there for an


additional 28 min. to provide time for a re-


alignment of the Singer Kearfott inertial measurement unit. The inertial unit func-


tioned normally, but it has a prescribed limit to its hold time without realignment.


At T-16 min. in the second Apr. 10
countdown, the computer problem was re-


peated, and the launch attempt was scrubbed at 9:59 a.m. EST.


Analysis of the timing skew, described by
e one NASA official as "a statistical Murphy," indicated later that day that the complex of four primary computers had picked up the wrong timing by one "minor cycle," during the initial program loading, which occurs at about T-15 hr.


The primary computer set operates in
closely synchronized steps, but each com-


puter in this group takes its timing from the first one started, so there is no communica-
tion problem within the redundant group, Stone said.


One explanation is that the pulse code modulation (PCM) master unit for timing may have "a little too much tolerance," he said. The backup system, pulling the net-


work system, detected that the timing cycle was not just right because it did not receive an answer within the required 40 min. frame. When it determined that the two network signal processors for Strings (channel) 1 and 3 were not provid-


ing replies within the required time frame, the backup computer announced a fault.


The fix adopted by NASA was simply to determine that the unlikely statistical event did not recur by dumping the primary sys-


tem's data early in the final countdown. If the time skew appeared, it could be eliminated simply by re-initializing the primary system from standby, Stone said.


The fix was evaluated the night of Apr. 10 and "worked fine," according to NASA offi-


icals.


The primary system remained up in antici-
pation of the successful launch countdown


Apr. 12. As the T-20 min. point neared, ten-


sion grew, but the backup computer was activated on schedule, and cheers greeted the announcement that "mission control in Houston has verified that the primary system is in synchronization."


At T-17 min., it was further verified that all four primary machines were communicat-


ing with the backup computer.


"We know what we have to do to preclude that problem and will add that to our proce-


dures," George F. Page, director of shuttle operations here, said.


“One possibility behind the software skew is that we could have just had a chain of


"worst case" timing that stacked to put the data outside the 40-millisec. window," accord-


ing to Charles Floyd. He is technical assistant for software integration to Walter Murphy, chief of the guidance digital elec-


tronics and software division here. Both men have had extensive experience in NASA operations, here and in Houston, since the early 1960s, most recently with the launch processing system. Floyd worked on soft-


ware for the primary onboard processing system. “Some of the timing variables in the system were collective judgments on the part of the hardware and software people involved,” Floyd said. “If certain things then line up in a particular way, we’ve got a problem.”


“In all likelihood it’s variability in the hard-


ware execution,” he added. “Re-timing in the backup system may have had to try a master timing unit or pulse code modulation timing unit signal exchange, and this could have kicked the timing off enough to miss the window,” Floyd said. The timing skew would only affect the network signal proces-


 sor input/output, causing Strings 1 and 3 to be faulted down, he added.


This timing skew would not affect internal operations among the four primary comput-


ers, which have synchronization point codes within a 4-millisec. time allowance, accord-


ing to William Madden, IBM senior engineer. Actual data transmission within these 4-


millisec. windows occupies about 50-100 microsec., Madden said.


The four primary computers and the single backup are all identical modified IBM AP-


101 computers, an extension of the compa-


ny’s System/4 51 line of aerospace hard-


ware. IBM programs the four primary machines; only the backup is independently pro-


grammed by Rockwell.
mnanver Columbia into the OMS-1 burn attitude, with the vehicle still inverted but with the nose about 15 deg. above the horizon. As the burn approached, the nose of the vehicle's cockpit ray tube displays counted down the time to ignition.

When the timer hit the T-15 sec. point, guidance began continually updating the burn targets and the word "execute" (execute) began to flash on the display. This was a cue to Crippen to push "execute" on his computer STS-1's end, in effect telling Columbia that the crew was ready for OMS ignition.

At 10 min. 32 sec. mission elapsed time, the two engines ignited for 1 min. 27 sec. A 132 X 57 naut. mi. orbit was reached, compared with the approximately 81 X 13 naut. mi. orbit achieved at sun engine cutoff to inaugurate a suborbital trajectory for the external tank. The OMS-2 burn to achieve the 130 naut. mi. circular orbit was performed in the same manner, essentially completing the launch phase.

"One thing that absolutely flabbergasted us was that we saw the whole OMS-1 burn at Bermuda [tracking station] and got a preflight cutoff vector on both the C- and S-band radars at Bermuda," Hutchinson said. "We have never done that in two and one-half years of simulations because we just didn't think the tracking network could hang in there that long."

This could be extremely helpful on future launches if a crew is forced into an abort once around into Northrop Strip at White Sands, N. M., because of a non-engine performance emergency.

The Apr. 12 liftoff occurred on time primarily because of intense last-minute discussions in the Mission Control Center and Launch Control Center in Houston when Kennedy's S-band radar failed to come on line for tracking the early ascent phase.

C-band radar tracking was available but not considered as accurate to hold track, or at best to provide data for guidance and trajectory updates in the event of a vehicle problem early in flight. Flight dynamics officer Greene recommended proceeding with the count, Hutchinson said, because the C-band data also been lost at liftoff, leaving Mission Control with no active tracking, they could have regained the capability again by the time the spacecraft reached C- and S-band radar coverage on Bermuda.

The autonomous nature of the shuttle's avionics capability enhanced the decision to go without the S-band radar, which Hutchinson said under mission rules probably was considered mandatory for launch. "As it turned out we got C-band radar coverage from the pad and never lost it for the entire launch," he said. The loss of S-band radar occurred when the spacecraft reached a switch that would link cameras to the S-band radar drive. What the personnel involved did not realize was that when the camera drive is activated radar data is inhibited, Hutchinson said.

At liftoff, Young called "roll init," then "roll complete," several seconds before the commander said he saw the maneuver halt and the pitch to the heads-down altitude increase.

Young and Crippen said earlier that they were looking forward to the scenery at the point in launch trajectory where Kennedy pitched its nose from 18 deg. above the horizon to 4 deg. below it, beyond the spacecraft's large 180-deg. windshield to a maximum view of the Atlantic 70 mi. below.

At about Mach 7, 4 min. 20 sec. into the flight, Crippen's expectations became reality when he observed, "Man, what a view, what a view!"

The crew's day on Apr. 12 began about 3 a.m. EST when they were awakened here for their second launch attempt in two days.

The astronauts reached the white room on Pad 39A at 4:20 a.m. EST near the end of a 2-hr. built-in countdown hold at the T-2 hr. 5 min. point. The count was picked up at 4:25 a.m. and the only problem encountered occurred 25 min. later with a quick disconnect fitting in the ejection seat/oxygen suit flow system. The problem was resolved quickly by repositioning a pin in the system. Astronaut support pilot USAF Maj. Loren J. Shriver was in the cockpit at this time assisting Young and Crippen.

Columbia's hatch was closed at 5:20 a.m. EST at T-1 hr. 9 min. in the count, which proceeded to the T-20 min. point, where a 20-min. built-in hold was executed, and then to the T-9 min. point in the count, where a 10-min. hold was placed. At the T-9 min. point, Kennedy shuttle launch director George Page called the crew and read a message from President Reagan, following it with a message from the launch crew.

Ground launch sequencer and the spacecraft's redundant launch sequence (AWST Apr. 6, p. 4), found no faults among the thousands of parameters monitored after the T-9 min. point, and Young and Crippen then smoothly flew Columbia through a 5-min. D-Mach 2.5 altitude regime never before traversed by a winged vehicle.

"Having simulated for years, practicing every malfunction we could possibly dream up, I just kept waiting for something to go wrong and nothing did," Hutchison said. "We took this brand-new vehicle that's never been in the air, ran it through its paces and it performed absolutely admirably."
Orbital Objectives Achieved

Johnson Space Center, Tex.—Orbital performance of the space shuttle exceeded expectations and demonstrated that the U.S. has attained an unmatched capability to operate a high-performance, reusable, manned system with broad commercial, scientific and military applications.

Only a few, relatively minor anomalies marked the unprecedented smooth first flight of this new-generation manned space system. None of the problems encountered prevented achievement of mission objectives.

Enthusiasm of Columbia commander John W. Young and pilot Robert L. Crippen and operations personnel here was evident during and after completion of the shuttle’s historic first flight.

When Mission Control Center informed Young and Crippen approximately 3 hr. after launch that they were cleared to proceed with the orbital mission, the spacecraft commander responded, “Let’s go on for orbit. This thing [orbiter] is performing just outstanding.”

Similar praise was voiced by the crew and Mission Control Center personnel throughout the flight.

Following the Apr. 14 landing at Edwards AFB, in California, Johnson Space Center director of flight operations, Peter Frank, said: “It’s hard to believe the mission went as well as it did. It’s hard to believe it worked so great.”

The major discrepancy uncovered during the flight was the loss of small portions of the heat-protection tile coverings on each pod containing the spacecraft’s rear-mounted orbital maneuvering system engines.

This was discovered approximately 2 hr. after launch following deployment of the spacecraft’s payload bay doors and radiators. Television pictures of the gaps in the tiles were transmitted to the Mission Control Center and the public by the orbiter’s onboard cameras.

Study of the television pictures by Mission Control Center technicians determined that at least one, possibly two complete tiles, the largest being 8 in. × 8 in., were missing. There appeared to be at least 15 tile discrepancies on the top surface of the OMS engine pods, nine on the top of the right pod and six on the left. In most cases, it appeared that only portions of tiles were gone.

NASA personnel said the affected areas were not high-temperature critical during the reentry phase, experiencing brief transients in the 700-750°F range and getting the higher temperature exposure during the ascent rather than the reentry phase of flight. Also, they said, the undersurface of the skin in this area had an additional 2 in. of insulation, further attenuating heat and protecting interior structure and fluid lines.

NASA teams were formed in the center to review in detail definitive test data relating to the protective tiles and other technical information. As a result of these studies, they determined that the damage visible was not critical and did not pose a life-threatening situation for the crew.

Concurrently, NASA contacted the Defense Dept. to bring into play ground-based high-resolution optical telescope equipment at Mauna Kea, Hawaii, to attempt to photograph the orbiter during passes over the site.

Cloud cover, or low elevation angles of the spacecraft as it passed over the sites, however, prevented any useful photography from being obtained, according to Mission Control Center personnel.

A major problem in attempting to use ground sensors to study the underside of the spacecraft, which would experience critical heat loads during reentry, was that the orbiter was in an attitude with the payload bay doors facing Earth.

Further study made NASA officials confident that the spacecraft had suffered no damage or tile loss in its critical areas and the mission plan was continued without alteration.

The entirety of other discrepancies experienced onboard the spacecraft were related to erratic performance of some transducers, flowmeters, system gauges and valves.

These compromised systems operation to a minor extent, since adequate work-around measures, including manual operations in some cases or alterations in procedures resulted in getting the affected items to perform.

Flight operations personnel explained that most of the discrepancies could be attributed to the fact that the components

Space shuttle Columbia, generating nearly 7.5 million lb. of thrust, translates northward while clearing lightning mast atop Launch Pad 39A service structure. Data indicates translation was as expected. Translation occurs because vehicle’s main engines were canted relative to local vertical at ignition. The vehicle aligns thrust center of gravity starting 2 sec. after liftoff.