

STS-107 Entry Timeline

**Compiled by William Harwood
CBS News**

**As of 08/01/03
Rev. J**

Changes and additions:

- A.** 02/09/03: Initial release; includes preliminary telemetry and NASA commentator transcript
- B.** 02/15/03: Posting integrated timeline with detailed telemetry and flight director audio loop
- C.** 02/17/03: Fixing flight director loop transcription errors; expanding abbreviations; adding LSO to mission control personnel
- D.** 02/18/03: Correcting acronym explanations (DSC (two instances) and TSU)
- E.** 02/21/03: Posting rev. 13 of the NASA telemetry timeline
- F.** 03/01/03: Adding transcript of crew cabin video/intercom
- G.** 03/10/03: Adding significant updates based on NASA's baseline entry timeline (rev. 14)
- H.** 03/14/03: Adding updates from NASA's baseline entry timeline (rev. 15); adding video AOS/LOS times, viewing locations
- I.** 04/07/03: Adding initial OEX recorder data (OEX start time, seven data points, PCM/FDM data stop times)
- J.** 08/01/03: Rev. 19; final timeline update; to be included in Columbia Accident Investigation Board final report

Editor's Note...

The following timeline was compiled by William Harwood, CBS News, from realtime telemetry and data from Columbia's recovered OEX recorder (through rev. 19 of NASA's internal entry timeline reconstruction), transcriptions of the NASA-Select commentary, mission control audio loops and portions of a 13-minute in-cabin video recovered after the accident.

The telemetry and OEX recorder data timing is exact, but the mission control audio and commentary entries are approximations. All such entries are tied to the assumption that shuttle commander Rick Husband's final transmission began at 8:59:32 a.m. EST, the moment the last valid data frame was transmitted from the orbiter. Likewise, the crew cabin comments by the astronauts were timed off on the assumption the tape began at exactly 8:35 a.m., which is the time NASA gave in a press release.

Audio loop entries will be updated as warranted based on digital time stamps from the Johnson Space Center audio control center. As it stands, however, the audio loop entries are believed accurate to within a few seconds.

To prevent interrupting the telemetry/mission control narrative, the NASA commentator entries are presented in blocks, as they were spoken. Readers should note, however, other events may be happening while the commentator is talking, as reflected in the times listed for those events.

Many telemetry/OEX data entries include altitude in feet, Mach number and latitude and longitude in parentheses with north (+) latitude first followed by west (-) longitude, i.e., +36.398-150.847 means 36.398 degrees north latitude, 150.847 degrees west longitude. OEX data also reflect the

number of seconds before and after entry interface, or EI, the moment Columbia reached the discernible atmosphere.

The timing of amateur video coverage of Columbia's re-entry is included in NASA's Master Timeline (rev. 19) and in the integrated timeline below. The start/finish times refer to actual footage, not when the shuttle rose above or passed below the horizon as viewed from the photographer's location. Each video entry includes the shooter's latitude and longitude in the same format discussed above.

Personnel mentioned:

MCC-FLIGHT - Entry flight director - LeRoy Cain, mission control center
MCC-CAPCOM - Astronaut Charles Hobbaugh
MCC-FDO (Flight Dynamics Officer; pronounced "FIDO") - Richard Jones
MCC-INCO (Instrumentation and Communications Officer) - Laura Hoppe
MCC-MMACS (Maintenance, Mechanical, Arm and Crew Systems Officer) - Jeff Kling
MCC-GNC (Guidance, Navigation and Control Officer) - Mike Sarafin
MCC-GC (Ground Control Officer) - Bill Foster
MCC-GPO (Guidance and Procedures Officer) - Doyle Hensley
MCC-EECOM (Emergency, Environmental and Consumables Operation Manager) - Katie Rogers
MCC-LSO (Landing and Support Officer) - Martin Linde
MCC-MOD (Mission Operations Directorate Representative) - Phil Engelauf
MCC-Commentator - James Hartsfield, NASA/JSC public affairs officer
STS-A/G (Shuttle Commander, air-to-ground audio) - Shuttle commander Rick Husband, aboard Columbia
STS-ICOM - Indicates cockpit intercom voice traffic captured on in-cabin video

Shuttle Columbia's Final Re-Entry: A Voyage into History

Flying upside down and backward over the Indian Ocean, commander Rick Husband and pilot William "Willie" McCool fired Columbia's twin orbital maneuvering system braking rockets at 8:15:30 a.m. EST to begin the shuttle's long glide back to Earth. There were no signs of any technical problems and the weather at the Kennedy Space Center was improving after initial concerns about cloud cover.

Columbia fell into the discernible atmosphere 400,000 feet above the Pacific Ocean northwest of Hawaii at 8:44:09 a.m. Re-entry was normal until 8:48:39 a.m. when a strain gauge in the shuttle's left wing began showing an unusual increase. Twenty seconds later, a temperature sensor in the left wing's leading edge began showing an off-nominal increase as hot gas shot into a cavity behind the U-shaped reinforced carbon carbon panels making up the leading edge.

Additional left wing sensors soon began registering elevated temperatures and data from a series of sensors across the back of the left wing simply stopped flowing. At almost the same time, Columbia's flight control system began sensing unexpected aerodynamic drag on the left side of the spacecraft and commands were sent to adjust the shuttle's roll trim using the elevons at the back of each wing. This unusual drag steadily worsened as Columbia streaked across the southwestern United States.

It now appears a breach in the shuttle's wing, on the lower side of reinforced carbon carbon panel No. 8, allowed a plume of hot plasma to enter the wing structure. The wiring for the failed sensors at the back of the wing was routed just to the left and then in front of the left main landing gear wheel well. Analyses and testing on the ground show a breach in RCC panel 8 is the most likely explanation for what happened during Columbia's re-entry.

That said, here is a timeline of the final hour of Columbia's 28th flight. NOTE: This is a complete writethrough based on NASA's final timeline revision (rev. 19). Some entries in previous versions of this timeline have been deleted, others have been added and others have been moved based on updated timing.

08:10:39 a.m. - TIG-5 minutes: APU-2 startup.

08:15:30 a.m. - TIG-0: Deorbit ignition. Change in velocity: 176 mph; Burn duration: two minutes and 38 seconds. Location (latitude/longitude in minutes:seconds): -33:35+98:10; altitude: 175.95 statute miles. Velocity: 17,319.7 mph

08:18:08 a.m. - Deorbit burn complete.

08:26:09 a.m. - Forward reaction control system propellant dump begins.

08:27:12 a.m. - FRCS dump complete.

08:31:25 a.m. - APU-1 startup. Entry interface (EI) minus 13 minutes.

08:31:29 a.m. - EI-760 seconds - APU-3 startup.

08:31:57 a.m. - EI-732 - APU-1 at normal operating pressure.

08:31:59 a.m. - EI-730 - APU-2 at normal operating pressure.

08:32:01 a.m. - EI-728 - APU-3 at normal operating pressure.

08:32:29 a.m. - EI-700 - Shuttle main engine stow sequence begins (thrust vector control system isolation valve 1 to close).

08:39:09 a.m. - EI-300. Transition to OPS-304 software load; aerojet digital autopilot and entry guidance are activated; open-loop guidance (angle of attack = 40 degrees, roll angle = 0 degrees). Mach: 24.40.

08:39:11 a.m. - EI-298 - Speedbrake closed; rudder commanded to zero degrees.

08:39:28.559 a.m. - EI-280.4 - OEX: Start of pulse code modulation - PCM - data block.

Editor's note: For clarity, mission control audio and cockpit voice loops have been omitted to this point. All conversations were normal and thus have no significance to the accident investigation. We pick up the timeline roughly two minutes before entry interface, the point where the shuttle enters the discernible atmosphere 400,000 feet above the Pacific Ocean.

08:41:35 a.m. - STS-ICOM: Commander Rick Husband: "Two minutes to entry interface."

08:41:43 a.m. - STS-ICOM: Laurel Clark: "I know about the line cable, Willie, I didn't understand your question. You don't want the camera back, right?"

08:41:51 a.m. - STS-ICOM: Pilot William "Willie" McCool: "I do not want the camera back.

STS-ICOM: Husband: "He's got one mounted in his HUD already."

STS-ICOM: Clark: OK. Yep, yep, yep. Yep, Replug."

08:41:54 a.m. - MCC-Commentator: "This is mission control, Houston. Columbia's altitude is now 90 miles above the Pacific Ocean to the north of the Hawaiian islands, about two minutes away from entering the Earth's atmosphere. All activities continuing to go smoothly en route toward a touchdown at the Kennedy Space Center at 8:16 a.m. Central time."

08:41:58 a.m. - STS-ICOM: McCool: "Replug, that's all you've gotta do."

08:42:08 a.m. - STS-ICOM: McCool: "When do we start moving our head around, Rick? When we start getting a little bit of Gs?"

STS-ICOM: Husband: "A little bit of Gs, yeah."

08:42:29 a.m. - STS-ICOM: Clark (operating a video camera): "KC, can you look at the camera a second? Look at me."

08:42:35 a.m. - STS-ICOM: Flight engineer Kalpana Chawla: "Me?"

STS-ICOM: Clark: Yep. Yeah. What KC?"

08:42:37 a.m. - MCC-Commentator: "Columbia is currently targeted toward runway three-three at the Kennedy Space Center, the runway selection continues to be discussed here in mission control, however. But for its approach to runway three-three, Columbia will perform a right overhead turn to align with the runway of about 214 degrees around the heading alignment cylinder, an imaginary cylinder created by the microwave landing system for the shuttle that assists in guiding it for its final approach."

08:42:38 a.m. - STS-ICOM: Chawla: "Oh, I just turn towards you, I see what you have there."

STS-ICOM: Clark: "Yeah." (laughter)

STS-ICOM: Chawla: "OK, Laurel."

08:42:51 a.m. - STS-ICOM: McCool: "Trash bag, KC, if you've got any."

STS-ICOM: Chawla: "We are gray taping, you can just give it to us."

08:42:57 a.m. - STS-ICOM: McCool: "That's six and a half bags."

STS-ICOM: Chawla: "OK, I'm going to have to give this to Laurel when she is done."

08:43:05 a.m. - STS-ICOM: Chawla: "I'm going to gray tape it behind, I mean (garble) tape it behind the seat, I think this is light enough that it will stay."

08:43:18 a.m. - STS-ICOM: McCool: "Laurel, you see lots of jets firing."

STS-ICOM: Clark: "I'm getting the jets firing, I'm trying to see if I can get an overhead window view yet."

08:43:25 a.m. - STS-ICOM: Husband: "OK. That's all I can do is three and a half bags out of four. So that'll work. If I can pass that back to you?"

08:43:32 a.m. - STS-ICOM: Chawla: "Rick, if you could wait just one second, I want to get to my gloves before Gs build, I don't want to get..."

STS-ICOM: Husband: "Certainly."

STS-ICOM: Chawla: "...two up."

STS-ICOM: Husband: "Certainly."

08:43:40 a.m. - STS-ICOM: Chawla: "Here comes (garble)."

08:43:42 a.m. - STS-ICOM: Husband: "OK. We're just past EI."

STS-ICOM: Clark: "Ok."

STS-ICOM: Chawla: "I have both gloves."

08:43:47 a.m. - STS-ICOM: Clark: "Is that jets firing on the DAP, I guess."

STS-ICOM: Chawla: "And Rick, I'll take your bag. And float it aft gently, I've got it."

08:43:58 a.m. - STS-ICOM: McCool: "That might be some plasma now."

STS-ICOM: Clark: "Think so, already?"

STS-ICOM: McCool: "Yeah, the jets are not firing right now."

STS-ICOM: Clark: "All right, it was quite a (GARBLE), actually."

STS-ICOM: McCool: "We see it out the front, also."

STS-ICOM: Husband: "That's some plasma."

08:44:09 a.m. - EI+0 - Actual moment of entry interface. The shuttle falls into the discernible atmosphere 395,010 feet over the Pacific Ocean at a velocity of Mach 24.57 (+30.833-167.556).

08:44:09 a.m. - STS-ICOM: Clark: "Copy, and there's some good stuff outside. I'm filming overhead right now."

STS-ICOM: McCool: "It's kind of dull."

STS-ICOM: Husband: "Oh, it'll be obvious when the time comes."

08:44:18 a.m. - STS-ICOM: Clark: "Well, Willy, I guess I could give you the camera to put out the front window."

STS-ICOM: Husband: "Here, let's, uh, no, let's don't do that."

STS-ICOM: Clark: "OK."

STS-ICOM: Husband: "Let's just, uh, let's go ahead and make sure you check your suit pressure integrity, too."

STS-ICOM: Clark: "All right."

08:44:51 a.m. - STS-ICOM: Husband: "And comm check on intercom. Put the, uh, visors down. CDR."

STS-ICOM: McCool: "PLT."

STS-ICOM: Clark: "PS1. (then laughing to correct herself) MS1."

STS-ICOM: Chawla: "I don't have my gloves on yet. MS2."

STS-ICOM: Husband: "All right, good enough."

08:45:09 a.m. - STS-ICOM: Clark: "And we're going to leave visors down, though."

STS-ICOM: Husband: "Oh, no. I'm just saying just check your suit's..."

STS-ICOM: Clark: "OK."

STS-ICOM: Husband: ".. pressure."

STS-ICOM: Clark: "And then I'm going to go back off. Yeah."

STS-ICOM: Husband: "Yeah."

08:45:16 a.m. - MCC-Commentator: "Columbia's altitude now 71 statute miles as it enters Earth's atmosphere above the Pacific Ocean en route to the Kennedy Space Center, its speed 17,000 miles per hour."

08:45:20 a.m. - STS-ICOM: Husband: "That's good enough for (GARBLE), I'm going to check one other thing."

08:45:32 a.m. - STS-ICOM: McCool: "Starting to glow a little bit more now, Laurel."

STS-ICOM: Husband: "Yeah... OK, all that's worked."

08:45:39-48:59 a.m. - OEX data: 16 temperature sensors on the lower surface to the left of, or on, the vehicle centerline show off-nominal early temperature trends (warmer rise rate compared to previous flights by Columbia). EI+90-290.

08:45:42 a.m. - MCC-Commentator: "Columbia with wings level and nose angled up at about 40 degrees to control heating as it descends into the atmosphere. It's altitude now 68 miles. As Columbia descends into the atmosphere and approaches the continental United States it'll perform the first in a series of four banks it performs as it approaches the Kennedy Space Center. That first bank to the right, then back to the left, then back to the right and then a final bank to the left as it approaches Kennedy and the Shuttle Landing Facility runway. Those designed to dissipate speed for the shuttle as it descends into the atmosphere toward landing."

08:45:49 a.m. - STS-ICOM: Husband: "It's noisy in there, isn't it?"

08:45:52 a.m. - STS-ICOM: McCool: "Do see it over my shoulder now, Laurel?"

STS-ICOM: Clark: "I was filming, it doesn't show up nearly as much as the back."

08:45:58 a.m. - STS-ICOM: McCool: "It's going pretty good, now. Ilan, it's really neat, just a bright orange yellow out over the nose, all around the nose."

08:46:10 a.m. - STS-ICOM: Husband: "Wait until you start seeing the swirl patterns out your left and right windows."

STS-ICOM: McCool: "Wow."

STS-ICOM: Husband: "Looks like a blast furnace."

08:46:31 a.m. - STS-ICOM: Husband: "Let's see here... look at that."

STS-ICOM: McCool: "Yep, we're getting some gees."

STS-ICOM: Husband: "Yeah."

STS-ICOM: McCool: "I let go of a card, and it falls."

08:46:26 a.m. - MCC-FLIGHT: "OK, FDO, go ahead."

MCC-FDO: "This data set is a spliced data set. This is my back room's attempt to, uh, get us some data off that first balloon that was broken. And it shows us 11 hundred 60 feet at the close-in aim point."

MCC-FLIGHT: "With the close..."

MCC-FDO: "Yes sir. And we're waiting for our re-release balloon, which was just released a few minutes ago."

MCC-FLIGHT: "OK. Now, uh, we lost the balloon at 6,000 feet and, did we get it back at some point? Or when you say 'spliced it together,' I mean, I don't want, I don't know whether I should..."

08:46:30 a.m. - MCC-Commentator: "Just under 30 minutes to touchdown for Columbia now, altitude 64 miles."

08:46:39 a.m. - STS-ICOM: McCool: "I got a bit flip here on the accel now."

08:46:48 a.m. - Qbar equals 0.5 pounds per square foot. Mach: 24.66

STS-ICOM: Husband: "Yep. Alright, we're at, uh, hundredth of a G."

08:46:51 a.m. - STS-ICOM: McCool: "This is amazing, it's really getting, uh, fairly bright out there."

08:46:56 a.m. - STS-ICOM: Husband: "Yep. Yeah, you definitely don't want to be outside now."

08:47:00 a.m. - MCC-FDO: "We did not, we did not get any data beneath 6K, I mean above 6K, excuse me..."

08:47:01 a.m. - STS-ICOM: Chawla: "What, like we did before?"

STS-ICOM: (laughter)

08:47:03 a.m. - MCC-FLIGHT: "OK."

MCC-FDO: "... and we spliced basically a previous data set..."

MCC-FLIGHT: "I got you."

MCC-FDO: "... on top of this one to give us an estimate."

08:47:03 a.m. - STS-ICOM: McCool: "How's it look out the back, Laurel?"

STS-ICOM: Husband (responding to Chawla): "Good point."

STS-ICOM: Clark: "Uh..."

08:47:09 a.m. - STS-ICOM: Clark(?): "Willie, I can see you in your mirror."

STS-ICOM: McCool: "Not yet?"

08:47:11 a.m. - MCC-FLIGHT: "Now let's see, from where we're releasing the balloons to, which way... are they going out over the water with the wind direction from the surface on up to about 10,000 feet, the direction is roughly out of the west, isn't it?"

MCC-FDO: "Yes, flight, they are going out the water, out over the water, I concur with that, we are..."

MCC-FLIGHT: "We start out with them far enough away from where our HAC really is and then they're going the wrong way."

08:47:14 a.m. - STS-ICOM: Clark: "Not, not, yeah, now I can."

STS-ICOM: McCool: "Now I can see your camera."

STS-ICOM: Husband: "OK." (said as if to tell the crew it's time to start paying attention)

08:47:19 a.m. - STS-ICOM: Clark: "Stop playing."

08:47:20 a.m. - STS-ICOM: Chawla: "I see 22-10. 10-52 is what we were looking for, for..."

STS-ICOM: Husband: "OK. 10-16, right? I've got 16 written here."

08:47:32 a.m. - STS-ICOM: McCool: "Yeah, 22 10 16."

STS-ICOM: Chawla: "Yeah, 22 10 16, that's correct. Sorry."

Editor's Note: The ICOM video tape ends at this point.

08:47:38 a.m. - MCC-FDO: "I would concur, we are seeing, we're definitely seeing some spatial differences here. From the STA (shuttle training aircraft) and this morning. I would concur with that."

MCC-FLIGHT: "OK, well yeah, and the STA, the last dive here - and we're not going to have him do any more - was 19 41 (1,941 feet) with close."

MCC-FDO: "Ummm"

08:47:48 a.m. - MCC-Commentator: "Columbia's course toward Florida will take it across the continental United States, crossing the California coast above the San Francisco bay area and continuing across Sacramento, California, providing a spectacular view for persons in that area of Columbia's descent through the atmosphere. That observation of the shuttle would begin about 5:51 a.m. Pacific standard time and continue for about four minutes, until about 5:55 a.m. Pacific time, with the shuttle at an elevation of about 78 degrees."

08:47:52 a.m. - EI+223 - QBAR = 2.0 psf; elevons and body flap are now available for attitude control. H=288,932; Mach: 24.66 (+36.398-150.847)

08:47:55 a.m. - MCC-FLIGHT: "He normalized to 19 41 with close."

MCC-FDO: "Yeah..."

MCC-FLIGHT: "Did I get that right?"

MCC-FDO: "X-corrected I heard was 17 84. The X-corrected normalized."

08:48:09 a.m. - MCC-FLIGHT: "Yeah, we're talking about the normalized."

MCC-FDO: "I think the STA performs a correction on top of the normalization to account for, ummm,

MCC-FLIGHT: "Yeah, you're talking XCN, I was just saying the normalized is 19 41."

MCC-FDO: "Yes sir."

08:48:15 a.m. - MCC-Commentator: "It'll be visible as well through much of the United States' southwest above southern Nevada and northern Arizona and central Mexico as it continues its descent through the atmosphere, trailing a plasma trail left as it heats the atmosphere around it during its descent.

08:48:24 a.m. - MCC-FLIGHT: "OK, what we've got, the last balloon data to come in before we make our decision."

MCC-FDO: "Yes sir."

08:48:39 a.m. - EI+270 - OEX: Strain gauge sensor V12G9921A, located inside left wing in line with RCC panel No. 9, begins to show a small but off-nominal increase. Sensor fails at EI+495 seconds. This is the first indication of anything amiss aboard Columbia.

08:48:40 a.m. - MCC-Commentator: "Columbia's altitude now 54 miles as it continues to descend into the atmosphere, wings level, nose angled up 40 degrees to control heating. Columbia's traveling about 17,000 miles per hour."

08:48:59 a.m. - EI+290 - OEX: Temperature sensor VO9T9910A mounted on the lower attach clevis between RCC 9 and 10 begins showing an off-nominal increase. This is the first sign of unusual heating. This sensor begins to fail at EI+492 seconds.

08:49:07 a.m. - EI+298 - Entry guidance begins closed loop roll control to converge aerodynamic drag to the reference drag profile. H=259,978; Mach: 24.58 (37.639-144.803)

08:49:16 a.m. - EI+307 - Roll jets deactivated. Qbar equals 10 pounds per square foot. From this point on, roll control is achieved through aileron positioning and yaw jet firings. Mach: 24.57

08:49:32 a.m. - EI+323 - Initial roll. Entry guidance software determines a non-zero roll is required to achieve desired drag level. Mach 24.51.

08:49:38 a.m. - MCC-GPO: "CLG (closed loop guidance) init."

MCC-FLIGHT: "Copy."

08:49:39 a.m. - EI+330 - OEX: Left wing front spar strain gauge V12G9169A shows early off nominal downward trend (trend may have started slightly earlier).

08:49:49-59 a.m. - EI+340/350 - OEX: Four left OMS pod sensors (VO7T9976A, VO7T9220A, VO7T9978A, VO7T9972A) start an off-nominal temperature trend, a cooler rise rate than previous flights followed by a large increase at EI+520 seconds.

08:50:03 a.m. - MCC-GPO: "Rolling right."

08:50:00 a.m. - EI+351 - Qbar about 15 psf; Mach 24.4; wing leading edge stagnation temperature about 2,520 degrees Fahrenheit.

08:50:00-43 a.m. - EI+351/394 - Five unexpected return link S-band communications drop outs; upper left aft antenna/TDRS-171 West. Out of family based on comparison with previous Columbia entries from 39-degree inclination orbits to KSC and similar look angles to TDRS West.

08:50:03 a.m. - MCC-Commentator: "Columbia's altitude 48 statute miles as it begins the first in a series of four banks to dissipate speed as it descends into the atmosphere, banking to the right now, a steep bank of 60 degrees and approaching the west coast of the United States. Columbia's speed 16,620 miles per hour, range to touchdown at the Kennedy Space Center runway 3,450 statute miles."

08:50:06 a.m. - STS-?: "garble in static"

08:50:09 a.m. - EI+360 - OEX: Left payload bay door surface temperature sensor V07T9925A starts an unusual trend, a cooler rise rate than previous flights followed by a large increase at EI+570 seconds.

08:50:19 a.m. - EI+370 - OEX: Left wing lower surface temperature sensor begins off-nominal increase from about 2,000 degrees to 2,200 degrees over 50 seconds followed by a short 100-degree temperature spike. Sensor fails at EI+496.

08:50:26 a.m. - MCC-MALE VOICE: "I got it."

08:50:30 a.m. - EI+381 - First indication of re-entry heating in downlinked telemetry; nominal rise in aft fuselage center bottom line bond temperature sensor.

08:50:53 a.m. - EI+404 - Start of peak heating region; this is the region during which the heating rate has stabilized at or near its maximum value. H=243,048; Mach: 24.12 (+38.744-136.142)

08:50:56 a.m. - MCC-Commentator: "Columbia in almost an 80-degree-bank to the right to dissipate speed, the first of four banks it performs as it approaches Florida to slow down as it descends. Altitude now 47 miles or about 248,000 feet. The shuttle's speed is 16,400 miles per hour."

08:51:14 a.m. - EI+411 - Qbar about 19 psf; Mach 24.1; wing leading edge stagnation temperature: 2,650 degrees.

08:51:14 a.m. - EI+425 - OEX: Temperature sensor V09T9895A, located inside the left wing roughly in line with RCC panel No. 9, begins showing an unusual temperature increase. This indicates a plume of hot gas has entered the wing's interior through a breach in the leading edge. Measurement fails at EI+520.

08:51:14 a.m. - EI+425 - OEX: Left wing temperature sensor V09T9910A at RCC panel 9 lower attach clevis (between RCC 9 and 10) begins a rapid increase. Measurement fails at EI+492.

08:51:26 a.m. - MCC-Commentator: "Aboard the shuttle on the flight deck are shuttle commander Rick Husband and pilot Willie McCool, flight engineer Kalpana Chawla and mission specialist Laurel Clark. On the lower deck of the shuttle for entry are payload commander Mike Anderson, mission specialist David Brown and payload specialist, from the Israel space agency, Ilan Ramon."

08:51:49 a.m. - EI+460 - OEX: Left OMS pod HRSI surface temperature sensor V07T9223A begins a higher-than-expected temperature trend.

08:13:52 a.m. - EI+471 - Qbar = 22 psf; Mach 23.7; wing leading edge stagnation temperature = 2,700 degrees.

08:52:05 a.m. - MCC-Commentator: "Columbia approaching the Coast of California now, it is predicted to cross the coast and be visible in the San Francisco area about 5:51 a.m. Central time, uh, Pacific standard time rather, and pass almost directly overhead of Sacramento, California. It actually crosses the California coast just to the north of the San Francisco area."

08:52:09-15 a.m. - EI+480/486 - Sixth unexpected S-band return link comm dropout. Out of family based on previous flight data.

08:52:09-49 a.m. - EI+480/520 - OEX: Nose cap RCC chin panel temperature sensor V09T9889A exhibits a temporary change in slope then returns to normal. An adjacent sensor shows no change.

08:52:15 a.m. - EI+486 - Second indication of normal entry heating in downlinked telemetry; nominal rise in center line bond temperature sensor (2). Mid fuselage "mid" skin temperature; mid fuselage bottom center bond line temperature at x1214.

08:52:16 a.m. - EI+487 - OEX: Two left wing and one right wing surface pressure measurements begin showing signs of failure. This is the first data on the OEX tape to show signs of failure.

08:52:16-53:17 a.m. - EI+487/522 - OEX: All active measurements (except PCM snapshot data) routed through wire bundles along the left wing leading edge begin to show signs of failure. Eighteen measurements in all.

08:52:16-56:24 a.m. - EI+487/735 - OEX: Nearly all left wing OEX measurements show signs of failure during this period, including all left wing temperature and pressure measurements and all strain gauge data aft of Xo 1040 with exception of three on the upper surface of the main landing gear wheel well. In addition, 30 right wing pressure measurements begin showing signs of failure.

08:52:17 a.m. - Approximate vehicle location as first signs of off-nominal telemetry were received on the ground: 300 miles from the California coast. H=236,800; Mach: 23.6 (+39.0-129.2).

08:52:17 a.m. - Left main gear brake temperature D sensor on wheel well sidewall aft of switch valves shows a one "bit flip" change, indicating an increase of about 1.5 degrees. This reading initially was believed to be the first sign of off-nominal heating inside the left wing but it may, in

fact, have been normal. NASA research shows at least 13 other missions saw similar bit flips in the same time frame. H=236,791; Mach: 23.58 (+38.993-129.151)

08:52:18 a.m. - EI+489 - OEX: Left wing lower spar cap strain gauge shows an unusual increase followed by a gradual decrease over 330 seconds until the measurement fails at EI+935.

08:52:21-24.8 a.m. - EI+492/495.8 - OEX: Two left wing temperature sensors begin an off-nominal response that appears to be an indication of wiring damage. Temperature sensor V09T9910A, located in front of the left wing spar behind RCC panel 9, drops off line after climbing to 50 degrees Fahrenheit. This sensor was insulated and presumably dropped off-scale low when its wiring was damaged or severed by hot gas.

08:52:22 a.m. - EI+493 - OEX: Unusual temperature shifts from five temperature sensors on a common power circuit.

08:52:24 a.m. - EI+495 - OEX: Left wing front spar RCC 9 strain gauge goes erratic for 20 seconds; appears to be failing at this point.

08:52:25 a.m. - EI+496 - OEX: left outboard elevon wide band accelerometer shows unusual vibration response of 2Gs, peak to peak. V08D9729A.

08:52:25-31 a.m. - EI+496/502 - Unexpected S-band return link comm drop outs (events 7 and 8).

08:52:29 a.m. - EI+500 - OEX: Approximately 10 percent of the strain gauges in the right wing show a small but unusual data trend; signal "flattens" followed by normal data increase or an increase in strain.

08:52:29 a.m. - EI+500 - OEX: Left wing surface temperature sensor V07T9674A begins showing an 80-degree drop over 20 seconds.

08:52:29 a.m. - EI+500 - OEX: Left OMS pod surface temperature sensor V07T9219A begins a slightly off-nominal erratic trend.

08:52:31 a.m. - EI+502 - OEX: Left outboard elevon wide-band accelerometer shows an unusual vibration (3Gs peak to peak).

08:52:31.3-38.4 a.m. - EI+502.3/509.4 - OEX: Five left wing temperature sensors begin off-nominal trends indicative of wiring failures (sensors in the group first mentioned at 8:52:16 a.m.

08:52:32 a.m. - EI+503 - Supply water dump nozzle temperature sensors A and B show temporary increase in temperature rise rate (15-second duration), then return to normal profile. Vacuum vent temperature shows temporary increase in rise rate (23 seconds) then returns to normal profile. H=235,602; Mach: 23.47 (+38.974-127.894)

08:52:34 a.m. - EI+505 - OEX: Left OMS pod HRSI temperature sensor V07T922A begins lower than expected trend until a sharp increase at EI+910; goes erratic at EI+940.

08:52:39-53:09 a.m. - EI+510/540 - OEX: Four left OMS pod surface temperature sensors showing a cooler rise rate than expected suddenly begin trending upward.

08:52:41 a.m. - EI+512 - Left main gear brake line temperature A sensor on strut facing the main landing gear door begins seeing an off-nominal temperature rise; left main gear brake line temperature sensor C sees off-nominal temperature rise. H=234,928; Mach: 23.40 (+38.995-127.191)

08:52:44-50 a.m. - EI+515/521 - First clear indication of off-nominal aero increments (delta yawing moment coefficient goes off nominal at 8:52:44 a.m.; delta rolling moment coefficient goes off nominal at 8:52:50 a.m.).

08:52:47 a.m. - EI+518 - Supply water dump nozzle temperature sensors A and B return to normal rise rate.

08:52:49-55 a.m. - EI+520/526 - Unexpected S-band return link comm dropout (event 9).

08:52:49.5-51.4 a.m. - EI+520.5/522.4 - OEX: Two left wing temperature sensors - V09T9895A, located inside the left wing behind RCC panel 9, and V09T9849A, outboard elevon lower surface edge - begin failing due to wiring damage.

08:52:54 a.m. - MCC-Commentator: "Columbia is on target for runway three-three at the Kennedy Space Center Shuttle Landing Facility runway."

08:52:55 a.m. - EI+526 - Vacuum vent temperature sensor returns to normal rise rate.

08:52:56 a.m. - EI+527 - Left inboard elevon lower skin temperature sensor starts an off-nominal trend downward.

08:52:59 a.m. - EI+530 - Left inboard elevon lower skin temperature goes off-scale low (drops off line). H=233,618; Mach: 23.25 (+38.895-125.714)

08:52:59.4-53:07.4 a.m. - EI+530.4/538.4 - OEX: Five left wing temperature sensors begin to show signs of wiring failure.

08:53:00 a.m. - EI+531 - Qbar = 25.5 psf; Mach 23.2; wing leading edge stagnation temperature = 2,800 degrees.

08:53:00 a.m. - MCC-Commentator: "The subject of runway selection has been discussed in mission control, it continues to be discussed some, but in the meanwhile at present the original targeting for Columbia is toward runway three-three..."

08:53:02 a.m. - EI+533 - Hydraulic system 1 left inboard elevon actuator return line temperature begins trending down; Hydraulic system 3 left outboard elevon return line temperature sensor begins trending down. H=233,457; Mach: 23.23 (+38.883-125.482)

08:53:03 a.m. - EI+534 - OEX: Left outboard elevon wide-band accelerometer exhibits signal saturation indicative of failure (10 Gs peak to peak).

08:53:10 a.m. - "... and as it approaches runway three-three, it will perform a right overhead 212-degree turn to align with that runway around the heading alignment cylinder, an imaginary cylinder

created by the microwave scan beam landing system at the shuttle runway that assists in the shuttle's guidance toward its final approach to the runway."

08:53:10 a.m. - Hydraulic system 3 left outboard elevon return line temperature sensor drops off-scale low (preceded by nominal temperature rise). H=232,864; Mach: 23.17 (+38.848-124.864)

08:53:11 a.m. - Hydraulic system 1 left inboard elevon actuator return line temperature sensor goes off-scale low (preceded by nominal temperature rise). H=232,793; Mach: 23.16

08:53:15 a.m. - EOC2-4-0064/Fairfield, California: Video coverage begins. (Lat/Lon TBD)

08:53:26 a.m. - Columbia crosses the California coastline. H=231,600; Mach: 23.0 (+38.7-123.5)

08:53:29 a.m. - EOC2-4-0056/Lick Observatory, California: Video coverage begins. (+37.342-121.643)

08:53:29 a.m. - EI+560 - OEX: Left fuselage side surface temperature sensor V07T9253A begins an off-nominal increase, jumping from 180 degrees to 400 degrees.

08:53:29 a.m. - EI+560 - OEX: Left payload bay door surface temperature sensor V07T9913A starts a slightly off-nominal erratic trend.

08:53:29 a.m. - EI+560 - OEX: Left payload bay door surface temperature sensor V0T9925A begins an unusual rise, peaking at EI+625, followed by a temperature drop and subsequent increase.

08:53:29 a.m. - EI+560 - OEX: Left fuselage side surface temperature sensor V07T9903A starts a slightly off-nominal erratic trend.

08:53:31 a.m. - EI+562 - Entry guidance enables limited change in angle of attack (alpha modulation) to help vehicle converge on desired drag profile.

08:53:31-34 a.m. - EI+562/565 - Hydraulic system 1 left outboard elevon return line temperature drops off-scale low. Preceded by normal temperature rise; data loss three seconds prior to event. H=231,304; Mach: 23.0

08:53:32 a.m. - MCC-Commentator: "Shuttle's altitude now 45 miles, speed 15,800 miles per hour, continuing in a right bank with wings angles 70 degrees, the first of four banks it performs to dissipate speed as it approaches landing."

08:53:32-34 a.m. - EI+563/565 - Unexpected S-band return link comm drop out (event 10).

08:53:34-55:57 a.m. - EI+565/668 - Third indication of re-entry heating in downlinked telemetry with nominal rise in three center line bond temperature sensors (mid fuselage bottom port bondline temps x620, x777 and forward fuselage lower skin bottom center line).

08:53:34 a.m. - EI+565 - Hydraulic system 2 left inboard elevon return line temperature begins trending down. H=231,077; Mach: 22.97 (+38.707-122.952)

08:53:36 a.m. - EI+567 - Hydraulic system 2 left inboard elevon return line temperature goes off-scale low. H=230,915; Mach 22.95

08:53:36 a.m. - EOC2-4-0026/Sparks, Nevada: Video coverage begins. (+39.541-119.768)

08:53:37 a.m. - EI+568 - OEX: Main landing gear forward spar wall strain gauge begins showing an unusual increases over a 115-second period followed by a sudden decrease.

08:53:38 a.m. - EI+569 - Inertial sideslip angle (beta) goes negative and stays negative until loss of signal; consistent with a negative rolling and yawing torque on the spacecraft.

08:53:44 a.m. - EI+575 - OEX: Left OMS pod HRSI surface temperature sensor begins an off-nominal lower-than-expected trend; goes erratic at EI+940.

08:53:45-47 a.m. - EI+576/578 - Debris No. 1: First report of debris observed leaving the orbiter. Seen just behind orbiter envelope. No evidence of RCS thruster firing. H=230,348; Mach: 22.88 (+38.631-122.119)

08:53:45 a.m. - MCC-Commentator: "Columbia crossing the California coast, again, just to the north of the San Francisco area. It's course will take it across Sacramento, California."

08:53:46-50 a.m. - EI+577/581 - Debris No. 2: Second report of debris observed leaving the orbiter, just aft of the shuttle envelope. No evidence of RCS thruster firing. H=230,276; Mach: 22.87 (+38.624-122.044)

08:53:46 a.m. - EI+577 - Left main gear brake line temperature A sensor on strut facing main landing gear door begins showing a rise from 1.4 degrees Fahrenheit per minute to 5.5 F/min; increases through loss of signal. H=230,203; Mach: 22.86 (+38.616-121.968)

08:53:47.6 a.m. - EI+578.6 - OEX: Another left wing temperature sensor begins off-nominal response that appears to be related to wiring damage.

08:53:54-58 a.m. - EI+585/589 - Debris No. 3: Third report of debris shedding, directly above Sacramento. Seen just aft of the shuttle. Momentary brightening of plasma trail. No evidence of RCS thruster firings. H=229,621; Mach: 22.79 (+38.554-121.367)

08:54:00 a.m. - EI+591 - Qbar = 29 psf; Mach 22.7; wing leading edge stagnation temperature = 2,850 degrees.

08:54:00-04 a.m. - EI+591/595 - Debris No. 4: Fourth report of debris shedding just east of Sacramento, seen just aft of the orbiter. No evidence of RCS thruster firings. H=229,113; Mach: 22.73 (+38.496-120.843)

08:54:03 a.m. - EOC2-4-0034/Reno, Nevada: Video coverage begins. (+39.53-119.813)

08:54:07-11 a.m. - EI+598/602 - Debris No. 5: Fifth report of debris shedding; seen just aft of orbiter envelope. No evidence of RCS thruster firings. H=228,817; Mach: 22.69 (+38.461-120.545)

08:54:10 a.m. - EI+601 - Left main gear brake line temperature B sensor begins showing an off-nominal temperature rise. H=228,460; Mach: 22.64 (+38.416-120.172)

08:54:11 a.m. - EI+602 - Roll moment coefficient changes from negative to positive, indicating lift acting on the left wing.

08:54:14-22 a.m. - EI+605/613 - Unexpected S-band return link comm drop out (event 11).

08:54:15 a.m. - EOC2-4-0009-B/Springfield, California: Video coverage begins. (+36.226-118.805)

08:54:18 a.m. - EOC2-4-0064/Fairfield, California: Video coverage ends. (Lat/Lon TBD; exact LOS time TBD)

08:54:20 a.m. - EI+611 - Start of slow elevon trim change to counteract the buildup of aerodynamic drag on the left wing. (Time approximate; +/- 10 seconds)

08:54:22 a.m. - EI+613 - Mid fuselage left bondline temperature sensor at x1215 begins reporting an unusual rise from 1 F/min to 7.5 F/min; Left aft fuselage sidewall temperature sensor at x1410 begins seeing an unusual increase from 2.7 F/min to 5.4 F/min. H=227,560; Mach: 22.52

08:54:24 a.m. - EI+615 - System 3 left main gear strut actuator temperature sensor begins reporting an off-nominal temperature increase. H=227,437; Mach: 22.51 (+38.270-119.068)

08:54:24 a.m. - MCC-MMACS: "Flight, MMACS."

MCC-FLIGHT: "Go ahead, MMACS."

MCC-MMACS: "FYI, I've just lost four separate temperature transducers on the left side of the vehicle, hydraulic return temperatures. Two of them on system one and one in each of systems two and three.

08:54:25 a.m. - EI+616 - Columbia crosses the California-Nevada state line. H=227,400; Mach: 22.5 (+38.3-119.0)

08:54:26 a.m. - EI+617 - S-band comm switched from upper left antenna to upper right antenna. Nominal event.

08:54:28 a.m. - EOC2-4-0056/Lick Observatory, California: Video coverage ends. (+37.342-121.643)

08:54:29 a.m. - EI+620 - OEX: Left fuselage side surface temperature sensor V07T9253A peaks and begins a downward trend.

08:54:33 a.m. - EOC2-4-0030/Las Vegas, Nevada: Video coverage begins. (+36.309-115.274)

08:54:33.3-33.9 a.m. - EI+624.3/624.9 - Flash No. 1: Orbiter envelope suddenly brightened for 0.3 seconds, leaving "noticeably luminescent" signature in Columbia's plasma trail. R3R and R2R

thrusters fired briefly at 8:54:33.52 and .76 respectively and again at 8:54:33.54 and 78).
H=226,894; Mach: 22.43

08:54:34 a.m. - EI+625 - OEX: Left fuselage side surface temperature sensor V07T9925A peaks and begins downward trend.

08:54:35-37 a.m. - EI+626/628 - Debris No. 6: Sixth report of debris leaving the shuttle; described as "very bright." Orbiter envelope brightened for 0.3 seconds. Debris events 6 and 14 are visually the brightest of all such events over the western United States. H=226,748; Mach: 22.41 (+38.154-118.265)

08:54:39 a.m. - EI+630 - OEX: Strain gauges on the upper surface of the left main landing gear wheel well show higher-than-expected strains.

08:54:39 a.m. - EI+630 - OEX: Left wing x1040 spar shows increase in strain; adjacent sensor shows no such increase.

08:54:41 a.m. - EOC2-4-0017/Flagstaff, Arizona: Video coverage begins. (+35.198-111.651)

08:54:45 a.m. - EOC2-4-0034/Reno, Nevada: Video coverage ends. (+39.53-119.813)

08:54:46 a.m. - MCC-FLIGHT: Four hyd return temps?"

MCC-MMACS: "To the left outboard and left inboard elevon."

MCC-FLIGHT: "OK, is there anything common to them? DSC (discrete signal conditioner) or MDM (multiplexer-demultiplexer) or anything? I mean, you're telling me you lost them all at exactly the same time?"

08:54:49 a.m. - EOC2-4-0026/Sparks, Nevada: Video coverage ends. (+39.541-119.768)

08:54:53 a.m. - EI+644 - Main landing gear left outboard wheel temperature begins off-nominal trend; two bit flips up. H=225,610; Mach: 22.22 (+37.933-116.896)

08:54:58 a.m. - MCC-MMACS: "No, not exactly. They were within probably four or five seconds of each other."

MCC-FLIGHT: "OK, where are those, where is that instrumentation located?"

08:55:00 a.m. - EI+651 - Qbar = 34.5 psf; Mach 22.1; wing leading edge stagnation temperature = 2,900 degrees.

08:55:04-06 a.m. - EI+655/657 - Debris No. 7: Seventh report of debris leaving the orbiter. No evidence of RCS thruster firings.

08:55:05 a.m. - EOC2-4-0028/St. George, Utah: Video coverage begins. (+37.22-113.622)

08:55:08 a.m. - MCC-MMACS: "All four of them are located in the aft part of the left wing, right in front of the elevons, elevon actuators. And there is no commonality."

08:55:11 a.m. - EOC2-4-0009-B/Springfield, California: Video coverage ends. (+36.226-118.805)

08:55:11 a.m. - EOC2-04-0021/St. George, Utah: Video coverage begins. (+37.591-115.059)

08:55:12 a.m. - EI+663 - System 3 left main landing gear brake sidewall valve return line temperature (forward) begins trending up. H=224,546; Mach: 22.02 (+37.674-115.479)

08:55:17-19 a.m. - EI+668/670 - Debris No. 7A, seen just aft of the orbiter envelope.

08:55:18 a.m. - MCC-FLIGHT: "No commonality."

08:55:21 a.m. - EI+672 - Drag is recorded at 11 feet per second squared. Flight control system begins incorporating drag measurements to derive altitude for vehicle navigation. Nominal event. H=224,002; Mach: 21.92 (37.535-114.781)

08:55:21-25 a.m. - EI+672/676 - Debris No. 8: Eighth report of debris leaving the shuttle. No evidence of RCS thruster firings.

08:55:22-28 a.m. - EI+673/679 - Debris shower A; report of debris just aft of the orbiter envelope. During this four seconds, a luminescent section of plasma appears to contain a shower of small particles and larger, discrete pieces of debris, including Debris 8, 9 and 10.

08:55:23 a.m. - EOC2-4-0005/Ivins, Utah: Video coverage begins. (+37.169-113.679)

08:55:24-28 a.m. - EI+675/679 - Debris No. 9: Ninth report of debris leaving the shuttle; seen inside shower 7A. No evidence of RCS thruster firings.

08:55:25-29 a.m. - EI+676/680 - Debris No. 10: Tenth report of debris leaving the orbiter; seen inside shower 7A, well aft of orbiter envelop. No evidence of RCS thruster firings.

08:55:30 a.m. - EOC2-04-0050/St. George, Utah: Video coverage begins. (+37.591-115.059)

08:55:32 a.m. - EI+683 - Columbia crosses the Nevada-Utah state line. H=223,400; Mach: 21.8 (+37.4-114.1)

08:55:33-35 a.m. - EI+684/686 - S-band return link comm dropout (event 12); first drop out after antenna switch to upper right aft antenna; inconclusive if this is off nominal.

08:55:35-39 a.m. - EI+686/690 - Debris No. 11: Eleventh report of debris leaving the orbiter; appears in a secondary parallel plasma trail well aft of orbiter envelope; a second piece of debris is also seen. No evidence of RCS thruster firings.

08:55:36 a.m. - EI+687 - OEX: Main landing gear forward wall spar strain gauge V12G9049A shows a sudden drop, followed by a gradual increase until going erratic at EI+930.

08:55:38-40 a.m. - EI+689/691 - Debris No. 11A, seen just aft of orbiter.

08:55:38-42 a.m. - EI+689/693 - Debris No. 11B, seen at the head of a parallel plasma trail aft of orbiter envelope.

08:55:38 a.m. - MCC-Commentator: "Columbia continuing in a right bank, the wings angled 43 degrees, speed 15,000 miles per hour, altitude 43 miles, 2,090 miles to touchdown at the Kennedy Space Center targeted for runway three-three at Kennedy at present. Crossing the continental United States, now crossing above southern Nevada to the north of Las Vegas."

08:55:41 a.m. - EI+692 - Mid fuselage port sill longeron temperature at x1215 detects an unusually high increase, from 0 F/min to 2.9 F/min. H=222,821; Mach: 21.69 (+37.238-113.405)

08:55:42-46 a.m. - EI+693/697 - Debris No. 11C, seen in a parallel plasma trail well aft of orbiter envelope.

08:55:44-46 a.m. - EI+695/697 - Debris No. 12: Twelfth report of debris leaving the orbiter; event was preceded and followed by secondary plasma trails. No evidence of RCS thruster firings.

08:55:49 a.m. - Columbia moves into sunlight from orbital darkness. (+37.096-112.795)

08:55:54 a.m. - EOC2-04-0050/St. George, Utah: Video coverage ends. (+37.591-115.059)

08:55:54-58 a.m. - EI+705/708 - Debris No. 13: Thirteenth report of debris leaving the orbiter; event was followed by a brief brightening of the plasma trail adjacent to debris. No evidence of RCS thruster firings.

08:55:55 a.m. - EI-706 - Columbia crosses the Utah-Arizona state line. H=222,100; Mach: 21.5 (+37.0-112.4)

08:55:57 a.m. - EOC2-4-0030/Las Vegas, Nevada: Video coverage ends. (+36.309-115.274)

08:55:57-59 a.m. - EI+708/710 - Debris No. 14: Fourteenth report of debris leaving the orbiter; seen just aft of orbiter envelope. Debris 6 and 14 are visually the brightest debris events seen.

08:56:00-03 a.m. - EI+711/714 - S-band return link comm dropout (event 13); on upper right aft antenna; not clear if this is off nominal.

08:56:02 a.m. - EI+713 - Qbar = 40 psf. Aft reaction control system pitch jets are deactivated. Pitch control is now provided by elevator and body flap commands. H=221,670; Mach: 21.45 (+36.883-111.924)

08:56:02 a.m. - MCC-FLIGHT: "MMACS, tell me again which systems they're for."

MCC-MMACS: "That's all three hydraulic systems. It's... two of them are to the left outboard elevon and two of them to the left inboard.

08:56:03 a.m. - EI+714 - Left lower wing skin temperature begins trending down due to possible sensor or wiring damage. H=221,612; Mach: 21.44 (+36.866-111.858)

08:56:06 a.m. - EOC2-4-0028/St. George, Utah: Video coverage ends. (+37.767-115.972)

08:56:08-12 a.m. - EI+719/723 - Debris No. 15: Fifteenth report of debris leaving the orbiter; seen just aft of orbiter envelope. RCS thruster R2R fired briefly at 8:56:17 and :54 and R3R fired briefly at 8:56:17 and :52.

08:56:10 a.m. - EOC2-4-0005/lvins, Utah: Video coverage ends. (+37.169-113.679)

08:56:12 a.m. - MCC-FLIGHT: "OK, I got you.

MCC-GNC: "Flight, guidance, we're processing drag with good residual."

MCC-FLIGHT: "Copy. Thank you."

08:56:16 a.m. - EI+727 - Hydraulic system 1 left main gear uplock actuator unlock line temperature increases from 0.7 F/min to 3.9 F/min; increases through LOS. H=220,778; Mach: 21.28 (+36.625-110.936)

08:56:17 a.m. - EI+728 - System 3 left main gear brake switch valve return line temperature (forward) sees an increase from 1.5 F/min to 8.8 F/min; remains constant to LOS. H=220,711; Mach: 21.27 (+36.607-110.871)

08:56:17 a.m. - EOC2-04-0021/St. George, Utah: Video coverage ends. (+37.591-115.059)

08:56:20 a.m. - EI+731 - Left main gear brake line temperature C sensor sees change from 1.3 F/min to 9.9 F/min; remains constant to LOS. H=220,488; Mach: 21.23 (36.554-110.676)

08:56:22 a.m. - EI+733 - Left main gear brake line temperature B sensor sees a rise rate change from 2.1 F/min to 9.1 F/min; continues increasing through LOS. H=220,374; mach: 21.21 (+36.518-110.546)

08:56:24 a.m. - EI+735 - Left upper wing skin temperature sensor sees start of off-nominal trend downward due to possible sensor or wiring damage). H=220,235; Mach: 21.17 (+36.482-110.417)

08:56:30 a.m. - EI+741 - Columbia begins the first of four banking maneuvers called roll reversals to bleed off energy. H=219,820; Mach: 21.13

08:56:39 a.m. - MCC-GC: "Flight, GC."

MCC-FLIGHT: "Go."

MCC-GC: "Your air-to-grounds are enabled for the landing count."

MCC-FLIGHT: "Thank you."

08:56:45 a.m. - EI+756 - Columbia crosses the Arizona-New Mexico state line. H=219,000; Mach: 20.9 (+36.1-109.0)

08:56:49 a.m. - MCC-Commentator: "Columbia's course continuing across Arizona and the Arizona and Mexico border near the four corners area of the United States. Its course will take it

almost directly above Albuquerque, Mexico, it's altitude now 225,000 feet or 42 miles, speed 14,300 miles per hour, 1,785 miles to touchdown at the Kennedy Space Center.

08:56:53 a.m. - EI+764 - System 3 left main gear strut actuator temperature sees increase from 1.7 F/min to 12.9 F/min; remains constant through LOS. H=218,839; Mach: 20.80

08:56:55 a.m. - EI+766 - First roll reversal complete. H=218,817; Mach: 20.76

08:57:00 a.m. - EI+771 - Qbar = 42 psf; Mach 20.7; wing leading edge stagnation temperature = 2,900 degrees.

08:57:00 a.m. - EI+771 - Body flap deflected upward 3 degrees; considered nominal.

08:57:09 a.m. - EI+780 - OEX: Fuselage side surface temperature sensor V07T9270A starts off-nominal trend (rise, fall, rise).

08:57:09 a.m. - EI+780 - OEX: Fuselage lower surface temperature sensor V07T9508A begins an unusual trend (shallow drop).

08:57:11 a.m. - MCC-Commentator: It's banking now back to the left, the second in a series of four banks that dissipate speed of the spacecraft as it becomes an aircraft and descends into the atmosphere toward Florida. Wings angled about 75 degrees to the left."

08:57:19-29 a.m. - EI+790/800 - Debris No. 16. Very faint debris observed leaving the orbiter over eastern Arizona and New Mexico. Observations by observers at Kirtland AFB Starfire Optical Range; numerous jet firings inferred from injector temperatures.

08:57:19 a.m. - EI+790 - Main landing gear left outboard tire pressure 1 begins an off-nominal trend (bit flip up). H=217,757; Mach: 20.45 (+35.385-106.785)

08:57:24 a.m. - EI+795 - Main landing gear left outboard tire pressure 2 begins an off-nominal trend (bit flip up). H=217,315; Mach: 20.38 (+35.290-106.481)

08:57:25 a.m. - MCC-FLIGHT: "GNC, FLIGHT."

MCC-GNC: "FLIGHT, GNC."

MCC-FLIGHT: "Everything look good to you, control and rates and everything is nominal, right?"

08:57:28 a.m. - EI+799 - Left lower wing skin temperature drops off-scale low (sensor failure). H=216,845; Mach: 20.31 (+35.215-106.239)

08:57:31 a.m. - EOC2-4-0017/Flagstaff, Arizona: Video coverage ends. (+35.198-111.651)

08:57:35 a.m. - MCC-GNC: "Control's been stable through the rolls that we've done so far, flight. We have good trims. I don't see anything out of the ordinary."

08:57:43 a.m. - EI+814 - Left upper wing skin temperature sensor drops off-scale low. H=215,020; Mach: 20.09

08:57:45 a.m. - MCC-FLIGHT: "OK. And MMACS, FLIGHT?"

MCC-MMACS: "FLIGHT, MMACS."

MCC-FLIGHT: "All other indications for your hydraulic system indications are good."

08:57:53 a.m. - MCC-MMACS: "They're all good. We've had good quantities all the way across."

MCC-FLIGHT: "And the other temps are normal?"

MCC-MMACS: "The other temps are normal, yes sir."

08:57:53.5-55.5 a.m. - EI+824.5/826.5 - Flare No. 1: Asymmetrical brightening of orbiter shape over Mexico. Observed by Starfire Optical Range personnel. Numerous rocket firings.

08:57:54 a.m. - EI+825 - System 2 left brake switch valve return temperature (aft) begins seeing an off-nominal temperature increase. H=213,270; mach: 19.91

08:57:59 a.m. - MCC-FLIGHT: "And when you say you lost these, are you saying that they went to zero..."

MCC-MMACS: "All four of them are off-scale low."

MCC-FLIGHT: "... or off-scale low."

MCC-MMACS: "And they were all staggered. They were, like I said, within several seconds of each other."

MCC-FLIGHT: "OK."

08:57:59.5-58:01.5 a.m. - EI+830.5/832.5 - Flare 2: Asymmetrical brightening of orbiter shape over eastern Arizona and New Mexico. Observed by Starfire Optical Range personnel. Numerous rocket firings.

08:58:00 a.m. - EI+831 - Qbar = 52.5 psf; Mach 19.8; wing leading edge stagnation temperature = 2,880 degrees.

08:58:03 a.m. - EI+834 - Start of "sharp" elevon trim increase to counteract increasing aerodynamic drag (timing +/- 10 seconds). H=212,007; Mach: 19.79

08:58:04 a.m. - EI+835 - OEX: Left fuselage side surface temperature sensor V07T9253A begins unusual increase.

08:58:04-58:19 a.m. - EI+835/850 - Substantial increase in calculated rolling and yawing moments and initial indication of unusual pitching moment change.

08:58:16 a.m. - EI+847 - Left main gear brake line temperature sensor D sees a rise rate change from 0.9 F/min to 11.7 F/min (not increasing) to LOS. H=210,304; Mach: 19.55 (+34.287-103.293)

08:58:20 a.m. - EI+851 - Columbia crosses the New Mexico-Texas state line. H=209,800; Mach: 19.5 (+34.2-103.1)

08:58:32 a.m. - EI+863 - Main landing gear left outboard/inboard tire pressure 1 sensors see pressure trending down to off-scale low; main landing gear left outboard wheel temperature begins trending down to off-scale low (timing not exact; follows 7-second loss of signal)

08:58:32-59:22 a.m. - EI+863/913 - System 2 left brake switching valve return temperature (aft) sees rise from 2.5 F/min to 40 F/min until peak at 8:59:22 a.m. H=208,380; Mach: 19.28 (+33.980-102.325)

08:58:36 a.m. - EI+867 - Main landing gear inboard wheel temperature begins trending down to off-scale low. H =207,918; Mach: 19.21 (+33.908-102.099)

08:58:36 a.m. - MCC-Commentator: "Columbia continuing toward Florida, now approaching the Mexico-Texas border. Altitude 40 miles..."

08:58:38 a.m. - EI+869 - Main landing gear outboard tire pressure 1 sensor drops off-scale low.

08:58:39 a.m. - EI+870 - Main landing gear left outboard wheel temperature goes off-scale low; main landing gear left outboard tire pressure 2 sensor begins trending down to off-scale low. (+33.873-101.987)

08:58:40 a.m. - EI+871 - Columbia's backup flight system (BFS) computer displays tire pressure fault message on a cockpit display.

08:58:40 a.m. - EI+871 - Main landing gear inboard tire pressure 1 sensor drops off-scale low. H=207,370; Mach: 19.13 (+33.837-101.875)

08:58:41 a.m. - EI+872 - Main landing gear left inboard tire pressure 2 sensor starts off-nominal increase, rising about 3.5 psia in 2 seconds. H=207,132; Mach: 19.09

08:58:43 a.m. - EI+874 - Main landing gear inboard tire pressure 2 begins trending down.

08:58:44 a.m. - MCC-FDO: "FLIGHT, FDO."

08:58:48 a.m. - STS-CDR: "And, uh, Hou(ston)..."

08:58:48 a.m. - EI+879 - Main landing gear left inboard wheel temperature and main landing gear inboard tire pressure 2 sensors drop off-scale low. H=206,403; Mach: 18.99

08:58:51 a.m. - MCC-Commentator: "... speed 13,200 miles per hour. Range to touchdown 1,400 miles. The shuttle in a left bank with the wings banked about 57 degrees to horizontal."

08:58:54 a.m. - EI+885 - Main landing gear left outboard tire pressure 2 sensor drops off-scale low. H=205,553; Mach: 18.86

08:58:56 a.m. - EI+887 - Backup flight system computer displays tire pressure fault message (final message). H=205,311; Mach: 18.83 (+33.541-100.931)

08:59:00 a.m. - EI+891 - Qbar = 63.5 psf; Mach 18.7; wing leading edge stagnation temperature = 2,850 degrees.

08:59:06 a.m. - MCC-FLIGHT: "FDO, FLIGHT."

MCC-FDO: "Uh, we have the balloon. It is being run through DDS (data display system) right now."

08:59:06 a.m. - EI+897 - Left main gear downlocked indication - transferred ON - uplock indicates no change. H=204,336; Mach: 18.86 (+33.370-100.384)

08:59:09-39 a.m. - EI+900/930 - OEX: Several left-side temperature readings show a rapid increase followed by erratic behavior and loss of data around EI+940; includes six left OMS pod sensors and three left fuselage sidewall sensors.

08:59:15 a.m. - MCC-MMACS: "FLIGHT, MMACS."

MCC-FLIGHT: "Go."

08:59:18 a.m. - MCC-MMACS: "We just lost tire pressure on the left outboard and left inboard, both tires."

08:59:22 a.m. - EI+913 - System 2 left brake switching valve return temperature sensor (aft) begins a sharp downward trend to off-scale low.

08:59:23 a.m. - EI+914 - Loss of realtime data in mission control workstations.

08:59:24 a.m. - MCC-CAPCOM: "And Columbia, Houston, we see your tire pressure..."

MCC-FLIGHT: "Copy..."

MCC-CAPCOM: "...messages and we did not..."

MCC-FLIGHT: "Is it instrumentation, MMACS? Gotta be..."

MCC-CAPCOM: "...copy your last."

08:59:26-28 a.m. - EI+917/919 - Sudden increase in rate of change of pitch, roll and yaw increments; magnitude begins to exceed the ability of the aileron to trim the vehicle.

08:59:30.66 a.m. - EI+921.66 - Start of R2R yaw jet firing; jets on at loss of signal to assist elevons in counteracting the increasing aerodynamic drag. H=200,767; Mach: 18.16 (+32.956-99.041)

08:59:30.68 a.m. - EI+921.68 - Start of R3R yaw jet firing; jet on at loss of signal to assist elevons in counteracting the increasing aerodynamic drag.

08:59:30 a.m. - MCC-MMACS: "FLIGHT, MMACS, those are..."

08:59:31 a.m. - EI+922 - Maximum observed elevon deflections; Left: -8.11 degrees up; Right: -1.15 degrees up

MCC-MMACS: "...also off-scale low."

08:59:31.4 a.m. - EI+922.4 - Flight control system channel 4 aerosurface position measurements start trending toward their null values. This indicates worsening effects of wiring shorts.

08:59:31.478 a.m. - EI+922.5 - All flight control system channel 4 bypass valves close (indicate bypass). This is an indication of aerosurface actuator (ASA) high-rate data failure.

08:59:31.7 a.m. - EI+922.7 - Speedbrake channel 4 OI position measurement indicates 19, 20 and 24 degrees open over last three samples prior to loss of signal. Speedbrake should be closed at 0 degrees. No change seen in actuator motion. Signature considered nominal response to bypass valve closing (see above).

08:59:32 a.m. - EI+923 - Maximum observed elevon trim at LOS (-2.3 degrees).

08:59:32 a.m. - EI+923 - Columbia is approaching Dallas, Texas. Approximate location at initial loss of signal. H=200,700; Mach: 18.1 (+32.9-99.0)

08:59:32 a.m. - STS-CDR: "Roger, uh buh (CUTOFF)" (Editor's note: Phonetically, sounded like first syllable of "before" or possibly "both;" he may have been responding to the BFS fault messages for both left-side main landing gear tires)

08:59:32 a.m. - EI+923 - Loss of signal for left mid fuselage bondline temperature sensor at x1215; left aft fuselage sidewall temperature at x1410; left main gear brake line temperatures (A: 172.2 F; B: 154.2 F; C: 104.8 F; D: 88.3 F); left main gear strut actuator temperature (76.3 F); hydraulic system 1 left main gear uplock actuator unlock line temperature (52.2 F); System 2 left brake switch valve return temperature (aft, 62.8 F); system 3 left main gear brake switch valve return line temperature (67.3 F)

08:59:32.13 a.m. - EI+923.13 - Flight control system channel 4 fail flags raised on all aerosurface actuators.

08:59:32.136 a.m. - EI+923.136 - INITIAL LOSS OF SIGNAL - Last valid data frame accepted by ODRC - OI/BFS/PASS. The backup flight system computer selected the upper right aft quad antenna to communicate with TDRS-West. The pointing angle was off the shuttle's tail at -65 degrees and trending further into blockage; previous experience shows a probable loss of communications at angles greater than -60 degrees. Therefore, the loss of communications experienced here is consider normal and not the result of any failure or attitude change by the orbiter.

Editor's note: The following data was reconstructed based on a final two-second burst of telemetry beginning at 9:00:02.66 a.m.

08:59:32.195 a.m. - EI+923.195 - ASA 4 remote power controller and A&C trip indication due to electrical short.

08:59:33.598 a.m. - EI+923.598 - Left outboard bypass valve reopens. A "force fight" between channels 1/2/3/4 begins, resulting in a difference of up to 0.5 degrees between left outboard and inboard elevons; indicates a short in the bypass valve.

08:59:33.680 a.m. - EI+924.680 - Backup flight system fault message (1): Flight control system Channel 4 (TDRS-East data). Error is detected by ATVC/ASA hardware when sensed change in pressure across the actuator exceeds a limit indicating the FCS channel is no longer driving the actuator.

08:59:33.863 a.m. - EI+924.863 - PASS flight computers announce a fault (1): Flight control system channel 4 (TDRS-East data).

08:59:33.976 a.m. - EI+924.976 - Master alarm sounds in the cockpit.

08:59:34.518 a.m. - EI+925.518 - Left outboard "force fight" ends; driver currents go to zero, indicating remote power controller B has tripped; all bypass valves would open.

08:59:34.561 a.m. - EI+925.561 - Speed brake force fight begins and continues to LOS; indicates opening of all bypass valves due to RPC B trip on ASA 4. Speedbrake is already at zero.

08:59:35-36 a.m. - EI+926/927 - Vehicle sideslip changes sign. Just prior to initial LOS, the magnitude of Columbia's negative sideslip started to decrease; Between 8:59:34 and 8:59:37, sideslip grew from -.6 to +.8 degrees. Aerodynamic forces due to sideslip are now reinforcing the drag caused by problems with the left wing.

08:59:36 a.m. - EI+927 - Bank attitude error begins growing. Up until this moment, the flight control system had been able to maintain a bank angle error around 5 degrees. Aerojet DAP (digital autopilot) drops the left wing to compensate for increasing drag, creating a bank attitude error.

08:59:36.8 a.m. - EI+927.8 - Aerojet DAP commands a third RCS jet - R4R - to fire to counteract increasing aerodynamic forces pulling vehicle to the left (yaw down relative to Earth); R4R fires and remains on through 8:59:37.396 a.m. when data is lost for 25 seconds.

08:59:37 a.m. - Begin hypothetical trajectory plot for an object with a ballistic number = 220 psf. This trajectory is projected to compute an approximate impact point.

08:59:37.3 a.m. - EI+928.3 - Aerojet DAP orders R1R to begin firing; stays on through LOS at 8:59:37.396 a.m.

08:59:37.X a.m. - EI+928.X - Last aileron data; position now approximately -5.2 degrees with about -2.5 degrees of trim. Rate of change had reached maximum allowed by flight control system.

08:59:37.396 a.m. - EI+928.396 - Loss of data for 25 seconds. Additional data in this 25-second gap is recovered in computer buffers during the final two second burst of telemetry.

08:59:39-14:00:19 a.m. - EI+930/970 - OEX: Starting at 8:59:39 a.m., all OEX data becomes erratic.

08:59:46-48 a.m. - EI+937/939 - Debris A: Large debris seen leaving the orbiter, falling away from orbiter envelope.

08:59:46.347 a.m. - EI+937.347 - PASS flight computers generate a "roll reference" fault message. This message is recovered during final two seconds of telemetry in a computer buffer. The timing of this message - 10 seconds after four aft jets began firing - indicates rapid change in lift-to-drag ratio. BFS does not have this message in the fault message stack. It is likely the BFS annunciated this message during the 25-second LOS. If so, it was pushed out of the stack by at least five additional fault messages.

08:59:52.114 a.m. - EI+943.114 - PASS fault message: Left RCS leak; found in PASS fault message buffer (data suspect); indicates a leak of either helium and/or propellant; also possible this is due to erroneous temperature and pressure readings.

08:59:58 a.m. - MCC-INCO: "FLIGHT, INCO."

MCC-FLIGHT: "Go."

MCC-INCO: "Just taking a few hits here. We're right up on top of the tail. Not too bad."

08:59:59 a.m. - EOC2-4-0018/Duncanville, Texas: Video coverage begins. (+32.653-96.908)

09:00:00 a.m. - EOC2-4-0024/Arlington, Texas: Video coverage begins. (+32.736-97.108)

09:00:00 a.m. - EI+951 - Wing leading edge stagnation temperature = 2,800 degrees.

09:00:01-03 a.m. - EI+952/954 - Debris B seen well aft of orbiter envelope.

09:00:01.540 a.m. - EI+952.540 - BFS fault message: Left RCS leak; found in BFS fault message buffer (data, timing suspect).

09:00:01.9 a.m. - EI+952.9 - BFS fault message: Left RCS leak; found in BFS fault message buffer (data, timing suspect).

09:00:02-04 a.m. - EI+953/955 - Debris C - large piece - seen leaving the orbiter and falling away.

09:00:02.654 a.m. - EI+953.654 - BFS fault message: Left RCS LJET (data suspect). Message generated when left-side RCS jet fails OFF/ON/LEAK.

09:00:02.660 a.m. - EI+953.660 - Telemetry resumes for approximately two seconds after a 25-second drop out. Data from this final burst is suspect because of multiple bit errors. Only one data sample was available for many measurements. As a result, some of the following conclusions may be in error.

- **NOMINAL SYSTEMS:** Columbia's APUs were running and the water spray boilers were providing cooling. The main propulsion system (aft engine compartment) was intact. The shuttle's electricity producing fuel cells were generating power and the fuel cell hydrogen/oxygen distribution lines were intact. Communications and navigation systems in the forward fuselage were performing normally. Rudder/speedbrake, body flap, main

engine and right wing temperature sensors appeared active. The flash evaporator system had shut down. Life support systems were operating normally, although the flash evaporator cooling system was in shutdown.

- **OFF-NOMINAL SYSTEMS:** All three hydraulic systems showed zero pressure and empty reservoirs. The left inboard and outboard elevon actuator temperatures were either off-scale low or show now data. The water spray boilers appeared to be over cooling the APU lubrication oil. The flash evaporator cooling system was in shutdown. The majority of the left orbital maneuvering system pod sensors were either off-scale low or showing no data. Multiple BFS and PASS fault messages for left OMS pod hardware were found in buffers (not enough data to determine if real leaks were present or if readings were due to loss of instrumentation). High temperatures at the bottom bondline centerline skin forward and aft of the wheel wells and at the port side structure over the left wing were seen. A general upward shift in main bus amps and downward shift in main bus volts was observed. AC3 phase A inverter appeared disconnected from the AC bus.
- **SHUTTLE ATTITUDE:** Guidance and navigation data suggests Columbia was in an uncommanded orientation, or attitude, and was exhibiting uncontrolled rates of motion. Yaw rate was at sensor maximum of 20 degrees per second, suggesting a possible tumble to the left. Because Columbia was in a left bank at the time, a yaw to the left would have had the effect of dropping the nose toward Earth. Flight control mode was in AUTO, meaning the pilots never took over manual control (see below). At this point, it appears the forward, mid and aft fuselage, the right wing and right OMS pod were still intact.

09:00:03.470 a.m. - EI+954.470 - BFS fault message: Left OMS tank pressure; found in BFS fault buffer. Fault is annunciated when OMS oxidizer or fuel tanks show pressures out of limits high or low (data suspect).

09:00:0X.XXX a.m. - BFS fault message: Unknown (timing unclear).

09:00:0X.XXX a.m. - BFS fault message: SM1 AC VOLTS. Occurred after left OMS tank pressure message (time info corrupted). Error message indicates AC bus 3 phase A, B or C voltage is out of limits high or low.

09:00:03.637 a.m. - EI+954.637 - PASS fault message: Left RCS PVT (data suspect).

09:00:03.637 a.m. - EI+954.637 - PASS fault message: Digital autopilot downmode rotational hand controller. One of the two rotational hand controller "joysticks" is moved beyond a preset limit, either because one of the pilots bumped it or because one of the pilots made a brief attempt to take over manual control. Because of software timing issues, this event could have occurred as early as 9:00:01.717 a.m. Fault message corroborated by an initialization flag for the Aerojet DAP roll stick function. However, during this two-second period, rotational hand controller remained centered (in detent) and DAP remains in AUTO through loss of signal. Data is potentially error prone.

09:00:04.826 a.m. - EI+955.826 - Last identifiable OI downlink frame.

09:00:05.2-06.2 a.m. - EI+956.2/957.2 - Late flash 1; sudden brightening of the orbiter envelope.

09:00:06.2-07.2 a.m. - EI+957.2/958.2 - Late flash 2; sudden brightening followed by a shower of debris seen aft of orbiter over next four seconds.

09:00:08-12 a.m. - EI+959/963 - Debris D; seen slightly aft of orbiter envelope, generating its own tail.

09:00:09-13 a.m. - EI+960/964 - Debris E; seen aft of debris D.

09:00:10-14 a.m. - EI+961/965 - Debris F; first seen aft of orbiter; generates its own tail.

09:00:13-17 a.m. - EI+964/968 - Debris shower; multiple objects seen just aft of orbiter envelope over next two seconds.

09:00:13.439 a.m. - EI+964.439 - OEX: PCM (pulse code modulation) loss of synch; end of data.

09:00:18 a.m. - MCC-FLIGHT: "MMACS, FLIGHT."

09:00:17.8-18.8 a.m. - EI+968.8/969.8 - Catastrophic event of unknown nature; orbiter envelope suddenly brightens followed by dramatic change in the plasma trail. Presumed main body breakup.

09:00:19.44 a.m. - EI+970.44 - OEX: FDM (frequency division multiplexer) data ends. Prior to this moment, the fuselage was still intact and power was still flowing from Columbia's fuel cells.

09:00:21 a.m. - EOC2-4-0025/Camp Swift, Texas: Video coverage begins. (+30.191-97.292)

09:00:21-25 a.m. - Onset of vehicle main body breakup.

MCC-MMACS: "FLIGHT, MMACS."

MCC-FLIGHT: "And there's no commonality between all these tire pressure instrumentations and the hydraulic return instrumentations."

09:00:23 a.m. - EOC2-4-0024/Arlington, Texas: Video coverage ends. (+32.736-97.108)

09:00:27 a.m. - MCC-MMACS: "No sir, there's not. We've also lost the nose gear down talkback and the right main gear down talkback."

MCC-FLIGHT: "Nose gear and right main gear down talkbacks?"

MCC-MMACS: "Yes sir."

09:00:30 a.m. - Time-stamped video from Apache helicopters flying near Fort Hood, Texas, shows multiple contrails.

09:00:32 a.m. - RV2/Fort Hood, Texas: Video coverage begins. (+31.117-97.728)

09:00:35 a.m. - EOC2-4-0018/Duncanville, Texas: Video coverage ends. (+32.653-96.908)

09:00:51 a.m. - MCC-EECOM: "And FLIGHT, EECOM."

MCC-FLIGHT: "EECOM."

MCC-EECOM: "I've got four temperature sensors on the bond line data that are off-scale low."

09:00:53 a.m. - EI+1004 - End of peak heating region.

09:01:01 a.m. - EOC2-4-0025/Camp Swift, Texas: Video coverage ends. (+30.191-97.292)

09:01:16 a.m. - MCC-Commentator: "Columbia out of communications at present with mission control as it continues its course toward Florida..."

09:01:19 a.m. - RV2/Fort Hood, Texas: Video coverage ends. (+31.117-97.728)

09:01:29 a.m. - MCC-INCO: "FLIGHT, INCO, I didn't expect, uh, this bad of a hit on comm."

09:01:38 a.m. - MCC-FLIGHT: "GC, how far are we from UHF? Is that two-minute clock good?"

MCC-UNKNOWN: "Affirmative, FLIGHT."

09:02:00 a.m. - MCC-GNC: "FLIGHT, GNC."

MCC-FLIGHT: "Go."

MCC-GNC: "If we have any reason to suspect any sort of controllability issue, I would keep the control cards handy on page four-dash-13."

MCC-FLIGHT: "Copy."

09:02:21 a.m. - MCC-Commentator: "Fourteen minutes to touchdown for Columbia at the Kennedy Space Center. Flight controllers are continuing to stand by to regain communications with the spacecraft..."

09:02:29 a.m. - MCC-FLIGHT: "INCO, we were rolled left last data we had and you were expecting a little bit of ratty comm, but not this long?"

09:02:37 a.m. - MCC-INCO: "That's correct, FLIGHT. I expected it to be a little intermittent. And this is pretty solid right here."

MCC-FLIGHT: "No onboard system config changes right before we lost data?"

MCC-INCO: "That is correct, FLIGHT. All looked good."

MCC-FLIGHT: "Still on string two and everything looked good?"

MCC-INCO: "String two looking good."

09:03:03 a.m. - MCC-GC: "Two minutes to MILA."

09:03:12 a.m. - MCC-CAPCOM: "Columbia, Houston, comm check."

09:03:23 a.m. - MCC-FDO: "FLIGHT, FDO."

MCC-FLIGHT: "Go."

MCC-FDO: "Close-end aim point with the one-hour balloon shows us touching down at 1,496, 1,500 feet down the runway. Our crosswind right now is on the left, from the left on the three-three end."

09:03:34 a.m. - Reference trajectory ground impact in western Louisiana for hypothetical object with a ballistic number = 220 psf. (+30.781-92.557)

09:03:40 a.m. - MCC-CAPCOM: "Columbia, Houston, UHF comm check."

09:03:45 a.m. - MCC-Commentator: "CAPCOM Charlie Hobaugh calling Columbia on a UHF frequency as it approaches the Merritt Island tracking station range in Florida. Twelve-and-a-half minutes to touchdown, according to clocks in mission control." (listeners hear unease in the voice inflection)

09:03:46 a.m. - MCC-FDO: "FLIGHT, I'd like to stay where we're at."

MCC-FLIGHT: "I copy."

09:03:53 a.m. - MCC-MMACS: "FLIGHT, MMACS."

MCC-FLIGHT: "MMACS?"

MCC-MMACS: "On the tire pressures, we did see them go erratic for a little bit before they went away, so I do believe it's instrumentation."

MCC-FLIGHT: "OK."

09:04:05 a.m. - MCC-CAPCOM: "Columbia, Houston, UHF comm check."

09:04:35 a.m. - MCC-FDO: "FLIGHT, FDO."

MCC-FLIGHT: "Go."

MCC-MALE VOICE: "I know this data's a little late, the one-hour balloon protects us for winds..."

09:04:41 a.m. - MCC-CAPCOM: "Columbia, Houston, UHF comm check."

MCC-FDO: "...I think we're in a smaller wind persistence case than that. In other words, we shouldn't expect as big of a change. I'm comfortable with 1,500 feet down the runway."

09:04:54 a.m. - MCC-Commentator: "Flight controllers are standing by for Columbia to move within communications range of the Merritt Island tracking station in Florida to regain communications with Columbia."

09:04:57 a.m. - MCC-GC: "Flight, GC."

MCC-FLIGHT: "Go."

MCC-GC: "MILA not reporting any RF at this time."

MCC-INCO: "FLIGHT, INCO, SPC just should have taken us to STDN low."

MCC-FLIGHT: "OK."

09:05:13 a.m. - MCC-FLIGHT: "FDO, when are you expecting tracking?"

MCC-FDO: "One minute ago, FLIGHT."

09:05:21 a.m. - MCC-Commentator: "Also, flight controllers standing by for tracking data of Columbia that's also received through the Merritt Island tracking station."

09:05:26 a.m. - MCC-CAPCOM: "Columbia, Houston, UHF comm check."

09:05:51 a.m. - MCC-Commentator: "Ten and a half minutes to anticipated touchdown for Columbia." (voice inflection signals uncertainty)

09:06:29 a.m. - MCC-GC: "And FLIGHT, GC, no C-band yet."

MCC-FLIGHT: "Copy."

09:06:56 a.m. - MCC-Commentator: "Flight controllers are still standing by for C-band tracking data from the Merritt Island tracking station of Columbia and UHF communications."

09:07:08 a.m. - MCC-CAPCOM: "Columbia, Houston, UHF comm check."

09:07:22 a.m. - MCC-INCO: "FLIGHT, INCO."

MCC-FLIGHT: "Go."

MCC-INCO: "I could swap strings in the blind."

09:07:36 a.m. - MCC-FLIGHT: "OK, command us over."

MCC-INCO: "In work, FLIGHT."

09:08:07 a.m. - MCC-Commentator: "Eight minutes on the touchdown clock for Columbia, flight controllers continuing to stand by to regain communications with the spacecraft."

09:08:25 a.m. - MCC-INCO: "FLIGHT, INCO, I've commanded string one in the blind."

MCC-FLIGHT: "INCO?"

MCC-INCO: "I've commanded string one in the blind, FLIGHT."

MCC-FLIGHT: "Copy."

09:08:34 a.m. - MCC-Commentator: "Flight controllers standing by for communications through the Merritt Island tracking station, a ground tracking site in Florida."

09:09:27 a.m. - MCC-GC: "And FLIGHT, GC."

MCC-FLIGHT: "Go."

MCC-GC: "MILA's taking one of their antennas off into a search mode."

MCC-FLIGHT: "Copy. FDO, FLIGHT?"

MCC-FDO: "Go ahead, FLIGHT."

MCC-FLIGHT: "Did we get, have we gotten any tracking data?"

MCC-FDO: "We got a blip of tracking data, it was a bad data point, FLIGHT. We do not believe that was the orbiter. We're entering a search pattern with our C-bands at this time. We do not have any valid data at this time."

09:09:29 a.m. - Projected time Columbia's velocity would have dropped to Mach 2.5 had this been a normal approach.

09:09:55 a.m. - MCC-FLIGHT: "OK. Any other trackers that we can go to?"

MCC-FDO: "Let me start talking, FLIGHT, to my navigator."

09:10:07 a.m. - MCC-Commentator: "This is mission control, Houston. Flight controllers are continuing to seek tracking data of Columbia. Touchdown clocks countdown to six minutes to touchdown for the anticipated shutdown, touchdown of Columbia at the Kennedy Space Center runway. Tracking data is being sought through the Merritt Island tracking station located near the Kennedy Space Center in Florida."

09:10:35 a.m. - MCC-Commentator: "Communications with Columbia were lost at about 8 a.m. Central time, about 10 minutes ago."

09:11:38 a.m. - Projected time Columbia's velocity would have dropped below the speed of sound had this been a normal approach.

09:12:34 a.m. - MCC-Commentator: "This is mission control, Houston. Flight controllers are continuing to stand by for communications from Columbia. The last communications with the spacecraft occurred about 8 a.m. Central time as it was above central Texas. Currently seeking communications or tracking data from the spacecraft through C-band radar and ground tracking sites located at the Merritt Island tracking station in Florida."

09:12:39 a.m. - Projected time Columbia would have been banking on the heading alignment cylinder to line up on runway 33 had this been a normal approach.

09:12:40 a.m. - (time approximate) Mission operations representative Phil Engelauf, sitting directly behind Cain, gets a call informing him that multiple contrails have been sighted along Columbia's

path. This is the first notification of vehicle breakup in mission control, but it is not based on hard data. Engelauf tells Cain about the report. The flight director pauses a moment, digesting this, and then turns back to the flight control team to declare a contingency.

09:12:55 a.m. - MCC-FLIGHT: "GC, FLIGHT. GC, FLIGHT."

MCC-GC: "FLIGHT, GC."

MCC-FLIGHT: "Lock the doors."

MCC-GC: "Copy."

09:13:17 a.m. - MCC-FLIGHT: "FDO, do you have any tracking?"

MCC-FDO: "No sir."

09:13:43 a.m. - MCC-MOD: "FLIGHT, MOD, on the flight loop."

09:13:51 a.m. - MCC-FDO: "FLIGHT, FDO."

MCC-FLIGHT: "Go."

MCC-FDO: "My C-bands have not acquired anything. We are only in track, uh, acquiring false locks at this time."

09:14:11 a.m. - MCC-FLIGHT: "I copy, FDO."

09:14:26 a.m. - MCC-Commentator: "This is mission control, Houston. Flight controllers continue to seek tracking or communications with Columbia through Merritt Island tracking station. Last communications with Columbia was at 8 a.m. Central time, approximately above Texas as it approached the Kennedy Space Center for its landing. Flight director LeRoy Cain is now instructing controllers to get out their contingency procedures and begin to follow those."

09:14:29 a.m. - MCC-FLIGHT: "OK, all flight controllers on the flight loop, we need to kick off the FCOH (Flight Control Operations Handbook) contingency plan procedure, FCOH checklist page 2.8-5."

09:14:52 a.m. - MCC-FLIGHT: "FDO, FLIGHT. ... FDO, FLIGHT."

MCC-FDO: "Go ahead."

MCC-FLIGHT: "Do you have any information or reports from Space Command?"

09:15:04 a.m. - MCC-Commentator: "Flight dynamics officer reports no tracking data from the C-band radar at the Merritt Island tracking station has been reported of any objects."

09:15:50 a.m. - Columbia's scheduled touchdown time on runway 33 at the Kennedy Space Center.

09:17:57 a.m. - MCC-FLIGHT "OK, all flight controllers, on page 9, of the FCOH procedure you need to make sure you step through the actions required in step 20, that's for your workstation logs, display printouts, there's a whole list of data collection items we need to make sure we log through."

09:18:20 a.m. - MCC-Commentator: "This is mission control, Houston. Flight director LeRoy Cain is instructing controllers to follow contingency procedures. The last communications with the shuttle Columbia during its descent from orbit were at about 8 a.m. Central time as it was descending through the atmosphere..."

09:18:36 a.m. - MCC-FLIGHT: "And GC, FLIGHT?"

MCC-GC: "FLIGHT, GC."

MCC-FDO: "FDO, FLIGHT"

MCC-FLIGHT: "We need to take the equivalent of a command server TSU (Trajectory Server Upgrade) checkpoint..."

MCC-FDO: "Yes sir."

MCC-GC: "Copy."

MCC-FLIGHT: "We don't have the old DSC (Dynamic Standby Computer) checkpoint but we have the equivalent capability that we need to do."

MCC-GC: "We'll get that done."

09:18:40 a.m. - MCC-Commentator: "...at an altitude of about 207,000 feet en route to the Kennedy Space Center in Florida and a touchdown that was anticipated to occur about two-and-a-half minutes ago. Flight controllers received no further communications with the spacecraft after about 8 a.m. Central time and no further tracking data from the spacecraft was gained from C-band tracking radar at the Merritt Island tracking station in Florida."

09:18:58 a.m. - MCC-FLIGHT: "GC, FLIGHT."

MCC-GC: "FLIGHT, GC."

MCC-FLIGHT: "You understand how to do the end-of-file log tapes we need..."

MCC-GC: "Yes sir."

MCC-FLIGHT: "...in the checklist? OK."

09:19:14 a.m. - MCC-Commentator: "Contingency procedures in effect in mission control require all operators to conserve all their data and logbooks and notes that have been taken, that being instructed by flight director LeRoy Cain for controllers to begin following those steps and secure all information."

09:19:34 a.m. - MCC-FLIGHT: "And folks, listen up again on the flight loop. No phone calls off site outside of this room, our discussions are on these loops, the recorded DVIS (digital voice integrated system) loops only, no data, no phone calls, no transmissions anywhere, into or out."

MCC-GC: "FLIGHT, GC."

MCC-FLIGHT: "GC."

MCC-GC: "We have no way of disabling the black phones."

MCC-FLIGHT: "I understand."

09:20:10 a.m. - MCC-Commentator: "Again, flight director LeRoy Cain has declared a contingency. Flight controllers here in mission control are securing all their information, notes and data gathered from the spacecraft. The last communications with Columbia at 8 a.m. Central time as it was descending toward Florida for its landing. At that time, about 207,000 feet above central Texas traveling approximately 12,500 miles per hour, 1,192 miles from its touchdown at Kennedy Space Center. Since 8 a.m., no communications were received with Columbia and no tracking data received through the Merritt Island tracking station, those efforts made. The flight dynamics officer reports no objects tracked through that tracking data."