The CBS News

Space Reporter's Handbook
Mission Supplement

Shuttle Mission STS-128/ISS-17A:
Resupplying the International Space Station

Written and Produced By

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Revision History

Editor's Note
Mission-specific sections of the Space Reporter's Handbook are posted as flight data becomes available. Readers should check the CBS News "Space Place" web site in the weeks before a launch to download the latest edition:

http://www.cbsnews.com/network/news/space/current.html

DATE	RELEASE NOTES
08/21/09	Initial STS-128 release

Introduction

This document is an outgrowth of my original UPI Space Reporter's Handbook, prepared prior to STS-26 for United Press International and updated for several flights thereafter due to popular demand. The current version is prepared for CBS News. As with the original, the goal here is to provide useful information on U.S. and Russian space flights so reporters and producers will not be forced to rely on government or industry public affairs officers at times when it might be difficult to get timely responses. All of these data are available elsewhere, of course, but not necessarily in one place.

The STS-128 version of the CBS News Space Reporter's Handbook was compiled from NASA news releases, JSC flight plans, the Shuttle Flight Data and In-Flight Anomaly List, NASA Public Affairs and the Flight Dynamics office (abort boundaries) at the Johnson Space Center in Houston. Sections of NASA's STS-128 press kit, crew bios and the mission TV schedule are downloaded via the Internet, formatted and included in this document. Word-for-word passages (other than lists) are clearly indicated.

The SRH is a work in progress and while every effort is made to insure accuracy, errors are inevitable in a document of this nature and readers should double check critical data before publication. As always, questions, comments and suggestions for improvements are always welcome. And if you spot a mistake or a typo, please let me know!

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NASA Media Information

NASA Television Transmission

NASA Television is now carried on an MPEG-2 digital signal accessed via satellite AMC-6, at 72 degrees west longitude, transponder 17C, 4040 MHz, vertical polarization. A Digital Video Broadcast (DVB) - compliant Integrated Receiver Decoder (IRD) with modulation of QPSK/DBV, data rate of 36.86 and FEC 3/4 is needed for reception. NASA TV Multichannel Broadcast includes: Public Services Channel (Channel 101); the Education Channel (Channel 102) and the Media Services Channel (Channel 103).

The new Digital NASA TV will have four digital channels:

1. NASA Public Service ("Free to Air"), featuring documentaries, archival programming, and coverage of NASA missions and events;
2. NASA Education Services ("Free to Air/Addressable"), dedicated to providing educational programming to schools, educational institutions and museums;
3. NASA Media Services ("Addressable"), for broadcast news organizations; and
4. NASA Mission Operations (Internal Only)

The new digital NASA Public Service Channel will be streamed on the Web. All you'll need is access to a computer. ... You may want to check with your local cable or satellite service provider whether it plans to continue carrying the NASA Public Service "Free to Air" Channel. If your C-Band-sized satellite dish is capable of receiving digital television signals, you'll still need a Digital Video Broadcast (DVB)-compliant MPEG-2 Integrated Receiver Decoder, or IRD, to get the new Digital NASA's Public Service "Free to Air" Channel.

An IRD that receives "Free to Air" programming like the new Digital NASA Public Service Channel can be purchased from many sources, including "off-the-shelf" at your local electronics store.

The new Digital NASA TV will be on the same satellite (AMC 6) as current analog NASA TV, but on a different transponder (17). In Alaska and Hawaii, we'll be on AMC 7, Transponder 18.

Satellite Downlink for continental North America: Uplink provider = Americom
Satellite = AMC 6
Transponder = 17C
72 Degrees West
Downlink frequency: 4040 Mhz
Polarity: Vertical
FEC = 3/4
Data Rate r= 36.860 Mhz Symbol = 26.665 Ms
Transmission = DVB

"Public" Programming: Program = 101, Video PID = 111, Audio PID = 114
"Education" Programming: Program = 102, Video PID = 121, Audio PID = 124
"Media" Programming = Program = 103, Video PID = 1031, Audio PID = 1034
"SOMD" Programming = Program = 104, Video PID = 1041, Audio PID = 1044

Home Page:	http://www.nasa.gov/multimedia/nasatv/index.html
Daily Programming:	http://www.nasa.gov/multimedia/nasatv/MM_NTV_Breaking.html
Videofile Programming:	ftp://ftp.hq.nasa.gov/pub/pao/tv-advisory/nasa-tv.txt
NTV on the Internet:	http://www.nasa.gov/multimedia/nasatv/MM_NTV_Web.html

NASA Public Affairs Contacts

Kennedy Space Center	321-867-2468 (voice) 321-867-2692 (fax) 321-867-2525 (code-a-phone)
Johnson Space Center	281-483-5811 (voice) 281-483-2000 (fax) 281-483-8600 (code-a-phone)
Marshall Space Flight Center	256-544-0034 (voice) 256-544-5852 (fax) 256-544-6397 (code-a-phone).

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STS-128: Internet Pages of Interest

CBS Shuttle Statistics	http://www.cbsnews.com/network/news/space/spacestats.html
CBS Current Mission Page	http://www.cbsnews.com/network/news/space/current.html
CBS Challenger/Columbia Page	http://www.cbsnews.com/network/news/space/SRH_Disasters.htm
NASA Shuttle Home Page	http://spaceflight.nasa.gov/shuttle/
NASA Station Home Page	http://spaceflight.nasa.gov/station/
NASA News Releases	http://spaceflight.nasa.gov/spacenews/index.html
KSC Status Reports	http://www-pao.ksc.nasa.gov/kscpao/status/stsstat/current.htm
JSC Status Reports	http://spaceflight.nasa.gov/spacenews/reports/index.html
STS-128 NASA Press Kit	http://www.shuttlepresskit.com/
STS-128 Imagery	http://spaceflight.nasa.gov/gallery/images/shuttle/STS-128/ndxpage1.html
STS-128 Home Page	http://www.nasa.gov/mission_pages/shuttle/main/index.html
Spaceflight Meteorology Group	http://www.srh.noaa.gov/smg/smgwx.htm
Hurricane Center	http://www.nhc.noaa.gov/index.shtml
Melbourne, Fla., Weather	http://www.srh.noaa.gov/mlb/
Entry Groundtracks	http://spaceflight.nasa.gov/realdata/index.html
KSC Video	http://science.ksc.nasa.gov/shuttle/countdown/video/
ELV Video	http://countdown.ksc.nasa.gov/elv/elv.html
Comprehensive TV/Audio Links	http://www.idb.com.au/dcottle/pages/nasatv.html

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CBS News STS-128 Mission Preview

Shuttle Discovery poised for launch on space station resupply mission

By WILLIAM HARWOOD
CBS News Space Consultant

KENNEDY SPACE CENTER, Fla. -- After last-minute debate over external tank insulation, the shuttle Discovery is poised for launch early Tuesday on a three-spacewalk mission to deliver more than seven tons of supplies, experiment hardware and life-support gear to the International Space Station.

Along with replacing a 1,800-pound ammonia coolant tank in the station's main power truss during their first two spacewalks, the astronauts will deliver two sophisticated science racks, one devoted to fluid physics and the other to materials science, an experiment sample freezer, a new air revitalization rack, a crew sleep station and a treadmill named after comedian Stephen Colbert.

The "Combined Operational Load Bearing External Resistance Treadmill," or COLBERT, received its name after the comedian launched a successful tongue-in-cheek write-in campaign to name a final station module in his honor. NASA managers declined, naming the new module Tranquility instead, but renamed the treadmill after Colbert.

Astronaut Nicole Stott, a former shuttle engineer at the Kennedy Space Center who joined the astronaut corps in 2000, is hitching a ride to the space station aboard Discovery to replace flight engineer Timothy Kopra, launched to the lab complex in July and returning to Earth in Stott's place.

Remaining behind when Discovery departs, Stott will join Expedition 20 commander Gennady Padalka, NASA flight engineer Michael Barratt, cosmonaut Roman Romanenko, Canadian Robert Thirsk and European Space Agency astronaut Frank De Winne as a member of the station's full-time crew.

Discovery's flight is the last shuttle mission that will rotate space station crew members. While Stott will ride a shuttle home in November, future The shuttle Discovery's crew. station crew members will travel up and down aboard Russian Soyuz capsules. NASA is paying the Russian space agency roughly $50 million per seat while the U.S. agency closes out shuttle operations and works to develop a replacement spacecraft not expected to fly until 2015 at the earliest.

From left to right: commander Rick Sturckow, Danny Olivas, Christer Fuglesang, pilot Kevin Ford, Nicole Stott, Patrick Forrester and Jose Hernandez. (NASA)

Only six shuttle flights are planned after Discovery's mission, all of them devoted to finishing the space station and loading it with supplies, spare parts and other equipment to protect against failures after the shuttle fleet is retired.

Launching enough supplies and equipment to support a full-time crew of six is a major challenge and one that Stott will face right away. She will be responsible for operating the station's robot arm to capture and attach an unmanned Japanese supply ship being prepared for its maiden launch Sept. 10. If all goes well, Stott will pluck the HTV craft out of orbit Sept. 17 and dock it to the Harmony module's Earth-facing port.

The International Space Station

Discovery's flight is equally critical to maintaining a permanent presence in space. Along with delivering science hardware and life support equipment, the shuttle crew also will bring up 1,600 pounds of food and other supplies, including carbon dioxide-absorbing lithium hydroxide canisters, used to supplement the station's U.S. and Russian CO2 scrubbers.

"We're bringing up seven racks that will be transferred to the space station," said European Space Agency astronaut Christer Fuglesang, making his second shuttle flight. "Three of them are really to keep the station's six crew members well and alive. There's a crew quarters, a treadmill - you have to exercise twice a day if you stay in space up to six months - and then there's a system to keep the air clean. Then we're bringing up three racks dedicated to science. And of course, there's a lot of food and other things."

Fuglesang, Stott and their shuttle crewmates - commander Rick Sturckow, pilot Kevin Ford, Jose Hernandez, John "Danny" Olivas and Patrick Forrester - are scheduled for liftoff at 1:36:05 a.m. on Aug. 25. Ford, Hernandez and Stott are space rookies making their first flight. Sturckow is a three-flight veteran, Forrester has two previous missions to his credit while Olivas and Fuglesang each have one.

Hernandez, a father of five, became an astronaut after a childhood of migrant farm work and support from hard-working parents who believed in the value of education.

"I come from a traditional migrant farm working family," he told CBS News. "Every year, my dad in central Mexico used to pile up the kids and my mom in the car and we'd take a two-day trip up to southern California, this is in the March timeframe, and then we would go to about three or four different places all the way up to northern California, Stockton was our last point where we'd spend the bulk of our time and we'd work on whatever crops were in season.

"We'd work on picking the cucumbers, cherries, tomatoes, spring tomatoes for market, peaches, grapes, hard work. The difference between my parents and the typical migrant farm working families is they gave importance, in spite of their third grade education, to give more importance to education. So Monday through Friday we would be in school, unlike some other kids who would be working seven days a week. Saturday and Sunday, we were always working out in the fields. We hated summer vacation because we knew what that meant. That meant seven days a week in the fields!"

"Then November would roll around, he would ask us to get two or three months of homework and we would head back to Mexico and the process repeated itself," Hernandez said. "It wasn't until I was in the second grade - I'm the youngest in the family - I told my second grade teacher I needed my homework, she rolled her eyes and said 'tell your parents I'm going to pay them a visit.'

"So she came and in her broken Spanish and my parent's broken English, basically told my parents 'look, I've had all four of your kids, they're all bright, they have a good future in school. Stay in one place so they have a good chance of getting a good education.' And my Dad, again, in spite of a third grade education, gave that a lot of importance coming from a teacher. So we started making Stockton our home and the rest is history."

Hernandez will serve as flight engineer during Discovery's launch and landing, operate the shuttle's robot arm for heat shield inspections the day after launch and at the end of the mission before re-entry, set up the shuttle's laptop computer network and oversee critical instrument readings during rendezvous and docking with the space station. He also will help spacewalkers Olivas, Fuglesang and Stott suit up for three planned excursions.

Hernandez' wife, children, siblings and parents planned to attend Discovery's launch at the Kennedy Space Center.

"They were happy if we finished high school" Hernandez said of his parents, "because that means we weren't going to work in the fields. They were ecstatic all four of us got a college education. Now I tell everybody that the minute I blast off into space, they're going to be in a higher orbit than I am, as happy as they're going to be."

Assuming an on-time liftoff, Sturckow will guide Discovery to a link up with the space station on Aug. 26. As with all station-shuttle dockings, Sturckow will briefly stop the approach 600 feet directly below the lab complex, piloting the shuttle through a 360-degree back flip maneuver while Padalka and Barratt, using cameras with 400-mm and 800-mm telephoto lenses, document the condition of the ship's heat shield.

Those photos, along with ascent imagery and laser-scan data collected by Hernandez and Forrester the day after launch, will be examined by engineers at the Johnson Space Center in Houston to make sure Discovery's critical reinforced carbon carbon nose cap, wing leading edge panels and belly tiles are in good condition for re-entry.

A potential source of debris for ascent impact damage is foam insulation from the shuttle's external tank. A major question mark going into Discovery's launch campaign was the integrity of that foam after an unusual amount of insulation fell away from the shuttle Endeavour's tank during launch July 15.

Most of the lost foam fell from ET-131's central intertank region, along with a small piece from a so-called ice-frost ramp that helps secure a pressurization line to the upper liquid oxygen section of the tank.

Some of the debris struck Endeavour's heat shield, but the impacts occurred after the shuttle was out of the denser lower atmosphere, which can result in higher impact velocities, and damage was minimal. Impact modeling is not an exact science, however, and engineers were concerned about possible adhesion problems.

As a result, Discovery's tank was subjected to nearly 200 plug-pull tests in which small cores cut in the intertank foam were pulled on with a known force to make sure the insulation was held in place with the required strength. In all cases, the adhesion was at or above specification.

The ice-frost ramp foam loss was more troublesome because Endeavour's flight was the second in a row in which insulation fell away from a specific IFR. Engineers believe the insulation popped off when air trapped in voids in the foam expanded due to atmospheric heating during ascent. But with two foam shedding incidents in a row, engineers worried a generic processing problem might be resulting in bigger voids and more shedding than usual.

The IFR in question on Discovery's tank was examined with a non-destructive terahertz scanner and found to be free of any major voids. But three other IFRs, none of them with a history of foam shedding, were not inspected. Some elements of the shuttle engineering community later recommended rolling Discovery back to the Vehicle Assembly Building for additional inspections, work that would have delayed launch to mid October.

Engineers in the Vehicle Assembly Building test foam insulation on ET-132's central intertank.

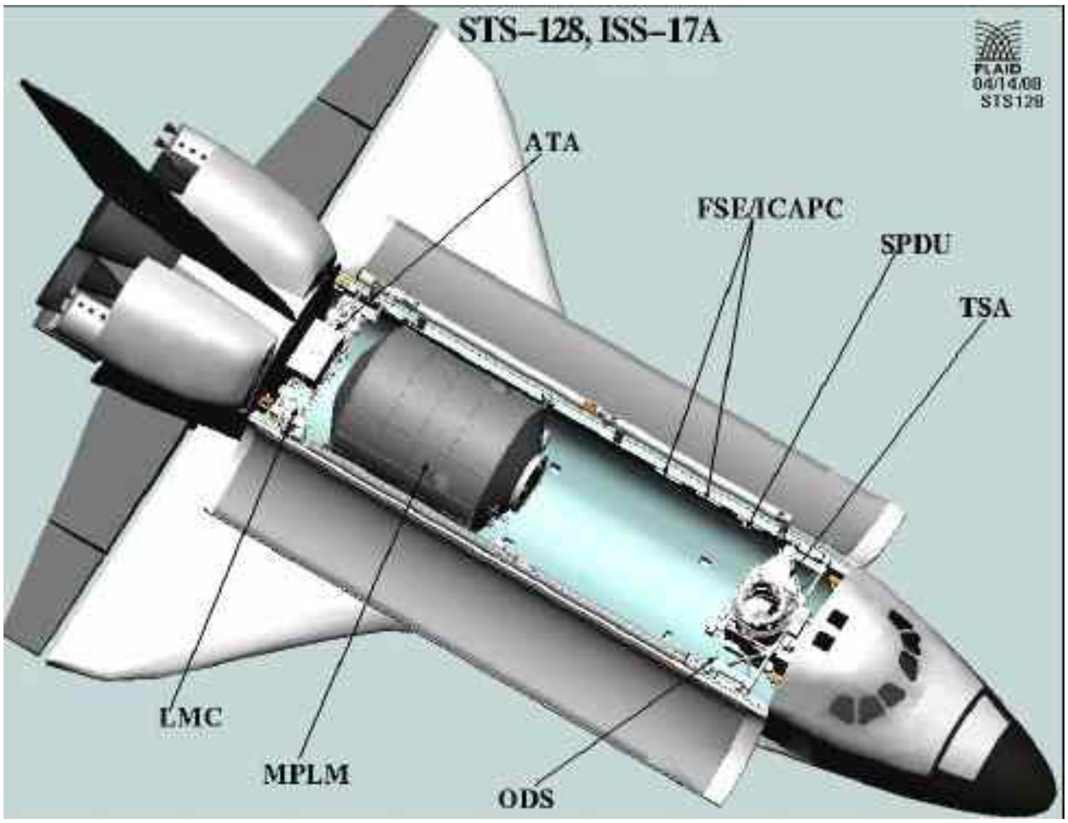
Instead, NASA managers ordered additional terahertz scans of the IFRs on the next tank in the launch sequence to make sure there was not a generic problem. No major problems were found and senior managers at an executive-level flight readiness review cleared Discovery for launch as is.

"On Columbia, we had a 2.2-pound piece of foam come off and damage the wing," said shuttle Program Manager John Shannon, referring to the shuttle Columbia's destruction in 2003. "The loss we had on the last flight that generated all of this discussion over the last two weeks was 0.044 pounds, which is one-fiftieth the size of the Columbia foam.

"That's how close we're looking, that's how sensitive we are. It generated four days of flight readiness review discussion, and a whole lot of work and additional testing. And that's exactly what we want the team to do, to look at it that closely. I feel extremely good about the results of the meeting. I think we have done absolute due diligence on the foam piece of it."

While Discovery's tank will separate from the shuttle in orbital darkness following the climb to space, a robotic camera mounted in the belly of the spaceplane will use a flash to capture photos giving engineers a chance to assess the condition of the tank's insulation.

Close-up photos shot by the station astronauts during Discovery's pitch-around maneuver on docking day also will be transmitted to the Johnson Space Center for detailed analysis. If any problems are seen, the astronauts will carry out a "focused" inspection later in the mission to collect additional data.



Following the rotational pitch maneuver, Sturckow plans to guide Discovery in an arc up to a point about 450 feet directly in front of the space station, with the shuttle's nose pointed toward space, it's tail to Earth and its open payload bay facing a docking port on the front end of the Harmony module. From there, Sturckow will manually guide the 270,000 pound shuttle to a docking with the 700,000-pound space station as both spacecraft streak through space at five miles per second.

With Discovery's arrival, the space station will once again be home to an international crew of 13, a record set during Endeavour's July mission. The first item on the agenda after docking will be the transfer of Stott's custom-fitted Soyuz seat liner, which will enable her to use one of the station's Russian life boats. From that point on, Stott will be considered a member of the station crew while Kopra will join Sturckow and company.

The day after docking, Ford and Barratt, operating the space station's robot arm, will lock onto the Leonardo multi-purpose logistics module, or MPLM, mounted in the back of Discovery's cargo bay. Loaded with 7.5 tons of equipment and supplies, Leonardo will be attached to Harmony's Earth-facing port.

"As we transition to six-person crew, there's a big step up in terms of consumables," said Kirk Shireman, deputy manager of the space station program at the Johnson Space Center. "And this flight will really get us in a robust configuration for keeping six-person crew and to fully utilize the ISS.

"We're launching about 1,590 pounds of crew supplies, that's food and other things to keep the crew alive and happy, we're launching 6,190 pounds of what I call vehicle hardware, and this is things in preparation for assembly, spares, those kinds of things. And we're launching over 6,050 pounds of utilization hardware. That's several racks and payloads themselves. So it's a big flight to fully utilize the International Space Station."

Fuglesang is the "load master" responsible for overseeing the logistics transfers to and from the MPLM, assisted by Sturckow and other crew members. Along with the new science racks, major items of interest include a new crew sleep station and the COLBERT treadmill.

The space station currently is equipped with four small crew cabins, two in the Russian Zvezda command module, used by Padalka and Romanenko, and two U.S.-built cabins on the port and starboard side of the Harmony module, used by Barratt and Kopra. De Winne uses a temporary sleep station, or TESS, in the U.S. Destiny laboratory module while Thirsk bunks in a similar makeshift cabin in the Japanese Kibo module.

Stott will take over Kopra's cabin in Harmony while Thirsk will enjoy the new NASA crew cabin, which will be temporarily mounted in Kibo and eventually moved to Harmony. A fourth U.S. sleep station will be launched next year and installed in Harmony as well.

The U.S. sleep stations are sound-proofed and feature their own lighting, air ducts, computer ports, communications gear and alarm systems. Arranged in a ring around Harmony, plastic sheathing at the back of each cabin also provides radiation shielding.

"They are very cool," Stott said. "I think it's going to be nice. You show some people the space that's available and they're like, oh my gosh, how could you possibly do that? You think about it, though, it's like this volume that's available to you, it's the whole volume, you're not relying on sticking to a wall somewhere or anything like that. Just like the station in general, you have this whole volume to use."

The new sleep station delivered by Discovery's crew eventually will be mounted in the new Tranquility module, along with the COLBERT treadmill, the second built for the space station. A half-dozen other exercise devices are available as well to facilitate daily exercise by all six crew members to help counteract the long-term effects of weightlessness.

Because of the connection with Stephen Colbert, the new treadmill, also known as T2, has generated more publicity than usual.

"We're always thankful for another outlet for positive exposure of the station, the hardware and the good things that are going on up there," Stott said. "We will be spending, I think, roughly 30 to 40 hours putting this treadmill together, between Mike Barratt and I.

"I think the highlight will be the first time we actually get to run on it. That will be a really good day, because we have the opportunity then to continue to sustain six people on station and have healthy crew members up there. So I think it's a very positive thing."

After the MPLM is attached to the station, Stott and Olivas will spend the night in the space station's Quest airlock module to prepare for the mission's first spacewalk the next day. The primary goals of the excursion are to remove a depleted ammonia tank assembly, or ATA, and attach it to the space station's robot arm for temporary storage. The astronauts also will retrieve two experiment packages mounted on the European Space Agency's Columbus lab module.

The COLBERT treadmill

Tipping the scales at some 1,800 pounds on Earth, the ATA is the most massive space station component ever handled by spacewalking astronauts.

"In zero G (gravity), we sort of think of everything as being weightless and being easy to move around," said Zeb Scoville, the lead spacewalk officer at JSC. "The thing to remember is that although those things have no weight, they still have mass. ... They're going to have to try to manipulate that mass so it doesn't try to pull them out of their foot restraints. Keeping control of this is certainly a challenge, again because of the mass, the inertia and the fact that it sometimes wants to resist being turned or re-oriented."

Another issue is potential ammonia contamination.

"Several days before the first spacewalk, the fluid lines that run internal to the ammonia tank and also run from that ammonia tank along the truss structure into the fluid system, a section of that line will be vented so there will only be residual bits of ammonia inside, there won't be the large pressurization volume of ammonia in those lines when they are demated," Scoville said. "So the amount of ammonia that could potentially leak is limited in that regard.

"If a crew member does get sprayed, we'll have time outside, exposed to the sun, the warm external environment, to bake off any ammonia ice that may be stuck on the suit. Beyond that bake-out scenario, we have some testing hardware once the crew ingresses the airlock. They can do a test at 5 psi that will detect any ammonia that may be off gassing from the suit. So, we'll be able to verify the crew is in a clean configuration before they come inside."

Stott and Olivas will disconnect the old ammonia tank from the port-1 truss segment and pull it out. Holding it in their gloved hands, the astronauts will orient the tank so Ford, operating the station's robot arm, can lock on. The tank will remain on the end of the station arm until after the new ammonia tank is installed during the crew's second spacewalk. After that, the old tank will be mounted on a cargo carrier in the shuttle's payload bay for return to Earth, refurbishment and relaunch next year.

"Nicole and Danny have a lot of work to do to disconnect the plumbing and electrical and all that stuff and make sure the (old) tank's vented and everything," Ford said. "It's going to be interesting, they're going to actually hold that tank out there and position it in their hands while I grapple it with the big arm. Then I'll take that away from them and I'll hold onto that until almost the end of EVA-2."

With the old ammonia tank safely locked to the station's robot arm, Stott and Olivas will move to the outboard end of the Columbia module and retrieve two experiment packages, mounting them in Discovery's cargo bay for return to Earth.

Fuglesang, Olivas and Hernandez inspect the ammonia tank assembly.

The next day, the shuttle astronauts will focus on logistics transfers from the MPLM, moving the fluid physics, materials science and freezer racks to the space station. Olivas and Fuglesang will end the day retiring to the Quest airlock to gear up for spacewalk No. 2 on Aug. 30.

The goal of the second EVA is to finish the ammonia tank swap out. With the old ATA still attached to the station's robot arm, Olivas and Fuglesang will work in the back of the shuttle's cargo bay to unbolt the new tank from an external storage platform.

With his feet anchored to a foot restraint on the end of the arm, Fuglesang will hand carry the fully charged ATA from the shuttle's cargo bay up to the P1 truss segment.

"It has motivated me a little extra to go to the gym quite often," he said before launch.

He and Olivas then will slide the new tank into place and make the necessary structural and electrical connections, along with hooking up a nitrogen pressurization line and an ammonia coolant line.

With the new tank in place, the robot arm will release the old tank and Olivas will hold it in place for a handoff to Fuglesang. The Swedish astronaut, riding the robot arm, will carry the old tank back to Discovery's cargo bay where it will be bolted down on the same carrier used by the new tank for the ride to orbit.

The next day, the shuttle crew will enjoy a half-day off amid work to continue logistics transfers from the MPLM The day after that, Olivas and Fuglesang will stage a third and final spacewalk to deploy an external cargo mounting mechanism, swap out a rate gyro assembly and make preparations for the attachment next year of the new Tranquility module.

Tranquility, also known as node 3, is the third multi-hatch connecting module built for the space station. It will be mounted on the central Unity module's left port directly across from the Quest airlock. The new Air Revitalization System rack and the COLBERT treadmill ultimately will be installed in Tranquility.

To pave the way for Tranquility's attachment, Olivas and Fuglesang plan to run two 55-foot-long electrical cables from the station's central power truss to the port side of the Unity module, unrolling the cables and tying them down as they go.

"These cables are about an inch-and-a-half to two inches in diameter and they're really stiff," Scoville said. "If you bend them, they'll hold that shape pretty well. And so we'll definitely be aware of any sort of memory, or stiffness, that these cables may have or if they want to retain the shape they initially had."

The spacewalkers will carry the cables from the Quest airlock rolled up in loops about two feet across.

"With each coil, we've taken one of these copper wire ties ... and we twist each loop with one of these wire ties," Scoville said. "As they pull off one loop, they can release that one wire tie, pull off maybe just five or so feet, secure that down to structure while they hold onto the rest of it. They can move down the truss structure a little bit, undo one twist tie, get the second loop off and start working on that.

"As controlled as that may sound, cables have always presented a challenge in the past just because they do have a lot of memory and sort of a mind of their own," he said. "We've done our best to try to control that."

Said Olivas: "Just think about when you're hanging up Christmas lights. The Christmas before you end up just kind of sticking them in the box and then when it's time for Christmas, you pull them out, you think to yourself, oh, what did I do?"

The cable coils "are big and they're bulky, but when we pull them out of the bag it seems like every time we pull them out it's just like pulling out one of those big strands of lights," he said. "You don't have a ladder you can use up in space, you're floating around there. So it is a bit of a challenge. But we've trained it, we've had an opportunity to work with the engineering community to make sure we understand all the aspects of that EVA. So we're well prepared for it."

With the third spacewalk behind them, the Discovery astronauts will enjoy another half-day off after spending the morning on final MPLM transfers. The next day - Sept. 3, assuming an on-time launch - the crew will close up the Leonardo module and Ford will use the station's robot arm to move it back to its mounting point in Discovery's cargo bay.

With Leonardo safely locked down for the trip home, the astronauts will hold a traditional farewell ceremony in the Harmony module before Sturckow, Ford, Hernandez, Olivas, Forrester, Fuglesang and Kopra float back into the shuttle and hatches between the two spacecraft are closed and leak tested.

Undocking is scheduled the following day, around 4:50 p.m. on Sept. 4. With Ford at the controls, Discovery will pull out in front of the station before initiating a 360-degree photo-documentation fly around at a distance of about 600 feet. A rocket firing at the end of the maneuver will cause the shuttle to slowly leave the area.

At that point, Hernandez and Forrester will carry out a final inspection of Discovery's nose cap and wing leading edge panels to look for signs of micrometeoroid or space debris impact damage that might have occurred since the inspection they carried out the day after launch.

Assuming no problems are found, the astronauts will test the shuttle's re-entry systems the next day and pack up for landing Sept. 6 back at the Kennedy Space Center.

"We're really happy to have this mission," Sturckow said in an interview. "It's great to fly on the shuttle, we've had a great flow together as a crew with our training. We're excited and looking forward to the mission."

STS-128 Mission Priorities[1]

As with every space shuttle flight, NASA has established a set of mission priorities and defined what is required for minimum and full mission success. The priorities, in order, are:

Mission Priorities [CAT 1 & 2]

- ❑ Dock to PMA-2 and perform mandatory safety briefing for all crew members.
- ❑ Berth MPLM to ISS Node 2 nadir; activate and check out MPLM.
- ❑ Transfer mandatory quantities of water from Orbiter to ISS per Flight 17A TPL.
- ❑ Rotate E19/20 FE-2 crew member (Kopra) with E20/21 FE-2 crew member (Stott).
- ❑ Transfer Node 3 Air Revitalization System rack (N3 ARS)
- ❑ Transfer Treadmill-2 (t-2) rack and components; stow in a temporary location on ISS.
- ❑ Transfer critical cargo items per Flight 17A TPL.
- ❑ Transfer and install ISS MPLM racks to the ISS: CQ, MELFI-2, FIR, MSRR.
- ❑ Transfer new ATA from the LMC to the P1 site.
- ❑ Return used P1 ATA to the LMC.
- ❑ Return MPLM to the Orbiter payload bay.
- ❑ Transfer EuTEF from Columbus EPF to the LMC.
- ❑ Perform minimum crew handover of 2 hours per rotating crew member (which includes crew safety handover).
- ❑ Transfer MISSE 6A and 6B from the Columbus EPF to the sidewall carriers in the Orbiter payload bay.
- ❑ Transfer remaining cargo items per flight 17A TPL.

Mission Priorities [CAT 3]

- ❑ Perform HTV preparation tasks: DCP Switch checkout, OBTs, HCP checkout, SSRMS triple walk-off, charge BSA/REBA batteries, resize EMU.
- ❑ R&R S0 RGA.
- ❑ S3 Upper Outboard PAS deploy
- ❑ Additional Node 3 prep tasks (20A):

  a. Pre-route external channel 1/4 power and data cables and channel 2/3 power and data cables from S0 to Node 1 in preparation for Node 3 installation.
  b. Temporarily connect Node 1 port/PMA heater umbilical and install bootie on Node 1 nadir LTA connector.
  c. R&R RPCM S01A-D.

- ❑ Perform Hydrogen ORU calibration (OGS pressure sensor).
- ❑ Perform ISS payload status checks as required.
- ❑ Perform daily middeck activities to support payloads:

  a. GLACIER
  b. Mice Drawer System (MDS)
  c. National Lab Pathfinder (NLP)-vaccine-5
  d. Human Research Program (HRP)/ISS Integrate Immune (SDBI 1900)
  e. HRP/sleep long and sleep short (SDBI 1634)
  f. HRP/spinal elongation

- ❑ Perform ISS payload research operations tasks.

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[1] Word for word from the NASA Mission Operations Directorate flight readiness assessment.

- ❑ Transfer LHAs and BBAs from MPLM to ISS and return failed ones in MPLM.
- ❑ Perform CQ outfitting and activation to support crew habitation.
- ❑ Perform DTO-701A TRIDAR activities.
- ❑ Install SSRMS Camera Lens Cover on LEE B wrist camera (EVA).
- ❑ Transfer O2 from the Orbiter to the ISS A/L HPGTs if Orbiter margin allows.
- ❑ Perform water sampling for EVA ground testing.
- ❑ Perform the following IVA get-ahead tasks if time permits. Tasks do not fit but the crew is trained.

a. Perform CQ outfitting and activation as required to support full crew habitation.
b. Re-pressurization PMA 3.
c. Perform Node 1 port bulkhead feed through modifications in prep for Node 3: -portable water (J33), waste water (J30), ARS air sample (J40), N2 (J44), O2 (J45)
d. Remove heat shield from APFR #5.
e. Perform leak checks of Node 1 port bulkhead feedthroughs.
f. Install Node 2 HTV power jumper to Node 2 nadir vestibule bulkhead connector.

Mission Priorities [CAT 4]

- ❑ Perform the following EVA get-ahead tasks if time permits. Tasks do not fit but the crew is trained.

a. Remove Node 1 slidewire.
b. Reposition FGB LAN connector on Node 1 port.
c. Install GPS AA#2 and #4 on S0.
d. Install Node 1 MMOD shield.
e. Install camera lens cover on SSRMS LEE B elbow camera. (HTV)
f. Deploy S3 Nadir Outboard PAS.
g. Install bootie/ground connecting sleeves.
h. Add wire tie to airlock handrail to identify MMOD strike (sharp edge).

NASA STS-128 Mission Overview[2]

On the heels of the completion of the Japanese segment of the International Space Station, the shuttle Discovery is poised to blast off on a 13-day mission to deliver more than 7 tons of supplies, science racks and equipment, as well as additional environmental hardware to sustain six crew members on the orbital outpost.

Led by veteran shuttle Commander Rick Sturckow (STUR-coe) (Col., USMC), 48, Discovery is set for launch no earlier than 1:58 a.m. EDT Aug. 24 from Launch Pad 39-A at the Kennedy Space Center. This will be Sturckow's fourth flight into space. Kevin Ford (Col., USAF, ret.), 49, will serve as Discovery's pilot in his first flight into space. Patrick Forrester (Col., USA, ret.), 52, is making histhird flight into space.

The flight engineer for launch and landing is Jose Hernandez, 47. The son of an itinerant Mexican farming family, he did not learn English until he was 12 years old. Hernandez, on his first flight, will be involved in cargo transfer operations and the operation of the shuttle's robotic arm.

Lead spacewalker John "Danny" Olivas (oh-LEE-vuhs), 44, is making his second flight into space, having also flown with Sturckow on his previous mission. Olivas will participate in all three of the mission's spacewalks. Christer Fuglesang (FYU-gel-sang) of the European Space Agency, 52, will conduct two spacewalks with Olivas in his second flight into space.

They are joined by NASA's Nicole Stott, 46, a former processing director for the shuttle Endeavour at the Kennedy Space Center, who replaces NASA astronaut Tim Kopra (CO-prah) (Col., USA), 46, as a long-duration crew member on the space station and a member of the Expedition 20 and 21 crews. Stott, who will conduct the mission's first spacewalk with Olivas, is scheduled to spend three months on the complex while Kopra returns home aboard Discovery. Stott plans to return in November on the shuttle Atlantis as part of the STS-129 crew.

The day after launch, Ford, Forrester and Hernandez will take turns at Discovery's aft flight deck as they maneuver the shuttle's robotic arm to reach over to the starboard sill of the orbiter to grapple the Orbiter Boom Sensor System, a 50-foot-long crane extension. The extension is equipped with sensors and lasers that will be used in the traditional daylong scan of Discovery's thermal protection heat shield and the reinforced carbon-carbon on the leading edges of the shuttle's wings.

This initial inspection of the heat shield will provide imagery experts on the ground a close-up look at the tiles and blankets on the shuttle's skin to determine if the shuttle is ultimately safe to re-enter the Earth's atmosphere. A follow-up inspection will take place after Discovery undocks from the station.

While the inspection takes place, Olivas, Fuglesang and Stott will prepare the spacesuits they will wear for the three spacewalks to be conducted out of the Quest airlock at the station. Other predocking preparations will occupy the remainder of the crew's workday.

The following day, on the third day of the flight, Discovery will be flown by Sturckow and Ford on its approach for docking to the station. After a series of jet firings to fine-tune Discovery's path to the complex, the shuttle will arrive at a point about 600 feet directly below the station about an hour before docking. At that time, Sturckow will execute a one-degree-per-second rotational "backflip" to enable Expedtion 20 Commander Gennady Padalka and Flight Engineer Mike Barratt, using digital cameras with 400 and 800 millimeter lenses, to snap hundreds of detailed photos of the shuttle's heat shield and other areas of potential interest – another data point for imagery analysts to pore over in determining the health of the shuttle's thermal protection system.

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[2] Word for word from the NASA STS-128 Press Kit, available on line at:
http://www.nasa.gov/mission_pages/shuttle/main/index.html

Once the rendezvous pitch maneuver is completed, Sturckow will fly Discovery to a point about 600 feet in front of the station before slowly closing in for a linkup to the forward docking port on the Harmony module. Less than two hours later, hatches will be opened between the two spacecraft to begin almost nine days of work between the two crews.

Discovery's arrival at the station two days after launch will again place 13 crew members on the complex. The shuttle crew will join Padalka of Russia, and flight engineers Barratt and Kopra of NASA, Roman Romanenko of Russia, Bob Thirsk of the Canadian Space Agency and Frank De Winne of the European Space Agency.

Aside from the delivery of Stott to join the station crew, the primary objective of the flight will be the transfer of the science and environmental racks to the complex to mark a quantum leap in the scientific capability of the orbital laboratory.

Housed for the ride to the station in the Leonardo Multi-Purpose Logistics Module in Discovery's payload bay are the Materials Science Research Rack (MSRR-1), the Minus Eighty Degree Laboratory Freezer for ISS (MELFI) and the Fluids Integration Rack (FIR).

MSRR-1 will be used for basic materials research related to metals, alloys, polymers, semiconductors, ceramics, crystals and glasses in the microgravity environment. MELFI will be used for long-term storage of experiment samples that are to be returned to Earth for detailed analysis. The FIR is a fluid physics research facility designed to host investigations in areas such as colloids, gels, bubbles, wetting and capillary action, and phase changes, including boiling and cooling.

Leonardo, which serves as a large moving van for supplies and equipment back and forth from the station, also is carrying a new crew quarters to provide more sleeping space for the expanded station crew members and a new exercise device called the Combined Operational Load Bearing External Resistance Treadmill, or COLBERT, coined after late-night cable entertainment personality Stephen Colbert.

COLBERT will be transferred to a temporary location in the Harmony node, but will ultimately reside in the new Node 3 module – Tranquility – that will be launched to the station in 2010 as a final connecting point for other modules on the U.S. segment of the complex, including the Cupola, a multi-windowed module to provide a vista-like view of the universe. COLBERT will not be checked out and activated until later this year.

In addition to the new treadmill, also referred to as "T2," the crew will transfer a new Air Revitalization System (ARS) rack to the station for use in Tranquility to maintain a pristine environment for the expanded six-person crew on the outpost. The system includes another carbon dioxide removal system bed similar to the Carbon Dioxide Removal Assembly (CDRA) that resides in the U.S. Destiny laboratory.

The rack will be temporarily stowed in the Japanese segment of the station until Tranquility is in place to accept it on a permanent basis. If the CDRA is operating when Discovery arrives at the station, the new ARS rack will be temporarily stowed in the Japanese Kibo module and not activated until it is installed in Tranquility next year. If a problem develops with the CDRA, however, the new rack could be temporarily installed in the Destiny lab in place of the current CDRA and activated to assist in the removal of carbon dioxide.

Ford and Barratt will hoist Leonardo out of Discovery's cargo bay using the station's Canadarm2 robotic arm on the fourth day of the flight and will berth it to the Earth-facing port on the Harmony module. Once leak checks are performed, the hatch to Leonardo will be opened to mark the start of transfer operations that will be supervised by Fuglesang and Hernandez.

Three spacewalks will be conducted on flight days 5, 7 and 9 during the docked phase of the mission.

The first spacewalk will see Olivas, who conducted two spacewalks on STS-117, and Stott venture outside to remove an empty ammonia tank from the port 1 (P1) truss of the station. The tank, which itself weighs about 1,800 pounds, contains 600 pounds of ammonia to provide the proper cooling for the thermal control system in the truss. Ammonia in the tank flows in the truss' Pump Module Assembly, which is the heart of the thermal control system.

Olivas will work in tandem with Stott to remove the used tank that will be grappled by the Canadarm2 through a fixed grapple bar. The grapple bar will be attached to the tank before it is parked on a cargo carrying platform in Discovery's payload bay for the trip home. The tank that will be removed still will contain about 200 pounds of ammonia but is considered used and ready for replacement.

Olivas and Stott also will remove two experiments from the hull of the European Columbus module during the first spacewalk. The European Technology Exposure Facility, or EuTEF, was installed during the STS-122 mission in February 2008. EuTEF is a suite of nine experiments designed to collect data during its lengthy stay in the microgravity environment. The spacewalkers also will remove a materials science experiment called Materials International Space Station Experiment (MISSE), a device resembling an open suitcase that enables a variety of experiments to be exposed to the space environment. This latest in the series of MISSE experiments was moved to the outside of Columbus from a prior location on the station during the STS-123 mission in March 2008.

Olivas will be joined by Fuglesang for the second spacewalk. Fuglesang conducted three spacewalks on his first mission, STS-116. This excursion will be exclusively devoted to installing a new Ammonia Tank Assembly on the P1 truss and stowing the empty tank on the cargo carrying platform in Discovery's payload bay.

Olivas and Fuglesang team up for the final spacewalk two days later to begin preparations for the arrival of the Tranquility connecting module, Node 3, and its Cupola viewing port scheduled for launch next year. The spacewalkers will begin by completing a task that could not be accomplished during the STS-127 mission; i.e., the deployment of a payload attachment bracket on the starboard truss to which several critical spare parts will be attached during the STS-129 mission later this year.

Next, Olivas and Fuglesang will route avionics systems cables from the S0 truss at the midpoint of the station's backbone to the port side of the complex where Tranquility will be permanently attached. After that, they will rig cables for heaters that will keep the berthing port warm on the port side of the Unity connecting module to which Tranquility will be mated.

They will replace a failed component on the S0 truss called a rate gyro assembly that works with the station's Global Positioning System (GPS) hardware to tell the station what its orientation is in relation to the Earth, replace a faulty power control module on the S0 that is used to route electricity to various components inside the complex and install two new GPS antennas on the S0 truss.

On the following day, flight day 10, the crew will enjoy some off-duty time and complete transfer operations before closing the hatch to Leonardo on flight day 11 so it can be unberthed from Harmony and returned to Discovery's payload bay. Ford and Hernandez will operate Canadarm2 from the robotics workstation on the station to demate Leonardo from its temporary parking spot and lower it onto latches in the shuttle's cargo bay.

Once the cargo module is berthed in Discovery, the two crews will say goodbye to one another and close the hatches between the shuttle and station to set the stage for undocking.

With Ford at the controls on flight day 12, Discovery will separate from the station. He will slowly back the shuttle away to a distance of about 400 feet from the station. At that point, he will conduct a radial flyaround of the complex before firing jets to depart the vicinity of the outpost.

With undocking complete, Ford, Forrester and Hernandez will use the shuttle's robotic arm and its Orbiter Boom Sensor System extension to conduct a "late" inspection of the orbiter's thermal heat shield – one more opportunity to ensure that it is in good shape to support landing.

Sturckow, Ford and Hernandez will conduct the traditional checkout of the shuttle's flight control systems and steering jets on flight day 13, setting Discovery up for its supersonic return to Earth on flight day 14. A special recumbent seat will be set up in the shuttle's lower deck for Kopra to ease his reorientation to a gravity environment for the first time in almost two months.

Finally, weather permitting, Sturckow and Ford will guide Discovery to a landing at the Kennedy Space Center on the evening of Sept. 5 to wrap up the 37th flight for the shuttle's fleet leader, the 128th mission in shuttle program history and the 30th shuttle visit to the International Space Station.

NASA STS-128 Payload Overview[3]

The space shuttle payload will include the Leonardo Multi-Purpose Logistics Module (MPLM) and the Lightweight Multi-Purpose Experiment Support Structure Carrier (LMC). The total payload weight, not counting the middeck, is 31,694 pounds. The expected return weight is 19,053 pounds.

On the middeck of the space shuttle, it will carry GLACIER, a freezer designed to provide cryogenic transportation and preservation capability for samples. The unit is a double locker equivalent unit capable of transport and operation in the middeck and in-orbit operation in the EXPRESS Rack.

The space shuttle will carry on its middeck (ascent) the following items: GLACIER (Sortie) with refrigerated samples, NLP-Vaccine (Sortie), MDS & Support HDW, HRP Integrated Immune (SDBI 1900), HRP Sleep Short (SDBI 1634) and Sleep Long, JAXA Area Dosimeter (PADLES3), JAXA Space Seed, JAXA Payload Maintenance, JAXA Rad Silk Refrigerated Samples, ESA-CARD, and ESA SOLO.

On its return, among the items carried on the middeck will be GLACIER (Sortie) with frozen samples, NLP-Vaccine (Sortie), ESA 3D-Space, Integrated Immune, Lada-VPU P3R root modules and frozen plant samples, HRP ISSMP frozen samples, JAXA Area Dosimeter (PADLES2), JAXA RAD Silk & Microbe refrigerated and frozen samples, and a double coldbag with refrigerated samples.

LEONARDO MULTI-PURPOSE LOGISTICS MODULE (MPLM) FLIGHT MODULE 1 (FM1)

The Leonardo Multi-Purpose Logistics Module (MPLM) is one of three differently named large, reusable pressurized elements, carried in the space shuttle's cargo bay, used to ferry cargo back and forth to the station. The STS-128 flight will be the second to the last time that Flight Module 1 (FM1) will be launched in its full configuration. After STS-128, FM1 will be modified to remove hardware to reduce the weight of the module so that more hardware can be launched on STS-131/Flight 19A. The cylindrical module includes components that provide life support, fire detection and suppression, electrical distribution and computers when it is attached to the station. The cylindrical logistics module acts as a "moving van" for the space station, carrying cargo, experiments and supplies for delivery to support the six-person crew on board the station, and to return spent materials, trash and unneeded hardware to Earth. The MPLM is designed to fit in the space shuttle cargo bay and can take up six bays. Each module is approximately 21 feet long and 15 feet in diameter.

On the STS-128 mission, Leonardo will carry two research racks, four station system racks, seven Resupply Stowage Platforms (RSPs), two Resupply Stowage Racks (RSRs), one Zero Stowage Rack (ZSR) and one Integrated Stowage Platform (ISP) and will include Aft Cone Stowage (first used on STS-126/ Flight Utilization Logistics Flight 2 on Nov. 14, 2008). The aft cone modification allows 12 additional cargo bags which are similar to the size of carry-on suitcases. In the aft endcone, additional Lithium Hydroxide (LiOH) canisters, which support the station's Environmental Control Life Support System (ECLSS) system, additional Remote Power Control Modules (RPCM), which support the Electrical Power System (EPS), as well as food containers and other hardware to support the crew will be flown.

In addition, the sixth set of Materials International Space Station Experiment (MISSE) labeled 6a and 6b will be removed by the spacewalk crew from Columbus and transferred into the MPLM for return to Earth. MISSE is a series of experiments mounted externally on the station that investigate the effects of long-term exposure of materials to the harsh space environment. MISSE 6a and 6b were launched by space shuttle Endeavour during mission STS-123 on March 13, 2008, and contained more than 400 specimens of various materials.

[3] Word for word from the NASA STS-128 Press Kit, available on line at: http://www.nasa.gov/mission_pages/shuttle/main/index.html

The two research racks carried in Leonardo are: Fluid Integrated Rack (FIR) and Materials Science Research Rack (MSRR). The four station system racks are: Crew Quarters (CQ), Minus Eighty-Degree Laboratory Freezer 2 (MELFI-2), Node 3 Air Revitalization System Rack (ARS), and Treadmill 2, which was renamed Combined Operational Load Bearing External Resistance Treadmill or COLBERT for short by NASA.

The following are more detailed descriptions on each of these racks:

Crew Quarters (CQ)

The crew quarters delivered on STS-128/17A will be installed in the Japanese Experiment Module (JEM) pressurized module. Two crew quarters are already installed in Node 2 and able to accommodate two crew members. The CQ provides private crew member space with enhanced acoustic noise mitigation, integrated radiation reduction material, controllable airflow, communication equipment, redundant electrical systems, and redundant caution and warning systems. The rack-sized CQ is a system with multiple crew member restraints, adjustable lighting, controllable ventilation, and interfaces that allow each crew member to personalize their CQ workspace.

Fluids Integrated Rack (FIR)

The Fluids Integrated Rack (FIR) is a complementary fluid physics research facility designed to host investigations in areas such as colloids, gels, bubbles, wetting and capillary action, and phase changes including boiling and cooling. Fluids under microgravity conditions perform differently than those on Earth. Understanding how fluids react in these conditions will lead to improved designs on fuel tanks, water systems and other fluid-based systems.

The FIR features a large user-configurable volume for experiments. The volume resembles a laboratory optics bench. An experiment can be built up on the bench from components, or it can be attached as a self-contained package, or a combination. The FIR provides data acquisition and control, sensor interfaces, laser and white light sources, advanced imaging capabilities, power, cooling, and other resources. Astronauts can quickly mount and set up the experiment with final operations accomplished by remote control from the NASA Glenn Research Center's Telescience Support Center (TSC) in Cleveland or from the principal investigator home institution. The FIR offers the crew members easy access to the back of the optics bench for maintenance and experiment reconfiguration.

Materials Science Research Rack 1 (MSRR-1)

The Materials Science Research Rack-1 (MSRR-1) will be used for basic materials research in the microgravity environment of the station. MSRR-1 can accommodate and support diverse Experiment Modules (EMs). In this way many material types, such as metals, alloys, polymers, semiconductors, ceramics, crystals, and glasses, can be studied to discover new applications for existing materials and new or improved materials. Initially, the MSRR-1 will house the European Space Agency-developed Materials Science Laboratory (MSL) and the Low Gradient Furnace (LFG). Sample cartridge assemblies will be inserted into the furnace and heated, then cooled down to resolidify the sample material free from the effects of gravity. MSRR-1 will be moved by the crew from the MPLM to its rack location in the Destiny laboratory.

Minus Eighty-Degree Laboratory Freezer 2 (MELFI-2)

Minus Eighty-Degree Laboratory Freezer for ISS (MELFI) is a European Space Agency-built, NASA-operated freezer that allows samples to be stored on the station at temperatures as low as -80 degrees centigrade. It comprises four independent dewars which can be set to operate at different temperatures. Each dewar is a cylindrical vacuum-insulated 75-liter container and can accommodate samples of a variety of sizes and shapes. The total capacity of the unit is 300 liters. The first MELFI unit, FU-1, was flown to the station on STS-121, installed in the Destiny laboratory, and commissioned by Thomas Reiter. The MELFI was subsequently relocated to the "Kibo" Japanese Experiment Module. The second one will be installed in the U.S. laboratory.

Node 3 Air Revitalization System Rack (N3 ARS)

The N3 ARS will provide a Carbon Dioxide Removal Assembly (CDRA) to remove carbon dioxide from the cabin atmosphere in the International Space Station. The rack also contains a Trace Contaminant Control Subassembly (TCCS) that removes potentially hazardous trace contaminants from the cabin atmosphere. The third element contained in the rack is called a Major Constituent Analyzer (MCA), which monitors the cabin atmosphere for major constituents (N2, O2, CO2, CH4, H2, and water vapor). The N3 ARS will be temporarily installed in the JEM pressurized module and eventually transferred to Node 3 when it arrives.

COMBINED OPERATIONAL LOAD BEARING EXTERNAL RESISTANCE TREADMILL (COLBERT)

Training for future exploration missions is a key goal for the International Space Station Program, and a new treadmill launching on STS-128 will help doctors determine just how important "training" is to humans on long-space journeys.

That's training as in exercise, and treadmill as in COLBERT, or the Combined Operational Load Bearing External Resistance Treadmill, so named for comedian Stephen Colbert of Comedy Central's "The Colbert Report."

The COLBERT will be the second treadmill on the space station, adding to a complement of six different exercise devices already in orbit that range from stationary bicycles to resistive exercise devices. First and foremost, the new treadmill is a critical countermeasure device that will be used to keep the international crew healthy while in orbit, and prepare them for return to Earth.

In addition, the COLBERT will feature data collection devices that will allow doctors and scientists to evaluate how effective the treadmill exercise is in reducing the amount of bone and muscle density loss due to life without gravity. Data on treadmill speed, session duration and body load of each crew member's exercise spaceflight-induced physiological changes in the cardiovascular, muscle, bone and sensorimotor systems.

The first experiment to use the COLBERT will be the Functional Task Test (FTT), a multidisciplinary study designed to identify the key underlying physiological factors that contribute to performance of functional tests that are representative of critical mission tasks for lunar and Mars operations. FTT's principal investigator is Jacob Bloomberg of NASA's Johnson Space Center (JSC), Houston.

This is not the first treadmill on the station. Station residents currently are using the Treadmill with Vibration Isolation System (TVIS) that's recessed in the floor of the Zvezda service module. Expedition 20 flight engineers Mike Barratt and Koichi Wakata just performed a complete overhaul of that treadmill to extend its life. Both treadmills will continue to be used, which will nearly double the availability of this critical work-out device for six-person crews.

While the purpose and general functionality of TVIS and COLBERT will be the same, there are a couple of significant differences. First, the actual treadmill for COLBERT was purchased from Woodway USA, Waukesha, Wis., while TVIS was developed in- house at JSC. The COLBERT and supporting subsystems (power, cooling, etc.) will be housed in an International Standard Payloads Rack (ISPR). The entire assembly will be housed initially in the station's Harmony module, then be moved to the Tranquility module after it is launched in early 2010. Tranquility is a pressurized module that will provide room for many of the space station's life support systems. Attached to the node is a cupola, which is a unique workstation with six windows on the sides and one on top.

Second, the two use different methods to keep the vibrations generated by runners from shaking the sensitive microgravity experiments on the station. TVIS uses an active system of throw masses that sense running forces and "throw" a counterweight in the opposite direction to counteract the vibrations. TVIS also uses some light tethers and a gyroscope. COLBERT was designed to be heavy, so that its inertial mass will be the primary method for dampening the vibrations. The total weight of the COLBERT rack is 2,200 pounds fully configured in orbit. Launch weight is around 1,600 pounds. Individual treadmill weighs about 300 pounds. The entire rack will have a modified Passive Rack Isolation System (PaRIS) that uses two-stage isolators, or springs, to dampen different vibration frequencies.

The main reasons for the different approach were to simplify the system, making it easier and less costly to maintain. The simpler design also is expected to result in higher reliability, making the new treadmill consistently available to the crew, which must work out daily to counteract the loss of bone and muscle density that is a side effect of long-duration stays in orbit. If all goes as expected, the COLBERT will have a five-year service life.

There are a number of COLBERT and TVIS similarities. Both have running surfaces made of aluminum. The COLBERT treadmill surface uses the exact same aluminum as a commercial treadmill, but a rubber coating is stripped off the top of the treads and that aluminum is anodized to provide surface roughness and protection.

Both treadmills meet the payload requirements for vibration isolation. COLBERT and TVIS are very close in most frequencies, but each is able to dampen some frequencies better than the other.

COLBERT's maximum speed is 12.4 miles an hour, but don't expect crew members to run that fast because 12.4 miles an hour is faster than the Olympic 100-meter race record. An average person runs 7- to- 8 miles an hour, and most crew members will run about 4- to- 8 miles an hour.

Another improvement is that COLBERT is designed so that ground experts tracking crew health in orbit can create individual exercise prescriptions and uplink them to the crew as a profile. COLBERT will use the same control interface as that used for the Advanced Resistive Exercise Device (ARED) so that crew members won't have to learn a new interface. The interface is modeled on commercial treadmills and looks nearly identical to what you'd find in many gyms on Earth. The standard rack connection device, the same seat tracks used in Boeing airliners, will provide locations where the crew can mount devices such as laptop computers so they can entertain themselves while exercising.

Each crew member is required to work out a total of two and a half hours a day, about an hour of that on the treadmill. Astronauts are expected to burn between 250 and 500 calories while working out on COLBERT, which has instrumented load cells and three-axis accelerometers that can measure the foot force of running. Ground experts will be able to use this information to determine how well they are being conditioned or losing their deconditioning, and adjust exercise prescriptions accordingly.

Setting up for an exercise session on COLBERT should be fairly simple. The first runner of the day will turn it on by flipping the rack power switch. After waiting a couple minutes for all systems to activate, they'll position the control interface to a location comfortable for them. They'll connect bungee cords to provide a load that will generate the foot force necessary to give the astronaut's bones and muscles a workout in the absence of gravity. They'll put on the harness that connects them to the bungees, set the desired load and verify that they agree with their prescription. Then, they'll log into the system, pick a profile, hit start and go. In the future, a new load system being developed by the European Space Agency will provide highly accurate, continuous force that's closer to a full one-gravity body weight.

The two treadmills provide side benefits for the entire crew, because as humans exercise they respire (breathe) and perspire (sweat) and that moisture is reclaimed by the station's systems that recycle moisture from the station's atmosphere.

NASA chose the acronym COLBERT after the television comedian's campaign for write-in votes to name the next module after himself. NASA chose to name the module Tranquility instead, in honor of the 40th anniversary of the first Apollo landing on the moon. Expedition 14 and 15 astronaut Suni Williams made the announcement on "The Colbert Report" two years after running the Boston Marathon in space.

The COLBERT rack, treadmill and support hardware will launch in the Leonardo Multi-purpose Logistics Module and be transferred to the station on flight day 5. The new workout machine will be set up and used after the shuttle Discovery departs.

MPLM BACKGROUND INFORMATION

The Italian-built, U.S.-owned logistics modules are capable of ferrying more than 7.5 tons (15,000 pounds) of cargo, spares and supplies. This is the equivalent of a semi-truck trailer full of station gear bringing equipment to and from the space station. Return equipment includes container racks with science equipment, science experiments from NASA and its international partners, assembly and spare parts; other return hardware items include completed experiments, system racks, station hardware that needs repair and refuse from the approximately 220-mile-high outpost. Some of these items are for disposal on Earth while others are for analysis and data collection by hardware providers and scientists.

Including STS-128, the MPLMs in total have flown nine times since 2001. This will be the sixth flight for Leonardo. Of the three MPLM modules, only two remain in active service to NASA for future flights. The space shuttle flies logistics modules in its cargo bay when a large quantity of hardware has to be ferried to the orbiting habitat at one time. The modules are attached to the inside of the bay for launch and landing. When in the cargo bay, the module is independent of the shuttle cabin, and there is no passageway for shuttle crew members to travel from the shuttle cabin to the module. After the shuttle has docked to the outpost, typically on the fourth flight day after shuttle launch, Leonardo is mated to the station using the station's robotic arm to the Node 2 nadir port. In the event of a failure or issue which may prevent the successful latching of the MPLM to the nadir port, the Zenith port can be used to mate the MPLM to the station. Nodes are modules that connect the elements to the station, and Unity was the first element to the station to connect the U.S. and Russian segments of the outpost. For its return trip to Earth, Leonardo will be detached from the station and positioned back into the shuttle's cargo bay.

Dimensions:

Length: 21 feet
Diameter: 15 fee
Payload Mass (launch): 27,510 lbs
Payload Mass (return): 16,268 lbs
Empty Weight: 9,810 lbs

NASA solely owns the modules which were acquired in a bartered agreement between NASA and the Italian Space Agency for using the modules in exchange for allowing the Italians to have crew time on board station.

Leonardo is named after the Italian inventor and scientist Leonardo da Vinci. It was the first MPLM to deliver supplies to the station. The two other modules are named Raffaello, after master painter and architect Raffaello Sanzio, and Donatello, for one of the founders of modern sculpture, Donato di Niccolo Di Betto Bardi. Raffaello has flown three times. Leonardo has flown the most because it is equipped with programmable heater thermostats on the outside of the module that allow for more mission flexibility. Donatello is not currently on the shuttle manifest to fly because of the cost associated with getting the module up to flight status code. There is only one more MPLM flight scheduled on STS-131/19A before the station is complete and space shuttle retires in 2010.

Under its Checkout, Assembly and Payload Processing Services (CAPPS) contract with NASA, Boeing processes every major payload that flies on all space shuttle flights, and the team performs all aspects of payload support, including the planning and receiving of payloads, payload processing, maintenance of associated payload ground systems, logistics support, integration of payloads with the space shuttle, launch support and space shuttle post-landing payload activities. On this particular mission, Leonardo's micrometeoroid panel bolts were inspected by Boeing technicians at the recommendation of the Marshall Space Flight Center MPLM project office and the chief engineer's office. All 290 bolts were inspected and 16 were replaced on 68 debris shields.

THE LIGHTWEIGHT MULTI-PURPOSE EXPERIMENT SUPPORT STRUCTURE CARRIER (LMC)

Located behind Leonardo in the space shuttle payload is the Lightweight Multi-Purpose Experiment Support Structure Carrier (LMC), a non-deployable cross-bay carrier providing launch and landing transportation. The LMC is a light-weight shuttle stowage platform that is maintained by the Goddard Space Flight Center and ATK Space for NASA and has flown on four previous missions (STS-108/UF-1, STS-114/LF1, STS-121/ULF1.1 and STS-126/ULF2). The LMC weighs 1,108 pounds. The launch weight of the integrated LMC is 3,926 pounds and the return weight will be 4,146 pounds.

The LMC is the platform which carries the Ammonia Tank Assembly (ATA), a critical spare Orbital Replacement Unit (ORU), in the space shuttle payload bay to the International Space Station and returns with a spent ATA, as well as the European Technology Exposure Facility (EuTEF).

The LMC will be carrying a replacement ATA. The tank, installed on the port one truss, is part of the station's cooling system for the electronic components. The ATA that the space shuttle returns with will have about 30 percent of its ammonia remaining in its tank.

EuTEF will be removed from its orbital mounting platform outside of the Columbus module. There will be a special Contingency Pin Kit (CPK) carried on the LMC. The CPK provides the EVA crew with frontside access to the backside release mechanism of the Passive Flight Releasable Attach Mechanism (PFRAM) to Orbital Replacement Unit (ORU) restraint system if required for safe return of an ORU on the LMC.

EuTEF carries a suite of 13 different experiments in the fields of exobiology, fundamental physics, and technology requiring exposure to the space environment. The experiments and facility infrastructure are accommodated on the Columbus External Payload Adaptor (CEPA), consisting of an adapter plate, the Active Flight Releasable Attachment Mechanism and the connectors and harness. The experiments are mounted either directly on the adapter plate or an intermediate support structure that elevates them for optimum exposure to the direction of flight or pointing away from the Earth.

The suite of experiments on EuTEF consists of:

• Exposure Experiment (Expose): Exobiological organic samples exposure facility

• Dosimetric Telescope (DOSTEL): cosmic radiation environment measurement

• EuTEF Thermometer (EuTEMP): EuTEF's thermal environment measurement

• Earth Viewing Camera (EVC): Earth observing camera

• DEBris In-orbit Evaluator (DEBIE-2): Micrometeoroid and orbital debris detector

• Flux (Phi) Probe EXperiment (FIPEX): Atomic oxygen detector

• Material Exposure and Degradation Experiment (MEDET): Materials degradation examination

• Plasma Electron Gun Payload (PLEGPAY): Plasma discharge in orbit

• Experiments on Space Tribology (Tribolab): Testbed for tribology (study of friction on moving parts) and properties of materials

NASA STS-128 Spacewalk Overview[4]

EVA-1

Duration: 6 hours, 30 minutes
Crew: Olivas and Stott
IV Crew: Forrester
Robotic Arm Operators: Ford and Thirsk

EVA Operations
- ❑ **Old ammonia tank assembly removal**
- ❑ **EuTEF removal**
- ❑ **MISSE 6 removal**

The work to replace the ammonia tank assembly on the first port segment of the station's truss – P1 – will begin on the first spacewalk of the mission. Olivas and Stott will be removing the depleted tank from the truss, so that it may be picked up by the station's robotic arm for storage until after the second spacewalk.

To remove it from the station's truss, Olivas and Stott will disconnect two lines used to transfer its ammonia, two lines which provide nitrogen for pressurization, and two electrical connections and release four bolts. They'll then work together to lift the tank away from the truss and maneuver it into position for the robotic arm to latch onto.

While the arm is still holding the tank assembly, Stott will install a foot restraint on it as well, which she'll then climb into for the removal of the European Technology Exposure Facility, or EuTEF. While Stott gets into place, Olivas will document the experiment's condition by taking some photographs. Olivas will then detach the experiment by releasing one bolt, and Stott will lift it away from its place on the Columbus laboratory. From there, Ford and Thirsk will drive her via the robotic arm to the shuttle's cargo bay, where she'll work with Olivas to store it on a cargo carrier for transport back to Earth. One bolt will be used to attach it to the carrier.

The spacewalkers' final task will be the removal of the sixth Materials International Space Station Experiment – or MISSE. Stott will climb out of the robotic arm's foot restraint and meet Olivas back at Columbus. (Although MISSE is a NASA experiment, it is located on the exterior of the Columbus laboratory.) While he waits for Stott to arrive, Olivas will close the passive experiment containers in which the two parts of the MISSE experiment are housed, and disconnect two cables. Olivas will then remove the first of the containers and pass it on to Stott for installation in a storage location. The second will be removed and stowed by Olvias.

EVA-2

Duration: 6 hours, 30 minutes
Crew: Olivas and Fuglesang
IV Crew: Forrester
Robotic Arm Operators: Ford and Stott

EVA Operations
- ❑ **New ammonia tank assembly installation**
- ❑ **Old ammonia tank assembly storage**

[4] Word for word from the NASA STS-128 Press Kit, available on line at: http://www.nasa.gov/mission_pages/shuttle/main/index.html

The entire second spacewalk of the mission will focus on completing the ammonia tank assembly swap. Olivas will begin by removing insulation on the new ammonia tank while Fuglesang gets into position in the robotic arm's foot restraint. He and Olivas will then work together to release the four bolts securing the assembly to the cargo carrier inside the shuttle's cargo bay. Ford and Stott will then drive the robotic arm – carrying Fuglesang and both ammonia tanks – to the installation site on the P1 truss segment.

Olivas will meet Fuglesang there, and together they'll drive the four bolts that will hold it in place. Olivas will then connect two electrical cables and four fluid lines.

With the new tank assembly installed, Olivas and Fuglesang will prepare for the storage of the old tank assembly, still latched to the robotic arm. Olivas will tether the old tank assembly to himself and then give Ford and Stott the OK to command the robotic arm to release it. Then Fuglesang will attach his tether to the assembly and Olivas will remove his tether, allowing Fuglesang and the old tank to make their way back to the shuttle's cargo bay via robotic arm.

Once there, Olivas and Fuglesang will install it on the cargo carrier with four bolts.

EVA-3

Duration: 6 hours, 30 minutes
Crew: Olivas and Fuglesang
IV Crew: Forrester
Robotic Arm Operators: None

EVA Operations:
- ❑ **S3 upper, outboard payload attachment system deploy**
- ❑ **S0 rate gyro assembly replacement**
- ❑ **S0 remote power control module replacement**
- ❑ **Pressurized mating adapter 3 heater cable connection**
- ❑ **Tranquility node avionics cable routing**
- ❑ **Unity node slidewire removal**
- ❑ **Robotic arm camera and light assembly insulation installation**

The first tasks of the final spacewalk of the mission will finish work left by the previous space shuttle mission. The STS-127 spacewalkers completed the deployment of the one cargo attachment system on the P1 truss segment, but had to leave the set up of similar systems on S3 for future missions. On STS-119 a jammed detent pin on the first of the systems prevented them from deploying the P1 system. A special tool was built to assist with the deployment. The STS-127 spacewalkers were successful in clearing the jam. Olivas and Fuglesang will have the same tool on hand for use if needed.

If the detent pin does not jam, however, the cargo attachment system will be set up by removing brackets and pins holding it in place, moving it into its correct position and then reinstalling the brackets and pins.

Once that's complete, Olivas and Fuglesang will work together to remove and replace a failed rate gyro assembly in the center of the station's truss. To remove the failed assembly, Olivas will disconnect two cables and remove two bolts. Fuglesang will remove the final two holding the assembly in place, and then Olivas will remove it and temporarily store it nearby. To install the new one, Olivas and Fuglesang will each drive four bolts, and Olivas will then connect its two cables before moving on to the next task.

At this point in the spacewalk, Olivas and Fuglesang will split up. Olivas will set up heater cables that will be used to keep the PMA 3 berthing port between the Unity and the coming Tranquility node warm so it can be pressurized. This will allow the station crew to prepare the vestibule for Tranquility node's arrival. That will involve disconnecting four cables and wire-tying them into place along a handrails on the Unity node. One of them will be connected to an outlet on Unity, the rest will have caps installed on them.

Meanwhile, Fuglesang will replace a failed remote power control module on the center segment of the station's truss. To remove the failed module, he'll simply release one bolt. To install the new unit, he'll slide it into place on a guide rail and then secure it using one bolt. He'll follow that up by installing an insulation sleeve on a cable inside the truss.

With those tasks done, Fuglesang and Olivas will come together again in the center of the truss to route avionics systems cables. They'll be using wire ties to secure two cable bundles to handrails along the truss system and the Unity node, and then a panel on the truss.

Olivas will wrap up the spacewalk by removing a damaged slidewire from a stanchion on Unity, while Fuglesang installs a lens cover on a camera and light assembly on the space station's robotic arm.

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STS-128: Quick-Look Mission Data

Position/Age	Astronaut/Flights	Family/TIS	DOB/Seat
Commander	USMC Col. Frederick Sturckow	M/?	08/11/61
48	3: STS-88,105,117	37.7 *	Up-1/Dn-1
Pilot	Kevin Ford, Ph.D.	M/2	07/07/60
49	0: Rookie	0.0	Up-2/Dn-2
MS1	Patrick Forrester	M/2	03/31/57
52	2: STS-105,117	25.9	Up-3/Dn-3
MS2/RMS	Jose Hernandez	M/4	07/07/62
47	0: Rookie	0.0	Up-4/Dn-4
MS3/EV1	John Danny Olivas, Ph.D.	M/5	05/25/65
44	1: STS-117	14.0	Up-5/Dn-5
MS4/EV2	Christer Fuglesang, Ph.D.	M/3	03/18/57
52	1: STS-116	13.0	Up-6/Dn-6
MS5/EV3/ISS	Nicole Stott	M/1	11/19/62
46	0: Rookie	0.0	Up-7
ISS 20 CDR	Gennady Padalka, CIS	M/3	06/21/58
51	3: Mir E26, ISS-9,ISS-19/20	531.5	N/A
ISS-20 FE	Michael Barratt, M.D., NASA	M/5	04/16/59
50	1: ISS-19/20	146.5	N/A
ISS 20 FE	USA Col. Timothy Kopra	M/2	04/09/63
46	1: STS-127/ISS-20/128	35.1	Dn-7
ISS-20 FE	Maj. Roman Romanenko, CIS	M/1	08/09/71
38	1: ISS-20	0.0	N/A
ISS-20 FE	Frank De Winne, ESA	M/3	04/25/61
48	2: Soyuz TMA-1,ISS-20	9.0	N/A
ISS-20 FE	Robert Thirsk, M.D., CSA	M/?	08/17/53
56	2: STS-78,ISS-20	17.0	N/A

Shuttle Hardware and Flight Data	
STS Mission	STS-128 (flight 128)
Orbiter	Discovery (37th flight)
Payload	MPLM, ATA, crew rotation
Launch	01:36:05 AM 08.25.09
Pad/MLP	LC-39A/MLP-2
Prime TAL	Zaragoza, Spain
Landing	08:40:05 PM 09.06.09
Landing Site	Kennedy Space Center
Duration	13+1+2 days
Discovery	323/04:19:34
STS Program	1,224/02:13:53
MECO	135.7 X 35.7 sm
OMS Ha/Hp	141.5 X 97.8 sm
ISS docking	220 statute miles
Period	92.06
Inclination	51.6
Velocity	17,183.47
EOM Miles	5,325,646
EOM Orbits	202
SSMEs	2052 / 2051 / 2047
ET/SRB	ET-132/Bi139/RSRM 107
Software	OI-34
Left OMS	LP01/40
Right OMS	RP03/38
Forward RCS	FRC3/37
OBSS/RMS	TBD/202
Cryo/GN2	5 PRSD/6 GN2
Spacesuits	3

International Space Station

STS-128 Mission Patch

Flight Plan	EDT
Docking	
8/26/09	10:27 PM
EVA-1	
8/28/09	07:26 PM
EVA-2	
8/30/09	06:56 PM
EVA-3	
9/1/09	06:26 PM
Undocking	
9/4/09	04:48 PM
Landing	
9/6/09	08:40 PM

Flight Control Personnel	
Richard Jones	Ascent
Tony Ceccacci	Orbit 1 FD (lead)
Kwatsi Alibaruho	Orbit 2 FD
Gary Horlacher	Planning
Richard Jones	Entry
Ron Spencer	ISS Orbit 1 FD
Heather Rarick	ISS Orbit 2 FD (lead)
Royce Renfrew	ISS Orbit 3 FD
Pete Nickolenko	Launch director
C. Blackwell-Th.	NTD
Mike Moses	MMT
Mike Curie	Countdown PAO
Rob Navias	Ascent PAO

This will be the...	
128th	Shuttle mission
15th	Post-Columbia mission
103rd	Post-Challenger mission
37th	Flight of Discovery
33rd	Night launch
75th	Launch off pad 39A
20th	Night launch off pad 39A
TBD	51.6-degree inclination
23rd	Night landing
72nd	KSC landing
17th	KSC night landing
23.59	Years since STS-51L
6.57	Years since STS-107

* Ages as of launch date *Days in space as of: 8/19/09

Compiled by William Harwood

STS-128: Quick-Look Program Statistics

Orbiter	D/H:M:S	Flights	Most Recent Flight
Challenger*	062/07:56:22	10	STS-51L: 01/28/86
Columbia*	300/17:40:22	28	STS-107: 01/16/03
Discovery	323/04:19:34	36	STS-119: 03/15/09
Atlantis	271/04:44:15	30	STS-125: 5/11/09
Endeavour	266/15:33:20	23	STS-127: 07/15/09
Total	**1,224/02:13:5**	**127**	* Vehicle lost

Launches	LC-39A	LC-39B	Total	
Night	19	13	32	Daylight:
Daylight	55	40	95	SR+3 mins
Total	74	53	127	to
Most Recent	7/15/09	12/9/06		SS-3 mins

Landings	KSC	EAFB	WSSH	Total
Night	16	6	0	22
Daylight	55	47	1	103
Total	71	53	1	125
Most Recent	7/31/09	5/24/09	3/30/82	

STS Aborts	Date	Time	Abort	Mission
Discovery	6/26/84	T-00:03	RSLS-1	STS-41D
Challenger	7/12/85	T-00:03	RSLS-2	STS-51F
Challenger	7/29/85	T+05:45	ATO-1	STS-51F
Columbia	3/22/93	T-00:03	RSLS-3	STS-55
Discovery	8/12/93	T-00:03	RSLS-4	STS-51
Endeavour	8/18/94	T-00:02	RSLS-5	STS-68

Increment	Launch	Land	Duration	Crew
ISS-01	10/31/00	03/21/01	136/17:09	2
ISS-02	03/08/01	08/02/01	147:16:43	3
ISS-03	08/10/01	12/17/01	117/02:56	3
ISS-04	12/05/01	06/19/02	181/00:44	3
ISS-05	06/05/02	12/07/02	171/03:33	3
ISS-06	11/23/02	05/03/03	161/01:17	3
ISS-07	04/26/03	10/28/03	184/21:47	2
ISS-08	10/18/03	04/30/04	194/18:35	2
ISS-09	04/19/04	10/23/04	187/21:17	2
ISS-10	10/14/04	04/24/05	192/19:02	2
ISS-11	04/15/05	10/11/05	179/23:00	2
ISS-12	10/01/05	04/08/06	189/19:53	2
ISS-13	03/30/06	09/28/06	182/22:44	2/3
ISS-14	09/18/06	04/20/07	215/08:23	3
ISS-15	03/07/07	10/21/07	196/17:05	3
ISS-16	10/10/07	04/19/08	191/19:07	3
ISS-17	04/08/08	10/24/08	198/16:20	3
ISS-18	10/12/08	04/08/09	178/00:15	3
ISS-19	03/26/09	N/A	N/A	3
ISS-20	05/27/09	TBD	TBD	6

Demographics	127	128
Total Fliers	502	505
Nations	36	36
Male	451	453
Female	51	52
Total Tickets	1,102	1,109
United States	324	327
United States men	282	284
United States Women	42	43
USSR	72	72
USSR Men	70	70
USSR Women	2	2
CIS	32	32
CIS Men	31	31
CIS Women	1	1
Non US/Russian	74	74
Men	68	68
Women	6	6
Men with 7 flights	2	2
Men with 6 flights	6	6
Women/6	0	0
Men/5	15	15
Women/5	6	6
Men/4	58	59
Women/4	6	6
Men/3	69	69
Women/3	6	6
All/2	132	133
All/1	202	203

Minimum Duration STS Missions	
1. Columbia/STS-2	Fuel cell
11/21/81	MET: 2/06:13
2. Atlantis/STS-44	IMU
11/19/91	MET: 6/23:52
3. Columbia/STS-83	Fuel cell
4/4/97	MET: 3/23:13

Soyuz Aborts/Failures	
Soyuz 1 Entry Failure	04/24/67
Soyuz 11 Entry Failure	06/30/71
Soyuz 18A Launch Abort	04/05/75
Soyuz T-10A Pad Abort	09/26/83

Shuttle Failures	
1. STS-51L/Challenger	01/28/86
RH SRB at T+73s	
2. STS-107/Columbia	02/01/03
Left wing breach/re-entry	

Compiled by William Harwood

STS-128 NASA Crew Thumbnails

Position/Age	Astronaut/Flights/Education	Fam/TS	DOB/Seat	Home/BKG	Hobbies/notes
Commander	USMC Col. Frederick Sturckow	M/?	08/11/61	Lakeside, Calif.	Flying and physical
Age: 48	3: STS-88,105,117	37.7 *	Up-1/Dn-1	Desert Storm	training; > 4,790 hours
	Bachelor's in mechanical engineering			USAF test pilot	flying time in 50 aircraft
Pilot	Kevin Ford, Ph.D.	M/2	07/07/60	Montpelier, Ind.	No hobbies listed; >4,300 hours
49	0: Rookie	0.0	Up-2/Dn-2	USAF test pilot	hours flying time; F-16 test
	Doctorate in astronautical engineering			Comm. Licenses	pilot
MS1	Patrick Forrester	M/2	03/31/57	El Paso, Tex.	Baseball, running;
52	2: STS-105,117	25.9	Up-3/Dn-3	West Point	>4,400 hours flying time;
	Master's in mechanical/aerospace engineering			Helicopter pilot	
MS2/RMS	Jose Hernandez	M/4	07/07/62	Stockton, Calif.	No hobbies listed
47	0: Rookie	0.0	Up-4/Dn-4	Materials science	
	Master's in electrical/computer engineering			Lawrence Liv.	
MS3/EV1	John Danny Olivas, Ph.D.	M/5	05/25/65	El Paso, Tex.	Running, weight lifting,
44	1: STS-117	14.0	Up-5/Dn-5	Aircraft engineer	hunting, fishing, surfing.
	Doctorate in mechanical engineering			JPL engineer	
MS4/EV2	Christer Fuglesang, Ph.D.	M/3	03/18/57	Stockholm	Sports, sailing, skiing,
52	1: STS-116	13.0	Up-6/Dn-6	CERN	Frisbee, games, reading.
	Doctorate in particle physics			Math teacher	
MS5/EV3/ISS	Nicole Stott	M/1	11/19/62	Clearwater, Fla.	Flying, snow skiing, scuba
46	0: Rookie	0.0	Up-7	Shuttle engineer	diving, woodworking,
	Master's in engineering management			Private pilot	painting, gardening
ISS 20 CDR	Gennady Padalka, CIS	M/3	06/21/58	Krasnodar, Russia	Theater, sky diving
51	3: Mir E26, ISS-9,ISS-19/20	531.0	N/A	AF pilot	>300 parachute jumps
	Engineering/ecology			>1500 hours	
ISS-20 FE	Michael Barratt, M.D., NASA	M/5	04/16/59	Camas, Wash.	Family and church activity,
50	1: ISS-19/20	146.0	N/A	NASA surgeon,	writing, sailing, boat
	MD in aerospace medicine			Mir support	restoration and maintenance
ISS 20 FE	USA Col. Timothy Kopra	M/2	04/09/63	Austin, TX	Running, swimming, biking;
46	1: STS-127/ISS-20/128	34.6	Dn-7	Desert Storm/	military/experimental
				Shield chopper plt	helicopter pilot
ISS-20 FE	Maj. Roman Romanenko, CIS	M/1	08/09/71	Schelkovo, Russia	Underwater hunting, tennis,
	1: ISS-20	0.0	N/A	Tu-134 pilot	auto repair, tourism,
	Russian Air Force pilot school			>500 hours	yachting, volllyball, music
ISS-20 FE	Frank De Winne, ESA	M/3	04/25/61	Ghent, Belgium	Football, small PC program,
	2: Soyuz TMA-1,ISS-20	9.0	N/A	Mirage pilot	gastronomy
	Master's, civil engineering			>2,300 hours	
ISS-20 FE	Robert Thirsk, M.D., CSA	M/?	08/17/53	New Westminster,	None listed
	2: STS-78,ISS-20	17.0	N/A	B.C.; family doctor	
				CSA astronaut	

Current Space Demographics (post STS-127)

Post STS-127	
Total Fliers	502
Nations	36
Men	451
Women	51
Total Tickets	1102
United States	324
US Men	282
US Women	42
Soviet Union	72
USSR Men	70
USSR Women	2
CIS	32
CIS Men	31
CIS Women	1
Others	74
Other Men	68
Other Women	6
Men with 7 flights	2
Women with 7 flights	0
Men with 6 flights	6
Women with 6 flights	0
Men with 5 flights	15
Women with 5 flights	6
Men with 4 flights	58
Women with 4 flights	6
Men with 3 flights	69
Women with 3 flights	6
All with 2 flights	132
All with 1 flight	202
TOTAL	502
In-flight Fatalities	18
U.S. Fatalities	13
Soviet/CIS Fatalities	4
Other Nations	1

	Nation	No.
1	Afghanistan	1
2	Austria	1
3	Belgium	2
4	Brazil	1
5	Britain	1
6	Bulgaria	2
7	Canada	8
8	China	6
9	CIS	32
10	Cuba	1
11	Czech.	1
12	E. Germany	1
13	France	9
14	Germany	9
15	Hungary	1
16	India	1
17	Israel	1
18	Italy	5
19	Japan	7
20	Malaysia	1
21	Mexico	1
22	Mongolia	1
23	Netherlands	2
24	N. Vietnam	1
25	Poland	1
26	Romania	1
27	Saudi Arabia	1
28	Slovakia	1
29	South Africa	1
30	South Korea	1
31	Spain	1
32	Sweden	1
33	Switzerland	1
34	Syria	1
35	USA	324
36	USSR	72
	TOTAL	502

Rank	Space Endurance	Days/FLTs
1	**Sergei Krikalev**	**803/6**
2	Sergei Avdeyev	748/3
3	Valery Polyakov	679/2
4	Anatoly Solovyev	652/5
5	Alexander Kaleri	611/4
6	Victor Afanasyev	556/4
7	Yury Usachev	553/4
8	Musa Manarov	541/2
9	Yuri Malenchenko	515/4
10	Alexander Viktorenko	489/4
11	Nikolai Budarin	446/3
12	Yuri Romanenko	430/3
13	Alexander Volkov	392/3
14	Yury Onufrienko	389/2
15	Vladimir Titov	387/4
16	Gennady Padalka	387/2
17	Vasily Tsibliev	383/2
18	Valery Korzun	382/2
19	Pavel Vinogradov	381/2
20	**Peggy Whitson**	**377/2**
21	Leonid Kizim	375/3
22	Mike Foale	374/6
23	Alexander Serebrov	374/4
24	Valery Ryumin	372/4
25	Mike Fincke	366/2
26	Vladimir Solovyev	362/2
27	Mikhail Tyurin	344/2
28	Talgat Musabayev	342/3

Rank	Top Spacewalkers	EVAs/H:M
1	**Anatoly Solovyov**	**16/82:22**
2	**Mike Lopez-Alegria**	**10/67:40**
3	Jerry Ross	9/58:21
4	John Grunsfeld	8/58:30
5	Steven Smith	7/49:48
6	Scott Parazynski	7/47:05
7	Joe Tanner	7/46:29
8	Robert Curbeam	7/45:33
9	Niolai Budarin	8/44:25
10	James Newman	6/43:13

Projected Space Demographics (post STS-128)

Post STS-128	
Total Fliers	**505**
Nations	36
Men	453
Women	52
Total Tickets	1109
United States	**327**
US Men	284
US Women	43
Soviet Union	**72**
USSR Men	70
USSR Women	2
CIS	**32**
CIS Men	31
CIS Women	1
Others	**74**
Other Men	68
Other Women	6
Men with 7 flights	2
Women with 7 flights	0
Men with 6 flights	6
Women with 6 flights	0
Men with 5 flights	15
Women with 5 flights	6
Men with 4 flights	59
Women with 4 flights	6
Men with 3 flights	69
Women with 3 flights	6
All with 2 flights	133
All with 1 flight	203
TOTAL	**505**
In-flight Fatalities	**18**
U.S. Fatalities	13
Soviet/CIS Fatalities	4
Other Nations	1

	Nation	No.
1	Afghanistan	1
2	Austria	1
3	Belgium	2
4	Brazil	1
5	Britain	1
6	Bulgaria	2
7	Canada	8
8	China	6
9	CIS	32
10	Cuba	1
11	Czech.	1
12	E. Germany	1
13	France	9
14	Germany	9
15	Hungary	1
16	India	1
17	Israel	1
18	Italy	5
19	Japan	7
20	Malaysia	1
21	Mexico	1
22	Mongolia	1
23	Netherlands	2
24	N. Vietnam	1
25	Poland	1
26	Romania	1
27	Saudi Arabia	1
28	Slovakia	1
29	South Africa	1
30	South Korea	1
31	Spain	1
32	Sweden	1
33	Switzerland	1
34	Syria	1
35	USA	327
36	USSR	72
	TOTAL	**505**

Rank	Space Endurance	Days/FLTs
1	**Sergei Krikalev**	**803/6**
2	Sergei Avdeyev	748/3
3	Valery Polyakov	679/2
4	Anatoly Solovyev	652/5
5	Alexander Kaleri	611/4
6	Victor Afanasyev	556/4
7	Yury Usachev	553/4
8	Musa Manarov	541/2
9	Yuri Malenchenko	515/4
10	Alexander Viktorenko	489/4
11	Nikolai Budarin	446/3
12	Yuri Romanenko	430/3
13	Alexander Volkov	392/3
14	Yury Onufrienko	389/2
15	Vladimir Titov	387/4
16	Gennady Padalka	387/2
17	Vasily Tsibliev	383/2
18	Valery Korzun	382/2
19	Pavel Vinogradov	381/2
20	**Peggy Whitson**	**377/2**
21	Leonid Kizim	375/3
22	Mike Foale	374/6
23	Alexander Serebrov	374/4
24	Valery Ryumin	372/4
25	Mike Fincke	366/2
26	Vladimir Solovyev	362/2
27	Mikhail Tyurin	344/2
28	Talgat Musabayev	342/3

Rank	Top Spacewalkers	EVAs/H:M
1	**Anatoly Solovyov**	**16/82:22**
2	**Mike Lopez-Alegria**	**10/67:40**
3	Jerry Ross	9/58:21
4	John Grunsfeld	8/58:30
5	Steven Smith	7/49:48
6	Scott Parazynski	7/47:05
7	Joe Tanner	7/46:29
8	Robert Curbeam	7/45:33
9	Niolai Budarin	8/44:25
10	James Newman	6/43:13

Space Fatalities

Name	Nation	Date	In-flight Fatalities
Komarov, Vladimir	USSR	04/24/67	Soyuz 1 parachute failure
Dobrovolsky, Georgy	USSR	06/29/71	Soyuz 11 depressurized during entry
Patsayev, Victor	USSR	06/29/71	Soyuz 11 depressurized during entry
Volkov, Vladislav	USSR	06/29/71	Soyuz 11 depressurized during entry
Scobee, Francis	US	01/28/86	SRB failure; Challenger, STS-51L
Smith, Michael	US	01/28/86	SRB failure; Challenger, STS-51L
Resnik, Judith	US	01/28/86	SRB failure; Challenger, STS-51L
Onizuka, Ellison	US	01/28/86	SRB failure; Challenger, STS-51L
McNair, Ronald	US	01/28/86	SRB failure; Challenger, STS-51L
Jarvis, Gregory	US	01/28/86	SRB failure; Challenger, STS-51L
McAuliffe, Christa	US	01/28/86	SRB failure; Challenger, STS-51L
Husband, Rick	US	02/01/03	Entry breakup; Columbia, STS-107
McCool, William	US	02/01/03	Entry breakup; Columbia, STS-107
Chawla, Kalpana	US	02/01/03	Entry breakup; Columbia, STS-107
Anderson, Michael	US	02/01/03	Entry breakup; Columbia, STS-107
Brown, David	US	02/01/03	Entry breakup; Columbia, STS-107
Clark, Laurel	US	02/01/03	Entry breakup; Columbia, STS-107
Ramon, Ilan	Israel	02/01/03	Entry breakup; Columbia, STS-107
TOTAL:	**18**		
			Other Active-Duty Fatalities
Freeman, Theodore	US	10/31/64	T-38 jet crash in Houston
Bassett, Charles	US	02/28/66	T-38 jet crash in St Louis
See, Elliott	US	02/28/66	T-38 jet crash in St Louis
Grissom, Virgil	US	01/27/67	Apollo 1 launch pad fire
White, Edward	US	01/27/67	Apollo 1 launch pad fire
Chaffee, Roger	US	01/27/67	Apollo 1 launch pad fire
Givens, Edward	US	06/06/67	Houston car crash
Williams, Clifton	US	10/15/67	Airplane crash near Tallahassee
Robert Lawrence	US	12/08/67	F-104 crash (MOL AF astronaut)
Gagariin, Yuri	USSR	03/27/68	MiG jet trainer crash near Star City
Belyayev, Pavel	USSR	01/10/70	Died during surgery
Thorne, Stephen	US	05/24/86	Private plane crash near Houston
Levchenko, Anatoly	USSR	08/06/88	Inoperable brain tumor
Shchukin, Alexander	USSR	08/18/88	Experimental plane crash
Griggs, David	US	06/17/89	Plane crash
Carter, Manley	US	05/04/91	Commuter plane crash in Georgia
Veach, Lacy	US	10/03/95	Cancer
Robertson, Patricia	US	05/24/01	Private plane crash near Houston
			Compiled by William Harwood

STS-128/ISS-20 NASA Crew Biographies

1. Commander: Frederick "Rick" Sturckow, 48

PERSONAL DATA: Born August 11, 1961, and raised on a farm near Lakeside, California. Married to the former Michele A. Street of Great Mills, Maryland. He enjoys flying and physical training (PT). His father, Karl H. Sturckow, resides in Lakeside and his mother, Janette R. Sturckow, resides in La Mesa, California.

EDUCATION: Graduated from Grossmont High School, La Mesa, California, in 1978. Bachelor of Science degree in Mechanical Engineering from California Polytechnic State University, 1984.

SPECIAL HONORS: Defense Superior Service Medal, Legion of Merit, Distinguished Flying Cross, Defense Meritorious Service Medal, Single Mission Air Medal with Combat "V", Strike/Flight Air Medals (4), Navy and Marine Corps Commendation Medal, Navy and Marine Corps Achievement Medal, NASA Space Flight Medals (3), NASA Exceptional Service Medal, NASA Outstanding Leadership Medals (2).

EXPERIENCE: Sturckow was commissioned in December, 1984. An Honor Graduate of The Basic School, he earned his wings in April, 1987. Following initial F/A-18 training at VFA-125, he reported to VMFA-333, MCAS Beaufort, South Carolina. While assigned to VMFA-333 he made an overseas deployment to Japan, Korea, and the Philippines and was then selected to attend the Navy Fighter Weapons School (TOPGUN) in March, 1990. In August of 1990 he deployed to Sheik Isa Air Base, Bahrain for a period of eight months. Sturckow flew a total of forty-one combat missions during Operation Desert Storm. In January, 1992 he attended the United States Air Force Test Pilot School at Edwards AFB, California. In 1993 he reported to the Naval Air Warfare Center- Aircraft Division, Patuxent River, Maryland for duty as the F/A-18 E/F Project Pilot. Sturckow also flew a wide variety of projects and classified programs as an F/A-18 test pilot.

He has logged over 4,790 flight hours and has flown over 50 different aircraft.

NASA EXPERIENCE: Selected by NASA in December 1994, Sturckow reported to the Johnson Space Center in March 1995. He completed a year of training and evaluation and was initially assigned to work technical issues for the Vehicle Systems and Operations Branch of the Astronaut Office. Since then he has served as Deputy for the Shuttle Operations Branch of the Astronaut Office, Lead for KSC Operations Support, and Chief of the Astronaut Office CAPCOM Branch, and Chief of the Astronaut Office ISS Branch. A veteran of three space flights Sturckow has logged over 904 hours in space. He served as pilot on STS-88 in 1998 (the first International Space Station assembly mission), and on STS-105 (2001) and was the Crew Commander on STS-117 (2007). Sturckow will command space shuttle Discovery on the STS-128 mission, targeted for launch in August 2009. Discovery will carry a Multi-Purpose Logistics Module filled with science and storage racks to the station. The mission will include two spacewalks to remove and replace a materials processing experiment outside ESA's Columbus module and return an empty ammonia tank assembly. The mission will also exchange ISS crew members.

SPACE FLIGHT EXPERIENCE: STS-88 Endeavour (December 4-15, 1998) was the first International Space Station assembly mission. During the 12-day mission, Unity, the U.S. built node, was mated with Zarya, the Russian built Functional Cargo Block (FGB). Two crew members performed three space walks to connect umbilicals and attach tools/hardware in the assembly and outfitting of the station. Additionally, the crew performed the initial activation and first ingress of the International Space Station preparing it for future assembly missions and full time occupation. The crew also performed IMAX Cargo Bay Camera (ICBC) operations, and deployed two satellites, Mighty Sat 1 built by the USAF Phillips Laboratory and SAC-A the first successful launch of an Argentine satellite. The mission was accomplished in 185 orbits of the Earth in 283 hours and 18 minutes.

STS-105 Discovery (August 10-22, 2001) was the 11th mission to the International Space Station. While at the orbital outpost, the STS-105 crew delivered the Expedition-3 crew, attached the Leonardo Multi-Purpose Logistics Module, and transferred over 2.7 metric tons of supplies and equipment to the station. During the mission, two spacewalks were performed by two crewmembers. They also brought home the Expedition-2 crew. The STS-105 mission was accomplished in 186 orbits of the Earth, traveling over 4.9 million miles in 285 hours and 13 minutes.

STS-117 Atlantis (June 8-22, 2007) was the 118th Shuttle mission and the 21st mission to visit the International Space Station. The successful construction and repair mission involved multiple EVAs by 4 astronauts to install the S3/4 Truss Segment, the heaviest element ever delivered by the Shuttle to the ISS. The mission also delivered and returned with an expedition crew member. STS-117 returned to land at Edwards Air Force Base, California, having traveled 5.8 million miles in 14-days.

MAY 2009

2. Pilot: Kevin A. Ford (colonel, USAF, retired), 49

PERSONAL DATA: Born July 7, 1960 in Portland, Indiana. Montpelier, Indiana is his hometown. Married to the former Kelly Bennett. They have two children, Anthony and Heidi. His parents, Clayton and Barbara Ford, reside in Indiana.

EDUCATION: Graduated from Blackford High School, Hartford City, Indiana in 1978. He received his Bachelor of Science Degree in Aerospace Engineering from the University of Notre Dame in 1982, a Master of Science in International Relations from Troy State University in 1989, a Master of Science in Aerospace Engineering from the University of Florida in 1994, and a Ph.D. in Astronautical Engineering from the Air Force Institute of Technology in 1997. Graduate of Squadron Officer School, the Air Command and Staff College Associate Program, and Air War College.

SPECIAL HONORS: Distinguished Graduate of Detachment 225, Reserve Officer Training Corps, 1982. Distinguished Graduate of Undergraduate Pilot Training, Columbus AFB, Mississippi, 1984. Distinguished Graduate of the United States Air Force Test Pilot School, 1990. Awarded the Legion of Merit, the Air Force Meritorious Service Medal, the Air Force Commendation Medal, the Aerial Achievement Medal, and the Armed Forces Expeditionary Medal. Recipient of the Air Force Test Pilot School David B. Barnes Outstanding Flight Instructor Award, 1998.

EXPERIENCE: Ford was commissioned through the Reserve Officer Training Corps program in 1982 and completed primary Air Force jet training at Columbus Air Force Base, Mississippi in 1984. He trained in the F-15 Eagle and was assigned to the 22nd Tactical Fighter Squadron, Bitburg Air Base, Germany, from 1984-1987, and then to the 57th Fighter Interceptor Squadron at Keflavik Naval Air Station, Iceland until 1989, intercepting and escorting 18 Soviet combat aircraft over the North Atlantic. After spending 1990 as a student at the United States Air Force Test Pilot School, Edwards Air Force Base, California, Kevin flew flight test missions in the F-16 Fighting Falcon with the 3247th Test Squadron at Eglin Air Force Base, Florida from 1991-1994. Test experience there included multiple F-16 flutter missions, development of the ALE-47 Countermeasures Dispenser System, multiple safe separation, ballistics, and fuse tests, and air-to-air missile development testing, including the first AMRAAM shot from the F-16 Air Defense Fighter variant. Following a three-year assignment to pursue full-time studies as a doctoral candidate at Wright-Patterson Air Force Base, Ohio, he was assigned to the Air Force Test Pilot School where he served as the Director of Plans and Programs, taught academics, and instructed students on flight test techniques in the F-15, F-16, and gliders. Kevin has 4300 flying hours and holds FAA commercial certificates for airplanes, helicopters, and gliders. He is a certificated flight instructor in airplanes and gliders. He retired from active duty military service in June 2008.

NASA EXPERIENCE: Selected as a pilot by NASA in July 2000, Ford reported for training in August 2000. Following the completion of two years of training and evaluation, he was assigned technical duties in the Astronaut Office Advanced Vehicles Branch, working advanced exploration issues, and to the Space Shuttle Branch, working on the development and test of the Shuttle Cockpit Avionics Upgrade. Served as Director of Operations at the Gagarin Cosmonaut Training Center in Star City, Russia from January to December of 2004. From January 2005 until July of 2008, he served as a Space Shuttle and International Space Station (ISS) CAPCOM in the Mission Control Center, working the STS-115, STS-116, STS-117, STS-120, STS-122, and STS-123 Shuttle missions, as well as ISS Expedition Stage Operations. Ford is assigned to serve as the pilot of Space Shuttle Discovery on the STS-128 mission targeted for launch in August 2009. Discovery will carry the Multi-Purpose Logistics Module “Leonardo” filled with science and storage racks to the ISS, and deliver a new Ammonia Tank Assembly. The mission will include three spacewalks. The mission will also exchange ISS Expedition crew members.

MAY 2009

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3. MS-1: Patrick G. Forrester (colonel, USA, retired), 52

PERSONAL DATA: Born March 31, 1957 in El Paso, Texas. Married to the former Diana Lynn Morris of Springfield, Virginia. They have two children. He enjoys baseball and running. His mother, Patsy L. Forrester, resides in Fort Walton Beach, Florida. His father, Colonel (ret.) Redmond V. Forrester is deceased. Her father, Colonel (ret.) Lurie J. Morris, resides in Jacksonville, Florida. Her mother, Bettye Morris, is deceased.

EDUCATION: Graduated from West Springfield High School, Springfield, Virginia in 1975; received a bachelor of science degree in applied sciences and engineering from the United States Military Academy, West Point, New York, in 1979, and a master of science degree in mechanical and aerospace engineering from the University of Virginia in 1989.

AWARDS: Defense Superior Service Medal; Legion of Merit; Meritorious Service Medal (2nd Oak Leaf Cluster); Army Commendation Medal; Army Achievement Medal; National Defense Service Medal; Expert Infantryman Badge.

SPECIAL HONORS: The Jack Northrop Award, Society of Experimental Test Pilots (1996). The Lyndon B. Johnson Space Center Certificate of Commendation (1995). NASA Space Flight Medal (2001, 2007). The Order of St. Michael (2001).

EXPERIENCE: Forrester graduated from West Point in June 1979 and was commissioned as a Second Lieutenant in the U.S. Army. He entered the U.S. Army Aviation School in 1979 and was designated an Army aviator in September 1980. He was subsequently assigned as an instructor pilot at the Aviation School and as the Aide-de-Camp to the Deputy Commanding General of the U.S. Army Aviation Center. In 1984, he was assigned to the 25th Infantry Division (Light), Schofield Barracks, Hawaii, where he served as a platoon leader, aviation company operations officer, and an assault helicopter battalion operations officer. After completing a Master of Science degree at the University of Virginia in 1989, he was assigned as a flight test engineer and as the research and development coordinator with the Army Aviation Engineering Flight Activity at Edwards Air Force Base, California. In June 1992, he graduated from the U.S. Naval Test Pilot School and was designated an experimental test pilot. In 1992, he was assigned as an engineering test pilot at the U.S. Army Aviation Technical Test Center, Fort Rucker, Alabama. Other military schools include the Army Parachutist Course, U.S. Army Ranger School, the Combined Arms Services Staff School, and the Command and General Staff College.

A Master Army Aviator, he has logged over 4400 hours in over 50 different aircraft.

Forrester retired from the Army in October 2005.

NASA EXPERIENCE: Forrester was assigned to NASA at the Johnson Space Center as an aerospace engineer in July 1993. His technical assignments within the Astronaut Office Operations Development Branch have included: flight software testing with the Shuttle Avionics Integration Laboratory (SAIL); astronaut office representative for Landing/Rollout issues, Multi-function Electronic Display System (MEDS) upgrade of the Orbiter fleet, and the Portable In-flight Landing Operations Trainer (PILOT). He has also served as the crew representative for robotics development for the International Space Station.

Forrester was selected as a mission specialist astronaut candidate by NASA in May 1996. Having completed two years of training and evaluation, he is qualified for flight assignment as a mission specialist. Initially, Forrester was assigned to duties at the Kennedy Space Center as a member of the astronaut support team, responsible for Shuttle prelaunch vehicle checkout, crew ingress and strap-in, and crew egress after landing. He next served as the technical assistant to the Director, Flight Crew Operations. Following that, Forrester served as the Shuttle training and on-board crew procedures representative. He has also served as a CAPCOM for both ISS and shuttle missions. Forrester flew on STS-105 (2001) and STS-117 (2007). He has logged over 621 hours in space, including four spacewalks totaling 25 hours and 22 minutes of EVA time. Forrester will serve as a mission specialist on space shuttle Discovery on the STS-128 mission, targeted for launch in August 2009. Discovery will carry a Multi-Purpose Logistics Module filled with science and storage racks to the station. The mission will include two spacewalks to remove and replace a materials processing experiment outside ESA's Columbus module and return an empty ammonia tank assembly. The mission will also exchange ISS crew members.

SPACE FLIGHT EXPERIENCE: STS-105 Discovery (Aug 10-22, 2001) was the 11th mission to the International Space Station. While at the orbital outpost, the STS-105 crew delivered the Expedition-3 crew, attached the Leonardo Multi-Purpose Logistics Module (MPLM), and transferred over 2.7 metric tons of supplies and equipment to the station. During the mission, Pat Forrester and Dan Barry performed two spacewalks totaling 11 hours and 45 minutes of EVA time. Forrester served as the prime robotics operator to install the MPLM. STS-105 also brought home the Expedition-2 crew. The STS-105 mission was accomplished in 186 orbits of the Earth, traveling over 4.9 million miles in 285 hours and 13 minutes.

STS-117 Atlantis (June 8-22, 2007) was the 118th Shuttle mission and the 21st mission to visit the International Space Station, delivering the second starboard truss segment, the third set of U.S. solar arrays, batteries and associated equipment. The successful construction and repair mission involved four spacewalks by two teams. Forrester accumulated 13 hours and 37 minutes of EVA time in two spacewalks. The mission also delivered and returned with an expedition crew member. STS-117 returned to land at Edwards Air Force Base, California, having traveled 5.8 million miles in 14 days.

MAY 2009

4. MS2/FE: Jose Hernandez, 47

PERSONAL DATA: Born August 7, 1962 in French Camp, California. Considers Stockton, California, to be his hometown.

EDUCATION: B.S., Electrical Engineering, University of the Pacific, 1984. M.S., Electrical & Computer Engineering, University of California-Santa Barbara, 1986

ORGANIZATIONS: Institute of Electrical and Electronic Engineers (IEEE), Society of Mexican American Engineers and Scientists (MAES).

SPECIAL HONORS: NASA Service Awards (2002, 2003), Lawrence Livermore National Laboratory "Outstanding Engineer Award" (2001), Upward Bound National TRIO Achiever Award (2001), U.S. Department of Energy "Outstanding Performance Commendation" (2000), Society of Mexican American Engineers and Scientists (MAES) "Medalla de Oro" recipient for professional and community contributions (1999), Hispanic Engineer National Achievement Award, "Outstanding Technical Contribution" (1995), Graduate Engineering Minority Fellow (GEM) (1985), and Eta Kappa Nu Electrical Engineering Honor Society member.

EXPERIENCE: 1987-2001 were spent at the Lawrence Livermore National Laboratory, Livermore, California.

1987-1991 Electronics Engineer, Material Analysis Group. Refined signal and image processing skills for applications in radar imaging, computed tomography, acoustic imaging and other non-destructive evaluation techniques

1991-1994 Electronics Engineer, Chemistry and Material Science Group. Developed quantitative x-ray film imaging analysis techniques that allowed the characterization of low-density materials for use in the development of an X-Ray laser as part of the Strategic Defense Initiative Program. Developed material x-ray transport models that allowed for the development of human tissue absorbed dose models useful for medical imaging applications.

1994-1996 Group Leader, Chemistry and Material Science Group. Managed the career development of twenty-nine professional technical staff members who supported chemistry and materials science research activities. Identified and developed the Group's programmatic research support opportunities. Carried out own research activities as a principal investigator in the area of x-ray physics and image processing.

1996-1999 Deputy Program Manager, Highly Enriched Uranium Implementation Program. Responsible for the implementation of a signed bilateral agreement between the U.S. and Russian Federation for the U.S. purchase of highly enriched uranium (HEU) in the form of low enriched uranium (LEU) derived from the dismantlement of Russian nuclear weapons. Responsibilities included utilizing national laboratory resources for the purpose of ensuring the U.S. government that the LEU purchased was derived from dismantled nuclear weapons. This was accomplished by developing technical training modules for U.S. multi-lab and multi-agency experts, which allowed them to visit Russian facilities and effectively perform inspections in accordance to U.S.-Russian signed agreements, protocols and annexes. Fiscal planning responsibilities for the $16 Million multi-lab implementation budget and direct oversight of the $6 million annual budget for the Lawrence Livermore National Laboratory component.

1999-2001 Program Manager, Office of International Material Protection and Emergency Cooperation. On a two-year change-of-station assignment at the U.S. Department of Energy, Washington, D.C. Managed the integration and allocation of Department of Energy assets and expertise, including the national laboratories and contractors, in planning, directing, and implementing U.S. cooperation with the Russian Federation in the program of Nuclear Materials, Protection, Control and Accounting (MPC&A). Developed and implemented policies, strategies and plans and objectives to enhance U.S. national security and reduce threat of nuclear proliferation and nuclear terrorism.

These goals were accomplished by rapidly improving the security of large quantities of attractive, weapons-usable nuclear material at the closed Ministry of Atomic Energy (MinAtom) cities that compromise Russia's nuclear weapons complex. Proposed, defended and executed annual budget of over $14 million to support extensive engineering, technical safety, security, and environmental research and policy development with regard to MPC&A at three of the seven MinAtom sites

NASA EXPERIENCE: In 2001 Hernandez joined the Johnson Space Center, in Houston, Texas.

Mar 01 – Jan 02 Materials Research Engineer, Materials & Processes Branch. Developed, evaluated, and selected advanced structural materials to aircraft and spacecraft structures and their power and propulsion systems. Conducted research in basic engineering materials and apply general engineering mechanics principles to define material behavior. Designed and fielded radiation effects experiments for electronic hardware. Served as the Engineering Directorate's liaison on the electrical wire integrity interagency working group.

Jan 02 – Jun 04 Branch Chief, Materials, & Processes Branch. Materials and Processes (M&P) branch chief within the Structural Engineering Division. Duties included managing the careers of 30 professional civil servants with diverse set of skills in materials science. Also serve as the overall technical monitor of contractor support that included more than 20 contractors. Responsible for the oversight of the branch's activities in the areas of materials and processes, fracture control, non destructive evaluation, failure analysis, and nano materials research. More specifically, managed branch resources to address materials usage issues with respect to flammability, toxicity, contamination, space environment compatibility, and corrosion. Materials testing and fracture control analysis of flight and non-flight hardware were also significant activities within the branch. Served as the project lead for the development of a space qualified borescope for future on-orbit EVA inspection applications.

Selected by NASA in May 2004. In February 2006 he completed Astronaut Candidate Training that included scientific and technical briefings, intensive instruction in Shuttle and International Space Station systems, physiological training, T-38 flight training, and water and wilderness survival training. Hernandez was initially assigned to the Astronaut Office Shuttle Branch supporting Shuttle launch and landing preparations at .Kennedy Space Center.

Hernandez is assigned to serve as a mission specialist on space shuttle Discovery on the STS-128 mission, targeted for launch in August 2009. Discovery will carry a Multi-Purpose Logistics Module filled with science and storage racks to the station. The mission will include two spacewalks to remove and replace a materials processing experiment outside ESA's Columbus module and return an empty ammonia tank assembly. The mission will also exchange ISS crew members.

APRIL 2009

5. MS3/EV1: John D. "Danny" Olivas, Ph.D., 44

PERSONAL DATA: Born in North Hollywood, California, 1966, and raised in El Paso, Texas. Married to the former Marie Schwarzkopf, also from El Paso, Texas. They have 5 children. Recreational interests include running, weightlifting, hunting, fishing and surfing.

EDUCATION: Graduate of Burges High School, El Paso, Texas; received a bachelor of science degree in mechanical engineering from the University of Texas-El Paso; a masters of science degree in mechanical engineering from the University of Houston and a doctorate in mechanical engineering and materials science from Rice University.

AWARDS: Six U.S. Patents; Four NASA Class One Tech Brief Awards; Five JPL-California Institute of Technology Novel Technology Recognitions; The University of Texas-El Paso Distinguished Alumnus, HENAAC Most Promising Engineer, McDonald's Hispanos Triunfadores Life Time Achievement Award, NASA ASEE Summer Faculty Fellowship Award, Dow Life Saving Award.

EXPERIENCE: After graduating with his undergraduate degree, Olivas worked for the Dow Chemical Company as a mechanical/materials engineer responsible for performing equipment stress/failure analysis for the operating facilities. Upon completing his master's degree, Olivas pursued his doctorate while supporting engine coating evaluations for C-5 maintenance operations at Kelly Air Force Base. He also supported the Crew and Thermal Systems Directorate at NASA Johnson Space Center, evaluating materials for application to the next generation space suits.

Upon completing his doctorate, he received a senior research engineer position at the Jet Propulsion Laboratory (JPL) and worked in the development of tools and methodologies for nondestructively evaluating microelectronics and structural materials subjected to space environments. He was promoted to Program Manager of the JPL Advanced Interconnect and Manufacturing Assurance Program, aimed at evaluating the reliability and susceptibility of state-of-the-art microelectronics for use in future NASA projects. Throughout his career, he has authored and presented numerous papers at technical conferences and in scientific journals.

NASA EXPERIENCE: NASA selected Olivas in 1998. Astronaut Training included orientation briefings and tours, numerous scientific and technical briefings, intensive instruction in Shuttle and International Space Station systems, physiological training and ground school to prepare for T-38 flight training, as well as learning water and wilderness survival techniques. From 1999 to 2002, he was assigned technical responsibilities within the Robotics Branch as lead for the Special Purpose Dexterous Manipulator Robot and the Mobile Transporter. From 2002 to 2005 he was assigned to the EVA Branch and supported the research effort focused on developing materials, tools and techniques to perform on-orbit shuttle repair. In 2006, he served as lead of the Hardware Integration Section of the Space Station Branch, responsible for ensuring proper configuration and integration of future station modules and visiting vehicles. In 2007 he flew on STS-117 logging 336 hours in space including over 14 EVA hours. In 2008 he was assigned to the Capsule Communicator (CAPCOM) Branch that is responsible for all interface with the flight control team at Mission Control in Houston and the on-orbit STS and ISS crews. Olivas is assigned to serve as a mission specialist on space shuttle Discovery on the STS-128 mission, targeted for launch in August 2009. Discovery will carry a Multi-Purpose Logistics Module filled with science and storage racks to the station. The mission will include two spacewalks to remove and replace a materials processing experiment outside ESA's Columbus module and return an empty ammonia tank assembly. The mission will also exchange ISS crew members.

SPACE FLIGHT EXPERIENCE: STS-117 Atlantis (June 8-22, 2007) was the 118th Shuttle mission and the 21st mission to visit the International Space Station, delivering the second starboard truss segment, the third set of U.S. solar arrays, batteries and associated equipment. The mission also entailed the first ever on-orbit EVA repair to the Space

Shuttle, Atlantis. During two spacewalks, Olivas accumulated 14 hours and 13 mins of EVA experience. The mission also delivered and returned with an expedition crew member. STS-117 returned to land at Edwards Air Force Base, California, having traveled more than 5.8 million miles in 13-day, 20 hours and 20 minutes.

APRIL 2009

6. MS4/EV-2: Christer Fuglesang, Ph.D., 52

PERSONAL DATA: Born March 18, 1957 in Stockholm, Sweden. Married to the former Elisabeth Walldie. They have three children. He enjoys sports, sailing, skiing, frisbee, games and reading.

EDUCATION: Graduated from Bromma Gymnasium, Stockholm, Sweden, in 1975; received a master of science degree in Engineering Physics from the Royal Institute of Technology (KTH), Stockholm, Sweden, in 1981; received a doctorate in Experimental Particle Physics from the University of Stockholm in 1987. He became a Docent in Particle Physics at the University of Stockholm in 1991.

SPECIAL HONORS: Honorary Doctorate from Umeå University, Sweden (1999). Honorary Doctorate from the University of Nova Gorica, Slovenia (2007). NASA Space Flight Medal (2007). H.M. The King's Medal (Stockholm, 2007).

EXPERIENCE: As a graduate student, Fuglesang worked at CERN (European Research Center on Particle Physics) in Geneva on the UA5 experiment, which studied proton-antiproton collisions. In 1988 he became a Fellow of CERN, where he worked on the CPLEAR experiment studying the subtle CP-violation of Kaon-particles. After a year he became a Senior Fellow and head of the particle identification subdetector. In November 1990, Fuglesang obtained a position at the Manne Siegbahn Institute of Physics, Stockholm, but remained stationed at CERN for another year working towards the new large hadron collider project. Since 1980, when stationed in Sweden, Fuglesang taught mathematics at the Royal Institute of Technology.

In May 1992, Fuglesang was selected to join the Astronaut Corps of the European Space Agency (ESA) based at the European Astronaut Centre (EAC) in Cologne, Germany. In 1992 he attended an introductory training program at EAC and a four-week training program at TsPK (Cosmonauts Training Center) in Star City, Russia, with a view to future ESA-Russian collaboration on the Mir Space Station. In July 1993, he completed the basic training course at EAC.

In May 1993, Fuglesang and fellow ESA astronaut, Thomas Reiter, were selected for the Euromir 95 mission and commenced training at TsPK (Moscow) in preparation for their onboard engineer tasks, extra-vehicular activities (spacewalks) and operation of the Soyuz spacecraft. The Euromir 95 experiment training was organized and mainly carried out at EAC.

On 17 March 1995, he was selected as a member of Crew 2, the backup crew for the Euromir 95 mission, joining Genadi Manakov and Pavel Vinogradov. During the mission, which lasted 179 days, Fuglesang was the prime crew interface coordinator. From the Russian Mission Control Center (TsUP) in Kaliningrad, he was the main contact with ESA Astronaut, Thomas Reiter, on Mir, and acted as coordinator between Mir and the Euromir 95 Payloads Operations Control Center, located in Oberpfaffenhofen, Germany, and project management. Between March and June 1996, he underwent specialized training in TsPK on Soyuz operations for de-docking, atmospheric re-entry and landing.

NASA EXPERIENCE: Christer Fuglesang entered the Mission Specialist Class at NASA Johnson Space Center, Houston, in August 1996, and qualified for flight assignment as a mission specialist in April 1998. From May to October 1998, he resumed training at TsPK on Soyuz-TM spacecraft operations for de-docking, atmospheric re-entry and landing. He was awarded the Russian 'Soyuz Return Commander' certificate, which qualifies him to command a three-person Soyuz capsule on its return from space.

In October 1998 he returned to NASA-JSC and was assigned technical duties in the Astronaut Office Station Operations System Branch on Russian Transfer Vehicles (i.e. Soyuz and Progress). Later he worked as prime

Increment Crew Support Astronaut for the Expedition Corps of the 2nd International Space Station increment crew. Christer Fuglesang has continued with some scientific work and was involved with the SilEye experiment which investigated light flashes in astronauts eyes on Mir between 1995 and 1999. This work is continuing on the International Space Station (ISS) with the Alteino and ALTEA apparatuses. The former is on ISS since 2002, the latter is planned to fly to the ISS in 2006. He has also initiated the DESIRE project to simulate and estimate the radiation environment inside ISS.

Christer Fuglesang is a member of ESA's European Astronaut Corps, whose home base is the European Astronaut Center located in Cologne, Germany. He was assigned collateral duties in the NASA-JSC Astronaut Office and was assigned to the ISS Payload Branch. Christer Fuglesang has logged over 308 hours in space, including 3 EVAs (spacewalks) totalling 18 hours and 14 minutes on an assembly and crew-rotation mission to the International Space Station with the crew of STS-116. Fuglesang is assigned to serve as a mission specialist on space shuttle Discovery on the STS-128 mission, targeted for launch in August 2009. Discovery will carry a Multi-Purpose Logistics Module filled with science and storage racks to the station. The mission will include two spacewalks to remove and replace a materials processing experiment outside ESA's Columbus module and return an empty ammonia tank assembly. The mission will also exchange ISS crew members.

SPACE FLIGHT EXPERIENCE: STS-116 Discovery (December 9-22, 2006). The seven-member crew on this 12-day mission continued construction of the ISS outpost by adding the P5 spacer truss segment during the first of four spacewalks. The next two spacewalks rewired the station's power system, preparing it to support the addition of European and Japanese science modules by future shuttle crews. The fourth spacewalk was added to allow the crew to coax and retract a stubborn solar panel to fold up accordion-style into its box. Discovery also delivered a new crew member and more than two tons of equipment and supplies to the station. Almost two tons of items no longer needed on the station returned to Earth with STS-116. Mission duration was 12 days, 20 hours and 45 minutes.

AUGUST 2009

7. MS5/EV-3/ISS-20 FE: Nicole Stott, 46

PERSONAL DATA: Born in Albany, New York. Her hometown is Clearwater, Florida. She enjoys flying, snow skiing, SCUBA diving, woodworking, painting, and gardening.

EDUCATION: Clearwater High School, Clearwater, Florida, 1980. B.S., Aeronautical Engineering, Embry-Riddle Aeronautical University, 1987. M.S., Engineering Management, University of Central Florida, 1992.

SPECIAL HONORS: Aircraft Operations Division, Newt Myers Team Spirit Award, KSC Public Affairs Certificate of Appreciation for Service; NASA Exceptional Achievement Medal; NASA Certificates of Commendation; NASA Performance Awards; NASA On-the-Spot Award; Lockheed Certificate of Appreciation.

EXPERIENCE: Ms. Stott began her career in 1987 as a structural design engineer with Pratt and Whitney Government Engines in West Palm Beach, Florida. She spent a year with the Advanced Engines Group performing structural analyses of advanced jet engine component designs. She is an instrument rated private pilot.

NASA EXPERIENCE: In 1988, Ms. Stott joined NASA at the Kennedy Space Center (KSC), Florida as an Operations Engineer in the Orbiter Processing Facility (OPF). After 6 months, she was detailed to the Director of Shuttle Processing as part of a two-person team tasked with assessing the overall efficiency of Shuttle processing flows, and implementing tools for measuring the effectiveness of improvements. She was the NASA KSC Lead for a joint Ames/KSC software project to develop intelligent scheduling tools. The Ground Processing Scheduling System (GPSS) was developed as the technology demonstrator for this project. GPSS was a success at KSC, and also a commercial success that is part of the PeopleSoft suite of software products. During her time at KSC, Ms. Stott also held a variety of positions within NASA Shuttle Processing, including Vehicle Operations Engineer; NASA Convoy Commander; Shuttle Flow Director for Endeavour; and Orbiter Project Engineer for Columbia. During her last two years at KSC, she was a member of the Space Station Hardware Integration Office and relocated to Huntington Beach, CA where she served as the NASA Project Lead for the ISS truss elements under construction at the Boeing Space Station facility. In 1998, she joined the Johnson Space Center (JSC) team in Houston, TX as a member of the NASA Aircraft Operations Division, where she served as a Flight Simulation Engineer (FSE) on the Shuttle Training Aircraft (STA).

Selected as a mission specialist by NASA in July 2000, Nicole reported for astronaut candidate training in August 2000. Following the completion of two years of training and evaluation, she was assigned technical duties in the Astronaut Office Station Operations Branch, where she performed crew evaluations of station payloads. She also worked as a support astronaut for the Expedition 10 crew and as an ISS CAPCOM. In April 2006 she was a crew member on the NEEMO 9 mission (NASA Extreme Environment Mission Operations) where she lived and worked with a 6 person crew for 18 days on the Aquarius undersea research habitat. Nicole is currently assigned to a long duration space flight as a member of the ISS Expeditions 20 and 21 crews. She is scheduled to launch to the International Space Station with the crew of STS-128 and return with the crew of STS-129.

MARCH 2009

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8. ISS-20 Commander: Gennady Ivanovich Padalka, 51

PERSONAL DATA: Born June 21, 1958, in Krasnodar, Russia. Married to Irina Anatolievna Padalka (Ponomareva). They have three daughters, Yulia, Ekaterina and Sonya. Gennady enjoys the theater, parachute sport and diving.

EDUCATION: Graduated from Eisk Military Aviation College in 1979; in 1994 he left UNESCO International Center of Instruction Systems, where he was an engineer–ecologist.

SPECIAL HONORS: Awarded the Star of Russian Federation Hero, and the title of Russian Federation Test-Cosmonaut.

EXPERIENCE : After graduation from the Military College in 1979, Gennady Padalka served as a pilot and a senior pilot in the Air Force.

He was selected as a cosmonaut candidate to start training at the Gagarin Cosmonaut Training Center in 1989. From June 1989 to January 1991 he attended basic space training. In 1991 Padalka was qualified as a test-cosmonaut.

Gennady Padalka is a First Class Pilot, has flown 6 types of aircraft, and has logged 1500 hours. He is an Instructor of General Parachute Training, and has performed more than 300 parachute jumps.

From August 28, 1996 to July 30, 1997, he trained for space flight on theSoyuz-TM transport vehicle/Mir orbital complex as a commander of the back up crew for Mir 24/NASA-5, 6 Russian-American program of the 24 th primary Expedition, Pegasus Russian–French program and Euro-Mir program).

October 1997 to August 1998 Padalka attended training for a space a flight aboard the Soyuz-TM/Mir orbital complex as a primary crew commander (Expedition 26 Program).

August 13, 1998 , to February 28, 1999, he served aboard the Soyuz-TM-28/Mir orbital complex as the Expedition 26 crew commander, and logged 198 days in space.

June 1999 through July 2000, Padalka attended training for a space flight on “Soyuz-TM” transport vehicle as an ISS contingency crew commander.

August 2000 to November 2001, Gennady Padalka attended training for a space flight as the ISS-4 back-up crew commander.

In March 2002, Padalka was assigned as station commander of the ISS Expedition-9 crew. Expedition-9 was launched from the Baikonur Cosmodrome, Kazakhstan aboard a Soyuz TMA-4 spacecraft, docking with the International Space Station on April 21, 2004. Following a week of joint operations and handover briefings, they replaced the Expedition-8 crew who returned to Earth. In a six-month tour of duty aboard the station Padalka continued ISS science operations, maintained Station systems, and performed four spacewalks. The Expedition-9 mission concluded after undocking and landing back in Kazakhstan on October 23, 2004. In completing this mission, Padalka logged an additional 187 days, 21 minutes and 17 seconds in space, and 15 hours, 45 minutes and 22 seconds of EVA time.

Padalka is assigned to command the Expedition-19 mission to the International Space Station. In March 2009 he will command the Soyuz spacecraft that will launch him and astronaut Michael Barratt to the station. They will be joined by Nicole Stott, who will arrive with the crew of STS-128.

FEBRUARY 2008

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9. ISS-20 FE: USA Col. Timothy Kopra, 46 (MS-5 down)

PERSONAL DATA: Born on April 9, 1963, in Austin, Texas. Married to the former Dawn Kaye Lehman of Lewisburg, Kentucky. They have two children. He enjoys running, swimming, and biking. His mother, Martha A. Kopra, resides in Austin, Texas. His father, Dr. Lennart L. Kopra, is deceased. Dawn's parents, Charles B. and Betty H. Lehman, reside in Lewisburg, Kentucky.

EDUCATION: McCallum High School, Austin, Texas, 1981. Bachelor of Science, United States Military Academy, West Point, New York, 1985. Master of Science in Aerospace Engineering, Georgia Institute of Technology, 1995. Master of Strategic Studies, U.S. Army War College, 2006.

ORGANIZATIONS: Society of Experimental Test Pilots; Army Aviation Association of America; American Helicopter Society; United States Military Academy Association of Graduates; West Point Society of Greater Houston; Phi Kappa Phi.

SPECIAL HONORS: Empire Test Pilot School Award for the best Developmental Test thesis, Class 110, U.S. Naval Test Pilot School (1996); Bronze Order of Saint Michael, Army Aviation Award (1999). Awarded the Bronze Star Medal, two Meritorious Service Medals, Air Medal, Army Commendation Medal, Army Achievement Medal, and various other service awards.

EXPERIENCE: Kopra received his commission as a second lieutenant from the U.S. Military Academy in May 1985 and was designated as an Army aviator in August 1986. He then completed a three-year assignment at Fort Campbell, Kentucky, where he served as an aeroscout platoon leader, troop executive officer, and squadron adjutant in the 101st Airborne Division's air cavalry squadron. In 1990, he was assigned to the 3rd Armored Division in Hanau, Germany, and was deployed to Southwest Asia where he served in Operations Desert Shield and Desert Storm. He completed his tour in Germany as an attack helicopter company commander and an operations officer. After returning to the United States and completing graduate studies at Georgia Tech, he was selected in 1995 to attend the U.S. Naval Test Pilot School. Upon graduation, he was assigned to the U.S. Army Aviation Technical Test Center, where he worked as an experimental test pilot on various projects and served as the developmental test director for the Comanche helicopter program. Other military schools include the Army Parachutist Course, Pathfinder Course, Air Assault Course, the Combined Services Staff School, and the Command and General Staff College.

NASA EXPERIENCE: Kopra was assigned to NASA at the Johnson Space Center in September 1998 as a vehicle integration test engineer. In this position, he primarily served as an engineering liaison for Space Shuttle launch operations and International Space Station (ISS) hardware testing. He was actively involved in the contractor tests of the Extravehicular Activity (EVA) interfaces for each of the space station truss segments.

Selected as an astronaut in July 2000, Kopra began his initial training the following month. Kopra then completed two years of intensive Space Shuttle, Space Station, and T-38 flight training. He then served in the Space Station Branch of the Astronaut Office, where his primary focus involved the testing of crew interfaces for two ISS pressurized modules as well as the implementation of support computers and operational Local Area Network on ISS. After completing a Russian language immersion course in Moscow, Russia, Kopra began training for a long duration space flight mission in July 2005. Since then, he has completed training at each of the international partner training sites and served as a backup crewmember to Expeditions 16 and 17. Kopra is assigned to Expedition 19. He will launch to the International Space Station with the crew of STS-128, targeted to launch in June 2009.

MAY 2009

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10. ISS-20 FE: Michael Barratt, M.D., 50

PERSONAL DATA: Born on April 16, 1959 in Vancouver, Washington. Considers Camas, Washington, to be his home town. Married to the former Michelle Lynne Sasynuik. They have five children. His father and mother, Joseph and Donna Barratt, reside in Camas, Washington. Personal and recreational interests include family and church activities, writing, sailing, boat restoration and maintenance.

EDUCATION: Graduated from Camas High School, Camas, WA, 1977. B.S., Zoology, University of Washington, 1981. M.D., Northwestern University, 1985. Completed three year residency in Internal Medicine at Northwestern University 1988, completed Chief Residency year at Veterans Administration Lakeside Hospital in Chicago, 1989; Completed residency and Master's program in Aerospace Medicine, Wright State University, 1991. Board certified in Internal and Aerospace Medicine.

ORGANIZATIONS: Aerospace Medical Association; American College of Physicians; Alpha Omega Alpha Medical Honor Society; American Institute for the Advancement of Science.

SPECIAL HONORS: W. Randolph Lovelace Award (1998), Society of NASA Flight Surgeons; Rotary National Award for Space Achievement Foundation Nominee (1998); Melbourne W. Boynton Award (1995), American Astronautical Society; USAF Flight Surgeons Julian Ward Award (1992); Wright State University Outstanding Graduate Student, Aerospace Medicine (1991); Alpha Omega Alpha Medical Honor Society, Northwestern University Medical School, Chicago, IL (1988); Phi Beta Kappa, University of Washington, Seattle, WA (1981).

EXPERIENCE: Dr. Barratt came to NASA JSC in May 1991 employed as aerospace project physician with KRUG Life Sciences. From May 91 to July 92, he served on the Health Maintenance Facility Project as manager of the Hyperbaric and Respiratory Subsystems for Space Station Freedom. In July 92 he was assigned as NASA Flight Surgeon working in Space Shuttle Medical Operations. In January 94 he was assigned to the joint US/Russian Shuttle – Mir Program. He spent over 12 months onsite working and training in the Cosmonaut Training Center, Star City, Russia in support of the Mir-18 / STS-71 mission.

From July 95 through July 98, he served as Medical Operations Lead for the International Space Station (ISS). A frequent traveler to Russia, he worked with counterparts at the Gagarin Cosmonaut Training Center and Institute of Biomedical Problems, as well as other International Partner centers. Dr. Barratt served as lead crew surgeon for first expedition crew to ISS from July 98 until selected as an astronaut candidate. He serves as Associate Editor for Space Medicine for the journal Aviation, Space and Environmental Medicine, and is senior editor of the textbook 'Principles of Clinical Medicine for Space Flight'.

NASA EXPERIENCE: Selected as a mission specialist by NASA in July 2000, Dr. Barratt reported for training in August 2000. Following the completion of two years of training and evaluation, he was assigned technical duties in the Astronaut Office Station Operations Branch. Dr. Barratt is currently assigned to Expedition-19 and scheduled to arrive at the International Space Station in March 2009 aboard a Soyuz spacecraft.

JUNE 2008

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11. ISS-20 FE: Roman Romanenko, 37

PERSONAL DATA: Born August 9, 1971, in Schelkovo, Moscow Region. His parents, Yuri Victorovich Romanenko and Aleftina Ivanovna, reside in Star City. He is married to Yulia Leonidovna Romanenko (Danilovskaya). They have one son. His hobbies include underwater hunting, tennis, car repairs, tourism, yachting, volleyball, and music.

EDUCATION: After graduation from Star City high school in 1986 Romanenko entered the Leningrad Suvorov military school from which he graduated in 1988. In 1988 he entered the Chernigov High Air Force School of pilots from which he graduated in 1992 as a pilot-engineer.

EXPERIENCE: Following graduation from pilot school Romanenko served as a second commander in the Air Force. He flew L-39 and Tu-134 aircraft. Romanenko has logged over 500 hours of flight time. He is a Class 3 Air Force pilot.

Romanenko was selected as a test-cosmonaut candidate of the Gagarin Cosmonaut Training Center Cosmonaut Office in December 1997. From January 1998 to November 1999, he completed his basic training course. In November 1999, he was qualified as a test cosmonaut.

AUGUST 2002

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12. ISS-20 FE: Robert Thirsk, M.D., 55

PERSONAL DATA: Born August 17, 1953, New Westminster, British Columbia.

EDUCATION: Attended primary and secondary schools in British Columbia, Alberta, and Manitoba. Received a Bachelor of Science degree in Mechanical Engineering from the University of Calgary in 1976, a Master of Science in Mechanical Engineering from the Massachusetts Institute of Technology (MIT) in 1978, a Doctorate of Medicine from McGill University in 1982, and a Master of Business Administration from the MIT Sloan School of Management in 1998.

EXPERIENCE: Dr. Thirsk was in the family medicine residency program at the Queen Elizabeth Hospital in Montréal when he was selected in December 1983 for the Canadian Astronaut Program. He began astronaut training in February 1984 and served as backup payload specialist to Marc Garneau for the October 1984 space shuttle mission STS-41G.

Dr. Thirsk has been involved in various Canadian Space Agency projects including parabolic flight campaigns and mission planning. He served as crew commander for two space mission simulations: the seven-day CAPSULS mission in 1994, at Defence Research and Development Canada in Toronto, and the 11-day NEEMO 7 undersea mission in 2004 at the National Undersea Research Center in Key Largo, Florida. He led an international research team investigating the effect of weightlessness on the heart and blood vessels. He works with educational specialists in Canada to develop space-related curriculum for grade school students. Initiatives such as Canolab, Space for Species, and Tomatosphere have allowed thousands of young Canadians to experience the thrill of scientific discovery.

In June and July 1996, Dr. Thirsk flew as a payload specialist aboard space shuttle mission STS-78, the Life and Microgravity Spacelab (LMS) mission. During this 17-day flight aboard Columbia, he and his six crewmates performed 43 international experiments devoted to the study of life and materials sciences. The life science experiments investigated changes in plants, animals, and humans under space flight conditions. The materials science experiments examined protein crystallization, fluid physics and high-temperature solidification of multi-phase materials in a weightless environment.

In 1998, Dr. Thirsk was assigned by the Canadian Space Agency to NASA's Johnson Space Center in Houston to pursue mission specialist training. This training program involved advanced instruction on both shuttle and space station systems, EVA (spacewalking), robotic operations, and Russian language. Within the NASA Astronaut Office, Dr. Thirsk serves as a Capcom (capsule communicator) for the International Space Station (ISS) program. Capcoms participate in actual and simulated space missions as a communication link between the ground team at Mission Control and the astronauts in orbit. Capcoms speak directly with the space station crew, and assist with technical planning for the mission and last-minute troubleshooting.

In 2004, Dr. Thirsk trained at the Yuri Gagarin Cosmonaut Training Centre near Moscow and became certified as a Flight Engineer for the Soyuz spacecraft. He served as backup Flight Engineer to European Space Agency (ESA) astronaut Roberto Vittori for the Soyuz 10S taxi mission to the ISS in April 2005. During the 10-day mission, Dr. Thirsk worked as Crew Interface Coordinator (i.e. European Capcom) at the Columbus Control Centre in Germany.

Dr. Thirsk has now returned to the Johnson Space Center in Houston and has begun ISS Expedition crew training. He is currently assigned to the Expedition-19 crew and scheduled to arrive at the International Space Station in May 2009 aboard a Soyuz spacecraft.

FEBRUARY 2008

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13. ISS-20 FE: Frank De Winne, 48

PERSONAL DATA: Born in Ghent, Belgium, 25 April 1961. He is married and has three children. Enjoys football, small PC applications and gastronomy .

EDUCATION: Frank De Winne graduated from the Royal School of Cadets, Lier, in 1979. He received a Masters degree in telecommunications and civil engineering from the Royal Military Academy, Brussels, in 1984. He was awarded the AIA Prize for the best thesis. In 1991, he completed the Staff Course at the Defence College in Brussels gaining the highest distinction. In 1992, he graduated from the Empire Test Pilots School (ETPS) in Boscombe Down, England, where he was awarded the McKenna Trophy.

ORGANIZATIONS: Chairman of the Belgian Armed Forces Flying Personnel Association.

SPECIAL HONORS: First non-American pilot to receive the Joe Bill Dryden Semper Viper Award, in 1997, for demonstrating exceptional skills during a flight. Appointed "Officier in de Orde van Oranje Nassau" by the Dutch Queen for shown leadership during operation Allied Force (July 1999). He was awarded the "Medal of Friendship" from the Russian Federation. In 2003 De Winne received an honorary doctorate from the University of Limburg.

EXPERIENCE : After completing his pilot training with the Belgian Air Force, in 1986, Frank De Winne was an operational pilot on Mirage V aircraft. Detached to the Company SAGEM in Paris in 1989, he then worked in the Mirage Safety Improvement Programme where he was responsible for the preparation of the operational and technical specifications of the Mirage upgrade programme.

In December 1992, he was appointed to the Test and Evaluation Branch of the Belgian Air Force. As a test pilot, he was involved in various activities, such as CARAPACE (an electronic warfare programme on F16) at Eglin Air Force Base, USA, and a Self-Protection Programme for the C130 aircraft. During that period, he also flew in Gosselies as a reception pilot in different aircraft types.

From January 1994 to April 1995, Frank De Winne was responsible for the flight safety programme of the 1st Fighter Wing at Beauvechain, Belgium.

From April 1995 to July 1996, as a senior test pilot in the European Participating Air Forces (EPAF), he was detached to Edwards Air Force Base, California, where he worked on the mid-life update of the F16 aircraft, focussing on radar testing.

From 1996 to August 1998, he was senior test pilot in the Belgian Air Force, responsible for all test programmes and for all pilot-vehicle interfaces for future aircraft/software updates.

From August 1998 to January 2000, Frank De Winne was the Squadron Commander of the 349th Fighter Squadron at Kleine Brogel Airbase, Belgium.

During Operation Allied Force, Frank De Winne was the detachment commander of the Deployable Air Task Force, a combined Belgian/Dutch detachment that flew about 2000 sorties during this Nato campaign. He has logged 17 combat sorties.

Frank De Winne has logged more than 2300 hours flying time on several types of high-performance aircraft including Mirage, F16, Jaguar and Tornado.

In January 2000, Frank De Winne joined the European Astronaut Corps of the European Space Agency (ESA), whose homebase is the European Astronaut Centre in Cologne, Germany.

De Winne provided technical support for the X38/ CRV Project Division within the Directorate of Manned Spaceflight and Microgravity, located at ESTEC, Noordwijk/Netherlands.

In August 2001, De Winne took up training at the Gagarin Cosmonaut Training Centre GCTC (Star City) near Moscow. Training includes elements of Basic Training for the International Space Station as well as training as Soyuz board engineer.

De Winne also supported the implementation of the White Paper on Space Policy with the European Commission and preparatory activities for the Soyuz at CSG (Guiana Space Centre) project.

In February 2007 De Winne was assigned as Expedition-16 back-up crew member and commenced training with Leo Eyharts, prime for Expedition-16.

He is currently assigned to the Expedition-19 crew and scheduled to arrive at the International Space Station in May 2009 aboard a Soyuz spacecraft

SPACEFLIGHT EXPERIENCE: From 30 October to 10 November 2002 De Winne participated in the Odissea mission, a support flight to the International Space Station. He served as flight engineer on the newly designed Soyuz TMA spacecraft during ascent, and on Soyuz TM during reentry.

A prime task of the 11-day mission was the replacement of the TM-34 Soyuz vehicle attached to the Space Station by the new TMA-1 spacecraft, in order to deliver a fresh "lifeboat" for the resident crew to be used in case of an emergency.

During his nine days on board the Space Station, De Winne, whose flight was sponsored by the Belgian Federal Office for Scientific, Technical and Cultural Affairs (OSTC), carried out successfully a programme of 23 experiments in the fields of life and physical sciences and education, including experiments in an important new research facility designed and developed in Europe, the Microgravity Science Glovebox (MSG).

FEBRUARY 2008

STS-128 Crew Photographs


CDR Rick Sturckow


PLT Kevin Ford


MS1 Patrick Forrester


MS2/FE Jose Hernandez


MS3/EV1 Danny Olivas


MS4/EV2 Christer Fuglesang


MS5/EV3 Nicole Stott

ISS-20 Crew Photographs


ISS-20 CDR Gennady Padalka


ISS-20 FE Timothy Kopra


ISS-20 FE Michael Barratt, M.D.


ISS-20 FE Roman Romanenko


ISS-20 FE Robert Thirsk, M.D.


ISS-20 FE Frank DeWinne

STS-128 Launch Windows

The launch window for STS-128 is defined by a requirement to launch within about five minutes of the moment Earth's rotation carries the launch pad into the plane of the International Space Station's orbit. To optimize ascent performance, NASA targets the middle of the 10-minute launch window.

STS-128 Launch Windows

Date	Window Open	Launch	Window Close	Space Station Docking
08/23/09	02:19:17 AM	02:24:17 AM	02:29:17 AM	Flight day 3
08/24/09	01:53:35 AM	01:58:35 AM	02:03:35 AM	FD 3
			02:06:49 AM	FD 4
08/25/09	01:31:05 AM	01:36:05 AM	01:41:05 AM	FD 3
08/26/09	01:05:21 AM	01:10:21 AM	01:15:21 AM	FD 3
			01:18:34 AM	FD 4
08/27/09	12:42:49 AM	12:47:49 AM	12:52:49 AM	FD 3
08/28/09	12:17:07 AM	12:22:07 AM	12:27:07 AM	FD 3
	12:20:20 AM	12:25:20 AM	12:30:20 AM	FD 4
08/28/09	11:54:35 PM	11:59:35 PM	12:04:35 AM	FD 3
08/29/09	11:28:53 PM	11:33:53 PM	11:38:53 PM	FD 3
	11:32:06 PM	11:37:06 PM	11:42:06 PM	FD 4
08/30/09	11:06:21 PM	11:11:21 PM	11:16:21 PM	FD 3
08/31/09	10:40:40 PM	10:45:40 PM	10:50:40 PM	FD 3
	10:43:52 PM	10:48:52 PM	10:53:52 PM	FD 4
09/01/09	10:18:07 PM	10:23:07 PM	10:28:07 PM	FD 3

STS-128 Launch and Flight Control Personnel

KSC/LCC	Launch Ops	LCC PAO	Fueling PAO
STS-128 LD	Pete Nickolenko	Mike Currie	N/A
STS-128 NTD	Charlie Blackwell-Thompson		
STS-128 OTC	John Kracsum		

JSC/MCC	Flight Ops	MCC PAO	STS CAPCOM
Ascent FD	Richard Jones	Rob Navias	Eric Boe
Weather			TBD
Orbit 1 FD (ld)	Tony Ceccacci	Rob Navias	Tony Antonelli
Orbit 2 FD	Kwatsi Alibaruho	Josh Byerly	Stan Love
Planning FD	Gary Horlacher	Nicole Cloutier	Shannon Lucid
Entry FD	Richard Jones	Rob Navias	Eric Boe
Weather			TBD
Team 4	Mike Sarafin		

Flight Support	Prime	Backup	Backup
STS manager	John Shannon		
MMT (JSC)	LeRoy Cain		
MMT (KSC)	Mike Moses		
Weather Coord.	Dom Gorie		
Weather flight	TBD		
Launch STA	Steve Lindsey		
Entry STA (KSC)	Steve Lindsey		
Entry STA (EAFB)	Dom Gorie		
TAL Zaragoza	John Phillips		
TAL Istres	Al Drew		
TAL Moron	M. Lopez-Alegria		
JSC PAO at KSC	Lynette Madison		
HQ PAO at KSC	Mike Cabbage		
Astro Support	S. Kimbrough	Joe Acaba	Ken Ham
Family Support	TBD		

STS-128 Crew	Name	Launch Seating	Entry Seating
Commander	Rick Sturckow	Up-1	Up-1
Pilot	Kevin Ford	Up-2	Up-2
MS1	Patrick Forrester	Up-3	Up-3
MS2/FE	Jose Hernandez	Up-4	Up-4
MS3/EV1	Danny Olivas	Down-5	Down-5
MS4/EV2	C. Fuglesang	Down-6	Down-6
MS5/EV3 (up)	Nicole Stott	Down-7	N/A
MS5 (dn)	Tim Kopra	N/A	Down 7

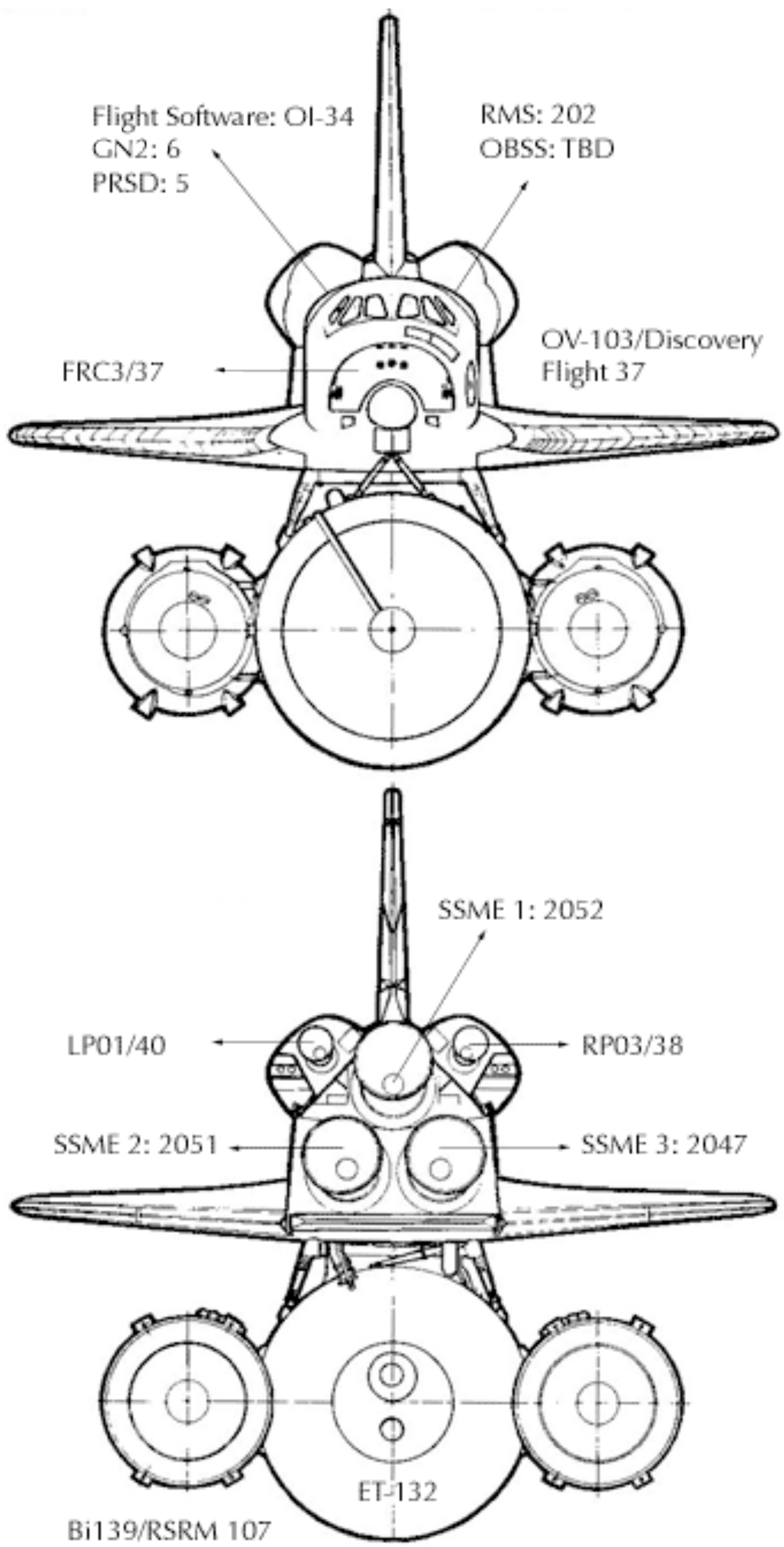
Bailout Order (ascent): TBD
Bailout Order (entry): TBD

Detail	Prime	Backup	Backup
FD-2 SRMS	Forrester	Ford	Hernandez
Late inspection	Forrester	Ford	Hernandez
ET Photo	Forrester	Fuglesang	
Photo/TV	Ford	Olivas	
PGSC/laptops	Hernandez	Fuglesang	
Cargo transfers	Sturckow	Hernandez	
Stowage	Olivas	Hernandez	
Water transfers	Ford	Sturckow	
Middeck to/from ISS	Olivas	Hernandez	

EVAs	Crew	Suit Markings	IV	Notes
EVA-1	Olivas	Red stripes	Forrester	
	Stott	No stripes		
EVA-2	Olivas	Red stripes	Forrester	
	Fuglesang	Broken stripes		

EVAs	Crew	Suit Markings	IV	Notes
EVA-3	Olivas Fuglesang	Red stripes Broken stripes	Forrester	

STS-128 Flight Hardware/Software



Discovery Flight History

Source: NASA

Discovery (OV-103), the third of NASA's fleet of reusable, winged spaceships, arrived at Kennedy Space Center in November 1983. It was launched on its first mission, flight 41-D, on August 30, 1984. It carried aloft three communications satellites for deployment by its astronaut crew. Other Discovery milestones include the deployment of the Hubble Space Telescope on mission STS-31 in April 1990, the launching of the Ulysses spacecraft to explore the sun's polar regions on mission STS-41 in October of that year and the deployment of the Upper Atmosphere Research Satellite (UARS) in September 1991.

Discovery is named for two famous sailing ships; one sailed by Henry Hudson in 1610-11 to search for a northwest passage between the Atlantic and Pacific Oceans, and the other by James Cook on a voyage during which he discovered the Hawaiian Islands.

FLT	#	STS	DD	HH	MM	SS	Launch	Mission Notes
N/A		41D	00	00	00	00	6/2/84	Flight readiness firing
N/A		41D	00	00	00	00	6/26/84	RSLS abort: SSME-3 MFV
01	12	41D	06	00	56	04	8/30/84	SBS, Syncom, Telstar
02	14	51A	07	23	44	56	11/7/84	Westar, Palapa retrieval
03	15	51C	03	01	33	23	1/24/85	DOD (Magnum?)
04	16	51D	06	23	55	23	4/12/85	Telesat, Syncom; EVA
05	18	51G	07	01	38	52	6/17/85	Morelos, Arabsat, Telstar
06	20	51I	07	02	17	42	8/27/85	ASC, Aussat, Syncom
N/A		26	00	00	00	00	8/10/88	FRF
07	26	26	04	01	00	11	9/29/88	TDRS-3 (return to flight)
08	28	29	04	23	38	50	3/13/89	TDRS-4
09	32	33	05	00	06	48	11/22/89	DOD
10	35	31	05	01	16	06	4/24/90	Hubble Space Telescope
11	36	41	04	02	10	04	10/6/90	Ulysses solar probe
12	40	39	08	07	22	23	4/28/91	DOD/SDI (unclassified)
13	43	48	05	08	27	38	9/12/91	UARS
14	45	42	08	01	14	44	1/22/92	IML-1
15	52	53	07	07	19	47	12/2/92	DOD-1 (payload classified)
16	54	56	09	06	08	24	4/8/93	ATLAS-2
N/A		51	00	00	00	00	8/12/93	RSLS abort
17	57	51	09	20	11	11	9/12/93	ACTS, SPAS
18	60	60	08	07	09	22	2/3/94	WSF-1, Russian MS
19	64	64	10	22	49	57	9/9/94	LITE, SAFER, SPIFEX; EVA
20	67	63	08	06	28	15	2/3/95	Mir-1, Spartan, EVA
21	70	70	08	22	20	07	7/13/95	TDRS-G
22	82	82	09	23	37	09	2/11/97	HST Servicing Mission
23	86	85	11	20	26	59	8/7/97	CRISTA-SPAS
24	91	91	09	19	53	57	6/2/98	Mir Docking No. 9
25	92	95	08	21	43	57	10/29/98	Spartan-201R; John Glenn
26	94	96	09	19	13	01	5/27/99	ISS 2A.1
27	96	103	07	23	10	47	12/19/99	HST SM-3A
28	100	92	12	22	21	41	10/11/00	ISS 3A
29	103	102	12	19	49	32	3/8/01	ISS 5A.1
30	106	105	11	21	12	44	8/10/01	ISS 7A.1
31	114	114	13	21	32	48	7/26/05	ISS ULF-1
32	115	121	12	18	36	48	7/4/06	ISS ULF-1.1
33	117	116	12	20	44	24	12/9/06	ISS 12A.1
34	120	120	15	02	23	00	10/23/07	ISS 10A
35	123	124	13	18	13	07	5/31/08	ISS 1J
36	125	119	12	19	29	33	3/15/09	ISS 15A
Vehicle Total			323	04	19	34		

STS-128 Countdown Timeline

Editor's Note…
All times up to and including the start of the final hold at T-minus nine minutes are targeted for the opening of the planar window. By convention, NASA rounds these times down in all cases.

EDT	EVENT
Fri 08/21/09	
10:30 PM	Call to stations
11:00 PM	Countdown begins
Sat 08/22/09	
09:00 AM	Fuel cell reactant load preps
02:30 PM	MEC/SRB power up
03:00 PM	Clear crew module
03:00 PM	Begin 4-hour built-in hold
03:00 PM	Clear blast danger area
03:45 PM	Orbiter pyro-initiator controller test
03:55 PM	SRB PIC test
04:55 PM	Master events controller pre-flight BITE test
07:00 PM	Resume countdown
08:30 PM	Fuel cell oxygen loading begins
11:00 PM	Fuel cell oxygen load complete
11:00 PM	Fuel cell hydrogen loading begins
Sun 08/23/09	
01:30 AM	Fuel cell hydrogen loading complete
02:30 AM	Pad open; ingress white room
03:00 AM	Begin 9-hour built-in hold
03:00 AM	Begin PRSD offload
03:00 AM	Crew module clean and vacuum
08:00 AM	PRSD offload complete
08:30 AM	OMBUU demate
12:00 PM	Countdown resumes
12:00 PM	Main engine preps; MECs 1 and 2 on
02:00 PM	FRCS Tyvek cover final inspection
06:30 PM	Deflate RSS dock seals
07:00 PM	Tile inspection
07:00 PM	TSM prepped for fueling
08:00 PM	Begin 13-hour 11-minute hold
09:30 PM	OIS communications check
10:20 PM	JSC flight control team on station
11:30 PM	Comm activation

EDT	EVENT
11:45 PM	L-1 engineering briefing
Mon 08/24/09	
12:00 AM	Crew weather briefing
01:00 AM	Flight crew equipment late stow
05:00 AM	RSS to park position
06:00 AM	Final TPS, debris inspection
07:00 AM	Ascent switch list
09:11 AM	Resume countdown
09:11 AM	ASP cockpit config
09:41 AM	Pad clear of non-essential personnel
09:31 AM	APU bite test
10:21 AM	Fuel cell activation
11:11 AM	Booster joint heater activation
11:41 AM	MEC pre-flight bite test
11:56 AM	Tanking weather update
12:41 PM	Final fueling preps; launch area clear
01:11 PM	Red crew assembled
01:56 PM	Fuel cell integrity checks complete
02:11 PM	Begin 2-hour built-in hold (T-minus 6 hours)
02:21 PM	Safe-and-arm PIC test
02:41 PM	Crew wakeup
03:11 PM	External tank ready for loading
03:34 PM	Mission management team tanking meeting
03:41 PM	Crew medical checks
04:11 PM	Resume countdown (T-minus 6 hours)
04:11 PM	LO2, LH2 transfer line chilldown
04:21 PM	Main propulsion system chill down
04:21 PM	LH2 slow fill
04:51 PM	LO2 slow fill
04:56 PM	Hydrogen ECO sensors go wet
05:01 PM	LO2 fast fill
05:04 PM	Crew medical checks
05:11 PM	LH2 fast fill
07:06 PM	LH2 topping
07:11 PM	LH2 replenish
07:11 PM	LO2 replenish
07:11 PM	Begin 2-hour 30-minute built-in hold (T-minus 3 hours)
07:11 PM	Closeout crew to white room
07:11 PM	External tank in stable replenish mode
07:26 PM	Astronaut support personnel comm checks
07:51 PM	Crew photo op (recorded)
07:56 PM	Pre-ingress switch reconfig
08:30 PM	NASA TV coverage begins
09:14 PM	Final crew weather briefing
09:24 PM	Crew suit up begins

EDT	EVENT
09:41 PM	Resume countdown (T-minus 3 hours)
09:46 PM	Crew departs O&C building
10:16 PM	Crew ingress
11:06 PM	Astronaut comm checks
11:31 PM	Hatch closure
Tue 08/25/09	
12:01 AM	White room closeout
12:21 AM	Begin 10-minute built-in hold (T-minus 20m)
12:31 AM	NASA test director countdown briefing
12:31 AM	Resume countdown (T-minus 20m)
12:32 AM	Backup flight computer to OPS 1
12:36 AM	KSC area clear to launch
12:42 AM	Begin final built-in hold (T-minus 9m)
01:07 AM	NTD launch status verification
01:27:05 AM	Resume countdown (T-minus 9m)
01:28:35 AM	Orbiter access arm retraction
01:31:05 AM	Launch window opens
01:31:05 AM	Hydraulic power system (APU) start
01:31:10 AM	Terminate LO2 replenish
01:32:05 AM	Purge sequence 4 hydraulic test
01:32:05 AM	IMUs to inertial
01:32:10 AM	Aerosurface steering profile
01:32:35 AM	Main engine steering test
01:33:10 AM	LO2 tank pressurization
01:33:15 AM	GOX vent arm retraction
01:33:30 AM	Fuel cells to internal reactants
01:33:35 AM	Clear caution-and-warning memory
01:34:05 AM	Crew closes visors
01:34:08 AM	LH2 tank pressurization
01:35:15 AM	Orbiter to internal power
01:35:34 AM	Shuttle computers take control of countdown
01:35:44 AM	SRB steering test
01:35:58 AM	Main engine start (T-6.6 seconds)
01:36:05 AM	SRB ignition (LAUNCH)

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STS-128 Weather Guidelines[5]

Landing Weather Flight Rules
All criteria refer to observed and forecast weather conditions except for the first day PLS, which is forecast weather only. Weather Flight Rules become more conservative for on-board or ground equipment problems. To launch, the RTLS forecast must be GO and at least one of the TAL sites must be GO.

RTLS / TAL / AOA / PLS Criteria
For RTLS (Return To Launch Site) with redundant MLS (Microwave Landing System) capability and a weather reconnaissance aircraft: The RTLS forecast must be GO to launch.

Cloud coverage 4/8 or less below 5,000 feet and a visibility of 4 statute miles or greater are required.

Wind (Peak): Crosswind component may not exceed 15 knots. Headwind may not exceed 25 knots. Tailwind may not exceed 15 knots. Peak winds must not be greater than 10 knots over the average wind.

Turbulence must not be greater than moderate intensity.

No thunderstorms, lightning, or precipitation within 20 nautical miles of the runway, or within 10 nautical miles of the final approach path extending outward to 30 nautical miles from the end of the runway. The 20 nautical mile standoff from the runway approximates the 10 nautical mile standoff to approaches at both ends of the runway. Under specific conditions, light rain showers are permitted within the 20 nautical mile radius providing they meet explicit criteria.

No detached opaque thunderstorm anvils less than three hours old within 15 nautical miles of the runway, or within 5 nautical miles of the final approach path extending outward to 30 nautical miles from the end of the runway.

For TAL (Trans-oceanic Abort Landing) sites with redundant MLS (Microwave Landing System) capability and a weather reconnaissance aircraft: To launch, at least one of the TAL sites must be GO.

Cloud coverage 4/8 or less below 5,000 feet and a visibility of 5 statute miles or greater are required.

Wind (Peak): Crosswind component may not exceed 15 knots. Headwind may not exceed 25 knots. Tailwind may not exceed 15 knots. Peak winds must not be greater than 10 knots over the average wind.

Turbulence must not be greater than moderate intensity.

No thunderstorms, lightning, or precipitation within 20 nautical miles of the runway, or within 10 nautical miles of the final approach path extending outward to 30 nautical miles from the end of the runway. The 20 nautical mile standoff from the runway approximates the 10 nautical mile standoff along the approaches to both ends of the runway. Under specific conditions, light rain showers are permitted within the 20 nautical mile radius providing they meet explicit criteria.

No detached opaque thunderstorm anvils less than three hours old within 15 nautical miles of the runway, or within 5 nautical miles of the final approach path extending outward to 30 nautical miles from the end of the runway.

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[5] Source: Spaceflight Meteorology Group, Johnson Space Center

For AOA (Abort Once Around) sites:

Cloud coverage 4/8 or less below 8,000 feet and a visibility of 5 statute miles or greater is required.

Wind (Peak): Crosswind component may not exceed 15 knots (PLS night landing crosswind may not exceed 12 knots). Headwind may not exceed 25 knots. Tailwind may not exceed 15 knots. Peak winds must not be greater than 10 knots over the average wind.

Turbulence must not be greater than moderate intensity.

No thunderstorms, lightning, or precipitation within 30 nautical miles of the runway. The 30 nautical mile standoff from the runway approximates the 20 nautical mile standoff along the approaches to both ends of the runway.

No detached opaque thunderstorm anvil cloud less than 3 hours old within 20 nautical miles of the runway or within 10 nautical miles of the final approach path extending to 30 nautical miles from the end of the runway.

For first day PLS (Primary Landing Sites):

Cloud coverage 4/8 or less below 8,000 feet and a visibility of 5 statute miles or greater is required.

Wind (Peak): Crosswind component may not exceed 15 knots (PLS night landing crosswind may not exceed 12 knots). Headwind may not exceed 25 knots. Tailwind may not exceed 15 knots. Peak winds must not be greater than 10 knots over the average wind.

Turbulence must not be greater than moderate intensity.

No thunderstorms, lightning, or precipitation within 30 nautical miles of the runway. The 30 nautical mile standoff from the runway approximates the 20 nautical mile standoff along the approaches to both ends of the runway.

No detached opaque thunderstorm anvil cloud less than 3 hours old within 20 nautical miles of the runway or within 10 nautical miles of the final approach path extending to 30 nautical miles from the end of the runway.

End-of-Mission Landing Weather Flight Rules:

Cloud coverage of 4/8 or less below 8,000 feet and a visibility of 5 miles or greater required.

Wind (Peak): Daylight crosswind component may not exceed 15 knots (12 knots at night). Headwind may not exceed 25 knots. Tailwind may not exceed 15 knots. Peak winds must not be greater than 10 knots over the average wind. Turbulence must not be greater than moderate intensity.

No thunderstorms, lightning, or precipitation within 30 nautical miles of the runway. The 30 nautical mile standoff from the runway approximates the 20 nautical mile standoff along the approaches to both ends of the runway.

Detached opaque thunderstorm anvils less than three hours old must not be within 20 nautical miles of the runway or within 10 nautical miles of the flight path when the orbiter is within 30 nautical miles of the runway.

Consideration may be given for landing with a "no go" observation and a "go" forecast if at decision time analysis clearly indicates a continuing trend of improving weather conditions, and the forecast states that all weather criteria will be met at\ landing time.

Weather Terms (Abbreviated Listing)

Cloud Coverage:

SKC	Sky Clear	(No clouds)
FEW	Few	
SCT	Scattered	(3/8 or 4/8 cloud coverage)
BKN*	Broken	(5/8 through 7/8 cloud coverage)
OVC*	Overcast	(8/8 cloud coverage)

* BKN and OVC are considered cloud ceilings

Cloud Height: Heights in hundreds of feet above ground level (e.g. 025 = 2,500 ft; 250 = 25,000 ft.)
Visibility: Distance in statute miles

The speed is in knots (1 knot = 1.15 MPH), typically given in average and peak (e.g. 10P16)

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STS-128 Ascent Events Summary

Flight Data	EDT	L-MM:SS	Terminal Countdown
STS-128	12:42:05 AM	L-45:00	**T-9 hold begins**
25-Aug-09	1:27:05 AM	L-09:00	Resume countdown
01:36:05 AM	1:28:35 AM	L-07:30	Orbiter access arm retraction
Win Close	1:31:05 AM	L-05:00	Auxilliary power unit start
01:41:05 AM	1:31:10 AM	L-04:55	Liquid oxygen drainback begins
-121:55:30	1:32:05 AM	L-03:55	Purge sequence 4 hydraulic test
	1:33:10 AM	L-02:55	Oxygen tank at flight pressure
SLF Max Wind:	1:33:15 AM	L-02:50	Gaseous oxygen vent arm retraction
TBD	1:33:30 AM	L-02:35	Fuel cells to internal
Wind Direction:	1:34:08 AM	L-01:57	Hydrogen tank at flight pressure
TBD	1:35:15 AM	L-00:50	Orbiter to internal power
SLF Crosswind:	1:35:34 AM	L-00:31	Shuttle computers control countdown
TBD	1:35:44 AM	L-00:21	Booster steering test
TBD	1:35:58 AM	L-00:06.6	Main engine ignition

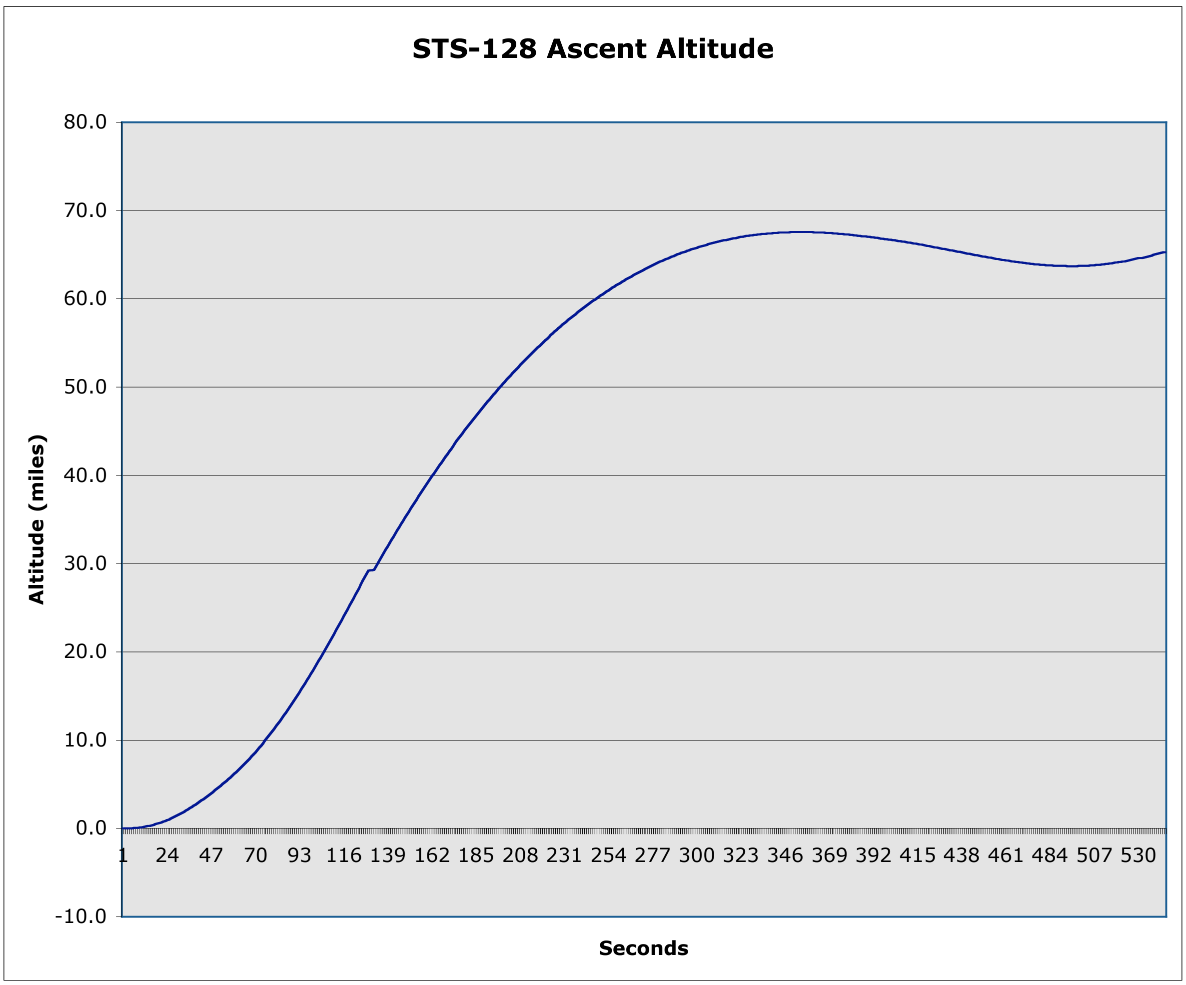
Abort Data		L+MM:SS	Ascent Events Timeline	MPH	FPS
0:02:30	**1:36:05 AM**	**T+0:00**	**LAUNCH**		
RTLS	1:36:16 AM	T+00:11	START ROLL MANEUVER	927	1,360
ONLY	1:36:23 AM	T+00:18	END ROLL MANEUVER	1,002	1,470
	1:36:39 AM	T+00:34	START THROTTLE DOWN (72%)	1,221	1,790
	1:36:54 AM	T+00:49	START THROTTLE UP (104.5%)	1,425	2,090
	1:37:07 AM	T+01:02	MAX Q (754 psf)	1,664	2,440
	1:38:08 AM	T+02:03	SRB STAGING	3,621	5,310
	1:38:18 AM	T+02:13	START OMS ASSIST (1:36 duration)	3,744	5,490
0:02:25	1:38:35 AM	T+02:30	**2 ENGINE TAL MORON (104.5%, 2s)**	4,023	5,900
TAL	1:38:40 AM	T+02:35	2 ENGINE TAL ZARAGOZA (104.5%, 2s)	4,091	6,000
	1:38:51 AM	T+02:46	2 ENGINE TAL ISTRES (104.5%, 2s)	4,296	6,300
	1:39:57 AM	T+03:52	NEGATIVE RETURN (KSC) (104.5%, 3s)	5,523	8,100
0:01:52	1:41:00 AM	T+04:55	**PRESS TO ATO (104.5%, 2s, 160 u/s)**	7,296	10,700
ATO	1:41:28 AM	T+05:23	DROOP ZARAGOZA (109%,0s)	8,183	12,000
	1:41:31 AM	T+05:26	SINGLE ENGINE OPS-3 ZARAGOZA (109%,0s,2EO SIMO)	8,251	12,100
	1:42:10 AM	T+06:05	SINGLE ENGINE TAL ZARAGOZA (104.5%,2s,2EO SIMO)	9,751	14,300
	1:42:10 AM	T+06:05	SINGLE ENGINE TAL MORON (109%,0s,2EO SEQ,1st EO @ VI)	11,115	16,300
	1:42:10 AM	T+06:05	SINGLE ENGINE TAL ISTRES (109%,0s,2EO SEQ,1st EO @ VI)	11,524	16,900
MECO Ha/Hp	1:42:52 AM	T+06:47	**PRESS TO MECO (104.5%, 2s, 160 u/s)**	11,660	17,100
	1:43:14 AM	T+07:09	SINGLE ENGINE PRESS-TO-MECO (104.5%, 2s, 588 u/s)	12,888	18,900
136 X 36 sm	1:43:27 AM	T+07:22	NEGATIVE MORON (2@67%)	13,569	19,900
	1:43:47 AM	T+07:42	LAST 2 ENG PRE-MECO TAL ZARAGOZA (67%)	14,865	21,800
OMS-2 Ha/Hp	1:43:47 AM	T+07:42	NEGATIVE ISTRES (2@67%)	14,865	21,800
141 X 98 sm	1:43:53 AM	T+07:48	LAST SINGLE ENG PRE-MECO TAL ZARAGOZA (104.5%)	15,342	22,500
	1:43:59 AM	T+07:54	LAST 3 ENG PRE-MECO TAL ZARAGOZA (67%)	15,683	23,000
	1:44:24 AM	T+08:19	LAST TAL DIEGO GARCIA	17,252	25,300
	1:44:29 AM	T+08:24	MECO COMMANDED	17,552	25,740
	1:44:40 AM	T+08:35	ZERO THRUST	17,592	25,800
			Compiled by William Harwood	**Inertial Velocity**	

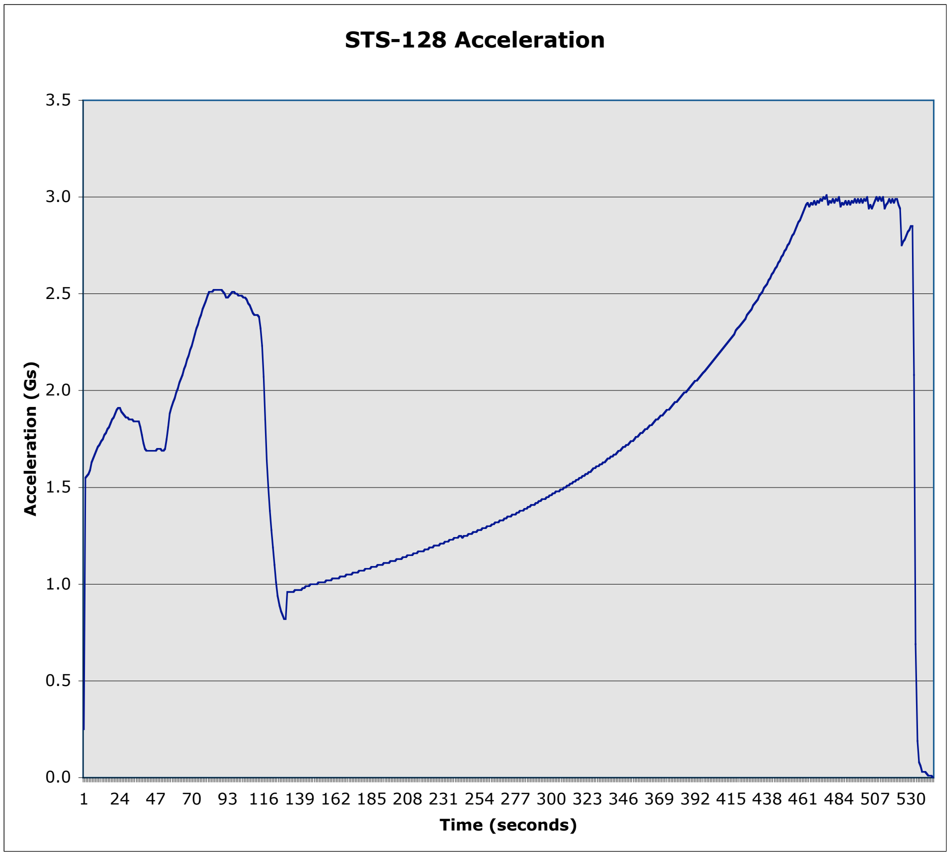
STS-128 Trajectory Data[6]

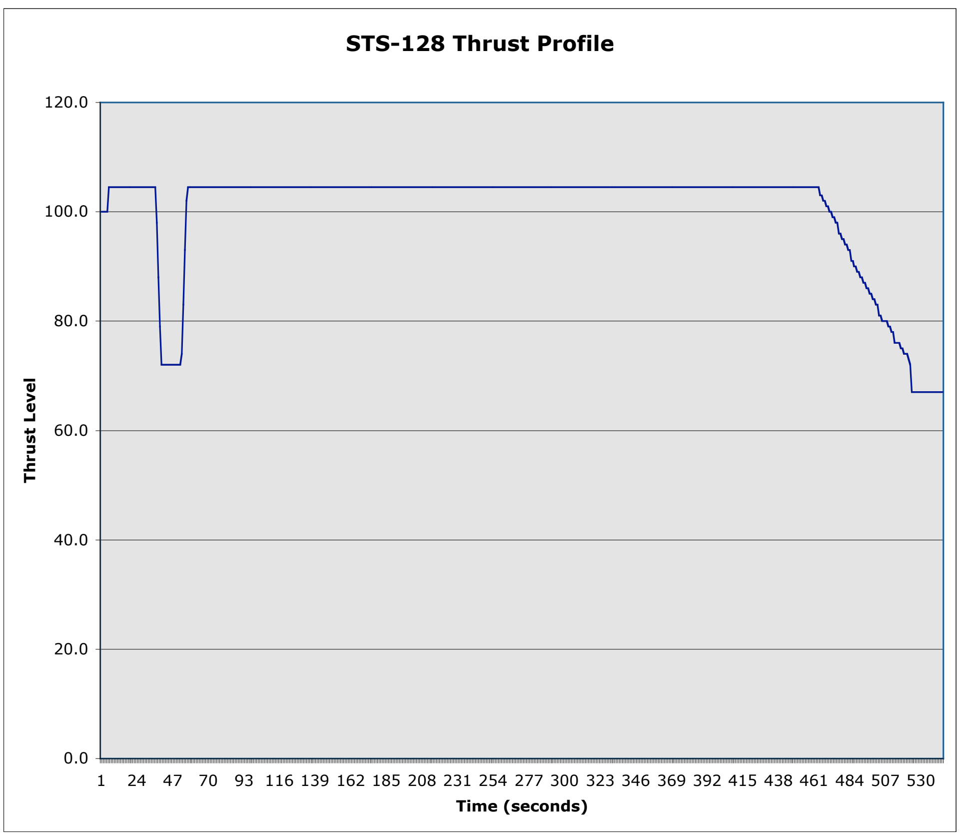
T+ MM:SS	Thrust (%)	Altitude FT	Altitude Miles	Mach Number	Vi MPH	Vi FPS	Gs	Range (sm)
00:00	100.0	-23	0.0	0.0	0.0	914.4	0.3	0.0
00:10	104.5	794	0.2	0.2	127.5	922.6	1.7	0.0
00:20	104.5	4,079	0.8	0.4	312.3	1,029.6	1.9	0.1
00:30	104.5	9,387	1.8	0.7	498.5	1,164.6	1.9	0.5
00:40	72.0	17,568	3.3	0.9	675.7	1,311.9	1.7	1.1
00:50	74.0	26,595	5.0	1.1	813.5	1,439.4	1.7	2.0
01:00	104.5	37,082	7.0	1.5	992.1	1,603.8	2.1	3.2
01:10	104.5	50,969	9.7	2.0	1,262.8	1,863.6	2.3	4.9
01:20	104.5	66,006	12.5	2.4	1,585.4	2,190.2	2.5	7.0
01:30	104.5	85,048	16.1	3.0	1,981.5	2,599.3	2.5	10.3
01:40	104.5	104,229	19.7	3.5	2,360.7	2,991.4	2.5	14.2
01:50	104.5	126,928	24.0	4.0	2,770.5	3,414.2	2.1	19.5
02:00	104.5	147,989	28.0	4.1	2,938.2	3,594.9	0.9	25.2
02:10	104.5	168,723	32.0	4.2	3,033.7	3,702.6	1.0	31.4
02:20	104.5	189,521	35.9	4.5	3,159.8	3,841.7	1.0	38.5
02:30	104.5	207,259	39.3	4.8	3,288.0	3,980.8	1.0	45.3
02:40	104.5	223,884	42.4	5.2	3,429.2	4,129.5	1.1	52.5
02:50	104.5	240,899	45.6	5.5	3,596.9	4,304.7	1.1	60.9
03:00	104.5	255,230	48.3	5.9	3,761.9	4,474.5	1.1	69.0
03:10	104.5	269,767	51.1	6.3	3,954.9	4,672.2	1.1	78.4
03:20	104.5	281,888	53.4	6.7	4,141.7	4,861.1	1.2	87.4
03:30	104.5	292,990	55.5	7.2	4,338.8	5,060.2	1.2	97.0
03:40	104.5	304,052	57.6	7.4	4,567.2	5,289.3	1.2	108.0
03:50	104.5	313,087	59.3	7.6	4,785.4	5,508.2	1.2	118.6
04:00	104.5	321,927	61.0	7.8	5,035.0	5,757.1	1.3	130.8
04:10	104.5	329,006	62.3	8.1	5,271.6	5,992.4	1.3	142.5
04:20	104.5	335,202	63.5	8.3	5,518.4	6,238.5	1.4	154.8
04:30	104.5	341,032	64.6	8.5	5,802.1	6,520.8	1.4	168.9
04:40	104.5	345,467	65.4	8.8	6,071.5	6,788.1	1.4	182.4
04:50	104.5	349,431	66.2	9.1	6,381.0	7,095.0	1.5	198.0
05:00	104.5	352,240	66.7	9.5	6,674.2	7,386.1	1.5	212.9
05:10	104.5	354,505	67.1	9.9	7,010.4	7,719.6	1.6	230.0
05:20	104.5	355,857	67.4	10.3	7,329.5	8,036.6	1.7	246.4
05:30	104.5	356,578	67.5	10.7	7,663.0	8,366.7	1.7	263.4
05:40	104.5	356,694	67.6	11.3	8,045.5	8,746.5	1.8	283.1
05:50	104.5	356,238	67.5	11.8	8,409.6	9,107.2	1.9	301.9
06:00	104.5	355,197	67.3	12.4	8,827.6	9,522.4	1.9	323.5
06:10	104.5	353,903	67.0	13.0	9,224.5	9,916.6	2.0	344.0
06:20	104.5	352,240	66.7	13.7	9,682.7	10,371.4	2.1	367.7
06:30	104.5	350,508	66.4	14.4	10,124.5	10,809.8	2.2	390.2
06:40	104.5	348,517	66.0	15.2	10,588.9	11,270.8	2.3	413.8
06:50	104.5	346,133	65.6	16.1	11,129.0	11,807.4	2.5	441.0
07:00	104.5	343,906	65.1	16.9	11,648.5	12,323.6	2.6	467.0
07:10	104.5	341,542	64.7	18.0	12,254.7	12,925.7	2.8	496.9
07:20	104.5	339,608	64.3	18.9	12,841.8	13,510.1	2.9	525.5
07:30	100.0	338,036	64.0	19.9	13,452.8	14,116.9	3.0	555.4
07:40	93.0	336,866	63.8	21.0	14,128.5	14,789.3	3.0	590.0

[6] Predicted data.

T+ MM:SS	Thrust (%)	Altitude FT	Altitude Miles	Mach Number	Vi MPH	Vi FPS	Gs	Range (sm)
07:50	87.0	336,398	63.7	22.0	14,740.9	15,398.2	3.0	622.9
08:00	81.0	336,669	63.8	23.0	15,415.9	16,069.8	3.0	660.7
08:10	76.0	337,785	64.0	23.8	16,028.3	16,680.1	3.0	696.5
08:20	67.0	339,993	64.4	24.6	16,671.9	17,320.4	2.8	736.2
08:30	67.0	343,064	65.0	24.7	16,957.7	17,604.8	0.0	775.9
08:31	67.0	343,374	65.0	24.7	16,957.7	17,605.4	0.0	779.8
08:32	67.0	343,684	65.1	24.7	16,958.3	17,605.4	0.0	783.6
08:33	67.0	343,994	65.2	24.7	16,958.3	17,606.1	0.0	787.5
08:34	67.0	344,305	65.2	24.6	16,958.3	17,606.1	0.0	791.3
08:35	67.0	344,616	65.3	24.6	16,958.3	17,605.4	0.0	795.2




STS-128 Acceleration
Acceleration (Gs)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1 24 47 70 93 116 139 162 185 208 231 254 277 300 323 346 369 392 415 438 461 484 507 530
Time (seconds)


STS-128 Thrust Profile
Thrust Level
120.0
100.0
80.0
60.0
40.0
20.0
0.0
1 24 47 70 93 116 139 162 185 208 231 254 277 300 323 346 369 392 415 438 461 484 507 530
Time (seconds)

STS-128 Flight Plan

Editor's Note…
Current as of 08/19/09

ACRONYMS: OMS: orbital maneuvering system rockets; RMS: shuttle robot arm; SSRMS: station robot arm; EMU: shuttle spacesuits; group B: backup computer powerdown/powerup; SAFER: spacewalk jet backpack; EVA: spacewalk; PMA: pressurized mating adaptor; FGB: Zarya core module; SM: Zvezda command module; PAO: public affairs office; FCS: flight control system; RCS: reaction control system rockets

DATE/ET	DD	HH	MM	SS	EVENT
Flight Day 1					
08/25					
Tue 01:36 AM	00	00	00	00	Launch
Tue 02:13 AM	00	00	37	48	OMS-2 rocket firing
Tue 02:26 AM	00	00	50	00	Post insertion timeline begins
Tue 04:06 AM	00	02	30	00	Laptop computer setup (part 1)
Tue 04:16 AM	00	02	40	00	SRMS powerup
Tue 05:04 AM	00	03	28	24	NC-1 rendezvous rocket firing
Tue 05:36 AM	00	04	00	00	Group B computer powerdown
Tue 05:46 AM	00	04	10	00	GIRA installation
Tue 05:51 AM	00	04	15	00	SRMS checkout
Tue 06:06 AM	00	04	30	00	Wing leading edge sensors activated
Tue 06:06 AM	00	04	30	00	ET photo
Tue 06:16 AM	00	04	40	00	Umbilcal camera downlink
Tue 06:36 AM	00	05	00	00	SRMS payload bay survey
Tue 06:36 AM	00	05	00	00	ET video downlink
Tue 06:56 AM	00	05	20	00	SEE setup
Tue 07:06 AM	00	05	30	00	RMS powerdown
Tue 08:06 AM	00	06	30	00	Crew sleep begins
Flight Day 2					
Tue 04:06 PM	00	14	30	00	Crew wakeup
Tue 06:35 PM	00	16	59	53	NC-2 rendezvous rocket firing
Tue 06:41 PM	00	17	05	00	SRMS unberths OBSS
Tue 06:56 PM	00	17	20	00	Ergometer setup
Tue 07:26 PM	00	17	50	00	Spacesuit checkout preps
Tue 07:56 PM	00	18	20	00	OBSS starboard wing survey
Tue 07:56 PM	00	18	20	00	Spacesuit checkout
Tue 09:41 PM	00	20	05	00	Crew meals begin
Tue 10:41 PM	00	21	05	00	OBSS nose cap survey
Tue 11:31 PM	00	21	55	00	OBSS port wing survey
08/26					
Wed 12:41 AM	00	23	05	00	Spacesuit prepped for transfer to station
Wed 01:36 AM	01	00	00	00	SRMS berths OBSS
Wed 01:41 AM	01	00	05	00	LDRI downlink
Wed 03:06 AM	01	01	30	00	Rendezvous tools checkout
Wed 03:26 AM	01	01	50	00	Centerline camera setup
Wed 03:36 AM	01	02	00	00	NC-3 rendezvous rocket firing

DATE/ET	DD	HH	MM	SS	EVENT
Wed 03:56 AM	01	02	20	00	Orbiter docking system ring extension
Wed 07:06 AM	01	05	30	00	Crew sleep begins
Flight Day 3					
Wed 03:06 PM	01	13	30	00	STS/ISS crew wakeup
Wed 04:26 PM	01	14	50	00	Group B computer powerup
Wed 04:31 PM	01	14	55	00	ISS daily planning conference
Wed 04:41 PM	01	15	05	00	Rendezvous timeline begins
Wed 06:17 PM	01	16	41	13	NC-4 rendezvous rocket firing
Wed 06:36 PM	01	17	00	00	Spacesuits removed from airlock
Wed 07:49 PM	01	18	13	41	TI burn
Wed 09:26 PM	01	19	50	00	Rendezvous pitch maneuver
Wed 10:27 PM	01	20	51	41	DOCKING
Wed 10:46 PM	01	21	10	00	Leak checks
Wed 11:16 PM	01	21	40	00	Group B computer powerdown
Wed 11:16 PM	01	21	40	00	Docking system set for ingress
Wed 11:31 PM	01	21	55	00	Post docking laptop reconfig
Wed 11:46 PM	01	22	10	00	Hatch open
08/27					
Thu 12:16 AM	01	22	40	00	Welcome aboard!
Thu 12:26 AM	01	22	50	00	Safety briefing
Thu 12:56 AM	01	23	20	00	Soyuz seatliner transfer/installation
Thu 02:31 AM	02	00	55	00	OBSS handoff to SRMS
Thu 02:46 AM	02	01	10	00	SSRMS ungrapples OBSS
Thu 03:01 AM	02	01	25	00	SSRMS ops review
Thu 03:06 AM	02	01	30	00	ISS: Sokol suit leak checks
Thu 04:06 AM	02	02	30	00	ISS evening planning conference
Thu 04:11 AM	02	02	35	00	Playback ops
Thu 06:36 AM	02	05	00	00	ISS crew sleep begins
Thu 07:06 AM	02	05	30	00	STS crew sleep begins
Flight Day 4					
Thu 03:06 PM	02	13	30	00	STS/ISS crew wakeup
Thu 05:06 PM	02	15	30	00	ISS daily planning conference
Thu 05:16 PM	02	15	40	00	SSRMS grapples MPLM
Thu 05:46 PM	02	16	10	00	SSRMS unberths MPLM
Thu 06:06 PM	02	16	30	00	ISS locker install
Thu 06:51 PM	02	17	15	00	Middeck transfers
Thu 07:06 PM	02	17	30	00	MPLM installation
Thu 07:36 PM	02	18	00	00	MPLM: 1st stage bolts
Thu 07:56 PM	02	18	20	00	MPLM: 2nd stage bolts
Thu 08:06 PM	02	18	30	00	Post-docking EVA transfers
Thu 08:41 PM	02	19	05	00	Crew meals begin
Thu 08:46 PM	02	19	10	00	SSRMS ungrapples MPLM
Thu 09:41 PM	02	20	05	00	MPLM vestibule pressurization
Thu 10:46 PM	02	21	10	00	REBA checkout
Thu 10:56 PM	02	21	20	00	MPLM vestibule readied for ingress
Thu 11:01 PM	02	21	25	00	EVA tools configured

DATE/ET	DD	HH	MM	SS	EVENT
Thu 11:16 PM	02	21	40	00	SSRMS ops review
08/28					
Fri 12:26 AM	02	22	50	00	MPLM activation (part 1)
Fri 12:31 AM	02	22	55	00	Equipment lock preps
Fri 02:11 AM	03	00	35	00	PAO event
Fri 02:21 AM	03	00	45	00	MPLM vestibule closeout
Fri 02:31 AM	03	00	55	00	EVA-1: Procedures review
Fri 02:41 AM	03	01	05	00	MPLM ingress
Fri 03:31 AM	03	01	55	00	ISS daily planning conference
Fri 05:01 AM	03	03	25	00	EVA-1: Mask/pre-breathe
Fri 05:46 AM	03	04	10	00	EVA-1: Airlock depress to 10.2 psi
Fri 06:06 AM	03	04	30	00	ISS crew sleep begins
Fri 06:36 AM	03	05	00	00	STS crew sleep begins
Flight Day 5					
Fri 02:36 PM	03	13	00	00	Crew wakeup
Fri 03:11 PM	03	13	35	00	EVA-1: 14.7 psi repress/hygiene break
Fri 04:01 PM	03	14	25	00	EVA-1: Airlock depress to 10.2 psi
Fri 04:21 PM	03	14	45	00	EVA-1: Campout EVA preps
Fri 04:21 PM	03	14	45	00	ISS daily planning conference
Fri 05:51 PM	03	16	15	00	EVA-1: Spacesuit purge
Fri 06:06 PM	03	16	30	00	EVA-1: Spacesuit prebreathe
Fri 06:06 PM	03	16	30	00	ZSR transfer
Fri 06:31 PM	03	16	55	00	ZSR deploy
Fri 06:56 PM	03	17	20	00	EVA-1: Crew lock depressurization
Fri 07:01 PM	03	17	25	00	Colbert rack transfer
Fri 07:26 PM	03	17	50	00	EVA-1: Spacesuits to battery power
Fri 07:31 PM	03	17	55	00	EVA-1: Airlock egress
Fri 07:46 PM	03	18	10	00	EVA-1: Setup
Fri 08:11 PM	03	18	35	00	EVA-1: P1 ATA release
Fri 08:21 PM	03	18	45	00	CQ rack transfer
Fri 09:56 PM	03	20	20	00	EVA-1: EUTEF retrieval/stow
Fri 10:36 PM	03	21	00	00	ARS rack transfer
Fri 11:46 PM	03	22	10	00	EVA-1/EV-1: MISSE 6 retrieval/stow
Fri 11:46 PM	03	22	10	00	EVA-1/EV-3: SSRMS reconfig
08/29					
Sat 12:11 AM	03	22	35	00	EVA-1/EV-3: MISSE 6 PEC stow
Sat 12:36 AM	03	23	00	00	EVA-1/EV-3: Get aheads
Sat 01:16 AM	03	23	40	00	EVA-1: Cleanup/airlock ingress
Sat 01:56 AM	04	00	20	00	EVA-1: Airlock pressurization
Sat 02:11 AM	04	00	35	00	Spacesuit servicing
Sat 03:21 AM	04	01	45	00	ISS evening planning conference
Sat 05:36 AM	04	04	00	00	ISS crew sleep begins
Sat 06:06 AM	04	04	30	00	STS crew sleep begins
Flight Day 6					
Sat 02:06 PM	04	12	30	00	Crew wakeup

DATE/ET	DD	HH	MM	SS	EVENT
Sat 03:56 PM	04	14	20	00	ISS daily planning conference
Sat 04:50 PM	04	15	14	00	F1 DOUG review
Sat 05:21 PM	04	15	45	00	Focused inspection (if needed)
Sat 05:21 PM	04	15	45	00	FIR rack transfer
Sat 06:21 PM	04	16	45	00	MSRR rack transfer
Sat 07:21 PM	04	17	45	00	MELFI-2 rack transfer
Sat 08:26 PM	04	18	50	00	Spacesuit swap
Sat 10:06 PM	04	20	30	00	PAO event
Sat 10:21 PM	04	20	45	00	EVA-2: Tools configured
Sat 10:21 PM	04	20	45	00	MPLM transfers
Sat 11:51 PM	04	22	15	00	Equipment lock preps
08/30					
Sun 01:41 AM	05	00	05	00	PAO event
Sun 02:01 AM	05	00	25	00	EVA-2: Procedures review
Sun 03:01 AM	05	01	25	00	Evening planning conference
Sun 04:31 AM	05	02	55	00	EVA-2: Mask pre-breathe
Sun 05:16 AM	05	03	40	00	EVA-2: Airlock depress to 10.2 psi
Sun 05:36 AM	05	04	00	00	ISS crew sleep begins
Sun 06:06 AM	05	04	30	00	STS crew sleep begins
Flight Day 7					
Sun 02:06 PM	05	12	30	00	Crew wakeup
Sun 02:41 PM	05	13	05	00	EVA-2: 14.7 psi repress/hygiene break
Sun 03:31 PM	05	13	55	00	EVA-2: Airlock depress to 10.2 psi
Sun 03:51 PM	05	14	15	00	EVA-2: Campout EVA preps
Sun 04:06 PM	05	14	30	00	ISS daily planning conference
Sun 05:06 PM	05	15	30	00	MPLM transfers
Sun 05:21 PM	05	15	45	00	EVA-2: Spacesuit purge
Sun 05:36 PM	05	16	00	00	EVA-2: Spacesuit prebreathe
Sun 06:26 PM	05	16	50	00	EVA-2: Crew lock depressurization
Sun 06:56 PM	05	17	20	00	EVA-2: Spacesuits to battery power
Sun 07:01 PM	05	17	25	00	EVA-2: Airlock egress
Sun 07:16 PM	05	17	40	00	EVA-2/EV-1: ATA worksite setup
Sun 07:16 PM	05	17	40	00	EVA-2/EV-2: SSRMS setup
Sun 07:51 PM	05	18	15	00	EVA-2: ATA removal from LMC
Sun 08:41 PM	05	19	05	00	EVA-2/EV-1: Prep for ATA install
Sun 08:41 PM	05	19	05	00	EVA-2/EV-2: Maneuver to ATA install
Sun 09:11 PM	05	19	35	00	EVA-2/EV-1: ATA zenith bolts
Sun 09:11 PM	05	19	35	00	EVA-2/EV-2: ATA nadir bolts
Sun 09:36 PM	05	20	00	00	EVA-2/EV-1: NH3/N2 electrical connections
Sun 09:36 PM	05	20	00	00	EVA-2/EV-2: Prep for ATA handoff
Sun 10:01 PM	05	20	25	00	EVA-2/EV-2: ATA handoff and move to LMC
Sun 11:31 PM	05	21	55	00	EVA-2: ATA intall on LMC
08/31					
Mon 12:51 AM	05	23	15	00	EVA-2: Cleanup and airlock ingress
Mon 01:26 AM	05	23	50	00	EVA-2: Airlock repressurization
Mon 01:41 AM	06	00	05	00	Spacesuit servicing
Mon 02:51 AM	06	01	15	00	Evening planning conference

DATE/ET	DD	HH	MM	SS	EVENT
Mon 05:06 AM	06	03	30	00	ISS crew sleep begins
Mon 05:36 AM	06	04	00	00	STS crew sleep begins
Flight Day 8					
Mon 01:36 PM	06	12	00	00	Crew wakeup
Mon 03:21 PM	06	13	45	00	ISS daily planning conference
Mon 04:36 PM	06	15	00	00	Shuttle crew off duty
Mon 09:06 PM	06	19	30	00	Crew meals
Mon 10:06 PM	06	20	30	00	Crew photo
Mon 10:26 PM	06	20	50	00	Crew mews conference
Mon 11:06 PM	06	21	30	00	MPLM transfer
Mon 11:06 PM	06	21	30	00	EVA-3: Tools configured
09/01					
Tue 12:51 AM	06	23	15	00	Equipment lock preps
Tue 01:36 AM	07	00	00	00	EVA-3: Procedures review
Tue 02:31 AM	07	00	55	00	Evening planning conference
Tue 04:01 AM	07	02	25	00	EVA-3: Mask pre-breathe
Tue 04:46 AM	07	03	10	00	EVA-3: Airlock depress to 10.2 psi
Tue 05:06 AM	07	03	30	00	ISS crew sleep begins
Tue 05:36 AM	07	04	00	00	STS crew sleep begins
Flight Day 9					
Tue 01:36 PM	07	12	00	00	STS/ISS crew wakeup
Tue 02:11 PM	07	12	35	00	EVA-3: 14.7 psi repress/hygiene break
Tue 03:01 PM	07	13	25	00	EVA-3: Airlock depress to 10.2 psi
Tue 03:21 PM	07	13	45	00	EVA-3: Campout EVA preps
Tue 03:36 PM	07	14	00	00	ISS daily planning conference
Tue 04:51 PM	07	15	15	00	EVA-3: Spacesuit purge
Tue 05:06 PM	07	15	30	00	EVA-3: Spacesuit prebreathe
Tue 05:56 PM	07	16	20	00	EVA-3: Crew lock depressurization
Tue 06:26 PM	07	16	50	00	EVA-3: Spacesuits to battery power
Tue 06:31 PM	07	16	55	00	EVA-3: Airlock egress
Tue 06:46 PM	07	17	10	00	EVA-3: Setup
Tue 07:01 PM	07	17	25	00	EVA-3: S3 UO PAS
Tue 08:31 PM	07	18	55	00	EVA-3: RGA 2 R&R
Tue 09:31 PM	07	19	55	00	EVA-3/EV-1: PMA-3 heater cable connect
Tue 09:31 PM	07	19	55	00	EVA-3/EV-2: S0 RPCM R&R
Tue 10:16 PM	07	20	40	00	EVA-3: Node 3 AV cable routing
09/02					
Wed 12:01 AM	07	22	25	00	EVA-3/EV-1: Node 1 SLD wire removal
Wed 12:01 AM	07	22	25	00	EVA-3/EV-2: CLA
Wed 12:21 AM	07	22	45	00	EVA-3: Cleanup and ingress
Wed 12:56 AM	07	23	20	00	EVA-3: Airlock repressurization
Wed 01:11 AM	07	23	35	00	Spacesuit servicing
Wed 02:21 AM	08	00	45	00	Evening planning conference
Wed 04:36 AM	08	03	00	00	ISS crew sleep begins
Wed 05:06 AM	08	03	30	00	STS crew sleep begins

DATE/ET	DD	HH	MM	SS	EVENT
Flight Day 10					
Wed 01:06 PM	08	11	30	00	Crew wakeup
Wed 02:36 PM	08	13	00	00	ISS daily planning conference
Wed 03:31 PM	08	13	55	00	PAO event
Wed 04:06 PM	08	14	30	00	MPLM transfer
Wed 05:16 PM	08	15	40	00	N2N CBM CPA install
Wed 07:46 PM	08	18	10	00	Crew meals begin
Wed 09:41 PM	08	20	05	00	SAFER checkout
Wed 10:06 PM	08	20	30	00	Shuttle crew off duty
09/03					
Thu 01:51 AM	09	00	15	00	ISS daily planning conference
Thu 04:36 AM	09	03	00	00	ISS crew sleep begins
Thu 05:06 AM	09	03	30	00	STS crew sleep begins
Flight Day 11					
Thu 01:06 PM	09	11	30	00	STS/ISS crew wakeup
Thu 02:51 PM	09	13	15	00	ISS daily planning conference
Thu 03:11 PM	09	13	35	00	MPLM egress
Thu 03:31 PM	09	13	55	00	MPLM deactivation
Thu 03:41 PM	09	14	05	00	PAO event
Thu 03:51 PM	09	14	15	00	MPLM vestibule demate
Thu 05:21 PM	09	15	45	00	MPLM vestibule depressurization
Thu 06:51 PM	09	17	15	00	Crew meals begin
Thu 07:51 PM	09	18	15	00	SSRMS grapples MPLM
Thu 08:21 PM	09	18	45	00	N2 CBM demate
Thu 09:06 PM	09	19	30	00	MPLM uninstall
Thu 10:21 PM	09	20	45	00	MPLM locked in payload bay
Thu 10:36 PM	09	21	00	00	SSRMS ungrapples MPLM
09/04					
Fri 12:06 AM	09	22	30	00	Farewell ceremony
Fri 12:21 AM	09	22	45	00	Egress and hatch closure
Fri 12:26 AM	09	22	50	00	Rendezvous tools checkout
Fri 12:51 AM	09	23	15	00	Leak checks
Fri 01:51 AM	10	00	15	00	ISS evening planning conference
Fri 04:06 AM	10	02	30	00	ISS crew sleep begins
Fri 04:36 AM	10	03	00	00	STS crew sleep begins
Flight Day 12					
Fri 12:36 PM	10	11	00	00	STS/ISS crew wakeup
Fri 01:56 PM	10	12	20	00	ISS daily planning conference
Fri 02:46 PM	10	13	10	00	Group B computer powerup
Fri 03:11 PM	10	13	35	00	Maneuver to undocking attitude
Fri 03:41 PM	10	14	05	00	Undocking timeline begins
Fri 04:48 PM	10	15	12	00	UNDOCKING
Fri 04:48 PM	10	15	12	00	Initial separation
Fri 06:03 PM	10	16	27	00	Separation burn No. 1

DATE/ET	DD	HH	MM	SS	EVENT
Fri 06:31 PM	10	16	55	00	Separation burn No. 2
Fri 06:31 PM	10	16	55	00	Post-undocking PGSC reconfig
Fri 07:26 PM	10	17	50	00	Group B computer powerdown
Fri 06:56 PM	10	17	20	00	Crew meals begin
Fri 07:56 PM	10	18	20	00	OBSS starboard wing survey
Fri 08:56 PM	10	19	20	00	EVA unpack and stow
Fri 09:36 PM	10	20	00	00	Nose cap survey
Fri 09:56 PM	10	20	20	00	PST ISS EVA entry preps
Fri 10:26 PM	10	20	50	00	Port wing survey
09/05					
Sat 12:11 AM	10	22	35	00	OBSS berthing
Sat 12:11 AM	10	22	35	00	LDRI downlink
Sat 01:11 AM	10	23	35	00	SRMS powerdown
Sat 02:11 AM	11	00	35	00	Undocking video playback
Sat 04:06 AM	11	02	30	00	STS crew sleep begins
Flight Day 13					
Sat 12:06 PM	11	10	30	00	STS crew wakeup
Sat 03:16 PM	11	13	40	00	Cabin stow
Sat 04:16 PM	11	14	40	00	FCS checkout
Sat 05:26 PM	11	15	50	00	RCS hotfire
Sat 05:41 PM	11	16	05	00	PILOT operations
Sat 07:01 PM	11	17	25	00	PAO event
Sat 08:01 PM	11	18	25	00	Deorbit review
Sat 08:31 PM	11	18	55	00	Crew meal
Sat 09:31 PM	11	19	55	00	Cabin stow resumes
Sat 11:01 PM	11	21	25	00	Ergometer stow
Sat 11:31 PM	11	21	55	00	Recumbent seat setup
09/06					
Sun 12:01 AM	11	22	25	00	LES checkout
Sun 12:21 AM	11	22	45	00	Wing leading edge sensor deact
Sun 12:41 AM	11	23	05	00	PGSC stow (part 1)
Sun 12:56 AM	11	23	20	00	KU antenna stow
Sun 04:06 AM	12	02	30	00	Crew sleep begins
Flight Day 14					
Sun 12:06 PM	12	10	30	00	Crew wakeup
Sun 02:36 PM	12	13	00	00	Group B computer powerup
Sun 02:51 PM	12	13	15	00	IMU alignment
Sun 03:37 PM	12	14	01	00	Deorbit timeline begins
Sun 07:37:03 PM	12	18	01	00	Deorbit ignition (rev. 248)
Sun 08:40:03 PM	12	19	04	00	Landing

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STS-128 Television Schedule

Editor's note:
NASA's daily video highlights reel will be replayed on the hour during crew sleep periods. The timeing of actual events is subject to change and some events may or may not be carried live on NASA television.

NASA Note: NASA Television is now carried on an MPEG-2 digital signal accessed via satellite AMC-6, at 72 degrees west longitude, transponder 17C, 4040 MHz, vertical polarization. A Digital Video Broadcast (DVB) - compliant Integrated Receiver Decoder (IRD) with modulation of QPSK/DBV, data rate of 36.86 and FEC 3/4 will be needed for reception. NASA mission coverage will be simulcast digitally on the Public Services Channel (Channel #101); the Education Channel (Channel #102) and the Media Services Channel (Channel #103). Further information is available at: http://www1.nasa.gov/multimedia/nasatv/digital.html. Mission Audio can be accessed on AMC-6, Transponder 13, 3971.3 MHz, horizontal polarization.

ORBIT EVENT MET EDT GMT

FRIDAY, AUGUST 21
...COUNTDOWN PREVIEW BRIEFING....,,,,,,,,,,,,,,,,,,,,,..10:00 AM...14:00
...ISS EXPEDITION 20 COMMENTARY...,,,,,,,,,,,,,,,,,,,,..11:00 AM...15:00
...VIDEO FILE...,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,..12:00 PM...16:00

SATURDAY, AUGUST 22
...COUNTDOWN STATUS BRIEFING.,,,,,,,,,,,,,,,,,,,,,,,....10:00 AM...14:00

SUNDAY, AUGUST 23
...ISS SCIENCE BRIEFING....,,,,,,,,,,,,,,,,,,,,,,,,,,,..01:00 PM...17:00
...STS-128 PRELAUNCH NEWS CONFERENCE....................03:00 PM...19:00

MONDAY, AUGUST 24
...ROTATING SERVICE STRUCTURE RETRACTION................05:00 AM...09:00
...VIDEO FILE...12:00 PM...16:00
...STS-128 FUELING COVERAGE BEGINS......................04:00 PM...20:00
...STS-128 LAUNCH COVERAGE BEGINS.......................08:30 PM...00:30

TUESDAY , AUGUST 25 - FD1/FD2

....LAUNCH...................................00/00:00...01:36 AM...05:36
....MECO.....................................00/00:08...01:44 AM...05:44
1...LAUNCH REPLAYS...........................00/00:13...01:49 AM...05:49
1...ADDITIONAL LAUNCH REPLAYS FROM KSC.......00/00:45...02:21 AM...06:21
1...POST LAUNCH NEWS CONFERENCE..............00/00:54...02:30 AM...06:30
2...PAYLOAD BAY DOOR OPENING.................00/01:25...03:01 AM...07:01
3...ASCENT FLIGHT CONTROL TEAM VIDEO REPLAY..00/03:54...05:30 AM...09:30
3...RMS CHECKOUT.............................00/04:15...05:51 AM...09:51
4...RMS PAYLOAD BAY SURVEY...................00/05:00...06:36 AM...10:36
5...DISCOVERY CREW SLEEP BEGINS..............00/06:30...08:06 AM...12:06
6...FLIGHT DAY 1 HIGHLIGHTS..................00/07:24...09:00 AM...13:00
8...VIDEO FILE...............................00/10:24...12:00 PM...16:00
10...DISCOVERY CREW WAKE UP (FD2)............00/14:30...04:06 PM...20:06
12...OBSS UNBERTH............................00/17:05...06:41 PM...22:41
13...EMU CHECKOUT............................00/18:20...07:56 PM...23:56

ORBIT EVENT MET EDT GMT

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13...RMS/OBSS SURVEY OF DISCOVERY TPS BEGINS.00/18:20...07:56 PM...23:56

WEDNESDAY, AUGUST 26 - FD2/FD3
16...MISSION STATUS BRIEFING.................00/23:54...01:30 AM...05:30
16...OBSS BERTH..............................00/23:55...01:31 AM...05:31
18...RENDEZVOUS TOOL CHECKOUT................01/01:35...03:11 AM...07:11
18...CENTERLINE CAMERA INSTALLATION..........01/01:50...03:26 AM...07:26
18...RMS OMS POD SURVEY......................01/02:05...03:41 AM...07:41
18...ODS RING EXTENSION......................01/02:20...03:56 AM...07:56
20...DISCOVERY CREW SLEEP BEGINS.............01/05:30...07:06 AM...11:06
21...FLIGHT DAY 2 HIGHLIGHTS.................01/06:24...08:00 AM...12:00
24...VIDEO FILE..............................01/10:24...12:00 PM...16:00
26...DISCOVERY CREW WAKE UP (FD3)............01/13:30...03:06 PM...19:06
26...POST MISSION MANAGEMENT TEAM BRIEFING...01/14:24...04:00 PM...20:00
27...RENDEZVOUS OPERATIONS BEGIN.............01/15:05...04:41 PM...20:41
29...TI BURN.................................01/18:14...07:50 PM...23:50
30...DISCOVERY RENDEZVOUS PITCH MANEUVER.....01/19:56...09:32 PM...01:32
31...DISCOVERY/ISS DOCKING...................01/20:52...10:28 PM...02:28
32...DISCOVERY/ISS CREW HATCH OPENING........01/22:45...12:21 AM...04:21

THURSDAY,  AUGUST 27 - FD3/FD4
32...SSRMS GRAPPLE/UNBERTH OBSS..............01/23:25...01:01 AM...05:01
33...KOPRA/STOTT SOYUZ SEATLINER SWAP........02/00:05...01:41 AM...05:41
33...DISCOVERY/ISS TRANSFERS BEGIN...........02/00:00...01:36 AM...05:36
34...MISSION STATUS  BRIEFING................02/00:24...02:00 AM...06:00
34...SSRMS HANDOFF OBSS TO SRMS..............02/00:55...02:31 AM...06:31
34...SHUTTLE VTR PLAYBACK OF DOCKING.........02/01:50...03:26 AM...07:26
36...ISS CREW SLEEP BEGINS...................02/05:00...06:36 AM...10:36
36...DISCOVERY CREW SLEEP BEGINS.............02/05:30...07:06 AM...11:06
37...FLIGHT DAY 3 HIGHLIGHTS.................02/06:24...08:00 AM...12:00
38...HD FLIGHT DAY 3 CREW HIGHLIGHTS.........02/08:24...10:00 AM...14:00
39...VIDEO FILE..............................02/10:24...12:00 PM...16:00
40...ISS FLIGHT DIRECTOR UPDATE..............02/11:54...01:30 PM...17:30
41...ISS FLIGHT DIRECTOR UPDATE REPLAY.......02/12:54...02:30 PM...18:30
41...ARES 1 FIVE-SEGMENT SOLID ROCKET MOTOR..02/13:24...03:00 PM...19:00
.....TEST FIRING AT PROMONTORY, UTAH
41...DISCOVERY/ISS CREW WAKE UP (FD4)........02/13:30...03:06 PM...19:06
42...POST MISSION MANAGEMENT TEAM BRIEFING...02/14:24...04:00 PM...20:00
43...SSRMS GRAPPLE & UNBERTH LEONARDO........02/15:40...05:16 PM...21:16
44...DISCOVERY/ISS TRANSFERS RESUME..........02/16:30...06:06 PM...22:06
45...SSRMS INSTALLATION OF LEONARDO..........02/18:20...07:56 PM...23:56
46...MISSION STATUS BRIEFING.................02/19:54...09:30 PM...01:30
46...MPLM VESTIBULE PRESSURIZATION...........02/20:35...10:11 PM...02:11

FRIDAY, AUGUST 28 - FD4/FD5
49...U.S. PAO EVENT..........................03/00:25...02:01 AM...06:01
49...EVA # 1 PROCEDURE REVIEW................03/00:55...02:31 AM...06:31
50...MPLM INGRESS............................03/01:35...03:11 AM...07:11
51...EVA # 1 CAMPOUT BEGINS..................03/03:25...05:01 AM...09:01
51...ISS CREW SLEEP BEGINS...................03/04:30...06:06 AM...10:06
52...DISCOVERY CREW SLEEP BEGINS.............03/05:00...06:36 AM...10:36
52...FLIGHT DAY 4 HIGHLIGHTS.................03/05:24...07:00 AM...11:00
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ORBIT EVENT MET EDT GMT

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54...HD FLIGHT DAY 4 CREW HIGHLIGHTS.........03/08:24...10:00 AM...14:00
55...VIDEO FILE..............................03/09:24...11:00 AM...15:00
56...ISS FLIGHT DIRECTOR UPDATE..............03/10:24...12:00 PM...16:00
57...ISS FLIGHT DIRECTOR UPDATE REPLAY.......03/12:24...02:00 PM...18:00
57...DISCOVERY/ISS CREW WAKE UP (FD5)........03/13:00...02:36 PM...18:36
57...EVA # 1 PREPARATIONS RESUME.............03/13:35...03:11 PM...19:11
59...MPLM TRANSFERS BEGIN....................03/16:00...05:36 PM...21:36
59...ZERO-G STOWAGE RACK TRANSFER............03/16:30...06:06 PM...22:06
60...C.O.L.B.E.R.T. TRANSFER TO ISS BEGINS...03/17:25...07:01 PM...23:01
60...EVA # 1 BEGINS (Olivas and Stott).......03/17:50...07:26 PM...23:26
61...P1 ATA RELEASE & TEMPORARY STOWAGE......03/18:35...08:11 PM...00:11
61...CREW QUARTERS TRANSFER TO ISS BEGINS....03/18:45...08:21 PM...00:21
62...EUTEF RETRIEVAL & STOWAGE...............03/20:20...09:56 PM...01:56
62...ARS RACK TRANSFER TO HARMONY............03/21:00...10:36 PM...02:36
63...MISSE-6 RETRIEVAL & STOWAGE.............03/22:10...11:46 PM...03:46

SATURDAY,  AUGUST 29 - FD5/FD6
64...EVA # 1 ENDS............................04/00:20...01:56 AM...05:56
66...MISSION STATUS BRIEFING.................04/02:24...04:00 AM...08:00
67...ISS CREW SLEEP BEGINS...................04/04:00...05:36 AM...09:36
67...DISCOVERY CREW SLEEP BEGINS.............04/04:30...06:06 AM...10:06
68...FLIGHT DAY 5 HIGHLIGHTS.................04/05:24...07:00 AM...11:00
69...HD FLIGHT DAY 5 CREW HIGHLIGHTS.........04/07:24...09:00 AM...13:00
71...ISS FLIGHT DIRECTOR UPDATE..............04/09:54...11:30 AM...15:30
72...ISS FLIGHT DIRECTOR UPDATE REPLAY.......04/11:54...01:30 PM...17:30
72...DISCOVERY/ISS CREW WAKE UP (FD6)........04/12:30...02:06 PM...18:06
75...FIR RACK INSTALLATION IN DESTINY........04/15:45...05:21 PM...21:21
75...ISS CREW QUARTERS OUTFITTING............04/15:50...05:26 PM...21:26
75...MSRR RACK INSTALLATION IN DESTINY.......04/16:45...06:21 PM...22:21
76...MELFI-2 INSTALLATION IN DESTINY.........04/17:45...07:21 PM...23:21
76...MISSION STATUS BRIEFING.................04/17:54...07:30 PM...23:30
77...U.S. PAO EVENT..........................04/19:30...09:06 PM...01:06
78...ISS CREW QUARTERS ACTIVATION............04/20:30...10:06 PM...02:06
78...REPLAY OF U.S. PAO EVENT................04/20:54...10:30 PM...02:30

SUNDAY, AUGUST 30 - FD6/FD7
80...U.S. PAO EVENT..........................05/00:05...01:41 AM...05:41
80...EVA # 2 PROCEDURE REVIEW................05/00:25...02:01 AM...06:01
82...EVA # 2 CAMPOUT BEGINS..................05/02:55...04:31 AM...08:31
83...ISS CREW SLEEP BEGINS...................05/04:00...05:36 AM...09:36
83...DISCOVERY CREW SLEEP BEGINS.............05/04:30...06:06 AM...10:06
83...FLIGHT DAY 6 HIGHLIGHTS.................05/05:24...07:00 AM...11:00
85...HD FLIGHT DAY 6 CREW HIGHLIGHTS.........05/07:24...09:00 AM...13:00
86...ISS FLIGHT DIRECTOR UPDATE..............05/09:54...11:30 AM...15:30
88...ISS FLIGHT DIRECTOR UPDATE REPLAY.......05/11:54...01:30 PM...17:30
88...DISCOVERY/ISS CREW WAKE UP (FD7)........05/12:30...02:06 PM...18:06
89...EVA # 2 PREPARATIONS RESUME.............05/13:05...02:41 PM...18:41
90...MPLM TRANSFERS RESUME...................05/15:30...05:06 PM...21:06
91...EVA # 2 BEGINS (Olivas and Fuglesang)...05/17:20...06:56 PM...22:56
92...NEW ATA REMOVAL FROM LMC................05/18:15...07:51 PM...23:51
93...NEW ATA INSTALLATION ONTO P1 TRUSS......05/19:35...09:11 PM...01:11
93...OLD ATA REMOVAL FROM SSRMS..............05/20:00...09:36 PM...01:36
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ORBIT EVENT MET EDT GMT

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94...OLD ATA INSTALLATION ONTO LMC..........05/21:55...11:31 PM...03:31

MONDAY, AUGUST 31 - FD7/FD8
96...EVA # 2 ENDS...........................05/23:50...01:26 AM...05:26
97...MISSION STATUS BRIEFING................06/01:24...03:00 AM...07:00
98...ISS CREW SLEEP BEGINS..................06/03:30...05:06 AM...09:06
98...DISCOVERY CREW SLEEP BEGINS............06/04:00...05:36 AM...09:36
99...FLIGHT DAY 7 HIGHLIGHTS................06/04:24...06:00 AM...10:00
100...HD FLIGHT DAY 7 CREW HIGHLIGHTS.......06/07:24...09:00 AM...13:00
101...VIDEO FILE............................06/08:24...10:00 AM...14:00
102...ISS FLIGHT DIRECTOR UPDATE............06/09:24...11:00 AM...15:00
103...ISS FLIGHT DIRECTOR UPDATE REPLAY.....06/11:24...01:00 PM...17:00
104...DISCOVERY/ISS CREW WAKE UP (FD8)......06/12:00...01:36 PM...17:36
106...DISCOVERY/ISS OFF-DUTY PERIOD BEGINS...06/15:00...04:36 PM...20:36
107...MISSION STATUS BRIEFING...............06/17:54...07:30 PM...23:30
109...JOINT CREW NEWS CONFERENCE............06/19:50...09:26 PM...01:26
110...MPLM TRANSFERS RESUME.................06/21:30...11:06 PM...03:06
110...REPLAY OF JOINT CREW NEWS CONFERENCE...06/22:24...12:00 AM...04:00

TUESDAY, SEPTEMBER 1 - FD8/FD9
111...EVA # 3 PROCEDURE REVIEW..............06/23:55...01:31 AM...05:31
113...EVA # 3 CAMPOUT BEGINS................07/02:25...04:01 AM...08:01
114...ISS CREW SLEEP BEGINS.................07/03:30...05:06 AM...09:06
114...DISCOVERY CREW SLEEP BEGINS...........07/04:00...05:36 AM...09:36
114...FLIGHT DAY 8 HIGHLIGHTS...............07/04:24...06:00 AM...10:00
116...HD FLIGHT DAY 8 CREW HIGHLIGHTS.......07/07:24...09:00 AM...13:00
117...VIDEO FILE............................07/08:24...10:00 AM...14:00
117...ISS FLIGHT DIRECTOR UPDATE............07/09:24...11:00 AM...15:00
119...ISS FLIGHT DIRECTOR UPDATE REPLAY.....07/11:24...01:00 PM...17:00
120...DISCOVERY/ISS CREW WAKE UP (FD9)......07/12:00...01:36 PM...17:36
120...EVA #3 PREPARATIONS RESUME............07/12:35...02:11 PM...18:11
123...EVA #3 BEGINS (Olivas and Fuglesang)...07/16:50...06:26 PM...22:26
123...MPLM TRANSFERS RESUME.................07/17:05...06:41 PM...22:41
123...S3 PAS DEPLOYMENT.....................07/17:25...07:01 PM...23:01
124...RGA #2 REMOVAL/REPLACEMENT BEGINS.....07/18:55...08:31 PM...00:31
125...PMA 3 HEATER CABLE CONNECTIONS........07/19:55...09:31 PM...01:31
125...TRANQUILITY NODE 3 AVIONICS CABLE.....07/20:40...10:16 PM...02:16
126...EVA #3 ENDS...........................07/23:20...12:56 AM...04:56

WEDNESDAY, SEPTEMBER 2 - FD9/FD10
128...MISSION STATUS BRIEFING...............08/01:24...03:00 AM...07:00
129...ISS CREW SLEEP BEGINS.................08/03:00...04:36 AM...08:36
130...DISCOVERY CREW SLEEP BEGINS...........08/03:30...05:06 AM...09:06
130...FLIGHT DAY 9 HIGHLIGHTS...............08/04:24...06:00 AM...10:00
132...HD FLIGHT DAY 9 CREW HIGHLIGHTS.......08/07:24...09:00 AM...13:00
132...VIDEO FILE............................08/08:24...10:00 AM...14:00
133...ISS FLIGHT DIRECTOR UPDATE............08/09:24...11:00 AM...15:00
134...ISS FLIGHT DIRECTOR UPDATE REPLAY.....08/10:54...12:30 PM...16:30
135...DISCOVERY/ISS CREW WAKE UP (FD10).....08/11:30...01:06 PM...17:06
135...HTV PREFLIGHT BRIEFING................08/11:54...01:30 PM...17:30
136...U.S. PAO EVENT........................08/13:55...03:31 PM...19:31
137...MPLM TRANSFERS RESUME.................08/14:30...04:06 PM...20:06
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138...HARMONY CONTROLLER PANEL INSTALLATION..08/15:40...05:16 PM...21:16
138...MISSION STATUS BRIEFING................08/16:24...06:00 PM...22:00
141...DISCOVERY CREW OFF DUTY PERIOD BEGINS..08/20:30...10:06 PM...02:06

THURSDAY, SEPTEMBER 3 - FD10/FD11
144...ESA PAO EVENT..........................09/01:10...02:46 AM...06:46
145...REPLAY OF ESA PAO EVENT................09/02:54...04:30 AM...08:30
145...ISS CREW SLEEP BEGINS..................09/03:00...04:36 AM...08:36
145...DISCOVERY CREW SLEEP BEGINS............09/03:30...05:06 AM...09:06
146...FLIGHT DAY 10 HIGHLIGHTS...............09/04:24...06:00 AM...10:00
148...HD FLIGHT DAY 10 CREW HIGHLIGHTS.......09/07:24...09:00 AM...13:00
148...VIDEO FILE.............................09/07:24...09:00 AM...13:00
149...ISS FLIGHT DIRECTOR UPDATE.............09/08:54...10:30 AM...14:30
150...ISS FLIGHT DIRECTOR UPDATE REPLAY......09/10:54...12:30 PM...16:30
151...DISCOVERY/ISS CREW WAKE UP (FD11)......09/11:30...01:06 PM...17:06
152...CREW CHOICE DOWNLINK...................09/13:15...02:51 PM...18:51
152...MPLM EGRESS AND DEACTIVATION...........09/13:35...03:11 PM...19:11
152...U.S. PAO EVENT.........................09/14:10...03:46 PM...19:46
153...REPLAY OF U.S. PAO EVENT...............09/15:24...05:00 PM...21:00
155...SSRMS GRAPPLES MPLM....................09/18:15...07:51 PM...23:51
156...SSRMS DEMATE MPLM FROM HARMONY.........09/19:30...09:06 PM...01:06
157...SSRMS BERTHS MPLM......................09/21:00...10:36 PM...02:36
157...MISSION STATUS BRIEFING................09/21:24...11:00 PM...03:00
158...FAREWELL AND HATCH CLOSURE.............09/22:30...12:06 AM...04:06
158...RENDEZVOUS TOOL CHECKOUT...............09/22:50...12:26 AM...04:26

FRIDAY, SEPTEMBER 4 - FD11/FD12
159...CENTERLINE CAMERA INSTALLATION.........09/23:50...01:26 AM...05:26
160...ISS CREW SLEEP BEGINS..................10/02:30...04:06 AM...08:06
161...DISCOVERY CREW SLEEP BEGINS............10/03:00...04:36 AM...08:36
161...FLIGHT DAY 11 HIGHLIGHTS...............10/03:24...05:00 AM...09:00
163...HD FLIGHT DAY 11 CREW HIGHLIGHTS.......10/07:24...09:00 AM...13:00
164...VIDEO FILE.............................10/08:24...10:00 AM...14:00
165...ISS FLIGHT DIRECTOR UPDATE.............10/09:24...11:00 AM...15:00
165...ISS FLIGHT DIRECTOR UPDATE REPLAY......10/10:24...12:00 PM...16:00
166...DISCOVERY/ISS CREW WAKE UP (FD12)......10/11:00...12:36 PM...16:36
169...DISCOVERY UNDOCKS FROM ISS.............10/15:12...04:48 PM...20:48
169...DISCOVERY FLYAROUND OF ISS BEGINS......10/15:37...05:13 PM...21:13
170...FINAL SEPARATION FROM ISS..............10/16:55...06:31 PM...22:31
171...RMS/OBSS LATE INSPECTION...............10/18:45...08:21 PM...00:21
172...MISSION STATUS BRIEFING................10/20:54...10:30 PM...02:30
174...OBSS BERTH.............................10/23:00...12:36 AM...04:36

SATURDAY, SEPTEMBER 5 - FD12/FD13
174...SHUTTLE VTR PLAYBACK OF UNDOCKING......10/23:50...01:26 AM...05:26
176...DISCOVERY CREW SLEEP BEGINS............11/02:30...04:06 AM...08:06
177...FLIGHT DAY 12 HIGHLIGHTS...............11/03:24...05:00 AM...09:00
179...HD FLIGHT DAY 12 CREW HIGHLIGHTS.......11/07:24...09:00 AM...13:00
181...DISCOVERY CREW WAKE UP (FD13)..........11/10:30...12:06 PM...16:06
183...CABIN STOWAGE BEGINS...................11/13:40...03:16 PM...19:16
184...POST MISSION MANAGEMENT TEAM BRIEFING..11/13:54...03:30 PM...19:30
184...FCS CHECKOUT...........................11/14:40...04:16 PM...20:16
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185...RCS HOT-FIRE TEST.....................11/15:50...05:26 PM...21:26
186...DISCOVERY U.S. PAO EVENT..............11/17:05...06:41 PM...22:41
188...BOUNDARY LAYER TRANSITION BRIEFING.....11/20:24...10:00 PM...02:00
188...KOPRA'S RECUMBENT SEAT SET UP.........11/21:10...10:46 PM...02:46
188...MISSION STATUS BRIEFING...............11/21:24...11:00 PM...03:00
190...KU-BAND ANTENNA STOWAGE...............11/23:15...12:51 AM...04:51

SUNDAY, SEPTEMBER 6 - FD13/FD14
192...DISCOVERY CREW SLEEP BEGINS...........12/02:30...04:06 AM...08:06
192...FLIGHT DAY 13 HIGHLIGHTS..............12/03:24...05:00 AM...09:00
195...HD FLIGHT DAY 13 CREW HIGHLIGHTS.......12/07:24...09:00 AM...13:00
197...DISCOVERY CREW WAKE UP (FD14).........12/10:30...12:06 PM...16:06
199...DEORBIT PREPARATIONS BEGIN............12/14:00...03:36 PM...19:36
200...PAYLOAD BAY DOOR CLOSING..............12/15:21...04:57 PM...20:57
202...DEORBIT BURN..........................12/18:01...07:37 PM...23:37
203...MILA C-BAND RADAR ACQUISITION.........12/18:51...08:27 PM...00:27
203...KSC LANDING...........................12/19:04...08:40 PM...00:40
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Appendix 1: Space Shuttle Flight and Abort Scenarios

The shuttle weighs 4.5 million pounds at launch and it hits 140 mph - going straight up - in about 10 seconds. The shuttle burns its fuel so fast that in less than 100 seconds it weighs half what it did at launch. In eight-and-a-half minutes, the vehicle is traveling some 17,000 mph, or five miles per second. That's about eight times faster than a rifle bullet, fast enough to fly from Los Angeles to New York in 10 minutes. Calling a shuttle launch "routine" misses the mark. The margin for error is very slim indeed and the astronauts face a limited number of survivable abort options.

The shuttle makes the climb to orbit using two solid-fuel boosters and three hydrogen-fueled main engines. Contrary to popular myth, the shuttle pilots do little more than monitor their instruments and computer displays during ascent; the shuttle's four flight computers do all the piloting barring a malfunction of some sort that might force the crew to take manual control.

Based on the type of main engines aboard Atlantis, NASA puts the odds of a catastrophic failure that would destroy the vehicle at about 1-in-438.

The main engines generate a combined 37 million horsepower, which is equivalent to the output of 23 Hoover Dams. They are ignited at 120 millisecond intervals starting 6.6 seconds prior to launch. Computers bolted to each powerplant monitor engine performance 50 times per second and, after all three are running smoothly, the boosters are ignited. Pressure inside the hollow boosters jumps from sea level to more than 900 pounds per square inch in a quarter of a second as the propellant ignites. Liftoff is virtually instantaneous.

The boosters burn for about two minutes and five seconds. They are far more powerful than the three main engines and provide all the shuttle's steering during the initial minutes of flight using hydraulic pistons that move the nozzles at the base of each rocket. After the boosters are jettisoned, the shuttle's three liquid-fueled engines provide steering and flight control.

The engines are throttled down to 65 percent power about 40 seconds into flight to lower the stress on the shuttle as it accelerates through the region of maximum aerodynamic pressure (715 pounds per square foot at 48 seconds). After that, the engines are throttled back up to 104 percent. All three engines shut down about eight and a half minutes after takeoff, putting the shuttle in a preliminary orbit. The empty external fuel tank is then jettisoned and breaks up in the atmosphere over the Indian or Pacific oceans. The initial orbit is highly elliptical and the shuttle's two orbital maneuvering rockets are fired about 43 minutes after launch to put the craft in a circular orbit.

There are no survivable booster failures like the one that destroyed Challenger 73 seconds after liftoff in 1986. Like a holiday bottle rocket, the boosters cannot be shut down once they are ignited. They are rigged with plastic explosives to blow open their cases and eliminate forward thrust should a catastrophic failure send a shuttle veering out of control toward populated areas or sea lanes. In that case, the crew is considered expendable. There is no survivable way to separate from the boosters while they are operating. They simply have to work.

But the shuttle system was designed to safely handle a single main engine failure at any point after startup. In all cases, such "intact" aborts begin after the solid-fuel boosters have been jettisoned. In other words, if an abort is declared 10 seconds after liftoff, it will not actually go into effect until 2 minutes and 30 seconds after launch.

An engine failure during the startup sequence will trigger a "redundant set launch sequencer abort," or RSLS abort. If one or more engine experiences problems during startup, the shuttle's flight computers will issue immediate shut-down commands and stop the countdown before booster ignition. This has happened five times in shuttle history (the most recent RSLS abort occurred in August 1994).

An RSLS abort does not necessarily threaten the safety of the shuttle crew, but hydrogen gas can be released through the engine nozzles during shutdown. Hydrogen burns without visible sign of flame and it's possible a brief pad fire can follow the engine cutoff. But the launch pad is equipped with a sophisticated fire extinguishing system and other improvements implemented in the wake of the 1986 Challenger accident that will automatically start spraying the orbiter with water if a fire is detected. Fire detection sensors are located all over the pad.

While in-flight abort regimes overlap to a degree, a return to the launch site (RTLS) is only possible during the first four minutes of flight. Beyond that point, a shuttle has flown too far to make it back to Florida with its remaining fuel. But in practice, an RTLS is only a threat in the first 2.5 minutes or so of flight. After that, a crew can press on to an emergency landing in Spain or Africa, the preferred option if there's a choice because it puts less stress on the shuttle.

A trans-Atlantic abort (TAL) is an option throughout ascent but after about five minutes, the shuttle is going fast enough to attempt an abort to a lower-than-planned orbit, depending on the shuttle's altitude and velocity at the time of the failure. If the shuttle crew has a choice between an RTLS and a TAL, they will select the TAL option. If the choice is between TAL and ATO, they will select the abort to orbit.

Here are the actual numbers for a recent shuttle flight (velocity includes a contribution from Earth's rotation at 28.5 degrees north latitude):

TIME	EVENT	MPH
0:10	THE SHUTTLE ROLLS TO "HEADS DOWN" ORIENTATION	920
0:40	START THROTTLE DOWN	1,405
0:48	MAXIMUM AERODYNAMIC PRESSURE	1,520
0:53	START THROTTLE UP TO 104%	1,589
2:04	SOLID-FUEL BOOSTERS ARE JETTISONED	3,818
2:10	THE SHUTTLE CAN NOW ABORT TO SPAIN OR AFRICA	3,955
3:45	THE SHUTTLE CAN NO LONGER RETURN TO KSC	5,591
4:12	THE SHUTTLE CAN NOW ABORT TO ORBIT	6,273
5:13	SHUTTLE CAN REACH NORMAL ORBIT WITH TWO ENGINES	8,045
5:48	THE SHUTTLE ROLLS TO "HEADS UP" ORIENTATION	9,205
6:32	SHUTTLE CAN REACH ORBIT WITH ONE ENGINE	11,114
7:24	ENGINES THROTTLE DOWN TO LIMIT G LOADS ON CREW	13,977
8:24	MAIN ENGINE CUTOFF	17,727

An RTLS abort is considered the riskiest of the abort procedures because the shuttle crew must reverse course to head back for Florida, which puts severe stresses on the vehicle. TAL is the preferred abort mode for early engine failures. A second engine failure during an RTLS makes the chances of a success slim while a TAL abort can be flown in many instances with two failures.

Normal Flight Details[7]

In the launch configuration, the orbiter and two solid rocket boosters are attached to the external tank in a vertical (nose-up) position on the launch pad. Each solid rocket booster is attached at its aft skirt to the mobile launcher platform by four bolts.

Emergency exit for the flight crew on the launch pad up to 30 seconds before lift-off is by slidewire. There are seven 1,200-foot- long slidewires, each with one basket. Each basket is designed to carry three persons. The baskets, 5 feet in diameter and 42 inches deep, are suspended beneath the slide mechanism by four cables. The slidewires carry the baskets to ground level. Upon departing the basket at ground level, the flight crew progresses to a bunker that is designed to protect it from an explosion on the launch pad.

At launch, the three space shuttle main engines-fed liquid hydrogen fuel and liquid oxygen oxidizer from the external tank-are ignited first. When it has been verified that the engines are operating at the proper thrust level, a signal is sent to ignite the solid rocket boosters. At the proper thrust-to-weight ratio, initiators (small explosives) at eight hold-down bolts on the solid rocket boosters are fired to release the space shuttle for lift-off. All this takes only a few seconds.

Maximum dynamic pressure is reached early in the ascent, nominally approximately 60 seconds after lift-off.

Approximately a minute later (two minutes into the ascent phase), the two solid rocket boosters have consumed their propellant and are jettisoned from the external tank. This is triggered by a separation signal from the orbiter. The boosters briefly continue to ascend, while small motors fire to carry them away from the space shuttle. The boosters then turn and descend, and at a predetermined altitude, parachutes are deployed to decelerate them for a safe splashdown in the ocean. Splashdown occurs approximately 141 nautical miles (162 statute miles) from the launch site. The boosters are recovered and reused.

Meanwhile, the orbiter and external tank continue to ascend, using the thrust of the three space shuttle main engines. Approximately eight minutes after launch and just short of orbital velocity, the three space shuttle engines are shut down (main engine cutoff), and the external tank is jettisoned on command from the orbiter.

The forward and aft reaction control system engines provide attitude (pitch, yaw and roll) and the translation of the orbiter away from the external tank at separation and return to attitude hold prior to the orbital maneuvering system thrusting maneuver.

The external tank continues on a ballistic trajectory and enters the atmosphere, where it disintegrates. Its projected impact is in the Indian Ocean (except for 57-degree inclinations) in the case of equatorial orbits (Kennedy Space Center launch) and in the extreme southern Pacific Ocean in the case of a Vandenberg Air Force Base launch.

Normally, two thrusting maneuvers using the two orbital maneuvering system engines at the aft end of the orbiter are used in a two-step thrusting sequence: to complete insertion into Earth orbit and to circularize the spacecraft's orbit. The orbital maneuvering system engines are also used on orbit for any major velocity changes. In the event of a direct-insertion mission, only one orbital maneuvering system thrusting sequence is used.

The orbital altitude of a mission is dependent upon that mission. The nominal altitude can vary between 100 to 217 nautical miles (115 to 250 statute miles).

The forward and aft reaction control system thrusters (engines) provide attitude control of the orbiter as well as any minor translation maneuvers along a given axis on orbit.

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[7] The remainder of this appendix, with clearly noted exceptions, is taken directly from shuttle-builder Rockwell International's Shuttle Reference book.

At the completion of orbital operations, the orbiter is oriented in a tailfirst attitude by the reaction control system. The two orbital maneuvering system engines are commanded to slow the orbiter for deorbit. The reaction control system turns the orbiter's nose forward for entry. The reaction control system controls the orbiter until atmospheric density is sufficient for the pitch and roll aerodynamic control surfaces to become effective.

Entry interface is considered to occur at 400,000 feet altitude approximately 4,400 nautical miles (5,063 statute miles) from the landing site and at approximately 25,000 feet per second velocity. At 400,000 feet altitude, the orbiter is maneuvered to zero degrees roll and yaw (wings level) and at a predetermined angle of attack for entry. The angle of attack is 40 degrees. The flight control system issues the commands to roll, pitch and yaw reaction control system jets for rate damping.

The forward reaction control system engines are inhibited prior to entry interface, and the aft reaction control system engines maneuver the spacecraft until a dynamic pressure of 10 pounds per square foot is sensed, which is when the orbiter's ailerons become effective. The aft reaction control system roll engines are then deactivated. At a dynamic pressure of 20 pounds per square foot, the orbiter's elevators become active, and the aft reaction control system pitch engines are deactivated. The orbiter's speed brake is used below Mach 10 to induce a more positive downward elevator trim deflection. At approximately Mach 3.5, the rudder becomes activated, and the aft reaction control system yaw engines are deactivated at 45,000 feet.

Entry guidance must dissipate the tremendous amount of energy the orbiter possesses when it enters the Earth's atmosphere to assure that the orbiter does not either burn up (entry angle too steep) or skip out of the atmosphere (entry angle too shallow) and that the orbiter is properly positioned to reach the desired touchdown point.

During entry, energy is dissipated by the atmospheric drag on the orbiter's surface. Higher atmospheric drag levels enable faster energy dissipation with a steeper trajectory. Normally, the angle of attack and roll angle enable the atmospheric drag of any flight vehicle to be controlled. However, for the orbiter, angle of attack was rejected because it creates surface temperatures above the design specification. The angle of attack scheduled during entry is loaded into the orbiter computers as a function of relative velocity, leaving roll angle for energy control. Increasing the roll angle decreases the vertical component of lift, causing a higher sink rate and energy dissipation rate. Increasing the roll rate does raise the surface temperature of the orbiter, but not nearly as drastically as an equal angle of attack command.

If the orbiter is low on energy (current range-to-go much greater than nominal at current velocity), entry guidance will command lower than nominal drag levels. If the orbiter has too much energy (current range-to-go much less than nominal at the current velocity), entry guidance will command higher-than-nominal drag levels to dissipate the extra energy.

Roll angle is used to control cross range. Azimuth error is the angle between the plane containing the orbiter's position vector and the heading alignment cylinder tangency point and the plane containing the orbiter's position vector and velocity vector. When the azimuth error exceeds a computer-loaded number, the orbiter's roll angle is reversed.

Thus, descent rate and downranging are controlled by bank angle. The steeper the bank angle, the greater the descent rate and the greater the drag. Conversely, the minimum drag attitude is wings level. Cross range is controlled by bank reversals.

The entry thermal control phase is designed to keep the backface temperatures within the design limits. A constant heating rate is established until below 19,000 feet per second.

The equilibrium glide phase shifts the orbiter from the rapidly increasing drag levels of the temperature control phase to the constant drag level of the constant drag phase. The equilibrium glide flight is defined as flight in which the flight path angle, the angle between the local horizontal and the local velocity vector, remains constant. Equilibrium glide flight provides the maximum downrange capability. It lasts until the drag acceleration reaches 33 feet per second squared.

The constant drag phase begins at that point. The angle of attack is initially 40 degrees, but it begins to ramp down in this phase to approximately 36 degrees by the end of this phase.

In the transition phase, the angle of attack continues to ramp down, reaching the approximately 14-degree angle of attack at the entry terminal area energy management interface, at approximately 83,000 feet altitude, 2,500 feet per second, Mach 2.5 and 52 nautical miles (59 statute miles) from the landing runway. Control is then transferred to TAEM guidance.

During the entry phases described, the orbiter's roll commands keep the orbiter on the drag profile and control cross range.

TAEM guidance steers the orbiter to the nearest of two heading alignment cylinders, whose radii are approximately 18,000 feet and which are located tangent to and on either side of the runway centerline on the approach end. In TAEM guidance, excess energy is dissipated with an S-turn; and the speed brake can be utilized to modify drag, lift-to-drag ratio and flight path angle in high-energy conditions. This increases the ground track range as the orbiter turns away from the nearest HAC until sufficient energy is dissipated to allow a normal approach and landing guidance phase capture, which begins at 10,000 feet altitude. The orbiter also can be flown near the velocity for maximum lift over drag or wings level for the range stretch case. The spacecraft slows to subsonic velocity at approximately 49,000 feet altitude, about 22 nautical miles (25.3 statute miles) from the landing site.

At TAEM acquisition, the orbiter is turned until it is aimed at a point tangent to the nearest HAC and continues until it reaches way point 1. At WP-1, the TAEM heading alignment phase begins. The HAC is followed until landing runway alignment, plus or minus 20 degrees, has been achieved. In the TAEM prefinal phase, the orbiter leaves the HAC; pitches down to acquire the steep glide slope; increases airspeed; banks to acquire the runway centerline; and continues until on the runway centerline, on the outer glide slope and on airspeed. The approach and landing guidance phase begins with the completion of the TAEM prefinal phase and ends when the spacecraft comes to a complete stop on the runway.

The approach and landing trajectory capture phase begins at the TAEM interface and continues to guidance lock-on to the steep outer glide slope. The approach and landing phase begins at about 10,000 feet altitude at an equivalent airspeed of 290, plus or minus 12, knots 6.9 nautical miles (7.9 statute miles) from touchdown. Autoland guidance is initiated at this point to guide the orbiter to the minus 19- to 17-degree glide slope (which is over seven times that of a commercial airliner's approach) aimed at a target 0.86 nautical mile (1 statute mile) in front of the runway. The spacecraft's speed brake is positioned to hold the proper velocity. The descent rate in the later portion of TAEM and approach and landing is greater than 10,000 feet per minute (a rate of descent approximately 20 times higher than a commercial airliner's standard 3-degree instrument approach angle).

At 1,750 feet above ground level, a preflare maneuver is started to position the spacecraft for a 1.5-degree glide slope in preparation for landing with the speed brake positioned as required. The flight crew deploys the landing gear at this point.

The final phase reduces the sink rate of the spacecraft to less than 9 feet per second. Touchdown occurs approximately 2,500 feet past the runway threshold at a speed of 184 to 196 knots (213 to 226 mph).

Intact Aborts

Selection of an ascent abort mode may become necessary if there is a failure that affects vehicle performance, such as the failure of a space shuttle main engine or an orbital maneuvering system. Other failures requiring early termination of a flight, such as a cabin leak, might require the selection of an abort mode.

There are two basic types of ascent abort modes for space shuttle missions: intact aborts and contingency aborts. Intact aborts are designed to provide a safe return of the orbiter to a planned landing site. Contingency aborts are designed to permit flight crew survival following more severe failures when an intact abort is not possible. A contingency abort would generally result in a ditch operation.

There are four types of intact aborts: abort to orbit, abort once around, transatlantic landing and return to launch site.

The ATO mode is designed to allow the vehicle to achieve a temporary orbit that is lower than the nominal orbit. This mode requires less performance and allows time to evaluate problems and then choose either an early deorbit maneuver or an orbital maneuvering system thrusting maneuver to raise the orbit and continue the mission.

The AOA is designed to allow the vehicle to fly once around the Earth and make a normal entry and landing. This mode generally involves two orbital maneuvering system thrusting sequences, with the second sequence being a deorbit maneuver. The entry sequence would be similar to a normal entry.

The TAL mode is designed to permit an intact landing on the other side of the Atlantic Ocean. This mode results in a ballistic trajectory, which does not require an orbital maneuvering system maneuver.

The RTLS mode involves flying downrange to dissipate propellant and then turning around under power to return directly to a landing at or near the launch site.

There is a definite order of preference for the various abort modes. The type of failure and the time of the failure determine which type of abort is selected. In cases where performance loss is the only factor, the preferred modes would be ATO, AOA, TAL and RTLS, in that order. The mode chosen is the highest one that can be completed with the remaining vehicle performance. In the case of some support system failures, such as cabin leaks or vehicle cooling problems, the preferred mode might be the one that will end the mission most quickly. In these cases, TAL or RTLS might be preferable to AOA or ATO. A contingency abort is never chosen if another abort option exists.

The Mission Control Center-Houston is prime for calling these aborts because it has a more precise knowledge of the orbiter's position than the crew can obtain from onboard systems. Before main engine cutoff, Mission Control makes periodic calls to the crew to tell them which abort mode is (or is not) available. If ground communications are lost, the flight crew has onboard methods, such as cue cards, dedicated displays and display information, to determine the current abort region.

Which abort mode is selected depends on the cause and timing of the failure causing the abort and which mode is safest or improves mission success. If the problem is a space shuttle main engine failure, the flight crew and Mission Control Center select the best option available at the time a space shuttle main engine fails.

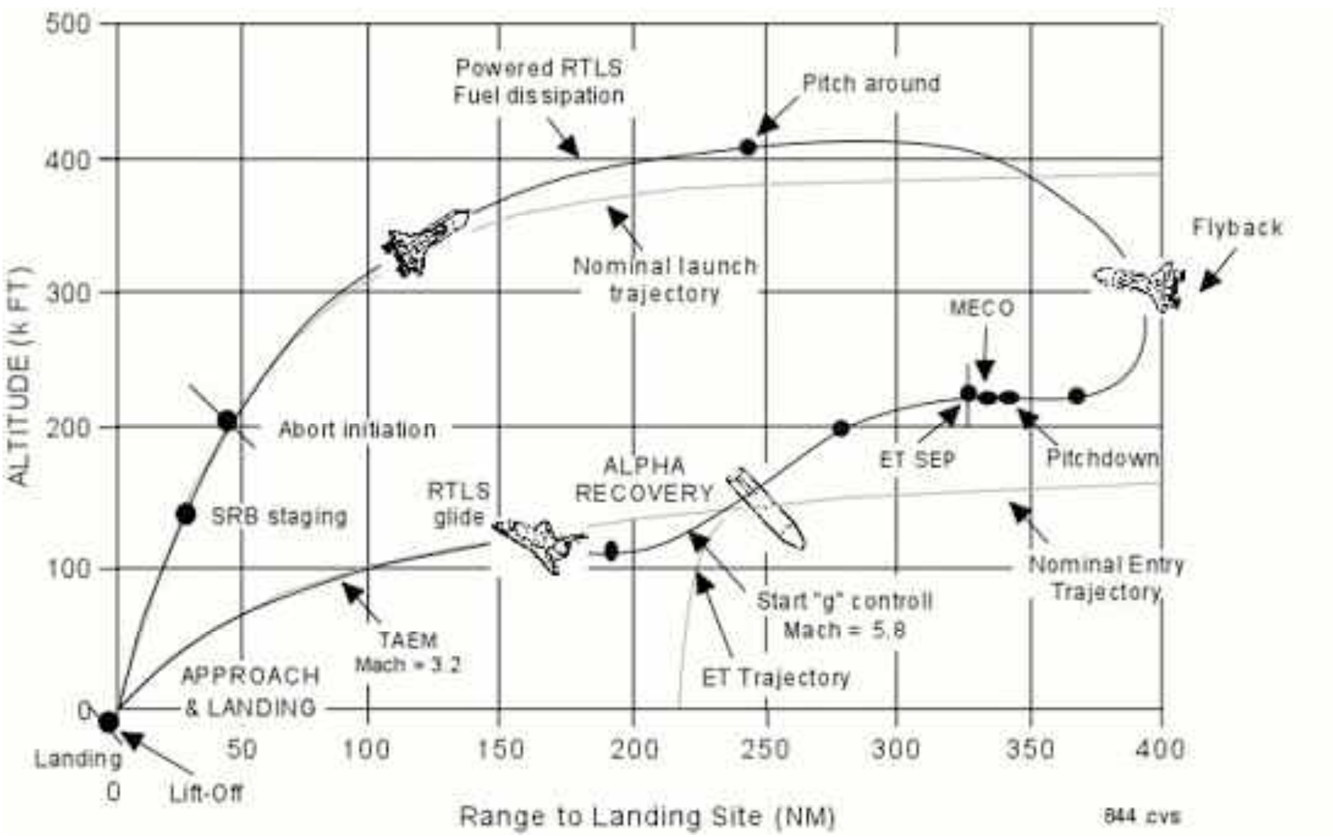
If the problem is a system failure that jeopardizes the vehicle, the fastest abort mode that results in the earliest vehicle landing is chosen. RTLS and TAL are the quickest options (35 minutes), whereas an AOA requires approximately 90 minutes. Which of these is selected depends on the time of the failure with three good space shuttle main engines.

The flight crew selects the abort mode by positioning an abort mode switch and depressing an abort push button.

1. Return to Launch Site (RTLS) Abort

The RTLS abort mode is designed to allow the return of the orbiter, crew, and payload to the launch site, Kennedy Space Center, approximately 25 minutes after lift-off. The RTLS profile is designed to accommodate the loss of thrust from one space shuttle main engine between lift-off and approximately four minutes 20 seconds, at which time not enough main propulsion system propellant remains to return to the launch site.

An RTLS can be considered to consist of three stages-a powered stage, during which the space shuttle main engines are still thrusting; an ET separation phase; and the glide phase, during which the orbiter glides to a landing at the Kennedy Space Center. The powered RTLS phase begins with the crew selection of the RTLS abort, which is done after solid rocket booster separation. The crew selects the abort mode by positioning the abort rotary switch to RTLS and depressing the abort push button. The time at which the RTLS is selected depends on the reason for the abort. For example, a three-engine RTLS is selected at the last moment, approximately three minutes 34 seconds into the mission; whereas an RTLS chosen due to an engine out at lift-off is selected at the earliest time, approximately two minutes 20 seconds into the mission (after solid rocket booster separation).



After RTLS is selected, the vehicle continues downrange to dissipate excess main propulsion system propellant. The goal is to leave only enough main propulsion system propellant to be able to turn the vehicle around, fly back towards the Kennedy Space Center and achieve the proper main engine cutoff conditions so the vehicle can glide to the Kennedy Space Center after external tank separation. During the downrange phase, a pitch-around maneuver is initiated (the time depends in part on the time of a space shuttle main engine failure) to orient the orbiter/external tank configuration to a heads up attitude, pointing toward the launch site. At this time, the vehicle is still moving away from the launch site, but the space shuttle main engines are now thrusting to null the downrange velocity. In addition, excess orbital maneuvering system and reaction control system propellants are dumped by continuous orbital maneuvering system and reaction control system engine thrustings to improve the orbiter weight and center of gravity for the glide phase and landing.

The vehicle will reach the desired main engine cutoff point with less than 2 percent excess propellant remaining in the external tank. At main engine cutoff minus 20 seconds, a pitch-down maneuver (called powered pitch-down) takes the mated vehicle to the required external tank separation attitude and pitch rate. After main engine cutoff has been commanded, the external tank separation sequence begins, including a reaction control system translation that ensures that the orbiter does not recontact the external tank and that the orbiter has achieved the necessary pitch attitude to begin the glide phase of the RTLS.

After the reaction control system translation maneuver has been completed, the glide phase of the RTLS begins. From then on, the RTLS is handled similarly to a normal entry.

2. Trans-Atlantic Landing (TAL) Abort

The TAL abort mode was developed to improve the options available when a space shuttle main engine fails after the last RTLS opportunity but before the first time that an AOA can be accomplished with only two space shuttle main engines or when a major orbiter system failure, for example, a large cabin pressure leak or cooling system failure, occurs after the last RTLS opportunity, making it imperative to land as quickly as possible.

In a TAL abort, the vehicle continues on a ballistic trajectory across the Atlantic Ocean to land at a predetermined runway. Landing occurs approximately 45 minutes after launch. The landing site is selected near the nominal ascent ground track of the orbiter in order to make the most efficient use of space shuttle main engine propellant. The landing site also must have the necessary runway length, weather conditions and U.S. State Department approval. Currently, the three landing sites that have been identified for a due east launch are Moron,, Spain; Dakar, Senegal; and Ben Guerur, Morocco (on the west coast of Africa).

To select the TAL abort mode, the crew must place the abort rotary switch in the TAL/AOA position and depress the abort push button before main engine cutoff. (Depressing it after main engine cutoff selects the AOA abort mode.) The TAL abort mode begins sending commands to steer the vehicle toward the plane of the landing site. It also rolls the vehicle heads up before main engine cutoff and sends commands to begin an orbital maneuvering system propellant dump (by burning the propellants through the orbital maneuvering system engines and the reaction control system engines). This dump is necessary to increase vehicle performance (by decreasing weight), to place the center of gravity in the proper place for vehicle control, and to decrease the vehicle's landing weight.

TAL is handled like a nominal entry.

3. East-Coast Abort and Landing (ECAL)[8] Abort

When the shuttle was originally designed, multiple main engine failures early in flight meant a ditching somewhere in the Atlantic Ocean. After Challenger, the shuttle was rigged with a bailout system to give the crew a better chance of survival. In the space station era, an additional option was implemented to give of a shuttle with multiple engine failures a chance to reach an East Coast runway.

To reach the space station, the shuttle must launch into to the plane of its orbit. That plane is tilted 51.6 degrees to the equator. As a result, shuttles bound for the station take off on a northeasterly trajectory that parallels the East Coast of the United States. Should two or three engines fail before the shuttle is going fast enough to reach Europe or to turn around and return to Florida, the crew would attempt a landing at one of 15 designated East Coast runways, 10 in the United States and five in Canada.

First, the shuttle's flight computers would pitch the nose up to 60 degrees to burn off fuel and yaw the ship 45 degrees to the left of its ground track to begin moving it closer to the coast. The shuttle also would roll about its vertical axis to put the crew in a "heads up" orientation on top of the external fuel tank. Based on velocity, fuel remaining and other factors, the shuttle eventually would pitch down and jettison the external tank. From there, the flight computers would attempt to steer the ship to the designated runway using angle of attack as the primary means of bleeding off energy.

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[8] ECALs were not included in the original Rockwell Shuttle Reference. This information is provided by the author.

An ECAL abort is a high-risk, last-resort option and would only be implemented if the only other alternative was to ditch in the ocean.

4. Abort to Orbit (ATO)[9] Abort

An ATO is an abort mode used to boost the orbiter to a safe orbital altitude when performance has been lost and it is impossible to reach the planned orbital altitude. If a space shuttle main engine fails in a region that results in a main engine cutoff under speed, the Mission Control Center will determine that an abort mode is necessary and will inform the crew. The orbital maneuvering system engines would be used to place the orbiter in a circular orbit.

5. Abort Once Around (AOA) Abort

The AOA abort mode is used in cases in which vehicle performance has been lost to such an extent that either it is impossible to achieve a viable orbit or not enough orbital maneuvering system propellant is available to accomplish the orbital maneuvering system thrusting maneuver to place the orbiter on orbit and the deorbit thrusting maneuver. In addition, an AOA is used in cases in which a major systems problem (cabin leak, loss of cooling) makes it necessary to land quickly. In the AOA abort mode, one orbital maneuvering system thrusting sequence is made to adjust the post-main engine cutoff orbit so a second orbital maneuvering system thrusting sequence will result in the vehicle deorbiting and landing at the AOA landing site (White Sands, N.M.; Edwards Air Force Base; or the Kennedy Space Center). Thus, an AOA results in the orbiter circling the Earth once and landing approximately 90 minutes after lift-off.

After the deorbit thrusting sequence has been executed, the flight crew flies to a landing at the planned site much as it would for a nominal entry.

6. Contingency Aborts

Contingency aborts are caused by loss of more than one main engine or failures in other systems. Loss of one main engine while another is stuck at a low thrust setting may also necessitate a contingency abort. Such an abort would maintain orbiter integrity for in-flight crew escape if a landing cannot be achieved at a suitable landing field.

Contingency aborts due to system failures other than those involving the main engines would normally result in an intact recovery of vehicle and crew. Loss of more than one main engine may, depending on engine failure times, result in a safe runway landing. However, in most three-engine-out cases during ascent, the orbiter would have to be ditched. The in-flight crew escape system would be used before ditching the orbiter.

Editor's Note… Here is a bit of background on the crew's bailout system from an earlier edition of the Space Reporter's Handbook:

> During the early phases of flight, two or more engine failures, depending on when they happened, could leave the shuttle without enough power to make it to a runway. In that case, the crew would have to "ditch" the orbiter somewhere in the ocean. Given that shuttles land at more than 200 mph, ditching is not considered a survivable option.

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[9] Aside from the Jan. 28, 1986, Challenger disaster, the only other in-flight engine shutdown in the history of the shuttle program occurred July 29, 1985, when Challenger's No. 1 engine shut down five minutes and 45 seconds after liftoff because of a faulty temperature sensor on the engine's high-pressure fuel turbopump. In that case, Challenger was able to abort to a lower-than-planned orbit and, after extensive replanning, complete its Spacelab mission.

In the wake of the Challenger disaster, NASA examined several possible escape systems ranging from ejection seats to simply jumping out the side hatch for a parachute descent. The agency ultimately settled on a bail out system that required modifications to let a crew blow the side hatch safely away from the shuttle during descent.

In the current system, a 248-pound, 8.75-foot telescoping pole is mounted along the ceiling of the crew cabin's lower deck. In a bailout, the pole extends through the open hatch. An astronaut then hooks his or her parachute harness to the pole and slides down it for a safe descent (without the pole, an astronaut probably would be blown into the left wing or the aft rocket pod).

To go along with the system, shuttle crews now take off and land wearing bulky, bright orange spacesuits capable of keeping them alive at altitudes up to 100,000 feet. The 70-pound suits feature a built-in life preserver and air supply with backpacks housing a parachute and a small, collapsible life raft.

To operate the system, an astronaut seated on the shuttle's lower deck pulls a handle that opens a vent at an altitude of about 40,000 feet to let cabin air pressure equalize at around 30,000 feet. The commander then orients the shuttle so that its rate of descent is just right to maintain the proper airspeed of between 185 knots and 195 knots. He then puts the shuttle on autopilot and climbs down to the lower deck.

At that point, the side hatch is jettisoned and the crew begins to bail out. As soon as the astronaut hits the water, the parachute is automatically cut free, a life preserver inflates and the life raft automatically fills with air. Assuming bail out started at 20,000 feet or so, all crew members would be clear of the shuttle by the time it had descended to an altitude of 10,000 feet. Each astronaut would hit the water about a mile apart from each other along the line following the shuttle's flight path.

Orbiter Ground Turnaround

Spacecraft recovery operations at the nominal end-of-mission landing site are supported by approximately 160 space shuttle Launch Operations team members. Ground team members wearing self-contained atmospheric protective ensemble suits that protect them from toxic chemicals approach the spacecraft as soon as it stops rolling. The ground team members take sensor measurements to ensure the atmosphere in the vicinity of the spacecraft is not explosive. In the event of propellant leaks, a wind machine truck carrying a large fan will be moved into the area to create a turbulent airflow that will break up gas concentrations and reduce the potential for an explosion.

A ground support equipment air-conditioning purge unit is attached to the right-hand orbiter T-0 umbilical so cool air can be directed through the orbiter's aft fuselage, payload bay, forward fuselage, wings, vertical stabilizer, and orbital maneuvering system/reaction control system pods to dissipate the heat of entry.

A second ground support equipment ground cooling unit is connected to the left-hand orbiter T-0 umbilical spacecraft Freon coolant loops to provide cooling for the flight crew and avionics during the postlanding and system checks. The spacecraft fuel cells remain powered up at this time. The flight crew will then exit the spacecraft, and a ground crew will power down the spacecraft.

At the Kennedy Space Center, the orbiter and ground support equipment convoy move from the runway to the Orbiter Processing Facility.

If the spacecraft lands at Edwards Air Force Base, the same procedures and ground support equipment are used as at the Kennedy Space Center after the orbiter has stopped on the runway. The orbiter and ground support equipment convoy move from the runway to the orbiter mate and demate facility at Edwards Air Force Base. After detailed inspection, the spacecraft is prepared to be ferried atop the shuttle carrier aircraft from Edwards Air Force Base to the Kennedy Space Center. For ferrying, a tail cone is installed over the aft section of the orbiter.

In the event of a landing at an alternate site, a crew of about eight team members will move to the landing site to assist the astronaut crew in preparing the orbiter for loading aboard the shuttle carrier aircraft for transport back to the Kennedy Space Center. For landings outside the U.S., personnel at the contingency landing sites will be provided minimum training on safe handling of the orbiter with emphasis on crash rescue training, how to tow the orbiter to a safe area, and prevention of propellant conflagration.

Upon its return to the Orbiter Processing Facility at the Kennedy Space Center, the orbiter is safed (ordnance devices safed), the payload (if any) is removed, and the orbiter payload bay is reconfigured from the previous mission for the next mission. Any required maintenance and inspections are also performed while the orbiter is in the OPF. A payload for the orbiter's next mission may be installed in the orbiter's payload bay in the OPF or may be installed in the payload bay when the orbiter is at the launch pad.

The spacecraft is then towed to the Vehicle Assembly Building and mated to the external tank. The external tank and solid rocket boosters are stacked and mated on the mobile launcher platform while the orbiter is being refurbished. Space shuttle orbiter connections are made and the integrated vehicle is checked and ordnance is installed.

The mobile launcher platform moves the entire space shuttle system on four crawlers to the launch pad, where connections are made and servicing and checkout activities begin. If the payload was not installed in the OPF, it will be installed at the launch pad followed by prelaunch activities.

Space shuttle launches from Vandenberg Air Force Base will utilize the Vandenberg launch facility (SL6), which was built but never used for the manned orbital laboratory program. This facility was modified for space transportation system use.

The runway at Vandenberg was strengthened and lengthened from 8,000 feet to 12,000 feet to accommodate the orbiter returning from space.

When the orbiter lands at Vandenberg Air Force Base, the same procedures and ground support equipment and convoy are used as at Kennedy Space Center after the orbiter stops on the runway. The orbiter and ground support equipment are moved from the runway to the Orbiter Maintenance and Checkout Facility at Vandenberg Air Force Base. The orbiter processing procedures used at this facility are similar to those used at the OPF at the Kennedy Space Center.

Space shuttle buildup at Vandenberg differs from that of the Kennedy Space Center in that the vehicle is integrated on the launch pad. The orbiter is towed overland from the Orbiter Maintenance and Checkout Facility at Vandenberg to launch facility SL6.

SL6 includes the launch mount, access tower, mobile service tower, launch control tower, payload preparation room, payload changeout room, solid rocket booster refurbishment facility, solid rocket booster disassembly facility, and liquid hydrogen and liquid oxygen storage tank facilities.

The solid rocket boosters start the on-the-launch-pad buildup followed by the external tank. The orbiter is then mated to the external tank on the launch pad.

The launch processing system at the launch pad is similar to the one used at the Kennedy Space Center.

Kennedy Space Center Launch Operations has responsibility for all mating, prelaunch testing and launch control ground activities until the space shuttle vehicle clears the launch pad tower. Responsibility is then turned over to NASA's Johnson Space Center Mission Control Center-Houston. The Mission Control Center's responsibility includes ascent, on-orbit operations, entry, approach and landing until landing runout completion, at which time the orbiter is handed over to the postlanding operations at the landing site for turnaround and relaunch. At the launch site the solid rocket boosters and external tank are processed for launch and the solid rocket boosters are recycled for reuse.

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Appendix 2: STS-51L and STS-107
Remembering Challenger and Columbia[10]

An impromptu memorial to the crew of STS-107 at the main entrance to the Johnson Space Center

STS-51L: Challenger's Final Flight

The shuttle Challenger, NASA's second manned orbiter, blasted off on its final mission at 11:38 a.m. EST on Jan. 28, 1986. The initial moments of the 25th shuttle flight appeared normal, but just over a minute into flight, Challenger exploded in a terrifying fireball. Here is part of one of the many stories the author wrote that day as Cape Canaveral bureau manager for United Press International (note: breaking news wire service stories are written "on the fly" in real time and readers familiar with Challenger's destruction will spot several inadvertent errors):

> **NASA says astronauts apparently dead**
> **By WILLIAM HARWOOD**
> CAPE CANAVERAL, Fla. (UPI) – The space shuttle Challenger exploded shortly after blastoff today and hurtled into the Atlantic Ocean. The seven crew members, including teacher Christa McAuliffe, apparently were killed in the worst disaster in space history.

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10 For additional information, including detailed timelines, please see the CBS News "Space Place" website at: **http://www.cbsnews.com/network/news/space/SRH_Disasters.htm**

"It is a national tragedy," said Jesse Moore, director of the Johnson Space Center. "I regret that I have to report … that searches … did not reveal any evidence that the crew members are alive."

He said data from instruments, launch pad systems and other sources would be impounded for an investigation.

The explosion occurred while two powerful booster rockets were still attached to the shuttle. There was no way for the crew to escape the out-of-control spacecraft, which fell into the ocean 18 miles off the coast. Burning debris falling from the sky kept rescuers from reaching the scene immediately.

"We have a report that the vehicle has exploded," said NASA spokesman Steve Nesbitt. "We are now looking at all the contingency operations awaiting word from any recovery forces downrange."

On board the Challenger were commander Francis "Dick" Scobee, co-pilot Michael Smith, Judith Resnik, Ellison Onizuka, Ronald McNair, satellite engineer Gregory Jarvis and McAuliffe, the Concord, N.H. social studies teacher who was chosen from 11,000 candidates to be the first private citizen to fly on a shuttle.

Blow by: In this photo, black smoke can be seen billowing from an O-ring joint at the base of Challenger's right-side solid-fuel booster moments after ignition. The joint resealed itself but eventually reopened, triggering the shuttle's destruction 73 seconds after liftoff.

Unlike the shuttle Columbia during its first flights at the dawn of the shuttle era, Challenger was not equipped with ejection seats or other ways for the crew to get out of the spacecraft. McAuliffe's parents, Edward and Grace Corrigan, watching from the VIP site three miles from the launch pad, hugged each other and sobbed as the fireball erupted in the sky. Students at her school, assembled to watch their teacher's launch, watched in stunned silence.

Other students, friends and fellow teachers in Concord cheered the blastoff and then fell into stony silence as the disaster was brought home to them on television. Mark Letalien, a junior at the Concord high school, said "I didn't believe it happened. They made such a big thing about it. Everyone's watching her and she gets killed."

It was the 25th shuttle flight, the 10th for Challenger and the worst disaster in the nation's space program. It came exactly 19 years and a day from the only previous accident - aboard the first Apollo moon capsule on its launch pad Jan. 27, 1967. Astronauts Virgil "Gus" Grissom, Edward White and Roger Chaffee died in that fire.

NASA said Challenger's launch appeared entirely normal until one minute and 15 seconds after liftoff, when the shuttle had accelerated to a speed of 1,977 mph, three times the speed of sound. It was 4.9 miles up and 18 miles out over the ocean.

"Challenger, go at throttle up," mission control told the spacecraft 52 seconds after launch. Scobee's final words to mission control were: "Roger, go at throttle up." Television replays showed close-ups of the speeding ship suddenly enveloped in a ball of fire. Its engines continued firing, raising it out of the flames, but it was out of control.

Multiple contrails could be seen streaking through the sky as the $1.1 billion shuttle arced out over the Atlantic and debris fell into the sea.

In Washington, President Reagan was in an Oval Office meeting whe4n aides brought him the grim news. He rushed into a study in time to see a television replay of the explosion. His face was creased with horror and anxiety. The House of Representatives recessed in the face of the national tragedy.

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A panel of outside experts led by former Secretary of State William Rogers concluded Challenger was destroyed by the rupture of an O-ring joint in the shuttle's right-side solid-fuel booster. The resulting "burn through" created a jet of flame that ultimately ate through Challenger's external tank, triggering its collapse 73 seconds after blastoff. Almost simultaneously, Challenger, traveling faster than sound, broke apart after being subjected to aerodynamic forces it was not designed to withstand. The ship's crew cabin broke away from the rest of the shuttle and crashed into the Atlantic Ocean at more than 200 mph (see photo at left).

The Rogers Commission report was delivered on June 6 to Camp David, Md., where President Reagan was spending the weekend. A formal presentation with the members of the commission was hgeld in the Rose Garden at the White House. The 256-page report was divided into nine chapters. The first two chapters presented a brief history of the shuttle program and past flights and detailed the events leading up to Challenger's launching on Jan. 28. The commission also presented a detailed timeline of the disaster before getting down to business in Chapter 4.

The Cause of the Accident

The Rogers Commission listed 16 findings on the primary cause of the accident before stating the following conclusion:

"The commission concluded that the cause of the Challenger accident was the failure of the pressure seal in the aft field joint of the right Solid Rocket Motor. The failure was due to a faulty design unacceptably sensitive to a number of factors. These factors were the effects of temperature, physical dimensions, the character of materials, the effects of reusability, processing and the reaction of the joint to dynamic loading."

A thorough analysis of all available evidence showed no abnormalities with the external fuel tank, Challenger and its three main engines or the shuttle's payload and records showed all the hardware used in flight 51-L met NASA specifications. Launch processing, from the initial stacking of the rocket boosters to work done at the launch pad was normal, but during assembly of the right-side booster, engineers ran into snags. One of the fuel segments that mated at the aft field joint was severely out of round and had to be forced into the proper shape with a high-power hydraulic tool. In addition, measurements showed that because of previous use, the two fuel segments in question had slightly larger diameters than normal but they still were within specifications.

Recall for a moment the construction of the joint. The upper rim of the bottom fuel segment, called a clevis, is an upward-facing U-shaped groove. The lower rim of the fuel segment above, called a tang, slides into the clevis and the resulting interlocking joint is bolted together with 177 high-strength steel pins. Running around the interior of the inner leg of the clevis are the two rubber O-ring seals. Because of the larger than normal joint diameters, at the moment of ignition, the tang and clevis had an average gap of .004 inches, which would have compressed the O-rings severely. Because the fuel segments were slightly out of round, the smallest gap was in the area where the rupture occurred during flight, although it is not known if the high compression on the O-ring was present at liftoff.

It was a record 36 degrees when Challenger took off and infrared measurements taken at the launch pad showed the temperature around the circumference of the aft field joint was in the neighborhood of 28 degrees in the area where the rupture occurred, the coldest spot on the booster. To understand the significance of the temperature factor, consider again the operation of the rocket motor at ignition when internal pressure shoots from zero to nearly 1,000 pounds per square inch. This tremendous force pushes outward and causes the joints to bulge slightly, a phenomenon known as joint rotation. During the ignition transient, the tang and clevis typically separate as much as .017 and .029 inches where the primary and secondary O-rings are located. The gap opening reaches maximum about 600 milliseconds after ignition when the motor reaches full pressure. To keep the joint sealed as the tang-clevis separation increases during ignition, the O-rings must seat properly and the commission said cold O-rings take longer to reach the proper position.

"At the cold launch temperature experienced, the O-ring would be very slow in returning to its normal rounded shape. It would not follow the opening of the tang-to-clevis gap. It would remain in its compressed position in the O-ring channel and not provide a space between itself and the upstream channel wall. Thus, it is probable the O-ring would not be pressure actuated to seal the gap in time to preclude joint failure due to blow-by and erosion from hot combustion gases," the report said.

Further, the commission found that experimental evidence showed other factors, such as humidity and the performance of the heat-shielding putty in the joint "can delay pressure application to the joint by 500 milliseconds or more." Records showed that in each shuttle launch in temperature below 61 degrees, one or more booster O-rings showed signs of erosion or the effects of heat. Complicating the picture, there was the possibility of ice in the suspect joint because Challenger had been exposed to seven inches of rainfall during its month on the launch pad prior to blastoff. Research showed ice could have prevented proper sealing by the secondary O-ring.

Launch pad cameras showed puffs of black smoke shooting from the region of the aft field joint beginning about the same time the motor reached full pressure. The commission said two overall failure scenarios were possible: a small leak could have developed at ignition that slowly grew to the point that flame erupted through the joint as photographs indicated some 58 seconds after blastoff. More likely, however, the gap between the burned O-rings and the clevis probably was sealed up by "deposition of a fragile buildup of aluminum oxide and other combustion debris. The resealed section of the joint could have been disturbed by thrust vectoring (steering), space shuttle motion and flight loads induced by changing winds aloft." NASA revealed after the accident that wind shear was higher for Challenger's mission than for any previous shuttle flight.

That the shuttle booster joints were faulty and overly dependent on a variety of factors was clear. The commission's findings on the secondary causes of the disaster were more subtle but just as damning to the space agency.

The Contributing Cause of the Accident

"The decision to launch the Challenger was flawed," the Rogers Commission said. "Those who made that decision were unaware of the recent history of problems concerning the O-rings and the joint and were unaware of the initial written recommendation of the contractor advising against the launch at temperatures below 53 degrees Fahrenheit and the continuing opposition of the engineers at Thiokol after the management reversed its position.

They did not have a clear understanding of Rockwell's concern that it was not safe to launch because of ice on the pad. If the decision makers had known all of the facts, it is highly unlikely that they would have decided to launch 51-L on January 28, 1986."

Before shuttles are cleared for flight, a formal "flight readiness review" is held by top NASA managers to discuss any open items that might affect a launch. Previous flights are reviewed to make sure any problems had been addressed before commiting the next shuttle for launch. Mulloy testified NASA management was well aware of the O-ring issue and cited the flight readiness review record as proof. He was correct in that during several preceding flight readiness reviews, the O-ring problem was mentioned. But it was only mentioned in the context that it was an acceptable risk and that the boosters had plenty of margin. It was not mentioned at all during the 51-L readiness review.

"It is disturbing to the commission that contrary to the testimony of the solid rocket booster project manager, the seriousness of concern was not conveyed in Flight Readiness Review to Level 1 and the 51-L readiness review was silent."

Keel said later the real turning point in the commission investigation came on Feb. 10 during a closed hearing in Washington. It was there the commission learned of the launch-eve debate over clearing Challenger for launch. Boisjoly would later recall the events of Jan. 27 in this manner:

Boisjoly: "I felt personally that management was under a lot of pressure to launch and that they made a very tough decision, but I didn't agree with it. One of my colleagues that was in the meeting summed it up best. This was a meeting where the determination was to launch and it was up to us to prove beyond a shadow of a doubt that it was not safe to do so. This is in total reverse to what the position usually is in a preflight conversation or a flight readiness review. It is usually exactly opposite that."

Commission member Arthur B.C. Walker: "Do you know the source of the pressure on management that you alluded to?"

Boisjoly: "Well, the comments made over the [teleconference network] is what I felt, I can't speak for them, but I felt it, I felt the tone of the meeting exactly as I summed up, that we were being put in a position to prove that we should not launch rather then being put in the position and prove that we had enough data for launch. And I felt that very real."

The Rogers Commission concluded that a "well structured" management system with the emphasis on flight safety would have elevated the booster O-ring issue to the status it deserved and that NASA's decision-making process was clearly faulty. One can only wonder how many other launch-eve debates occurred during the previous 24 missions that were never mentioned because the flight turned out to be a success.

"Had these matters been clearly stated and emphasized in the flight readiness process in terms reflecting the views of most of the Thiokol engineers and at least some of the Marshall engineers, it seems likely that the launch of 51-L might not have occurred when it did," the commission said.

The commission also determined that the waiving of launch constraints based on previous success came at the expense of flight safety because the waivers did not necessarily reach top-level management for a decision. Finally, the commission charged engineers at the Marshall Space Flight Center where the booster program was managed had a "propensity" for keeping knowledge of potentially serious problems away from other field centers in a bid to address them internally.

An Accident Rooted in History

"The Space Shuttle's Solid Rocket Booster problem began with the faulty design of its joint and increased as both NASA and contractor management first failed to recognize it as a problem, then failed to fix it and finally treated it as an acceptable flight risk," the Rogers Commission said.

Morton Thiokol won the contract to build shuttle boosters in 1973. Of the four competitors, Thiokol ranked at the bottom for design and development but came in first in the management category. NASA later said Thiokol was selected because "cost advantages were substantial and consistent throughout all areas evaluated." The result was an $800 million cost-plus-award-fee contract.

Morton Thiokol hoped to keep costs down by borrowing heavily from the design of the Titan 3 solid rocket motors. Both systems, for example, used tang and clevis joints but the shuttle design had major differences as well. Unlike in the Titan, which relied on a single O-ring seal, two rubber O-rings were employed in the shuttle booster and both faced heavy pressure loads at launch. The way the seals worked in the shuttle boosters was elegant in its simplicity. Before fuel joints were to be mated, an asbestos-filled putty would be used to fill in the gap between the two propellant faces of the fuel segments. The putty, then, would serve as a barrier to prevent hot gas from reaching the O-ring seals. But the putty was plastic so when the rocket was ignited, internal pressure would force the putty to flow toward the outside of the joint. In doing so, air between the putty and the O-ring would become pressurized, forcing the O-ring to "extrude" into the minute gap between the clevis and tang. In this manner, the joint would be sealed and even if the primary O-ring failed to operate, the secondary seal would fill in the gap, so to speak. To make sure the O-rings were, in fact, able to seal the joints prior to ignition, Thiokol included a "leak test port" in each booster joint. Once assembled, the space between the two O-rings could be pressurized with 50 psi air. If the pressure stayed steady, engineers would know the joint was airtight and that no path from the propellant to the primary O-ring existed for hot gas or flame.

So much for theory. When testing began, results were not what Thiokol engineers expected.

The design of the joint had led engineers to believe that once pressurized, the gap between the tang and clevis actually would decrease slightly, thereby improving the sealing action of the O-rings. To test the booster's structural integrity, Thiokol conducted "hydroburst" tests in 1977. In these tests, water was pumped inside a booster case and pressurized to 1.5 times actual operating pressure. Careful measurements were made and to their surprise, engineers realized that the tang and clevis joint actually bulged outward, widening the gap between the joint members. While Thiokol tended to downplay the significance of the finding at the time, engineers at Marshall were dismayed by the results. John Q. Miller, a chief booster engineer at the Alabama rocket center, wrote a memo on Jan. 9, 1978, to his superiors, saying, "We see no valid reason for not designing to accepted standards" and that improvements were mandatory "to prevent hot gas leaks and resulting catastrophic failure." This memo and another along the same lines actually were authored by Leon Ray, a Marshall engineer, with Miller's agreement. Other memos followed but the Rogers Commission said Thiokol officials never received copies. In any case, the Thiokol booster design passed its Phase 1 certification review in March 1979. Meanwhile, ground test firings confirmed the clevis-tang gap opening. An independent oversight committee also said pressurization through the leak test port pushed the primary O-ring the wrong way so that when the motor was ignited, the compression from burning propellant had to push the O-ring over its groove in order for it to extrude into the clevis-tang gap. Still, NASA engineers at Marshall concluded "safety factors to be adequate for the current design" and that the secondary O-ring would serve as a redundant backup throughout flight.

On Sept. 15, 1980, the solid rocket booster joints were classified as criticality 1R, meaning the system was redundant because of the secondary O-ring. Even so, the wording of the critical items list left much room for doubt: "Redundancy of the secondary field joint seal cannot be verified after motor case pressure reaches approximately 40 percent of maximum expected operating pressure." The joint was classified as criticality 1R until December 1982 when it was changed to criticality 1. Two events prompted the change: the switch to a non-asbestos insulating putty - the original manufacturer had discontinued production - and the results of tests in May 1982 that finally convinced Marshall management that the secondary O-ring would not function after motor pressurization. Criticality 1 systems are defined as those in which a single failure results in loss of mission, vehicle and crew. Even though the classification was changed, NASA engineers and their counterparts at Morton Thiokol still considered the joint redundant through the ignition transient. The Rogers Commission found this to be a fatal flaw in judgment.

Criticality 1 systems must receive a formal "waiver" to allow flight. On March 28, 1983, Michael Weeks, associate administrator for space flight (technical) signed the document that allowed continued shuttle missions despite the joint concerns.

"We felt at the time, all of the people in the program I think felt that this solid rocket motor in particular ... was probably one of the least worrisome things we had in the program," Weeks said.

Then came the flight of mission 41-B, the 10th shuttle mission, launched Feb. 3, 1984. Prior to that time, only two flights had experienced O-ring damage: the second shuttle mission and the sixth. In both cases, only a single joint was involved. But after 41-B, inspectors found damage to a field joint and a nozzle joint. Marshall engineers were concerned about the unexpected damage, but a problem assessment report concluded: "This is not a constraint to future launches." For the next shuttle flight, 41-C, NASA managers were advised launch should be approved but that there was a possibility of some O-ring erosion. Meanwhile, to make absolutely sure the O-rings were seated properly prior to launch, the leak test pressure was increased to 100 psi and later to 200 psi, even though Marshall engineers realized that increased the possibility of creating blow holes through the insulating putty. Such blow holes, in turn, could provide paths for hot gas to reach the O-rings. In any case, the statistics are simple: of the first nine shuttle flights, when joints were tested with 50 psi or 100 psi pressure, only one field joint problem was noticed. With the 200 psi tests, more than 50 percent of the shuttle missions exhibited some field joint O-ring erosion.

So even though research was underway to improve the joint design, shuttles continued flying. On Jan. 24, 1985, Atlantis took off on the first classified military shuttle mission, flight 51-C. The temperature at launch time was a record 53 degrees and O-ring erosion was noted in both boosters after recovery. Damage was extensive: both booster nozzle primary O-rings showed signs of blow by during ignition and both the primary and secondary seals in the right booster's center segment field joint were affected by heat. Thiokol engineers would later say temperature apparently increased the chances for O-ring damage or erosion by reducing resiliency. Concern mounted after the flight of mission 51-B in April 1985 when engineers discovered a nozzle primary O-ring had been damaged and failed to seat at all and that the secondary seal also was eroded. This was serious and more studies were ordered. Mulloy then instituted a launch constraint, meaning a waiver was required before every succeeding mission. Mulloy signed such waivers six flights in a row before Challenger took off for the last time.

On Aug. 19, 1985, NASA managers in Washington were briefed on the O-ring issue and the next day, Morton Thiokol established an O-ring task force because "the result of a leak at any of the joints would be catastrophic." But company engineers told the commission the task force ran into red tape and a lack of cooperation.

"The genesis of the Challenger accident - the failure of the joint of the right solid rocket motor - began with decisions made in the design of the joint and in the failure by both Thiokol and NASA's solid rocket booster project office to understand and respond to facts obtained during testing," the Rogers Commission concluded.

The panel said NASA's testing program was inadequate, that engineers never had a good understanding of the mechanics of joint sealing and that the material presented to NASA management in August 1985 "was sufficiently detailed to require corrective action prior to the next flight."

Pressures on the System

"With the 1982 completion of the orbital test flight series, NASA began a planned acceleration of the Space Shuttle launch schedule," the Rogers Commission said. "One early plan contemplated an eventual rate of a mission a week, but realism forced several downward revisions. In 1985, NASA published a projection calling for an annual rate of 24 flights by 1990. Long before the Challenger accident, however, it was becoming obvious that even the modified goal of two flights a month was overambitious."

When the shuttle program was conceived, it was hailed as the answer to the high cost of space flight. By building a reusable space vehicle, the United States would be able to lower the cost of placing a payload into orbit while at the same time, increase its operational capability on the high frontier. The nation's space policy then focused on the shuttle as the premier launcher in the American inventory and expendable rockets were phased out. Once shuttle flights began, NASA quickly fell under pressure to meet a heavy schedule of satellite launches for commercial, military and scientific endeavors. And as the flight rate increased, the space agency's resources became stretched to the limit. Indeed, the Rogers Commission said evidence indicated even if the 51-L disaster had been avoided, NASA would have been unable to meet the 16-launch schedule planned for 1986.

But NASA's can-do attitude refused to let the agency admit its own limitations as it struggled along against increasingly significant odds and diminishing resources. The Rogers Commission found that astronaut training time was being cut back, that frequent and late payload changes disrupted flight planning and that a lack of spare parts was beginning to manifest itself in flight impacts at the time of the Challenger accident.

The Rogers Commission concluded:

1. "The capabilities of the system were stretched to the limit to support the flight rate in winter 1985/1986," the commission wrote. "Projections into the spring and summer of 1986 showed a clear trend; the system, as it existed, would have been unable to deliver crew training software for scheduled flights by the designated dates. The result would have been an unacceptable compression of the time available for the crews to accomplish their required training.

2. "Spare parts are in short supply. The shuttle program made a conscious decision to postpone spare parts procurements in favor of budget items of perceived higher priority. Lack of spare parts would likely have limited flight operations in 1986.

3. "Stated manifesting policies [rules governing payload assignments] are not enforced. Numerous late manifest changes (after the cargo integration review) have been made to both major payloads and minor payloads throughout the shuttle program.

4. "The scheduled flight rate did not accurately reflect the capabilities and resources.

5. "Training simulators may be the limiting factor on the flight rate; the two current simulators cannot train crews for more than 12-15 flights per year.

6. "When flights come in rapid succession, current requirements do not ensure that critical anomalies occurring during one flight are identified and addressed appropriately before the next flight."

Other Safety Considerations

The Rogers Commission also identified a number of safety considerations to be addressed by NASA before the resumption of shuttle flights. The realization that Challenger's crew had no survivable abort options during solid rocket flight prompted the commission to recommend a re-evaluation of all possible abort schemes and escape options.

Two types of shuttle aborts were possible at the time of the Challenger accident: the four intact aborts, in which the shuttle crew attempts an emergency landing on a runway, and contingency aborts, in which the shuttle is not able to make it to a runway and instead "ditches" in the ocean. But the commission said tests at NASA's Langely Research Center showed an impact in the ocean probably would cause major structural damage to the orbiter's crew cabin. In addition, "payloads in the cargo bay are not designed to withstand decelerations as high as those expected and would very possibly break free and travel forward into the crew cabin." Not a pleasant prospect.

"My feeling is so strong that the orbiter will not survive a ditching, and that includes land, water or any unprepared surface," astronaut Weitz told the commission. "I think if we put the crew in a position where they're going to be asked to do a contingency abort, then they need some means to get out of the vehicle before it contacts earth."

If there was a clear "winner" in the Rogers Commission report is was the astronauts. Nearly every concern raised by Young and his colleagues was addressed and NASA managers privately grumbled that with the re-emergence of "astronaut power," the agency would become so conservative it would be next to impossible to get a shuttle off the ground.

Recommendations:

The Rogers Commission made nine recommendations to conclude its investigation of the worst disaster in space history.

1. A complete redesign of the solid rocket booster segment joints was required with the emphasis on gaining a complete understanding of the mechanics of seal operation; the joints should be as structurally stiff as the walls of the rockets and thus less susceptible to rotation; and NASA should consider vertical test firings to ensure duplication of the loads experienced during a shuttle launch. In addition, the panel recommended that NASA ask the National Research Council to set up an independent review committee to oversee the redesign of the booster joints.

2. NASA's shuttle program management system should be reviewed and restructured, with the program manger given more direct control over operations, and NASA should "encourage the transition of qualified astronauts into agency management positions" to utilize their flight experience and to ensure proper attention is paid to flight safety. In addition, the commission said NASA should establish a shuttle safety advisory panel.

3. The commission recommended a complete review of all criticality 1, 1R, 2 and 2R systems before resumption of shuttle flights.

4. NASA was told to set up an office of Safety, Reliability and Quality Control under an associate administrator reporting to the administrator of the space agency. This office would operate autonomously and have oversight responsibilities for all NASA programs.

5. Communications should be improved to make sure critical information about shuttle systems makes it from the lowest level engineer to the top managers in the program. "The commission found that Marshall Space Flight Center project managers, because of a tendency at Marshall to management isolation, failed to provide full and timely information bearing on the safety of flight 51-L to other vital elements of shuttle program management," the panel said. Astronauts should participate in flight readiness reviews, which should be recorded, and new policies should be developed to "govern the imposition and removal of shuttle launch constraints."

6. NASA should take action to improve safety during shuttle landings by improving the shuttle's brakes, tires and steering system and terminating missions at Edwards Air Force Base, Calif., until weather forecasting improvements are made at the Kennedy Space Center.

7. "The commission recommends that NASA make all efforts to provide a crew escape system for use during controlled gliding flight." In addition, NASA was told to "make every effort" to develop software modifications that would allow an intact landing even in the event of multiple engine failures early in flight.

8. Pressure to maintain an overly ambitious flight rate played a role in the Challenger disaster and the Rogers Commission recommended development of new expendable rockets to augment the shuttle fleet.

9. "Installation, test and maintenance procedures must be especially rigorous for space shuttle items designated criticality 1. NASA should establish a system of analyzing and reporting performance trends in such items." In addition, the commission told NASA to end its practice of cannibalizing parts from one orbiter to keep another flying and instead to restore a healthy spare parts program despite the cost.

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Along with redesigning the O-ring booster joints, the agency reviewed the status of the overall shuttle program and ordered hundreds of modifications and improvements to beef up the safety of the shuttle itself. The shuttle "critical items list," which ranks systems and components according to the results of a failure, underwent a thorough review with far-reaching results. Criticality 1 components are those in which a failure leads to loss of vehicle and crew while criticality 1R systems are those in which a redundant backup is in place. Before the Challenger disaster, NASA listed 617 criticality 1 and 787 criticality 1R systems, a total of 1,404. As a result of the post-Challenger review, 1,514 criticality 1 systems were identified along with 2,113 criticality 1R components, a total of 3,627.

The numbers increased because NASA took a much harder look at the shuttle and its systems in the wake of Challenger and while at first glance they would appear to imply the shuttle is more dangerous than before, in reality they mean NASA simply has a better, more realistic understanding of the ship.

In the shuttle itself, more than 210 changes were ordered for first flight along with about 30 to widen safety margins in the powerful hydrogen-fueled main engines by improving welds and reducing bearing wear and turbine blade cracks, a source of concern in the past. Among the shuttle modifications were landing gear brake improvements and a redesign of the 17-inch valves in the main engine propellant feed lines to prevent premature closure and inadvertent engine shutdown.

Other major changes include installation of ribs to strengthen the structure of the shuttle's airframe, an automatic cutoff system to prevent maneuvering rocket problems and modifications to improve the ability of the nose section of the shuttle to withstand the tremendous heat of atmospheric re-entry. About 100 changes were made in the computer programs that actually fly the shuttle to take into account the performance of modified hardware and to improve safety margins.

NASA re-emphasized safety in mission design, implementing stricter weather criteria, new launch commit criteria and a revamped management structure that gave the final responsibility for clearing a shuttle for launch to an astronaut.

Shuttle flights resumed Sept. 29, 1988, and NASA launched 87 successful flights in a row before Columbia returned to Earth on Feb. 1, 2003.

Challenger's crew: Back row, left to right: Ellison Onizuka, Christa McAuliffe, Greg Jarvis, Judy Resnik; Front row, left to right: Mike Smith, Dick Scobee, Ron McNair

The Fate of Challenger's Crew

"NASA is unable to determine positively the cause of death of the Challenger astronauts but has established that it is possible, but not certain, that loss of consciousness did occur in the seconds following the orbiter breakup." NASA Press Release

"We have now turned our full efforts to the future, but will never forget our seven friends who gave their lives to America's space frontier." - Rear Adm. Richard Truly, Associate Administrator for Space Flight

The Rogers Commission did not discuss the fate of the crew or provide much detail about the crew cabin wreckage. Indeed, all references to "contact 67," the crash site of the crew compartment, were deleted from the official record, including charts that mapped various debris areas. This was done, perhaps, to preclude the possibility that anyone could find out the latitude and longitude of the cabin wreck site for diving and personal salvage. But ultimately, it was simply an extension of NASA's policy of no comment when it came to the astronauts. After all, hundreds of reporters knew the exact coordinates by eavesdropping on Navy radio. In any case, while the astronauts were not discussed in the commission report, the crew module was.

Analysis of crew cabin wreckage indicates the shuttle's windows may have survived the explosion. It is thus possible the crew did not experience high altitude decompression. If so, some or all of the astronauts may have been alive and conscious all the way to impact in the Atlantic some 18 miles northeast of the launch pad. The cabin hit the water at better than 200 mph on Scobee's side. The metal posts of the two forward flight deck seats, for example, were bent sharply to the right by force of impact when the cabin disintegrated.

"The internal crew module components recovered were crushed and distorted, but showed no evidence of heat or fire," the commission report said. "A general consistency among the components was a shear deformation from the top of the components toward the +Y (to the right) direction from a force acting from the left. Components crushed or sheared in the above manner included avionics boxes from all three avionics bays, crew lockers, instrument panels and the seat frames from the commander and the pilot. The more extensive and heavier crush damage appeared on components nearer the upper left side of the crew module. The magnitude and direction of the crush damage indicates that the module was in a nose down and steep left bank attitude when it hit the water.

"The fact that pieces of forward fuselage upper shell were recovered with the crew module indicates that the upper shell remained attached to the crew module until water impact. Pieces of upper forward fuselage shell recovered or found with the crew module included cockpit window frames, the ingress/egress hatch, structure around the hatch frame and pieces of the left and right sides. The window glass from all of the windows, including the hatch window, was fractured with only fragments of glass remaining in the frames."

Several large objects were tracked by radar after the shuttle disintegrated. One such object, classified as "Object D," hit the water 207 seconds after launch about 18 nautical miles east of launch pad 39B. This apparently was the crew cabin. "It left no trail and had a bright white appearance (black and white recording) until about T+175 seconds," an appendix to the Rogers Commission report said. "The image then showed flashes of both white and black until T+187 seconds, after which time it was consistently black. The physical extent of the object was estimated from the TV recording to be about 5 meters." This description is consistent with a slowly spinning crew module, which had black heat-shield tiles on its bottom with white tiles on its side and top.

The largest piece of crew cabin wreckage recovered was a huge chunk of the aft bulkhead containing the airlock hatch that led into the payload bay and one of the two flight deck windows that looked out over the cargo hold. The bulkhead wreckage measured 12 feet by 17 feet.

Here is a chronology of the crew cabin recovery operation and the efforts to determine the fate of the astronauts:

Mid-March Four astronaut "personal egress air packs," called PEAPs, are recovered along with other cabin wreckage.

April 18 NASA announced the crew cabin recovery operation was complete and that identifiable remains of all seven astronauts were on shore undergoing analysis.
April 25 The Armed Forces Institute of Pathology notified NASA it had been unable to determine a cause of death from analysis of remains. Joseph Kerwin, director of life sciences at the Johnson Space Center, began an in-depth analysis of the wreckage in a search for the answer.
May 20 Johnson Space Center crew systems personnel began analysis of the four PEAPs, emergency air packs designed for use if a shuttle crew must attempt an emergency exit on the ground when dangerous vapors might be in the area.
May 21 Investigators found evidence some of the PEAPs had been activated.
June 4 Investigators determined PEAP activation was not caused by crew cabin impact in the ocean.
June 9 Smith's PEAP was identified by serial number.
June 25 The PEAPs were sent to th Army Depot in Corpus Christi, Texas, for further analysis.
June 27 Scobee's PEAP was identified by serial number; Army investigators determined that three of the four air packs had been activated.
July 18 Truly received Kerwin's preliminary report on the fate of the astronauts. On July 24, NASA began informing the astronauts' families about what the investigation had found.

Some of the first wreckage recovered included four flight computers and both the cabin's operational flight recorders, used to record data about various shuttle systems and also used for the cabin's intercom system. It was on this tape that NASA heard Smith say "Uh oh" an instant before the shuttle broke apart, showing that at least some of the astronauts had a brief moment of awareness before the explosion that would claim their lives. On July 28, six months to the day after the disaster, NASA staged a news conference in Washington to discuss the investigation. Kerwin said the cause and time of death remained unknown.

"The findings are inconclusive," he wrote in a letter to Truly. "The impact of the crew compartment with the ocean surface was so violent that evidence of damage occurring in the seconds which followed the explosion was masked. Our final conclusions are:

> The cause of death of the Challenger astronauts cannot be positively determined;
>
> The forces to which the crew were exposed during orbiter breakup were probably not sufficient to cause death or serious injury; and
>
> The crew possibly, but not certainly, lost consciousness in the seconds following orbiter breakup due to in-flight loss of crew module pressure."

Accelerometers, instruments that measure the magnitude and direction of forces acting on the shuttle during flight, lost power when the nose section ripped away two tenths of a second after structural break up began. Independent analysis of all recovered data and wreckage concluded the nose pitched down as soon as it broke away and then slowed rapidly from aerodynamic forces. Calculations and analysis of launch photography indicate the acceleration forces the astronauts felt were between 12 and 20 times the force of gravity in a vertical direction, that is, as the cabin broke away, the astronauts were violently pushed down in their seats.

"These accelerations were quite brief," Kerwin wrote. "In two seconds, they were below four G's; in less than 10 seconds, the crew compartment was essentially in free fall. Medical analysis indicates that these accelerations are survivable, and that the probability of major injury to crew members is low."

When Challenger broke up, it was traveling at 1.9 times the speed of sound at an altitude of 48,000 feet. The crew module continued flying upward for some 25 seconds to an altitude of about 65,000 feet before beginning the long fall to the ocean. From breakup to impact took two minutes and 45 seconds. Impact velocity was 207 mph, subjecting the module to a braking force of approximately 200 times the force of gravity. Any astronaut still alive at that moment was killed instantly.

When the cabin ripped away from the fuselage, the crew's oxygen supplies were left behind in the payload bay, "except for a few seconds supply in the lines," Kerwin said. But each astronaut's airtight flight helmet also was connected to a PEAP that contained about six minutes of breathing air. Kerwin said because of the design of the activation switch, it was highly unlikely the PEAPs were turned on by impact. But unlike the oxygen system, the PEAPs did not provide pressurized air and if the cabin lost pressure, they would not have allowed the crew to remain conscious.

"It is possible, but not certain, that the crew lost consciousness due to an in-flight loss of crew module pressure," Kerwin wrote. "Data to support this is:

> The accident happened at 48,000 feet and the crew cabin was at that altitude or higher for almost a minute. At that altitude, without an oxygen supply, loss of cabin pressure would have caused rapid loss of consciousness and it would not have been regained before water impact.
>
> PEAP activation could have been an instinctive response to unexpected loss of cabin pressure.
>
> If a leak developed in the crew compartment as a result of structural damage during or after breakup (even if the PEAPs had been activated), the breathing air available would not have prevented rapid loss of consciousness.
>
> The crew seats and restraint harnesses showed patterns of failure which demonstrates that all the seats were in place and occupied at water impact with all harnesses locked. This would likely be the case had rapid loss of consciousness occurred, but it does not constitute proof."

Challenger's crew departs the Kennedy Space Center

Despite NASA's best efforts, engineers were never able to determine if cabin pressure was lost. Astronaut Crippen said later he was convinced it did, however, because had the cabin maintained pressure there would have been no need to activate the PEAPs. He said in his view, the astronauts made a "desperate" attempt to survive by activating the PEAPs when pressure was suddenly lost.

Of the four PEAPs recovered, the one that belonged to Scobee had not been activated. Of the other three, one was identified as Smith's and because of the location of the activation switch on the back of his seat, Truly said he believed Resnik or Onizuka turned the pilot's emergency air supply on in a heroic bid to save his life. The exact sequence of events will never be known.

STS-107: Columbia's Final Voyage

The shuttle Columbia blasted off on mission STS-107 at 10:39 a.m. on Jan. 16, 2003. At the controls were commander Rick Husband, pilot William "Willie" McCool, flight engineer Kalpana Chawla, physician Laurel Clark, payload commander Michael Anderson, physician David Brown and Israeli astronaut Ilan Ramon. STS-107 was one of only two flights left on the shuttle manifest that were not bound for the international space station (the other was a Hubble Space Telescope servicing mission).

Columbia breaks up above Texas. Photographed by Jim Dietz at his home near Dallas.

The goal of the 16-day mission was to carry out space station-class research in a variety of disciplines, ranging from biology to medicine, from materials science to pure physics and technology development, research that, for a variety of reasons, had never made it to the international space station.

Columbia's launching appeared normal, but analysis of tracking camera footage later that day showed a large chunk of foam insulation broke away from the shuttle's external tank about 81 seconds after liftoff. The foam appeared to come from a the left bipod ramp, an aerodynamically shaped ramp of foam built up around one of the two struts holding the nose of the shuttle to the tank. The foam fell along the tank and disappeared under Columbia's left wing. A shower of whitish debris was seen an instant later exiting from under the wing. The foam had obviously struck the wing, but where? And what sort of damage, if any, did it cause?

Engineers ultimately would conclude the impact likely caused no entry-critical damage. Husband and his crew were only informed about the strike in passing, in an email from mission managers who were concerned the astronauts might hear about the strike from reporters during upcoming on-orbit interviews. As it turned out, only a few reporters even knew about the foam strike and no one asked the crew about it. For their part, Husband and company chalked up a near perfect science mission before packing up for the trip back to Earth.

The day before re-entry, flight director LeRoy Cain downplayed the foam strike, saying engineers "took a very thorough look at the situation with the tile on the left wing and we have no concerns whatsoever. We haven't changed anything with respect to our trajectory design. It will be a nominal, standard trajectory."

He was wrong.

Shuttle Columbia destroyed in entry mishap
By WILLIAM HARWOOD
CBS News

The shuttle Columbia suffered a catastrophic failure returning to Earth Saturday, breaking apart 207,135 feet above Texas en route to a landing at the Kennedy Space Center to close out a 16-day science mission. The shuttle's seven-member crew - two women and five men, including the first Israeli space flier - perished in the disaster, the first loss of life on the high frontier since the 1986 Challenger disaster.

The initial phases of the descent went normally and Columbia crossed above the coast of California just north of San Francisco around 5:51 a.m. local time, or 8:51 a.m. EST, on track for a landing on runway 33 at the Kennedy Space Center just 25 minutes later at 9:16 a.m.

The first sign of anything unusual came at 8:53 a.m., when the shuttle was flying high above the heartland of America.

Telemetry showed a sudden loss of hydraulic system data from the inboard and outboard wing flaps, or elevons, on Columbia's left wing. Three minutes later, sensors in the brake lines and tires of the shuttle's left-side main landing gear suddenly stopped providing data.

The shuttle continued to fly in a normal manner with no hint that a catastrophic failure was imminent.

Then at 8:58 a.m., sensors that monitor temperatures where the shuttle's protective thermal tiles are glued or bonded to the airframe suddenly dropped out followed one minute later by loss of data from landing gear pressure sensors on the left side tires. Columbia's flight computers alerted the astronauts to the pressure indication and one of the crew members acknowledged the alert in a brief call to mission control.

That was the final transmission from the space shuttle. Moments later, all data were lost and the vehicle broke up while traveling 18.3 times the speed of sound. Mission duration to that point was 15 days 22 hours 20 minutes and 22 seconds, translating to 8:59:22 a.m. EST (Editor's note: This time was later amended; see the detailed timeline below for exact timing). Wreckage was soon found strewn over a debris "footprint" stretching across eastern Texas and into Louisiana. There was no immediate word on where Columbia's reinforced crew module might have crashed to Earth.

In a brief address to the nation, President Bush said "this day has brought terrible news and great sadness to our country. ... Columbia is lost. There are no survivors."

"The same creator who names the stars also knows the names of the seven souls we mourn today," he said. "The crew of the shuttle Columbia did not return safely to Earth. Yet we can pray they are all safely home."

Said NASA Administrator Sean O'Keefe: "The loss of this valiant crew is something we will never be able to get over."

Family members were standing by at the shuttle runway to welcome their loved ones back to Earth. William Readdy, NASA's associate administrator for space flight and a veteran shuttle commander, praised the astronauts' families for showing an "incredible amount of dignity considering their loss."

"They knew the crew was absolutely dedicated to the mission they were performing," he said, barely able to control his emotions. "They believed in what they were doing and in the conversations with the families, they said we must find what happened, fix it and move on. We can't let their sacrifice be in vain.

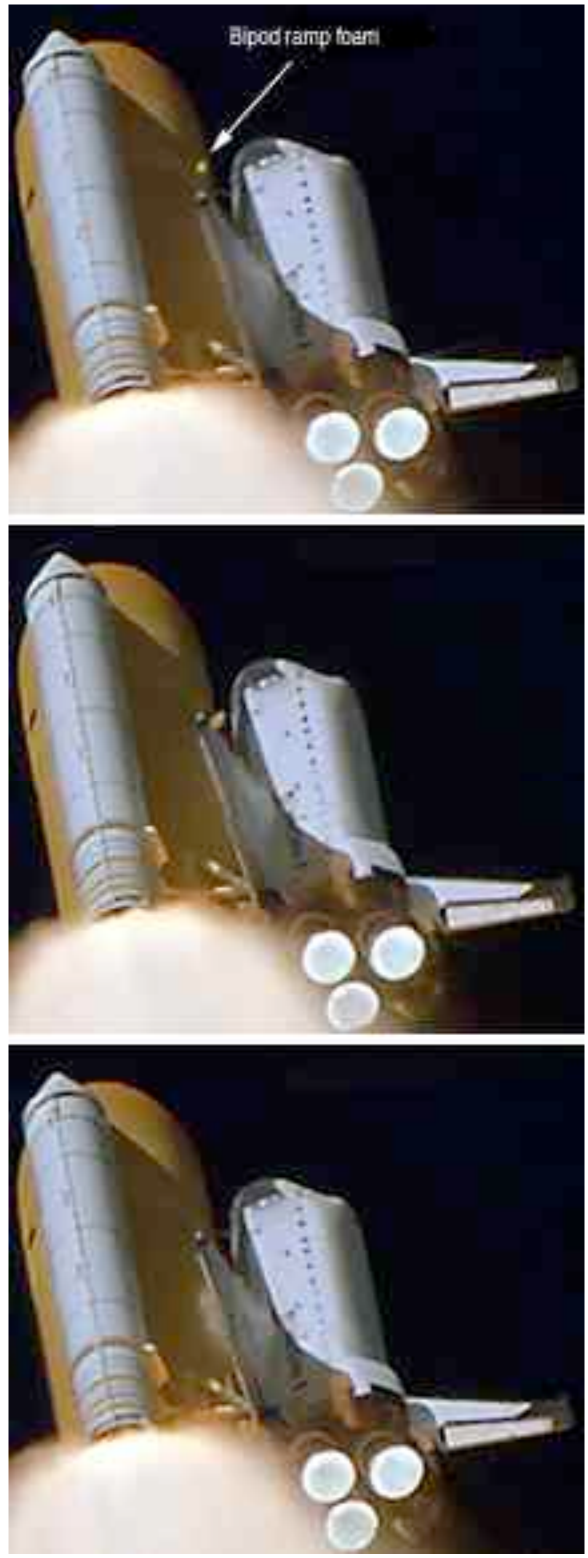
"Today was a very stark reminder this is a very risky endevour, pushing back the frontiers in outer space. Unfortunately, people have a tendency to look at it as something that is more or less routine. I can assure you, it is not.

"I have to say as the one responsible for shuttle and (space) station within NASA, I know the people in NASA did everything possible preparing for this flight to make it as perfect as possible," Readdy said. "My promise to the crew and the crew families is the investigation we just launched will find the cause. We'll fix it. And then we'll move on."

The goal of mission STS-107 was to carry out space station-class research in a variety of disciplines, ranging from biology to medicine, from materials science to pure physics and technology development, research that cannot yet be accommodated on the still-unfinished international space station.

More than 80 experiments were on board, most of them in a Spacehab research module in Columbia's cargo bay. To collect as much data as possible, the astronauts worked around the clock in two 12-hour shifts. By all accounts, the crew accomplished all of their major objectives.

At an afternoon news conference, shuttle program manager Ronald Dittemore and senior flight director Milt Heflin reviewed the telemetry from the shuttle and answered as many questions as possible. NASA's openness during the immediate aftermath of a devastating day was in stark contrast to the strict "no comment" policy implemented in the wake of the 1986 Challenger disaster that frustrated the public and tarnished the agency's reputation for openness.



10:40:22 a.m., Jan. 16, 2003: A briefcase-size chunk of foam breaks away from the left bi-pod ramp of Columbia's external fuel tank 81.7 seconds after liftoff as seen in these enhanced video frames from a NASA tracking camera. The shuttle's velocity is 1,568 mph and the foam breaks into several pieces as it tumbles in the airstream. In two-tenths of a second, the largest piece of debris slows to 1,022 mph as it disappears behind Columbia's left wing (photo 3). It emerges in a powdery looking shower of debris after hitting the wing at a relative velocity of about 545 mph.

"We're devastated because of the events that unfolded this morning," Dittemore said. "There's a certain amount of shock in our system because we have suffered the loss of seven family members. And we're learning to deal with that. Certainly, a somber mood in our teams as we continue to try to understand the events that occurred, but our thoughts and our prayers go out to the families.

"As difficult as this is for us, we wanted to meet with you and be as fair and open with you (as possible), given the facts as we understand them today," he said. "We will certainly be learning more as we go through the coming hours, days and weeks. We'll tell you as much as we know, we'll be as honest as we can with you and certainly we'll try to fill in the blanks over the coming days and weeks."

An internal NASA team of senior managers was named to handle the initial investigation into the disaster. An independent team of experts also was named to ensure objectivity. All flight control data and shuttle telemetry was impounded and "tiger teams" were formed to begin the painful tasks of sifting the data and coordinating the recovery of debris.

Dittemore said the shuttle fleet will remain grounded until engineers pinpoint what went wrong with Columbia and determine what corrections might be necessary.

Columbia's flight was one of only two remaining on NASA's long term launch schedule that does not involve the international space station. NASA had planned to launch the shuttle Atlantis around March 6 to ferry a fresh crew to the station and to bring the lab's current occupants back to Earth after 114 days in space.

Around 9:30 a.m. Saturday, flight controllers informed Expedition 6 commander Kenneth Bowersox, flight engineer Nikolai Budarin and science officer Donald Pettit that

Columbia had been lost during re-entry.

Bowersox and his crewmates have enough on-board supplies to remain aloft aboard the station through June. In fact, an unmanned Russian Progress supply ship is scheduled for launch Sunday from the Baikonur Cosmodrome in Kazakstan. That launch will proceed as planned, officials said.

If the shuttle fleet remains grounded through June, the station crew could be forced to abandon the station and return to Earth aboard a Russian Soyuz lifeboat. Fresh lifeboats are delivered to the station every six months to ensure the crew has a way to bail out in case of problems with the shuttle fleet or some other in-flight emergency.

With enough supplies on board to last Bowersox and his crewmates until late June, "there's some time for us to work through this," Dittemore said. "Right now, certainly there is a hold on future flights until we get ourselves established and understand the root cause of this disaster."

Astronaut Kalpana Chawla, working in Columbia's Spacehab research module, looks back toward the photographer through a tunnel connecting the lab to the shuttle's crew module.

Dittemore provided a sense of the loss felt by NASA and its contractors when he said "it's an emotional event, when we work together, we work together as family member and we treat each other that way. ... It's a sad loss for us.

"We understand the risks that are involved in human spaceflight and we know these risks are manageable and we also know they're serious and can have deadly consequences," he said. "So we are bound together with the threat of disaster all the time. ... We all rely on each other to make each spaceflight successful. So when we have an event like today, when we lose seven family members, it's just devastating to us."

Columbia blasted off on the 113th shuttle mission Jan. 16. The climb to space appeared uneventful, but about one minute and 20 seconds after liftoff, long-range tracking cameras showed a piece of foam insulation from the shuttle's external tank breaking away and hitting Columbia's left wing. The foam came from near the area where a forward bipod assembly attaches the nose of the shuttle to the tank. The debris hit the left wing near its leading edge.

Entry flight director Leroy Cain said Friday a detailed analysis of the debris impact led engineers to believe there was no serious damage. Columbia was not equipped with a robot arm for this Spacehab research mission and the impact area was not visible from the shuttle's crew cabin.

Whether the debris caused enough damage to compromise the integrity of the wing's thermal protection system is not yet known. But when the failure occurred, the shuttle was experiencing maximum heat loads of nearly 3,000 degrees Fahrenheit.

"If we did have a structural problem or a thermal problem, you would expect to get it at the peak heating," he said. "The most extreme thermal environment was right at mach 18 and that's where we lost the vehicle."

The shuttle Challenger was destroyed in 1986 by the failure of an O-ring seal in one of the ship's two solid-fuel boosters. All seven crew members perished, including New Hampshire social studies teacher Christa McAuliffe. McAuliffe's backup, Idaho teacher Barbara Morgan, witnessed the disaster from the NASA press site 4.2 miles from Challenger's launch pad.

In a painful footnote to Saturday tragedy, Morgan was once again at the Kennedy Space Center, this time as a full-time astronaut awaiting launch in November on Columbia's next mission. Morgan is the first member of a new class of educator astronauts, part of a program initiated by O'Keefe to help generate more student interest in science and technology.

Since the educator-astronaut program was announced last month, more than 1,000 teachers have expressed interest or been nominated as potential candidates by students, family members or friends. The status of that program, and the impact of Columbia's loss on Morgan's flight, is not yet known.

But as President Bush promised family members and the nation Saturday, "the cause for which they died will continue. ... Our journey into space will go on."

❏ ❏ ❏

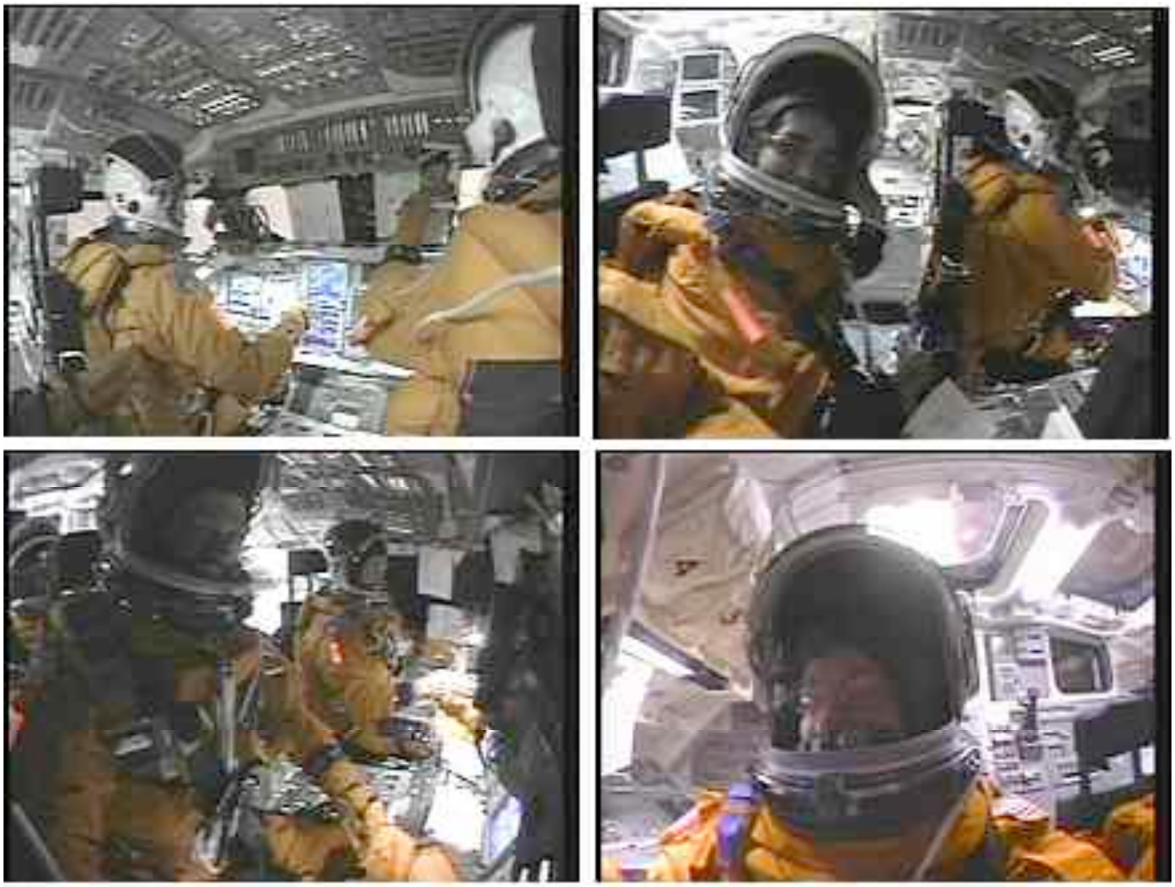
In the days, weeks and months ahead, an investigation of the disaster revealed echoes of Challenger: a long history of foam insulation problems that represented an unrecognized risk; bureaucratic inertia; slipshod internal communications and ineffective management at the top levels of NASA. The Columbia Accident Investigation Board, lead by retired Navy Adm. Harold Gehman, issued its report Aug. 28, 2005, concluding the so-called "NASA culture" was deeply flawed and in need of major modifications to prevent a repeat of the Columbia disaster in the years ahead.

"Based on NASA's history of ignoring external recommendations, or making improvements that atrophy with time, the Board has no confidence that the space shuttle can be safely operated for more than a few years based solely on renewed post-accident vigilance," the report stated.

Photographer Gene Blevins captured this shot of Columbia streaking high above California minutes before its destruction. By this point, Columbia's left wing was in the process of melting from the inside out.

Continuing, the report said that unless NASA took strong action to change its management culture to enhance safety margins in shuttle operations, "we have no confidence that other 'corrective actions' will improve the safety of shuttle operations. The changes we recommend will be difficult to accomplish - and they will be internally resisted."

For an agency with such a proud tradition - sending 12 men to the surface of the moon, establishing a permanent presence in low Earth orbit, exploring the solar system with unmanned robots and launching scientific sentinels to probe the depths of space and time - the criticism levied by the accident board seemed extreme in its harshness.



Columbia's flight deck, as captured by a videocamera operated by Laurel Clark, 15 minutes before the shuttle's destruction Feb. 1, 2003. In the top left frame, the heat of re-entry is evident out the windows in front of commander Rick Husband and pilot Willie McCool. In the top right frame, Chawla smiles for the camera. Bottom right: Clark turns the camera on herself.

But the accident investigation board members and their investigators clearly believed the sharp tone was appropriate, in their view essential to ensuring that wide-ranging corrective actions would be actually implemented. The board's investigation found that "management decisions made during Columbia's final flight reflect missed opportunities, blocked or ineffective communications channels, flawed analysis and ineffective leadership."

In the end, the report concluded, NASA managers never really understood the lessons of the 1986 Challenger disaster and "echoes of Challenger" abounded in the miscues that led to Columbia's destruction.

"Connecting the parts of NASA's organizational system and drawing the parallels with Challenger demonstrate three things," the board found. "First, despite all the post-Challenger changes at NASA and the agency's notable achievements since, the causes of the institutional failure responsible for Challenger have not been fixed.

"Second, the Board strongly believes that if these persistent, systemic flaws are not resolved, the scene is set for another accident. Therefore, the recommendations for change are not only for fixing the shuttle's technical system, but also for fixing each part of the organizational system that produced Columbia's failure.

"Third, the Board's focus on the context in which decision making occurred does not mean that individuals are not responsible and accountable. To the contrary, individuals always must assume responsibility for their actions. What it does mean is that NASA's problems cannot be solved simply by retirements, resignations, or transferring personnel."

The 13-member Columbia Accident Investigation Board spent seven months investigating the Feb. 1 Columbia disaster, reviewing more than 30,000 documents, conducting more than 200 formal interviews and collecting testimony from expert witnesses. The board also oversaw debris recovery efforts in Texas and Louisiana that involved more than 25,000 searchers. The investigation was expected to cost $19.8 million when all was said and done.

The board's 248-page report was released at the National Transportation and Safety Board in Washington. Reporters were allowed to review the report ahead of time, surrendering cell phones and wireless laptop network cards before entering a closed off "reading room" at 6 a.m. Gehman and other members of the panel discussed the report during a news conference.

"The people of NASA have accomplished great things," Dana Rohrabacher, D-Calif., chairman of a key House space committee, told CBS News. "They've put a man on the moon within a very short period of time, the people of NASA have been a source of great pride ... for the people of the United States.

"But for far too long, they've been resting on their laurels and bathing in past glories, nostalgic about the glory days," he continued. "It's time to look to the future and it's time to recapture a tough, hard-working body of people who have new challenges and are not just looking at the past but looking to the future. And that means Congress and the president have got to act on the Gehman report."

The CAIB report focused on two broad themes: The direct cause of the disaster - falling external fuel tank foam insulation that blasted a deadly hole in the leading edge of Columbia's left wing 82 seconds after liftoff - and the management system that failed to recognize frequent foam shedding as a potentially lethal defect before Columbia even took off.

The report also focuses on how NASA's mission management team, a panel of senior agency managers responsible for the day-to-day conduct of Columbia's mission, failed to recognize the severity of the foam strike that actually occurred, virtually eliminating any chance to save the shuttle's crew, either by attempting repairs in orbit or launching a rescue mission.

The report made 29 recommendations, 15 of which were to be implemented before shuttle flights resumed. Five of those were released earlier, requiring NASA to eliminate foam shedding to the maximum extent possible; to obtain better imagery from the ground and in orbit to identify any problems with the shuttle's thermal protection system; and development of tools and procedures to repair any such damage in space.

The more difficult recommendations addressed management changes and the establishment of an independent Technical Engineering Authority to verify launch readiness, oversee and coordinate requests for waivers and to "decide what is and is not an anomalous event." The TEA "should have no connection to or responsibility for schedule and program cost." In addition, the report concluded, NASA's Office of Safety and Mission Assurance should have direct authority over all shuttle safety programs and be independently funded.

"It is the Board's opinion that good leadership can direct a culture to adapt to new realities," the panel wrote. "NASA's culture must change, and the Board intends (its) recommendations to be steps toward effecting this change."

The foam strike that doomed Columbia was not seen until the day after launch when engineers began reviewing tracking camera footage as they do after every launching. A film camera in Cocoa Beach that could have photographed the impact on the underside of the left wing was out of focus. A video camera at the same site was

properly focused, but it lacked the resolution, or clarity, to show exactly where the foam hit or whether it caused any damage. A third camera at a different site showed the foam disappearing under the left wing and emerging as a cloud of debris after striking the underside. Again, the exact impact point could not be seen.
Stunned engineers immediately began analyzing the available film and video and ultimately determined the foam had struck heat shield tiles on the underside of the wing, perhaps near the left main landing gear door. No one ever seriously considered a direct heat on the reinforced carbon carbon panels making up the wing leading edge because no trace of foam debris was ever seen crossing the top of the wing. As the board ultimately concluded, however, the foam did, in fact, strike the leading edge on the lower side of RCC panel No. 8.

Senior shuttle managers inspect Columbia's wreckage. Left to right: Wayne Hale; Mission Management team Chairman Linda Ham; shuttle program manager Ron Dittemore; shuttle engineering chief Ralph Roe.

In hindsight, it's difficult to understand why the possibility of a leading edge impact didn't receive more attention. The board concluded that was due at least in part to the influential role of Calvin Schomburg, a senior engineer at the Johnson Space Center with expertise in the shuttle's heat-shield tiles.

"Shuttle program managers regarded Schomburg as an expert on the thermal protection system," the board wrote. "However, the board notes that Schomburg as not an expert on reinforced carbon carbon (RCC), which initial debris analysis indicated the foam may have struck. Because neither Schomburg nor shuttle management rigorously differentiated between tiles and RCC panels, the bounds of Schomburg's expertise were never properly qualified or questioned."

In any case, a team of Boeing engineers at the Johnson Space Center, under direction of NASA's mission management team, ultimately concluded the foam strike did not pose a safety of flight issue. Their analysis, using a computer program called CRATER, predicted areas of localized, possibly severe damage to the underside of the left wing, but no catastrophic breach. The concern, rather, was that any damage likely would require extensive repairs before Columbia could fly again.

While the damage assessment was getting under way, at least three different attempts were made to obtain spy satellite photography of the impact site to resolve the matter one way or the other. But in a series of communications miscues, the efforts ultimately were quashed by the MMT, under the direction of former flight director Linda Ham.

Ham said she was never able to find out who wanted such photographs and, without a formal requirement, had no reason to proceed. As for the debris assessment, Ham and other members of the MMT never challenged the hurried analysis or questioned the conclusion Columbia could safely return to Earth as is.

Many mid-level engineers said later they had serious misgivings about the debris assessment and heavy email traffic indicated fairly widespread concern about potentially serious problems if the foam strike had compromised Columbia's left main landing gear. Yet those concerns never percolated up the Ham, Dittemore or other members of the mission management team.

Ham and Dittemore both have said they were always open for questions or comments from lower-level engineers and that everyone on the team was encouraged, even duty bound, to bring any serious concerns to the attention of senior management.

But the CAIB disagreed.

"Communication did not flow effectively up to or down from program managers," the board wrote. "After the accident, program managers stated privately and publicly that if engineers had a safety concern, they were obligated to communicate their concerns to management. Managers did not seem to understand that as leaders they had a corresponding and perhaps greater obligation to create viable routes for the engineering community to express their views and receive information. This barrier to communications not only blocked the flow of information to managers but it also prevented the downstream flow of information from managers to engineers, leaving Debris Assessment Team members no basis for understanding the reasoning behind Mission Management Team decisions."

An impromptu memorial to one of Columbia's fallen astronauts in the Texas countryside.

As for not hearing any dissent, the board wrote, "managers' claims that they didn't hear the engineers' concerns were due in part to their not asking or listening."

"Management decisions made during Columbia's final flight reflect missed opportunities, blocked or ineffective communications channels, flawed analysis and ineffective leadership," the board wrote. "Perhaps most striking is the fact that management - including Shuttle Program, Mission Management Team, Mission Evaluation Room (personnel) and flight director and mission control - displayed no interest in understanding a problem and its implications.

"Because managers failed to avail themselves of the wide range of expertise and opinion necessary to achieve the best answer to the debris strike question - 'Was this a safety-of-flight concern?' - some space shuttle program managers failed to fulfill the implicit contract to do whatever is possible to ensure the safety of the crew. In fact, their management techniques unknowingly imposed barriers that kept at bay both engineering concerns and dissenting views and ultimately helped create 'blind spots' that prevented them from seeing the danger the foam strike posed."

Shuttle program manager Dittemore and members of the mission management team "had, over the course of the space shuttle program, gradually become inured to external tank foam losses and on a fundamental level did not believe foam striking the vehicle posed a critical threat to the orbiter," the board wrote.

In the end, it was a moot point. Once the foam breached the leading edge of Columbia's left wing, the crew was doomed. The astronauts had no way to repair the breach - no robot arm and no tile repair equipment - and there was no realistic chance another shuttle could be readied in time for a rescue mission.

Maybe so. But NASA's flawed management system never gave the agency a chance to prove it still had the "right stuff." And it was that institutional system, or "culture," at NASA that must be changed, the board said, to prevent another accident.

"An organization system failure calls for corrective measures that address all relevant levels of the organization, but the Board's investigation shows that for all its cutting-edge technologies, 'diving-catch' rescues and imaginative plans for the technology and the future of space exploration, NASA has shown very little understanding of the inner workings of its own organization," the report states.

"NASA's bureaucratic structure kept important information from reaching engineers and managers alike. The same NASA whose engineers showed initiative and a solid working knowledge of how to get things done fast had a managerial culture with an allegiance to bureaucracy and cost-efficiency that squelched the engineers' efforts.

"When it came to managers' own actions, however, a different set of rules prevailed. The Board found that Mission Management Team decision-making operated outside the rules even as it held its engineers to a stifling protocol. Management was not able to recognize that in unprecedented conditions, when lives are on the line, flexibility and democratic process should take priority over bureaucratic response."

NASA Administrator Sean O'Keefe said the space agency would use the Columbia Accident Investigation Board's final report as a blueprint for correcting the problems that led to Columbia's demise.

Retired Navy Adm. Harold Gehman, chairman of the Columbia Accident Investigation Board.

"We have accepted the findings and will comply with the recommendations to the best of our ability," O'Keefe said in a statement. "The board has provided NASA with an important road map as we determine when we will be 'fit to fly' again.

"Due to the comprehensive, timely and open public communication displayed by the Board throughout the investigative process, we already have begun to take action on the earlier issued recommendations, and we intend to comply with the full range of recommendations released today."

Gehman told CBS News after the CAIB report was released that NASA had little choice. In the panel's view, he said, NASA could not safely operate the space shuttle program without major changes in its management system.

"I think there's a little bit of denial that NASA, at least in the shuttle program, that NASA has modified its organizational structure over the years into one that no longer contains the attributes that they built their reputations on," Gehman said. "There may be some people who deny that, but the board is absolutely convinced, we think there's no room for any doubt whatsoever, the management system they have right now is not capable of safely operating the shuttle over the long term. That's the bottom line."

Gehman also said Congress and the White House must share blame for the Columbia disaster with NASA. Asked what he might tell President Bush about NASA and the agency's second in-flight tragedy, Gehman said he would point out that "NASA is a great organization that he and the country can have a lot of pride in. And that they are operating under and unrealistic set of rules and guidelines."

"Exploring space on a fixed cost basis is not realistic," the retired admiral said. "Launching shuttles on a calendar basis instead of an event-driven basis is not realistic. Demanding that you save money and run this thing in an efficient and effective way and that you get graded on schedule and things like that is not realistic. That the whole nation and Congress and the White House has an unrealistic view of how we do space exploration."

In addition, the board's report "clearly specifies that there is responsibility at both ends of Pennsylvania Avenue for this that are shared with NASA," Gehman said. "Now in some cases, NASA over markets what they can do. They promise more than they can deliver and they promise they can deliver it at a price that is less than it's really going to cost. But in some cases, it is demanded of them, in order to get a program approved, that they agree to unrealistic schedules and unrealistic price tags. So there's blame at both ends here."

The CAIB report focused heavily on decisions made by NASA's mission management team. But Gehman told CBS News the space agency's management system was so dysfunctional it hardly mattered who was in charge.

"We believe very, very strongly that you could substitute almost anybody in those positions and operate under the guidelines and rules and precedents that were being used in NASA and they would make the same errors," he said.

"Let me give you a specific case in point. Much has been made of the fact that the MMT didn't meet every day. NASA regulations require that they meet every day. So I had my board go back and see what were the meetings scheduled for the previous two shuttle missions? Guess what? They met every third day.

"So Linda Ham was doing her job according to the standards and precedents that were set by the establishment," he continued. "Even though the rules say you have to meet every day, you don't really have to. So that's an organizational flaw and she was performing her duties in that respect in accordance with the standards and precedents that had been previously established by her predecessors. And her predecessor's bosses had let that go on.

"So we feel very, very strongly that just moving the people around won't fix that problem. Unfortunately, we live in a town here in Washington, DC, in which they frequently demand someone pay. But we on the board were not influenced by that" and the board did not assign personal blame for any real or perceived errors in judgment.

Could a more experienced or proactive program manager or MMT chairman have made a different in Columbia's case?

"We feel there's some part of this, maybe even a lot of these problems, could have been mitigated by a stronger, a more suspicious, nervous kind of a person," Gehman said of the MMT and its chairman. "But our conclusion, our very, very strong conclusion is even if you had really brilliant people, really spectacular people, if you had the very, very best person you could get, that it would be a low probability bet that you could count on them to overcome the flaws in the organization. That is a low probability course of action."

Asked if NASA was "in denial" about serious management flaws and defects, Gehman said "in a lot of cases, they will deny that they have a basic organizational flaw which is dangerous. I think they'll deny that, some of them. Others will applaud it. It kind of depends on where you sit."

The CAIB's criticism of NASA drew an unusual response from Stephen Feldman, president of The Astronauts Memorial Foundation.

"One of the great risks of the Columbia tragedy and the subsequent report and commentary is that outstanding scientists and engineers may feel so criticized and unappreciated that they will leave NASA and the space program for higher paying and often less stressful jobs in the private sector," he said in a statement. "The outstanding safety record that NASA has compiled over the years shouldn't be forgotten because of one terrible accident on February 1, 2003."

But O'Keefe's promise to full implement the CAIB recommendations drew praise from the National Space Society, a nonprofit advocacy group founded by German rocket scientist Wernher von Braun.

"The National Space Society urges NASA to embrace the recommendations of the CAIB and work diligently to fundamentally reform its decision-making processes and safety organizations so that we can safely return the Space Shuttle fleet to service," said Executive Director Brian Chase. "However, in order for NASA to fully implement the CAIB recommendations and continue the exploration of space, the agency will need appropriate funding to accomplish those tasks.

"The White House and the U.S. Congress must accept their share of responsibility for the future of our nation's space exploration efforts and provide the necessary leadership.

"Perhaps most importantly, NASA and our nation's leaders need to take this opportunity to foster development of new space transportation systems and renew a long-term commitment to human space exploration."

Four and a half months after the CAIB report was released, President Bush gave a speech at NASA Headquarters in Washington in which he called for retirement of the shuttle by 2010; development of a new manned "crew exploration vehicle; the establishment of a permanent base on the moon by 2020 and eventual manned flights to Mars.

Recommendations of the Columbia Accident Investigation Board

PART ONE – THE ACCIDENT

Thermal Protection System

1 Initiate an aggressive program to eliminate all External Tank Thermal Protection System debris-shedding at the source with particular emphasis on the region where the bipod struts attach to the External Tank. [RTF]

2 Initiate a program designed to increase the Orbiter's ability to sustain minor debris damage by measures such as improved impact-resistant Reinforced Carbon-Carbon and acreage tiles. This program should determine the actual impact resistance of current materials and the effect of likely debris strikes. [RTF]

3 Develop and implement a comprehensive inspection plan to determine the structural integrity of all Reinforced Carbon-Carbon system components. This inspection plan should take advantage of advanced non-destructive inspection technology. [RTF]

4 For missions to the International Space Station, develop a practicable capability to inspect and effect emergency repairs to the widest possible range of damage to the Thermal Protection System, including both tile and Reinforced Carbon-Carbon, taking advantage of the additional capabilities available when near to or docked at the International Space Station.

For non-Station missions, develop a comprehensive autonomous (independent of Station) inspection and repair capability to cover the widest possible range of damage scenarios.

Accomplish an on-orbit Thermal Protection System inspection, using appropriate assets and capabilities, early in all missions.

The ultimate objective should be a fully autonomous capability for all missions to address the possibility that an International Space Station mission fails to achieve the correct orbit, fails to dock successfully, or is damaged during or after undocking. [RTF]

5 To the extent possible, increase the Orbiter's ability to successfully re-enter Earth's atmosphere with minor leading edge structural sub-system damage.

6 In order to understand the true material characteristics of Reinforced Carbon-Carbon components, develop a comprehensive database of flown Rein-forced Carbon-Carbon material characteristics by destructive testing and evaluation.

7 Improve the maintenance of launch pad structures to minimize the leaching of zinc primer onto Reinforced Carbon-Carbon components.

8 Obtain sufficient spare Reinforced Carbon-Car-bon panel assemblies and associated support components to ensure that decisions on Rein-forced Carbon-Carbon maintenance are made on the basis of component specifications, free of external pressures relating to schedules, costs, or other considerations.

9 Develop, validate, and maintain physics-based computer models to evaluate Thermal Protection System damage from debris impacts. These tools should provide realistic and timely estimates of any impact damage from possible debris from any source that may ultimately impact the Orbiter. Establish impact damage thresholds that trigger responsive corrective action, such as on-orbit inspection and repair, when indicated.

Imaging

10 Upgrade the imaging system to be capable of providing a minimum of three useful views of the Space Shuttle from liftoff to at least Solid Rocket Booster separation, along any expected ascent azimuth. The operational status of these assets should be included in the Launch Commit Criteria for future launches. Consider using ships or aircraft to provide additional views of the Shuttle during ascent. [RTF]

11 Provide a capability to obtain and downlink high-resolution images of the External Tank after it separates. [RTF]

12 Provide a capability to obtain and downlink high-resolution images of the underside of the Orbiter wing leading edge and forward section of both wings' Thermal Protection System. [RTF]

13 Modify the Memorandum of Agreement with the National Imagery and Mapping Agency to make the imaging of each Shuttle flight while on orbit a standard requirement. [RTF]

Orbiter Sensor Data

14 The Modular Auxiliary Data System instrumentation and sensor suite on each Orbiter should be maintained and updated to include current sensor and data acquisition technologies.

15 The Modular Auxiliary Data System should be redesigned to include engineering performance and vehicle health information, and have the ability to be reconfigured during flight in order to allow certain data to be recorded, telemetered, or both as needs change.

Wiring

16 As part of the Shuttle Service Life Extension Program and potential 40-year service life, develop a state-of-the-art means to inspect all Orbiter wiring, including that which is inaccessible

Bolt Catchers

17 Test and qualify the flight hardware bolt catchers. [RTF]

Closeouts

18 Require that at least two employees attend all final closeouts and intertank area hand-spraying procedures. [RTF]

Micrometeoroid and Orbital Debris

19 Require the Space Shuttle to be operated with the same degree of safety for micrometeoroid and orbital debris as the degree of safety calculated for the International Space Station. Change the micrometeoroid and orbital debris safety criteria from guidelines to requirements.

Foreign Object Debris

20 Kennedy Space Center Quality Assurance and United Space Alliance must return to the straightforward, industry-standard definition of “Foreign Object Debris” and eliminate any al-ternate or statistically deceptive definitions like “processing debris.” [RTF]

PART TWO – WHY THE ACCIDENT OCCURRED

Scheduling

21 Adopt and maintain a Shuttle flight schedule that is consistent with available resources. Although schedule deadlines are an important management tool, those deadlines must be regularly evaluated to ensure that any additional risk incurred to meet the schedule is recognized, understood, and acceptable. [RTF]

Training

22 Implement an expanded training program in which the Mission Management Team faces potential crew and vehicle safety contingencies beyond launch and ascent. These contingencies should involve potential loss of Shuttle or crew, contain numerous uncertainties and unknowns, and require the Mission Management Team to assemble and interact with support organizations across NASA/Contractor lines and in various locations. [RTF]

Organization

23 Establish an independent Technical Engineering Authority that is responsible for technical requirements and all waivers to them, and will build a disciplined, systematic approach to identifying, analyzing, and controlling hazards throughout the life cycle of the Shuttle System. The independent technical authority does the following as a minimum:

- Develop and maintain technical standards for all Space Shuttle Program projects and elements
- Be the sole waiver-granting authority for all technical standards
- Conduct trend and risk analysis at the sub-system, system, and enterprise levels
- Own the failure mode, effects analysis and hazard reporting systems
- Conduct integrated hazard analysis
- Decide what is and is not an anomalous event
- Independently verify launch readiness
- Approve the provisions of the recertification program called for in Recommendation R9.1-1. The Technical Engineering Authority should be funded directly from NASA Headquarters, and should have no connection to or responsibility for schedule or program cost.

24 NASA Headquarters Office of Safety and Mission Assurance should have direct line authority over the entire Space Shuttle Program safety organization and should be independently re-sourced.

25 Reorganize the Space Shuttle Integration Office to make it capable of integrating all elements of the Space Shuttle Program, including the Or-biter.

PART THREE – A LOOK AHEAD

Organization

26 Prepare a detailed plan for defining, establishing, transitioning, and implementing an independent Technical Engineering Authority, independent safety program, and a reorganized Space Shuttle Integration Office as described in R7.5-1, R7.5-2, and R7.5-3. In addition, NASA should submit annual reports to Congress, as part of the budget review process, on its implementation activities. [RTF]

Recertification

27 Prior to operating the Shuttle beyond 2010, develop and conduct a vehicle recertification at the material, component, subsystem, and system levels. Recertification requirements should be included in the Service Life Extension Program.

Closeout Photos/Drawing System

28 Develop an interim program of closeout photographs for all critical sub-systems that differ from engineering drawings. Digitize the close-out photograph system so that images are immediately available for on-orbit troubleshooting. [RTF]

29 Provide adequate resources for a long-term pro-gram to upgrade the Shuttle engineering draw-ing system including:

- Reviewing drawings for accuracy
- Converting all drawings to a computer-aided drafting system
- Incorporating engineering changes

❑ ❑ ❑

The Fate of Columbia's Crew

NASA released a detailed engineering study Dec. 30, 2008, outlining lessons learned about astronaut survival based on an analysis of the 2003 Columbia disaster. The study does not provide any significant new details about the fate of Columbia's crew - investigators earlier concluded the seven astronauts died of sudden oxygen loss and blunt force trauma as the crew module broke up - but a new timeline provides a wealth of data showing the pilots attempted to troubleshoot a cascade of problems in the final moments before the spacecraft's computers lost control.

The timeline also shows, in grim detail, the forces acting on the shuttle's crew module in the final seconds before it broke apart, subjecting the astronauts to a sudden loss of air pressure that occurred so rapidly they did not have time to close their helmet visors.

The study, the most detailed astronaut survival analysis ever conducted, includes 30 recommendations for improving crew safety on future flights based on a review of the safety equipment and procedures used during Columbia's mission.

"I call on spacecraft designers from all the other nations of the world, as well as the commercial and personal spacecraft designers here at home to read this report and apply these hard lessons, which have been paid for so dearly," said former shuttle Program Manager Wayne Hale, now serving as a NASA associate administrator. "This report confirms that although the valiant Columbia crew tried every possible way to maintain control of their vehicle, the accident was not ultimately survivable."

As part of its support for the Columbia Accident Investigation Board, NASA set up a Crew Survival Working Group in the wake of the Feb. 1, 2003, disaster that later evolved into the Spacecraft Crew Survival Integrated Investigation Team. The crew survival team began its study in October 2004 with the goals of expanding the earlier working group analysis and making recommendations to improve safety on future vehicles.

The Columbia breakup was not survivable, but the new report sheds light on how various shuttle safety systems performed and what sort of changes may be needed to improve safety in future spacecraft like the Orion capsules that will replace the shuttle after the fleet is retired in 2010.

The report was completed in December 2008, but its release was delayed "out of respect for the Columbia crew families," said veteran shuttle commander Pam Melroy, deputy project manager of the investigation. "At their request, we released it after Christmas but while the children were still out of school and home with their family members so they could discuss the findings and the elements of the report with some privacy. That's what drove the timing of today."

Columbia was destroyed by a breach in the leading edge of the shuttle's left wing that was caused by the impact of foam insulation from the ship's external tank during launch 16 days earlier. The wing melted from the inside out and eventually failed, either folding over or breaking away. The shuttle's flight computers then lost control and the crippled spacecraft went into a catastrophic spin. The nose section housing the crew module ripped away from the fuselage relatively intact, but the module broke apart within a few moments due to thermal stress and aerodynamic forces.

The analysis of Columbia's breakup identified five "lethal events:"

1. Depressurization: Shortly after Columbia's flight computers lost control due to the failure of the shuttle's heat-damaged left wing, the crew module broke away from the fuselage. The astronauts are believed to have survived the initial breakup. But within a few moments, the crew module lost pressure "so rapidly that the crew members were incapacitated within seconds, before they could configure the (pressure) suit for full protection from loss of cabin pressure," the new study concluded. "Although circulatory systems functioned for a brief time, the effects of the depressurization were severe enough that the crew could not have regained consciousness. This event was lethal to the crew."

Recommendations: Improve crew training to increase emphasis on the transition between problem solving and survival operations; future spacecraft must integrate pressure suit operations into the design of the vehicle.

2. Exposure of the unconscious or deceased astronauts to unexpected rotating forces without sufficient upper body restraints and helmets: When Columbia lost control, the resulting motion was not violent enough, in and of itself, to be lethal. The crew module separated from the fuselage "and continued to rotate," the study concluded. "After the crew lost consciousness due to the loss of cabin pressure, the seat inertial reel mechanisms on the crews' shoulder harnesses did not lock. As a result, the unconscious or deceased crew was exposed to cyclical rotational motion while restrained only at the lower body. Crew helmets do not conform to the head. Consequently, lethal trauma occurred to the unconscious or desceased crew due to the lack of upper body support and restraint."

Recommendations: Re-evaluate crew procedures; future seats and suits should be "integrated to ensure proper restraint of the crew in off-nominal situations."

3. Separation of the crew from the crew module and the seat: "The breakup of the crew module and the crew's subsequent exposure to hypersonic entry conditions was not survivable by any currently existing capability," the study says. ... "The lethal-type consequences of exposure to entry conditions included traumatic injury due to seat restraints, high loads associated with deceleration due to a change in ballistic number, aerodynamic loads, and thermal events. Crew circulatory functions ceased shortly before or during this event."

Recommendation: Optimize future spacecraft design for "the most graceful degradaton of vehicle systems and structure to enhance chances for crew survival."

4. Exposure to near vacuum, aerodynamic acceleration and low temperatures: Shuttle pressure suits are certified to a maximum altitude of 100,000 feet and a velocity of about 560 knots. "It is uncertain whether it can protect a crew member at higher altitudes and air speeds," the study says.

Recommendation: Pressure suits should be evaluated to determine weak points; improvements should be made as warranted.

5. Ground impact: The current parachute system requires manual action by the astronauts.

Recommendation: "Future spacecraft crew survival systems should not rely on manual activation to protect the crew."

The new study also made recommendations to improve future crew survival investigations.

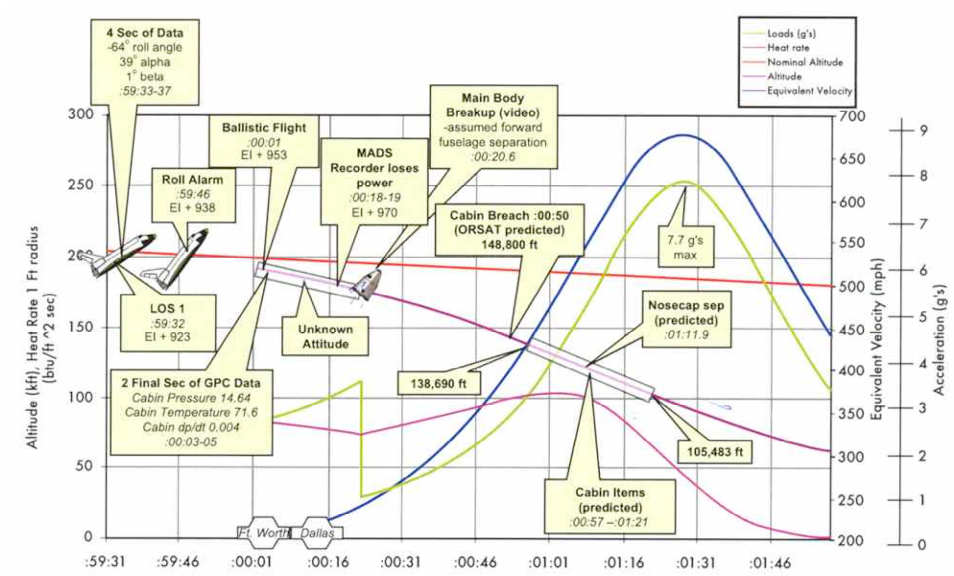
"The SCSIIT investigation was performed with the belief that a comprehensive, respectful investigation could provide knowledge that would improve the safety of future space flight crews and explorers," the group wrote. "By learning these lessons and ensuring that we continue the journey begun by the crews of Apollo 1, Challenger and Columbia, we help to give meaning to their sacrifice and the sacrifice of their families. it is for them, and for the future generations of explorers, that we strive to be better and go farther."

The 400-page report is posted on line at: http://www.nasa.gov/reports

One striking aspect of the initial 2003 accident board study was similarities between how the shuttle Challenger broke up during launch in 1986 and how Columbia met its fate during re-entry in 2003. In both cases, the reinforced crew modules broke away from the shuttle fuselage relatively intact. And in both cases, the astronauts are believed to have survived the initial breakup.

In an appendix to the Columbia accident board report, investigators concluded "acceleration levels seen by the crew module prior to its catastrophic failure were not lethal. LOS (loss of signal) occurred at 8:59:32 (a.m. EST). The death of the crew members was due to blunt force trauma and hypoxia. The exact time of death - sometime after 9:00:19 a.m. Eastern Standard Time - cannot be determined because of the lack of direct physical or recorded evidence."

"Failure of crew module was precipitated by thermal degradation of structural properties that resulted in a catastrophic sequential structural failure that happened very rapidly as opposed to a catastrophic instantaneous 'explosive' failure," the report said. "Crew module separation from the forward fuselage is not an anomalous condition in the case of a vehicle loss of control as has been the case in both 51-L (Challenger) and STS-107 (Columbia)."



Columbia Accident Investigation Board summary of critical events

But the shuttle crew module, on its own, has no power and no systems were present that could have saved either crew after breakup occurred.

Even so, "it is irrefutable, as conclusively demonstrated by items that were recovered in pristine condition whose locations were within close proximity to some crew members, that it was possible to attenuate the potentially hostile environment that was present during CM (crew module) break-up to the point where physically and thermally induced harmful effects were virtually eliminated," the CAIB concluded.

"This physical evidence makes a compelling argument that crew survival under environmental circumstances seen in this mishap could be possible given the appropriate level of physiological and environmental protection."

The CAIB went on to recommend that NASA "investigate techniques that will prevent the structural failure of the CM due to thermal degradation of structural properties to determine the feasibility for application. Future crewed vehicles should incorporate the knowledge gained from the (Challenger) and (Columbia) mishaps in assessing the feasibility of designing vehicles that will provide for crew survival even in the face of a mishap that results in the loss of the vehicle."

Columbia blasted off on mission STS-107 on Jan. 16, 2003. On board were commander Rick Husband, pilot William "Willie" McCool, Michael Anderson, David Brown, Kalpana Chawla, Laurel Clark and Ilan Ramon, the first Israeli to fly in space.

Some 81.7 seconds after liftoff, a briefcase-size chunk of foam insulation broke away from Columbia's external tank. Long-range tracking cameras showed the foam disappearing under the left wing and a cloud of debris emerging an instant later.

No one knew it at the time, but the foam had hit the underside of the left wing's reinforced carbon carbon leading edge, punching a ragged hole four to six inches across. During re-entry 16 days later, superheated air entered the breach and melted the wing from the inside out.

In the moments leading up the catastrophic failure, telemetry from the damaged shuttle indicated problems with the left wing, including loss of data from hydraulic line sensors and temperature probes and left main landing gear pressure readings. The astronauts - Husband, McCool, Chawla and Clark strapped in on the upper flight deck, Anderson, Brown and Ramon seated on the lower deck - presumably were unaware of anything unusual until just before the left wing either folded over or broke away and the vehicle's flight computers lost control.

The final words from Columbia's crew came at 8:59:32 a.m. when Husband, presumably responding to a tire alarm acknowledgement from mission control, said "Roger, uh, buh..." At that point, the shuttle was nearly 38 miles above Central Texas and traveling at 18 times the speed of sound. No more voice transmissions were received. But telemetry, some of it garbled, continued to flow for a few more moments.

That data, combined with stored telemetry on a data recorder that was found in the shuttle's wreckage and analysis of recovered debris, eventually allowed engineers to develop a rough timeline of events after the initial loss of signal.

In the new study, data show the crew received multiple indications of problems in the minute prior to loss of control, which probably occurred right around the time of Husband's last transmission. Fifty-eight seconds before that event, the first of four tire pressure alert messages was displayed. Thirty-one seconds before loss of control, the left main landing gear indicator changed state. Seven seconds before LOC, a pulsing yaw thruster light came on as the jets began firing continuously to keep the shuttle properly oriented. Less than one second before LOC, aileron trim exceeded 3 degrees.

"For the crew, the first strong indications of the LOC would be lighting and horizon changes seen through the windows and changes on the vehicle attitude displays," the report says. "Additionally, the forces experienced by the crew changed significantly and began to differ from the nominal, expected accelerations. The accelerations were translational (due to aerodynamic drag) and angular (due to rotation of the orbiter). The translational acceleration due to drag was dominant, and the direction was changing as the orbiter attitude changed relative to the velocity vector (along the direction of flight).

"Results of a shuttle LOC simulation show that the motion of the orbiter in this timeframe is best described as a highly oscillatory slow (30 to 40 degrees per second) flat spin, with the orbiter's belly generally facing into the velocity vector. It is important to note that the velocity vector was still nearly parallel to the ground as the vehicle was moving along its trajectory in excess of Mach 15. The crew experienced a swaying motion to the left and right (Y-axis) combined with a pull forward (X-axis) away from the seatback. The Z-axis accelerations pushed the crew members down into their seats. These motions might induce nausea, dizziness, and disorientation in crew members, but they were not incapacitating. The total acceleration experienced by the crew increased from approximately 0.8 G at LOC to slightly more than 3 G by the CE (catastrophic event).

"The onset of this highly oscillatory flat spin likely resulted in the need for crew members to brace as they attempted to diagnose and correct the orbiter systems. ... One middeck crew member had not completed seat ingress and strap-in at the beginning of this phase. Seat debris and medical analyses indicate that this crew member was not fully restrained before loss of consciousness. Only the shoulder and crotch straps appear to have been connected. The normal sequence for strap-in is to attach the lap belts to the crotch strap first, followed by the shoulder straps. Analysis of the seven recovered helmets indicated that this same crew member was the only one not wearing a helmet. Additionally, this crew member was tasked with post-deorbit burn duties. This suggests that this crew member was preparing to become seated and restrained when the LOC dynamics began. During a dynamic flight condition, the lap belts hanging down between the closely space seats would be difficult to grasp due to the motion of the orbiter, which may be why only the shoulder straps were connected."

Recovered cockpit switch panels indicate McCool attempted to troubleshoot hydraulic system problems. Either Husband or McCool also returned the shuttle's autopilot to the automatic setting at 9:00:03 a.m. after one of the two hand controllers apparently was inadvertently bumped. "These actions indicate that the CDR or the PLT was still mentally and physically capable of processing display information and executing commands and that the orbiter dynamics were still within human performance limitations," the study concludes.

"It was a very short time," Hale said. "We know it was very disorienting motion that was going on. There were a number of alarms that went off simultaneously. And the crews, of course, are trained to maintain or regain control in a number of different ways and we have evidence from (recovered debris that they) were trying very hard to regain control. We're talking about a very brief time, in a crisis situation, and I'd hate to go any further than that."

Said Melroy: "I'd just like to add we found that those actions really showed the crew was relying on their training in problem solving and problem resolution and that they were focused on attempting to recover the vehicle when they did detect there was something off nominal. They showed remarkable systems knowledge and problem resolution techniques. Unfortunately, of course, there was no way for them to know with the information they had that that was going to be impossible. But we were impressed with the training, certainly, and the crew."

From the point the crew cabin broke away from the fuselage to the point where depressurization occurred "can be narrowed to a range of 17 seconds, from between GMT 14:00:18 (9:00:18 a.m.) to GMT 14:00:35," the report states. "Crew module debris items recovered west of the main crew module debris field were 8 inches in diameter or smaller, were not comprised of crew module primary structure, and originated from areas above and below the middeck floor. This indicates that the crew module depressurization was due to multiple breaches (above and below the floor), and that these breaches were initially small.

"When the forebody separated from the midbody, the crew members experienced three dramatic changes in their environment: 1. all power was lost, 2. the motion and acceleration environment changed; and 3. crew cabin depressurization began within 0 to 17 seconds. With the loss of power, all of the lights and displays went dark (although each astronaut already had individual chem-lights activated). The intercom system was no longer functional and the orbiter O2 system was no longer available for use, although individual, crew worn Emergency Oxygen System (EOS) bottles were still available.

"As the forebody broke free from the rest of the orbiter, its ballistic number underwent a sharp change from an average ballistic number of 41.7 pounds per square foot (psf) (out of control intact orbiter) to 122 psf (free-flying forebody). The aerodynamic drag of the forebody instantaneously decreased, resulting in a reduction in the translational deceleration from approximately 3.5 G to about 1 G."

As experienced by the astronauts, the change from a normal re-entry to loss of control and separation of the crew module from the fuselage "all occurred in approximately 40 seconds. Experience shows that this is not sufficient time to don gloves and helmets."

"Histological (tissue) examination of all crew member remains showed the effects of depressurization. Neither the effects of CE nor the accelerations immediately post-CE would preclude the crew members who were wearing helmets from closing and locking their visors at the first indication of a cabin depressurization. This action can be accomplished in seconds. This strongly suggests that the depressurization rate was rapid enough to be nearly immediately incapacitating. The exact rate of cabin depressurization could not be determined, but based on video evidence complete loss of pressure was reached no later than (NLT) GMT 14:00:59 (9:00:59 a.m.), and was likely much earlier. The medical findings show that the crew could not have regained consciousness after this event. Additionally, respiration ceased after the depressurization, but circulatory functions could still have existed for a short period of time for at least some crew members."

For background, here are the results of the original Crew Survival Working Group's assessment, as reported in "Comm Check: The Final Flight of Shuttle Columbia" by Michael Cabbage and William Harwood (Free Press, 2004; some of the conclusions may change based on the new study):

> At the CAIB's request, NASA formed a Crew Survivability Working Group to determine, if possible, the cause of crew death. Here is what the group concluded (taken from page 77 of the Columbia Accident Investigation Report):

Medical and Life Sciences

The Working Group found no irregularities in its extensive review of all applicable medical records and crew health data. The Armed Forces Institute of Pathology and the Federal Bureau of Investigation conducted forensic analyses on the remains of the crew of Columbia after they were recovered. It was determined that the acceleration levels the crew module experienced prior to its catastrophic failure were not lethal. The death of the crew members was due to blunt trauma and hypoxia. The exact time of death sometime after 9:00:19 a.m. Eastern Standard Time cannot be determined because of the lack of direct physical or recorded evidence.

Failure of the Crew Module

The forensic evaluation of all recovered crew module/forward fuselage components did not show any evidence of over-pressurization or explosion. This conclusion is supported by both the lack of forensic evidence and a credible source for either sort of event. The failure of the crew module resulted from the thermal degradation of structural properties, which resulted in a rapid catastrophic sequential structural breakdown rather than an instantaneous "explosive" failure.

Separation of the crew module/forward fuselage assembly from the rest of the Orbiter likely occurred immediately in front of the payload bay (between Xo576 and Xo582 bulkheads). Subsequent breakup of the assembly was a result of ballistic heating and dynamic loading. Evaluations of fractures on both primary and secondary structure elements suggest that structural failures occurred at high temperatures and in some cases at high strain rates. An extensive trajectory reconstruction established the most likely breakup sequence, shown below (page 77 of the CAIB report).

The load and heat rate calculations are shown for the crew module along its reconstructed trajectory. The band superimposed on the trajectory (starting about 9:00:58 a.m. EST) represents the window where all the evaluated debris originated. It appears that the destruction of the crew module took place over a period of 24 seconds beginning at an altitude of approximately 140,000 feet and ending at 105,000 feet. These figures are consistent with the results of independent thermal re-entry and aerodynamic models. The debris footprint proved consistent with the results of these trajectory analyses and models. Approximately 40 to 50 percent, by weight, of the crew module was recovered.

The Working Group's results significantly add to the knowledge gained from the loss of Challenger in 1986. Such knowledge is critical to efforts to improve crew survivability when designing new vehicles and identifying feasible improvements to the existing Orbiters.

Crew Worn Equipment

Videos of the crew during re-entry that have been made public demonstrate that prescribed procedures for use of equipment such as full-pressure suits, gloves, and helmets were not strictly followed. This is confirmed by the Working Group's conclusions that three crew members were not wearing gloves, and one was not wearing a helmet. However, under these circumstances, this did not affect their chances of survival.

Columbia's crew
Blue shirts (left to right): David Brown, Willie McCool, Michael Anderson
Red shirts (left to right): Kalpana Chawla, Rick Husband, Laurel Clark, Ilan Ramon

Appendix 3: NASA Acronyms[11]

Acronym	Meaning
A/D	Analog-to-Digital
ac	Alternating Current
ACP	Astronaut Control Panel
ACS	Advanced Camera for Surveys
ACTR 5	Actuator 5
AFD	Aft Flight Deck
AID	Analog Input Differential
AKA	Active Keel Actuator
ALC	Automatic Light Control
AMSB	Advanced Mechanism Selection Box
APE	Auxiliary PFR Extender
ASIPE	Axial Science Instrument Protective Enclosure
ASLR	Aft Shroud Latch Repair
ATM	Auxiliary Transport Module
BAPS	Berthing and Positioning System
BAR	Berthing Assist and Restraint
BITE	Built-In Test Equipment
BOT	Beginning of Travel
BSP	BAPS Support Post
BSR	BITE Status Register
BTU	Bus Terminal Unit
CAB	Cabin
CASH	Cross Aft Shroud Harness
CAT	Crew Aids and Tools
CCTV	Closed Circuit Television
CDU	Common Drive Unit
CEP	Containment Environmental Package
CNTL	Control
COPE	Contingency ORU Protective Enclosure
COS	Cosmic Origins Spectrograph
CPC	Cyro Port Cover
CPT	Comprehensive Performance Test
CPUA	Clamp Pickup Assembly
CRES	Corrosion-Resistant Steel
CSM	Cargo Systems Manual
CSS	Center Support Structure
D/R	Deploy/Return
DBA	Diode Box Assembly
DBC	Diode Box Controller
DBC	Data Bus Coupler
dc	Direct Current
DI/DO	Discrete Input/Discrete Output
DIH	Discrete Input High
DIL	Discrete Input Low
DOF	Degree of Freedom
DOH	Discrete Output High
DOL	Discrete Output Low
DPC	Direct Power Converter
DPST	Double Pole, Single throw
ECU	Electronic Control Unit

[11] From the NASA STS-128 Press Kit: (http://www.nasa.gov/mission_pages/shuttle/shuttlemissions/hst_sm4/index.html)

Acronym	Meaning
EGSE	Electrical Ground Support Equipment
EMU	Extravehicular Mobility Unit
ENA	Enable
EOT	End of Travel
EPDSU	Enhanced Power Distribution and Switching Unit
EPDU	Electrical Power Distribution Unit
ESM	Electronic Support Module
ESS	Essential
ET	External Tank
EURM	Emergency Umbilical Retract Mechanism
EVA	Extravehicular Activity
EXT	External
FD	Flight Day
FDA	Failure Detection/Annunciation
FGS	Fine Guidance Sensor
FHST	Fixed Head Star Tracker
FMDM	Flexible Multiplexer/Demultiplexer
FOC	Faint Object Camera
FSS	Flight Support System
FWD	Forward
FXC	Forward X-Constraint
GPC	General Purpose Computer
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HOST	Hubble-On-Orbit Space Test
HPGSCA	HST Payload General Support Computer Assembly
HRD	Harness Restraint Device
HST	Hubble Space Telescope
HTR	Heater
I/F	Interface
I/O	Input/Output
ICD	Interface Control Document
IND	indicator
IOM	Input/Output Module
IPCU	Interface Power Control Unit
IVA	Intravehicular Activity
J-BOX	Junction Box
JSC	Johnson Space Center
L/A	Latch Assist
LAT	Latch
LIS	Load Isolation System
LOPE	Large ORU Protective Enclosure
LPS	Light and Particle Shield
LRU	Line Replaceable Unit
MCA	Motor Control Assembly
MCC	Mission Control Center
MDI	Magnetically Damped Isolator
MDM	Multiplexer/Demultiplexer
MET	Mission Elapsed Time
MGSE	Mechanical Ground Support Equipment
MIA	Multiplexer Interface Adapter
MLI	Multilayer Insulation
MMC	Mid-Motor Controller
MMCA	Mid-Motor Control Assembly

Acronym	Meaning
MNA	Main A
MNB	Main B
MOD	Mission Operations Directorate
MOPE	Multi-Mission ORU Protective Enclosure
MSID	Measurement Stimulus Identification
M-STRUT	Magnetic Strut
MULE	Multi-Use Lightweight Equipment
NBL	Neutral Buoyancy Lab
NCC	NICMOS CryoCooler
NCS	NICMOS Cooling System
NICMOS	Near Infrared Camera and Multi-Object Spectrometer
NOBL	New Outer Blanket Layer
NRZ-L	Non-Return-to-Zero Level
NT	NOBL Transporter
OPA	ORU Plate Assembly
ORB	Orbiter
ORU	Orbital Replacement Unit
ORUC	Orbital Replacement Unit Carrier
PA	Pallet Assembly
PBM	Payload Bay Mechanical
PCM	Pulse-Code Modulation
PCN	Page Change Notice
PCU	Power Control Unit
PCU	Power Conditioning Unit
PDI	Payload Data Interleaver
PDIP	Payload Data Interface Panel
PDRS	Payload Deployment and Retrieval System
PDSU	Power Distribution and Switching Unit
PE	Protective Enclosure
PFR	Portable Foot Restraint
PGT	Pistol Grip Tool
PI	Payload Interrogator
PL	Payload
PLB	Payload Bay
PLBD	Payload Bay Door
POH	Pulse Output High
PPCU	Port Power Conditioning Unit
PRB	Preload Release Bracket
PRCS	Primary Reaction Control System
PRLA	Payload Retention Latch Actuator
PROM	Programmable Read-Only Memory
PRT	Power Ratchet Tool
PSP	Payload Signal Processor
PWR	Power
RAC	Rigid Array Carrier
REL	Released
RF	Radio Frequency
RL	Retention Latch
RMS	Remote Manipulator System
RNS	Relative Navigation System
RSIPE	Radial Science Instrument Protective Enclosure
RSU	Rate Sensing Unit
RWA	Reaction Wheel Assembly
SA	Solar Array
SAC	Second Axial Carrier
SADA	Solar Array Drive Adapter

Acronym	Meaning
SADM	Solar Array Drive Mechanism
SAP	SAC Adapter Plate
SCM	Soft Capture Mechanism
SCRS	Soft Capture and Rendezvous System
SCU	Sequence Control Unit
SI	Science Instrument
SI C&DH	Science Instrument Command and Data Handling
SIP	Standard Interface Panel
SLIC	Super Lightweight Interchangeable Carrier
SLP	SpaceLab Pallet
SM	Servicing Mission
SM	Systems Management
SMEL	Servicing Mission Equipment List
SOPE	Small ORU Protective Enclosure
SORU	Small Orbital Replaceable Unit
SPCU	Starboard Power Conditioning Unit
SSE	Space Support Equipment
SSME	Space Shuttle Main Engine
SSP	Standard Switch Panel
SSPC	Solid State Power Controller
SSSH	Space Shuttle Systems Handbook
STBD	Starboard
STIS	Space Telescope Imaging Spectrograph
STOCC	Space Telescope Operations Control Center
STS	Space Transportation System
SURV	Survival
TA	Translation Aid
tb	Talkback
TM	Transport Module
TVAC	Thermal Vacuum
UA	Umbilical Actuator
UARS	Upper Atmospheric Research Satellite
UASE	UARS Airborne Structure Equipment
UDM	Umbilical Disconnect Mechanism
UPS	Under Pallet Storage
USA	United Space Alliance
VCU	Video Control Unit
VIK	Voltage Improvement Kit
WFC	Wide Field Camera
WFPC	Wide Field Planetary Camera
WRKLT	Worklight