*The CBS News*

# Space Reporter's Handbook
# Mission Supplement

## Shuttle Mission STS-119:
## Space Station Servicing Mission ULF-2

**Written and Edited 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/downloads.html

| DATE | RELEASE NOTES |
|---|---|
| 12/08/08 | Initial STS-119 release; crew bios, photos, personnel, flight plan |

# 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-119 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-119 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.

Here is additional satellite information you may find helpful:

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

# Acronyms Used in This Document

| Abbreviation | Meaning |
|---|---|
| Alt | Maximum altitude, or apogee, for shuttle missions |
| Apo | High point, or apogee, of an orbit |
| CDR | Mission commander; sits in left seat |
| Cryo | Shuttle fuel cell tank sets |
| D | Miles traveled |
| Day/Night | Day or night launch or landing |
| EOM | End of mission |
| ET | External tank |
| FE | Flight engineer |
| GPC | Shuttle computer software edition |
| Incl | Inclination |
| Lnd | Landing time |
| LV | Launch vehicle designation |
| ME | Space shuttle main engine serial number |
| MET | Mission elapsed time |
| MS | Mission specialist, i.e., a full-time astronaut |
| OMS | Orbital Maneuvering System |
| Pad | Launch pad |
| Per | Low point, or perigee, of an orbit |
| PLS | Primary landing site |
| PLT | Shuttle pilot; sits in right seat |
| PS | Payload specialist, i.e., not a full-time astronaut |
| Revs | Orbits |
| RMS | Shuttle robot arm (remote manipulator system) |
| RO,LO | Right OMS, Left OMS pod serial numbers |
| SET | Shuttle program elapsed time |
| SRB/SRM | Shuttle booster serial number |
| SSME | Space shuttle main engine |
| TD | Touchdown time |
| T-0 | Launch time |
| VET | Individual vehicle elapsed time |

# STS-119: 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-119 NASA Press Kit | http://www.shuttlepresskit.com/ |
| STS-119 Imagery | http://spaceflight.nasa.gov/gallery/images/shuttle/STS-119/ndxpage1.html |
| STS-119 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-119 Mission Preview

**By WILLIAM HARWOOD**
**CBS News Space Consultant**

KENNEDY SPACE CENTER, FL - After around-the-clock work to resolve concern about suspect hydrogen valves, the shuttle Discovery was cleared for launch March 11 on a four-spacewalk mission to attach a final set of solar arrays to the international space station. The huge solar panels, stretching 240 feet tip to tip, are the last major U.S.-built station components scheduled for launch on a space shuttle.

The first of up to five missions planned for 2009, STS-119 also will ferry Japan's first long-duration station flier - shuttle veteran Koichi Wakata - to the lab complex and bring flight engineer Sandra Magnus back to Earth after four months in space.

**Discovery's crew in training (left to right): Ricky Arnold, Steve Swanson, pilot Tony Antonelli, commander Lee Archambault, Koichi Wakata, John Phillips, Joe Acaba**

Launch is targeted for 9:20 p.m. EDT, roughly the moment Earth's rotation carries launch pad 39A into the plane of the space station's orbit. Joining Wakata aboard Discovery will be commander Lee Archambault, rookie pilot Dominic "Tony" Antonelli, shuttle and station veteran John Phillips, and spacewalkers Steve Swanson, Richard Arnold and Joseph Acaba.

Arnold and Acaba are former school teachers, selected as "educator-astronauts" and following in the footsteps of Barbara Morgan, Christa McAuliffe's backup in NASA's original Teacher in Space program.

But unlike McAuliffe and even Morgan, Arnold and Acaba will have no time for teaching.

"When Steve Lindsey, the chief of the (astronaut) office, assigned both me and Ricky to this flight, he wasn't looking at hey, we're going to fly two teachers," Acaba said. "He was looking for astronauts to fill the slots with a certain skill set and I think we fill those. These guys treat us like anybody else and everybody else in the office has been very supportive of the program. So it's been great."

Archambault is making his second flight and his first as commander. Swanson also is making his second flight while Phillips, veteran of a long-duration station tour of duty in 2005, will be logging his third space mission.

**ISS crew (top to bottom): Yury Lonchakov, commander Mike Fincke, Sandy Magnus**

Assuming an on-time liftoff, Archambault will guide Discovery to a docking with the space station around 6:30 p.m. on March 13. The shuttle astronauts will be welcomed aboard the station by Magnus, commander Mike Fincke and flight engineer Yury Lonchakov.

Swanson and Arnold plan to stage a spacewalk two days later to attach the new solar array truss segment. Three more spacewalks by Swanson, Arnold and Acaba, working in two-man teams, are planned for March 17, 19 and 21. Undocking is targeted for March 23 with landing back at the Kennedy Space Center expected around 3:27 p.m. on March 25.

Archambault and his crewmates originally hoped to begin their mission Feb. 12. But the flight was repeatedly delayed because of concern about possible cracks in the three hydrogen flow control valves used to pressurize the hydrogen section of the ship's external tank during the climb to space.

During the most recent shuttle flight last November, a small piece of one valve poppet broke free. It was the first such incident in shuttle history and while it caused no problems, NASA managers ordered tests to assess the safety of the system.

As it turned out, the valve cracked and liberated debris because of high-cycle fatigue, the result of harmonics in the flow environment inside the pressurization line that engineers had not suspected. While analysis continued, three valves that passed an electron microscope inspection were installed aboard Discovery.

**Engineers in Discovery's aft engine compartment installing replacement hydrogen flow control valves**

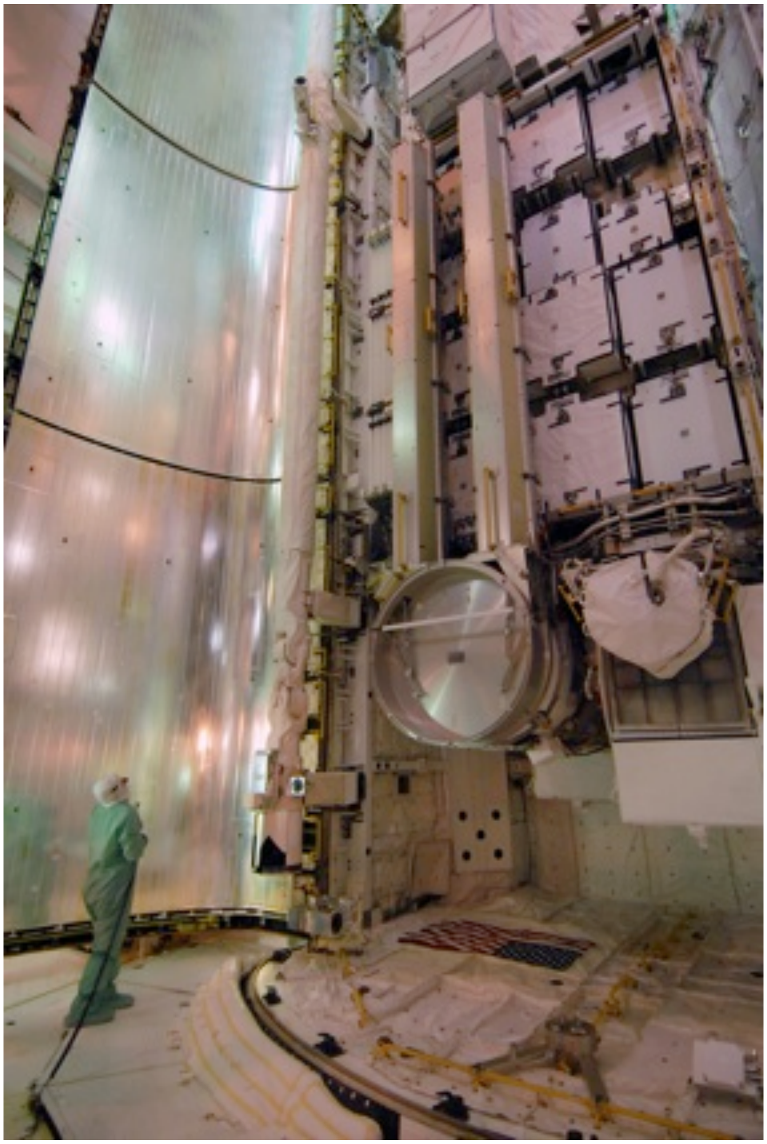
But testing continued and engineers discovered that surface roughness could mask small cracks, raising questions about the valves aboard Discovery. Those valves had flown about a dozen times each and they eventually were removed. Engineers planned to replace them with valves that had four, four and five flights respectively.

While all of that was going on, engineers carried out computer analysis to model the flow inside the hydrogen pressurization line and conducted impact testing to determine whether a piece of debris could cause damage if a fragment broke off in flight. Of special concern was a 90-degree bend in the line just five inches from each valve.

Against this backdrop, engineers came up with a new way to inspect the valves for cracks, adopting so-called eddy current analysis to look telltale defects indicative of cracks.

"It's a commercial way that they inspect bolt heads," said shuttle Program Manager John Shannon. "Basically, you put a magnetic field around the circumference of the bolt and then you measure the (induced) voltage you get through that magnetic field. Some of the really smart guys that we have ... adapted that to this problem and we ran several blind trials with (valve) poppets we knew had cracks. It performed so well that it found some cracks that we did not know we had, that we had not seen with the scanning electron microscope. So we had a lot of confidence in this inspection capability.

"So we took apart the valves that we had initially said we were going to put in with lower flight times and checked those out. Two of them were clean and one of them showed two cracks in it. That was a little bit of a surprise to us. So we screened the three valves that we had taken off of DIscovery that had 12 flights apiece and the first one we looked at had a crack in it. Then the next two did not have cracks in them. So we were able to put together, with a very high confidence level, a set of three valves and a flight spare that we could put in Discovery and have a lot of confidence that they did not have initiating cracks."



Computer modeling and detailed metallurgical analysis now shows cracks are unlikely to develop and propagate to failure in a single flight and that even if a failure occurred, large pieces are unlikely to break away. In addition, impact testing showed the plumbing can withstand hits from the sort of debris that would be released in a valve failure. Finally, a detailed study of the consequences of a impact puncture in the pressurization line showed much larger debris would be required to cause pressurization or flammability issues.

"So we really attacked this problem from all the different areas, we made sure we had good valves going in without cracks, we showed even if one or two start a crack and liberate, they would be small," Shannon said. "We showed that if it got in the plumbing it's very unlikely to cause damage and then we showed that even if it does cause damage, that damage is not something that we needed to worry about."

For downstream flights, NASA managers are assessing possible redesigns or the feasibility of simply launching with new, verified crack-free valves, each flight.

In the near term, NASA is facing a deadline of sorts with DIscovery. The Russians plan to launch a Soyuz spacecraft carrying the next space station commander and flight engineer on March 26. The docked phase of the shuttle mission must be done by then to avoid a conflict. To get in a full-duration four-spacewalk mission, Discovery must take off by March 13.

**The S6 solar array truss in shuttle Discovery's cargo bay**

By giving up one or two of the mission's planned spacewalks, along with off-duty time, Discovery could launch as late as March 16 or 17 in a worst-case scenario. After that, the flight would slip to April 7, the day Fincke and Lonchakov return to Earth aboard the station's current Soyuz ferry craft. But NASA managers are optimistic it won't come to that.

Discovery's flight comes at a crucial moment in the history of the international space station as NASA and its partners in Russia, Europe, Canada and Japan gear up to boost the lab's crew from three to six in late May. U.S. astronauts installed new water and urine recycling equipment late last year, gear NASA managers hoped to have fully tested and operational before the additional astronauts and cosmonauts arrive later this Spring.

But the vacuum distillation assembly at the heart of the U.S.-built urine recycling gear has failed to operate properly and a 180-pound backup unit will be launched aboard Discovery. Engineers do not yet know what caused the problem with the unit currently installed and they can't rule out the possibility the new unit might suffer the same fate.

At the same time, telemetry indicates a subtle pressure problem with the U.S. carbon dioxide removal system on board the station and a higher-than-expected bacteria count in the lab's potable water system. Chemicals to reduce the bacteria count will be launched aboard Discovery and new procedures are being implemented to reduce stress on the carbon dioxide scrubber.

Station Program Manager Mike Suffredini says the long-planned move to a six-person crew can continue even if the complex life support systems are not fully operational in May because the lab complex has a good supply of fresh water on board and there are multiple ways to scrub carbon dioxide out of the atmosphere.

In addition, visiting shuttles typically transfer around 1,000 pounds of water to the station each time they visit, a by-product of the reverse hydrolysis process that generates electricity in the ship's three fuel cells.

Other objectives of the 125th shuttle mission include work to ready the station for attachment of a Japanese experiment platform this summer and deployment of spare parts storage shelves on the station's hull that will be used to mount critical backup components before the shuttle fleet is retired in 2010.

The space station's mass will increase to 669,291 pounds - 335 tons - by the end of Discovery's mission and, with eight shuttle flights remaining before the fleet is retired in 2010, the complex will be 81 percent complete.

**Urine Processing Assembly/Distillation Assembly**

"We're flying the last power truss to the ISS," Suffredini said. "In fact, this is the last major U.S. element built ... by the Boeing Corp. and flown by the Boeing-NASA team and I couldn't be more proud of the performance to date."

The solar array truss segment, known as starboard 6 or S6 for short, will be attached to the far right end of the station's main power and cooling truss, which extends at right angles to the lab's pressurized modules.

S6 weighs 31,060 pounds and measures 16.3 feet wide, 45.4 feet long and 14.7 feet thick in the shuttle's cargo bay. According to Boeing, the price tag was $297,918,471, which includes costs from a lengthy Columbia-triggered launch delay.

Once attached to the station, its two wings will be deployed, giving the station four panels on each end of its power truss. Total surface area of all the arrays will be roughly one acre, generating 84 to 120 kilowatts of power, depending on the angle to the sun.

The S6 truss segment "takes up the entire payload bay, so unlike the last flight (in November), this is pretty much what our focus will be on the mission, getting the element installed and activated and the wings deployed," Suffredini said. "And after doing six wings we feel like we kind of understand them, so I'm hoping this one will be just a normal part of our everyday activation as an element. Of course, it won't turn out that way, but I can always hope."

In addition, he said, "this year is our year to go to six-person crew and important to that is not only this truss we're about to fly, but it's also getting all the (life support system) hardware active that we flew up on previous flights.

**Astronaut Steve Swanson inspects the attachment fittings that will hold the S6 solar array truss segment in place on the right end of the space station's power truss.**

"On orbit today, we've activated two of (four planned) crew quarters. ... The potable water dispenser is activated and operating. We have a slightly high bacterial count the last time we measured the water out of the ambient port. That's not unexpected when we don't use it very often and since we're not allowed to drink the water yet, the crew is not using the PWD as much as we will in the future and normal operation will keep the bacteria count down. So we'll flush that with some iodinated water and clear that up.

"The waste and hygiene compartment is working, it's been activated and is working fine. We haven't had any issues with that. The water processing assembly equally has been operating without any issue and we've figured out how to use the oxygen generation assembly (and) it's worked fine as well."

Another bit of good news for NASA is the improved performance of the station's right side solar alpha rotary joint, or SARJ. The lab is equipped with two such units, one on either side of the main power truss. Using massive 10-foot-wide drive gears, the SARJ units are designed to rotate the outboard solar arrays like giant paddle wheels to keep them face on to the sun as the station circles the planet.

The port-side SARJ has worked normally since its activation, but the right-side joint suffered extensive damage to one of its three bearing races due to an apparent lubrication failure after reaching orbit. Each SARJ features redundant drive gears, but NASA managers did not want to take the drastic step of switching to the backup and losing all redundancy in a critical system.

Instead, they began working on a plan to launch and install a replacement, a complex job that would have required multiple spacewalks. At the same time, movement of the starboard SARJ was sharply restricted to minimize vibrations and stress.

Late last year, spacewalking astronauts cleaned and lubricated the damaged gear's bearing races and Suffredini said telemetry indicates it now operates almost as smoothly as its port-side counterpart.

**The International Space Station in its current configuration. The P4 and P6 solar arrays are visible on the left side of the station's main power truss while the S4 segment stands alone on the right side. The new S6 truss segment will be attached to the right side during Discovery's mission**

The starboard SARJ is still considered damaged. But given its surprisingly good performance in the wake of its cleaning and lubrication, Suffredini said engineers have been cleared to operate the drive system in sun-pointing "auto-track" mode when necessary.

"Given this data, we're going to release some of the constraints to our ops team," he said. "Today, daily, they go to heroic efforts to manage systems so we can make sure we have enough power to operate the utilization hardware we need to operate. That is, they go in and turn off heaters and other systems every so often when we get to the beta angles that give us power challenges. ... That's an enormous amount of work for the team to do.

"So we're going to try to get ourselves out of that position or relieve some of the work the ops team has to do to provide power for all the systems. So what you'll see us do is give them release, such that when we get to those beta angles where we're challenged, you'll probably see the ops team auto-track for a little while in order to get past that hump as opposed to doing all the analysis to figure out what to turn off and how long to turn it off.

**The International Space Station assembly complete**

"In addition to that, we've begun a life test where we'll try to determine how much life we'll have on a degraded joint that's been lubricated," he said. "We're going to try to recreate the system as it is in orbit today and then we're going to put it to an accelerated life test and we're going to try to see if it degrades any further and if it does, can we determine life from that? In addition to that, we're going to try to figure out how often we need to re-lubricate that joint in order to keep the currents and vibration levels down to a level that's acceptable."

Testing should be complete later this summer. Engineers now plan to switch to the undamaged starboard drive gear in 2010 and use the current gear as a backup. Playing it safe, however, Suffredini said the replacement ring will be launched and stored on the station for future use if needed.

"Because we feel so good about the results so far, we believe we can keep this joint on orbit as the backup joint and perhaps now return to the concept of switching to outboard ops, make some modifications to the system so we can get the necessary redundancy when we go to outboard ops, and have this joint as a good backup," he said.

Despite the delay getting Discovery off the ground, NASA still hopes to launch five missions this year.

Next up is shuttle Atlantis, scheduled for launch May 12 on a mission to service and upgrade the Hubble Space Telescope. The shuttle Endeavour returns to space around June 13 for a mission to attach an external experiment platform on the space station's Japanese Kibo lab module.

Atlantis is scheduled to fly again in late August, followed by Discovery in November or December.

# NASA Press Kit STS-119 Mission Overview

***Editor's note...***
The following mission overview was taken from NASA's STS-119 press kit.

As the 28th mission to the International Space Station, STS-119 will continue the strides made to complete construction of the orbiting complex. Discovery and its crew will deliver to the station not only the final set of powergenerating solar array wings, but also the newest crew member.

Discovery is scheduled to launch at 7:32 a.m. EST Feb. 12, and arrive at the space station two days later. Once docked, the shuttle and station crews will begin 10 days of joint activities including four spacewalks.

Air Force Col. Lee Archambault (ARSH-umboh) will lead the STS-119 crew. Navy Cmdr. Tony Antonelli will serve as the pilot. The mission specialists for the flight are Joseph Acaba, John Phillips, Steve Swanson, Richard Arnold and Japan Aerospace Exploration Agency astronaut Koichi Wakata. Wakata will remain on the station, joining Expedition 18 Commander E. Michael Fincke, an Air Force colonel, and Flight Engineer Yury Lonchakov (LAHN'-chuh-coff), a Russian Air Force colonel. Wakata will replace Expedition 18 Flight Engineer Sandra Magnus, who will return to Earth with the STS-119 crew. Wakata will serve as a flight engineer for Expeditions 18 and 19.

Fincke and Lonchakov were launched to the complex in the Soyuz TMA-13 spacecraft on Oct. 12, 2008, from the Baikonur Cosmodrome in Kazakhstan. Wakata will return to Earth on shuttle mission STS-127, while Fincke and Lonchakov will return in the Soyuz in April. The STS-119 flight will deliver the final pair of power-generating solar array wings and truss element to the space station. The delivery and installation of the station's final, major U.S. truss segment, Starboard 6 (S6), during the STS-119 mission will signal the station's readiness to house a six-member crew for conducting increased science. With the installation of the 31,127-pound, 45.4-foot-long segment, the station's completed truss, or backbone, will measure 335 feet – more than the length of a football field.

## Flight Day 2

The day after launch, inspection of Discovery's thermal protection heat shield will be performed per the standard shuttle procedures. Phillips, Antonelli and Acaba will use the shuttle's robotic arm with a 50-foot extension boom to obtain detailed imagery of the reinforced carbon-carbon protection on the leading edge of the orbiter's wings and other critical surfaces. The Orbiter Boom Sensor System, or OBSS, uses laser devices and cameras to map the shuttle's heat shield. After Discovery is docked to the station, any focused inspection of the shuttle's thermal protection system would require a handoff of the sensor boom from the station's robotic arm to the shuttle's robotic arm because of interference created by the docking system linking the shuttle to the station.

The crew also will check out spacesuits to be used during the mission's four spacewalks and prepare for the next day's rendezvous and docking with the station by checking out rendezvous tools, installing the centerline camera and extending the orbiter's docking system ring.

## Flight Day 3

On the third day of the mission, after Discovery has closed within 600 feet of the station, Archambault will operate the shuttle's aft flight deck controls to approach the station for docking. First, Archambault will execute a slow backflip maneuver, presenting the belly of Discovery and other areas of its heat protective tiles to station residents Fincke and Magnus, who will use digital cameras equipped with 400 and 800 millimeter lenses to acquire high resolution photos of Discovery's heat shield. About two hours after Discovery attaches to the forward docking port at the end of the station's Harmony module, hatches will be opened between the two spacecraft to allow the 10 crew members to greet one another for the start of joint operations.

Following a standard safety briefing by Fincke, the crews will get to work, activating a Stationto- Shuttle Power Transfer System that will provide additional electricity to Discovery for the longer operation of shuttle systems. A few hours after hatch opening, Magnus and Wakata will exchange custom-made Russian Soyuz spacecraft seat liners. With that exchange, Wakata will become a member of the Expedition 18 space station crew and Magnus will become part of Discovery's crew.

**Flight Day 4**

The following day, joint activities begin in earnest. Magnus will join Phillips at the robotics workstation in the station's Destiny laboratory to use the station's robotic arm, Canadarm2, to grapple the S6 truss segment in the shuttle's payload bay. They'll use the multi-jointed arm to gently lift the S6 truss from the cargo bay and hand it to the shuttle robotic arm, controlled by Antonelli and Acaba at Discovery's aft flight deck. While the shuttle arm holds the truss segment, the station arm will be repositioned to the installation worksite. Once in position, the shuttle arm will hand the truss back over to the station robotic arm where it will remain in an overnight parked position. The rest of the day will focus on preparation for the first spacewalk of the mission.

All 10 crew members will join to review procedures for the first planned spacewalk before Swanson and Arnold make their way to the Quest airlock where they will spend the night. This "campout" procedure helps to purge nitrogen from the astronauts' bloodstream to prevent decompression sickness during the spacewalk.

**Flight Day 5**

On the fifth day of the flight, Swanson and Arnold will begin the first spacewalk by working with the crew inside to install the awaiting truss segment. Phillips, at the space station's robotic workstation, will work in tandem with the two spacewalkers to maneuver the truss segment into place where the spacewalkers can then work on the detailed installation tasks. The spacewalkers will provide visual cues to Phillips for the final alignment before bolting the segment, connecting umbilicals, removing thermal covers, and releasing and unstowing the solar array blanket boxes, which store the accordionlike arrays. They'll also prepare the truss' photovoltaic radiator for deployment.

**Flight Day 6**

The following day sets aside time for a focused inspection of Discovery's thermal protection system, if needed. If required, Archambault, Acaba and Antonelli will use the OBSS to conduct the inspection. The crews also will continue with the exchange of supplies and equipment from the shuttle to the station.

**Flight Day 7**

On flight day seven, Swanson will be joined by Acaba for the second spacewalk of the mission, the first ever for Acaba. They will prepare batteries on the Port 6 truss segment for replacement on a later mission and deploy an unpressurized cargo carrier attachment system on the P3 – or Port 3 truss segment. While still on the port side of the truss, Swanson will repair a thermal cover on a radiator beam valve module while Acaba installs fluid jumpers between the P1 and P3 truss segments. Next, they will move to the starboard side of the station's truss to deploy a payload attachment system on the S3 segment. Before heading back to the station's airlock, they'll relocate a tool stanchion from the Z1 truss segment to the exterior of the Destiny laboratory and pick up a foot restraint for stowage inside the airlock.

**Flight Day 8**

The station should look even brighter after flight day eight, when the solar array's wings are deployed. The crew will preside first over the deployment of the 1B electrical channel array toward the end of the station where Discovery is docked. When nearly half of the array's length is unfurled, the crew will take a short break and proceed with the remainder of the 1B deployment. Next, they'll move to the 3B electrical channel array deployment toward the

Russian segment of the complex, initially only deploying to the near-halfway point, and then to the full extension. This phased approach will give the onboard crew and the ground engineers time to monitor the deployment and ensure the arrays are unfolding properly. If focused inspection of the heat shield is not required on flight day six, then the solar array deployment will be moved up 48 hours earlier into the inspection's reserved time.

**Flight Day 9**

On flight day nine, Acaba and Arnold will venture out for the third spacewalk, the second for each of them. On this spacewalk, the two will relocate a Crew and Equipment Translation Aid (CETA) cart to be used with the future battery replacement activity. Arnold will next reconfigure a cover on the Special Purpose Dexterous Manipulator's orbital replacement unit tool changeout mechanism and remove a cover from one of its electronics units. When that task is complete, Arnold will lubricate one of the two end effectors of the space station robotic arm, duplicating the work done by spacewalker Shane Kimbrough during the STS-126 mission on the opposite end. Meanwhile, Acaba will work between the S1 and S3 truss segments to attach cables in a bolt bus controller panel on the segment-to-segment attach system and install a fluid jumper. Afterward, the spacewalkers will reunite near the center of the station to replace Remote Power Control Modules on the Port 1 and Starboard 0 truss segments.

**Flight Day 10**

The crew members will continue the transfer of supplies and equipment between the space station and Discovery. They also will participate in a joint news conference. They will review procedures for the fourth and final planned spacewalk of the mission. Swanson and Arnold will spend the night in the Quest airlock in preparation for that spacewalk.

**Flight Day 11**

Swanson and Arnold will conduct the fourth planned spacewalk. They will work separately for the first half of the mission's final spacewalk. Swanson will begin by installing a GPS antenna on the exterior of the Japanese logistics module. After that, he'll swap connectors on a patch panel on the station's zenith truss segment. Meanwhile, Arnold will photograph the radiators on the first port and starboard truss segments, using both regular and infrared cameras. In September, ground controllers noticed damage to one panel of the starboard radiator, and the photos will help them determine how the damage is affecting its operation.

After that, Swanson and Arnold will work together. First they'll install a wireless video system external transceiver assembly, or WETA, which supports the transmission of video from spacewalkers' helmet cameras, on the S3 truss segment. To do so, Swanson will remove a dummy box currently in the location, and then attach the WETA to a stanchion. Arnold will connect three cables to the assembly.

Afterward, Swanson and Arnold will prepare two more payload attachment systems on the S3 truss segment – one on the outboard side of the bottom of the segment, and one on the inboard side of the top of the segment. They will use the same process employed during the mission's second spacewalk.

**Flight Day 12**

The shuttle crew will complete the transfer of their spacewalk equipment back from the station's Quest airlock to Discovery on flight day 12, before saying farewell to the station crew and preparing for hatch closure between the two spacecraft.

**Flight Day 13**

Discovery is scheduled to undock from the station on flight day 13. Antonelli, flying the shuttle from the aft flight deck, will conduct a flyaround of the complex so the crew can capture detailed imagery of the station's new configuration with the last of its powerproducing solar arrays unfurled. After a little more than a lap around the station, Antonelli will fire the shuttle's jets to separate from the station. At that time, Antonelli, Acaba and Phillips will take turns with the shuttle's robotic arm and the OBSS to conduct a "late" inspection of the shuttle's heat shield, a final opportunity to confirm Discovery's readiness to return to Earth.

### Flight Day 14

On flight day 14, Archambault, Antonelli and Swanson will conduct the traditional checkout of the orbiter's flight control surfaces and steering jets in preparation for landing the next day. The shuttle crew also will stow equipment and supplies used during the mission, berth the sensor boom on the payload bay's starboard sill and shut down the shuttle's robotic arm systems for the remainder of the mission. The entire crew will conduct a review of landing procedures.

The crew also will stow any remaining equipment and set up a special "recumbent" seat in the middeck to assist Magnus as she readapts to Earth's gravity following three months of weightlessness.

Discovery is scheduled to return to Earth with a landing at NASA's Kennedy Space Center, Fla., in the pre-dawn hours, bringing to an end its 36th mission, the 28th shuttle flight to the International Space Station and the 125th flight in shuttle program history.

# NASA Press Kit STS-119 Timeline Overview

***Editor's note...***
The following mission overview was taken from NASA's STS-119 press kit.

**Flight Day 1 - March 11/12**
- Launch
- Payload Bay Door Opening
- Ku-Band Antenna Deployment
- Shuttle Robotic Arm Activation
- Umbilical Well and Handheld External Tank Photo and TV Downlink

**Flight Day 2 - March 12/13**
- Discovery Thermal Protection System Survey with Shuttle Robotic Arm/Orbiter Boom Sensor System (OBSS)
- Extravehicular Mobility Unit Checkout
- Centerline Camera Installation
- Orbiter Docking System Ring Extension
- Orbital Maneuvering System Pod Survey
- Rendezvous Tools Checkout

**Flight Day 3 - March 13/14**
- Rendezvous with the International Space Station
- Rendezvous Pitch Maneuver Photography by the Expedition 18 Crew
- Docking to Harmony/Pressurized Mating Adapter-2
- Hatch Opening and Welcoming
- Wakata and Magnus Exchange Soyuz Seatliners; Wakata Joins Expedition 18, Magnus Joins the STS-119 Crew
- U.S. Spacesuit Transfer from Discovery to Space Station

**Flight Day 4 - March 14/15**
- Canadarm2 Grapple and Unberth of S6 Truss from Discovery's Payload Bay
- Canadarm2 Handoff of S6 Truss to Shuttle Robotic Arm
- Canadarm2 Translation to S6 Installation Worksite
- Shuttle Robotic Arm Handoff of S6 Truss Back to Canadarm2
- Spacewalk 1 Procedure Review
- Spacewalk 1 Campout by Swanson and Arnold

**Flight Day 5 - March 15/16**
- Spacewalk Preparations
- Spacewalk by Swanson and Arnold (S6 Installation and Umbilical Connections, Solar Array Blanket Box Release and Unstow)
- S6 Truss Photovoltaic Radiator Deploy

**Flight Day 6 - March 16/17**
- Canadarm2 Grapple of OBSS and Handoff to Shuttle Robotic Arm
- Shuttle Robotic Arm/OBSS Focused Inspection of Discovery's Thermal Protection System, if Required
- Shuttle/Station Transfers
- Spacewalk 2 Procedure Review
- Spacewalk 2 Campout by Swanson and Acaba

**Flight Day 7 - March 17/18**
- Spacewalk Preparations
- Spacewalk 2 by Swanson and Acaba (P6 Battery Replacement Preparations for STS-127 Spacewalks, Deployment of P3 and S3 Truss Payload Attachment Systems, P1/P3 Fluid Jumper Connections and Radiator Beam Valve Module Thermal Cover Removal and P6 Power and Data Grapple Fixture Retrieval)
- Shuttle/Station Transfers

**Flight Day 8 - March 18/19**
- S6 1B and 3B Channel Solar Array Deployments (If no focused inspection is required, the solar array deployment activity will move to Flight Day 6.)
- Shuttle/Station Transfers
- Spacewalk 3 Procedure Review
- Spacewalk Campout by Acaba and Arnold

**Flight Day 9 - March 19**
- Spacewalk Preparations
- Spacewalk 3 by Acaba and Arnold (CETA Cart Relocation, Dextre Cover Removal Tasks, Canadarm2 Latching End Effector B Lubrication, P1 and S0 Truss Remote Power Control Module Replacement)
- Shuttle/Station Transfers

**Flight Day 10 - March 20**
- Crew Off Duty Period
- Shuttle/ISS Transfers
- Joint Crew News Conference
- Spacewalk 4 Procedure Review
- Spacewalk 4 Campout by Swanson and Arnold

**Flight Day 11 - March 21**
- Spacewalk Preparations
- Spacewalk 4 by Swanson and Arnold (Payload Attachment System Deployments, Video Signal Converter Installation, Fiber Optic Cable Installation)
- Shuttle/Station Transfers

**Flight Day 12 - March 22**
- Final Post-Spacewalk Hardware Transfers
- Crew Off Duty Periods
- Final Farewells and Hatch Closure
- Centerline Camera Installation

**Flight Day 13 - March 23**
- Undocking
- Flyaround of the International Space Station
- Final Separation
- OBSS Late Inspection of Discovery's Thermal Protection System

**Flight Day 14 - March 24**
- Flight Control System Checkout
- Reaction Control System Hot-Fire Test
- Cabin Stowage
- Magnus' Recumbent Seat Setup
- Crew Deorbit Briefing
- Ku-Band Antenna Stowage

**Flight Day 15 - March 25**
- Deorbit Preparations
- Payload Bay Door Closing
- Deorbit Burn
- Kennedy Space Center Landing

# NASA Press Kit STS-119 Payload Overview

***Editor's note...***
The following mission overview was taken from NASA's STS-119 press kit.

STS-119 will deliver the International Space Station's final, major U.S. truss segment, Starboard 6 (S6), providing the powergenerating capacity for a six-person crew to conduct increased science activities. With its two Solar Array Wings (SAWs) for converting solar energy into electrical power and a radiator for rejecting heat away from electrical components, the S6 is the final truss element and completes the station's 11-segment Integrated Truss Structure (ITS). Also called a Photovoltaic Module (PVM) because of its ability to generate, store and distribute electrical power to the station, the Starboard 6 segment will ensure the outpost is powered to its intended maximum potential.

A unique feature about the S6 is that it will carry two spare Battery Charge/Discharge Units (BCDUs), used for controlling the charge and discharge of spare batteries on the station. The S6 segment was modified to carry the additional BCDUs, attached to the segment's Long Spacer Truss structure.

The space station's solar arrays are the largest deployable space assemblies ever built and the most powerful electricity-producing arrays in orbit. Until deployed, each SAW remains folded in a special canister called a Solar Array Assembly (SAA) at the end of the S6 element. In the canister, each wing is equipped with an expandable mast. Two solar array blanket boxes, containing 32,800 solar cells, are connected to the ends of each canister and are restrained to the element frame for launch. The addition of S6 brings the station's total SAWs to eight. Each wing is 115 by 38 feet wide and, when all eight are fully deployed, will encompass an area of 32,528 square feet, minus the masts.

**S6 Specifications Dimensions:**

Width: 16.3 feet; 195.48 inches
Length: 45.4 feet; 545.16 inches
Height: 14.7 feet; 176.54 inches
On-Orbit Weight: 31,060 lbs
Cost $297,918,471

The 310-foot integrated truss structure to which the S6 will be attached forms the backbone of the space station, with mountings for unpressurized logistics carriers, radiators, solar arrays, and the various elements. The 45-footlong S6 began as an operations test item for its twin sister, the Port 6 truss segment that was launched during Endeavour's STS-97 mission on Nov. 30, 2000. The starboard element was delivered to Kennedy Space Center in Florida on Dec. 17, 2002.

Boeing, NASA's prime contractor for the station, designed the S6 and worked with major subcontractors Lockheed Martin, Honeywell, Space Systems/Loral, and Hamilton Sundstrand to build it. Pratt and Whitney Rocketdyne provided most of the electrical power system components.

**Integrated Truss Segments and Payload Structure**

The integrated truss segments started with Starboard 0 (S0) as the center assignment and were numbered in ascending order outward to the port (P) and starboard (S) sides. Starboard is the right side and port is the left side of the truss structure. Zenith (Z) is up, when the station is flying in its normal orientation. At one time, there was an S2 and a P2 planned, but they were eliminated when the station design was scaled back. From S0, the truss segments are P1, P3, P4, P5 and P6 and S1, S3, S4, S5 and S6. P6 is attached to P5, and once in orbit S6 will be attached to

S5. The S6 primary structure is made of a hexagonal-shaped aluminum structure and includes four bulkheads and six longerons, which are beams that connect the bulkheads.

During the STS-119 mission, S6 will be removed from the payload bay with the space station's robotic arm because the shuttle's arm is unable to remove the element with the current configuration of the station. The S6 element then will be handed to the shuttle arm and maneuvered to another location, while the station arm changes base points. The S6 then will be handed back to the station arm and maneuvered to an overnight park position. Removing the truss from the payload bay and maneuvering to an overnight park position takes an entire day. The following day the truss will be installed during a planned spacewalk.

Once the final truss segment is attached, S6 will support power generation and energy storage, utility routing, power distribution and Orbital Replacement Unit (ORU) storage.

### Major Subsystems

Major subsystems of the S6 truss are the starboard outboard Photovoltaic Module (PVM), the Photovoltaic Radiator (PVR), the Long Spacer Truss (LST) and the Modified Rocketdyne Truss Attachment System (MRTAS). The S6 PVM includes all equipment outboard S5, namely the two Photovoltaic Array Assemblies (PVAAs) and the Integrated Equipment Assembly (IEA). The PVR provides thermal cooling for the IEA. The MRTAS is used to provide a structural interface to the S5 truss element. Each PVAA consists of a SAW and Beta Gimbal Assembly (BGA).

### Major Elements

### Photovoltaic Modules (PVMs)

S6 will be the fourth and final of the four PVMs that convert sunlight to electricity in orbit. The primary functions of the power module are to collect, convert, store, and distribute electrical power to loads within the segment and to other station segments. Electrical power is a critical resource for the station because it allows astronauts to live comfortably, safely operate the station and perform complex scientific experiments. Since the only readily available source of energy for spacecraft is sunlight, technologies were developed to efficiently convert solar energy to electrical power.

The PVMs use large numbers of solar cells assembled onto solar arrays to produce high power levels. NASA and Lockheed Martin developed a method of mounting the solar arrays on a "blanket" that can be folded like an accordion for delivery to space and then deployed to its full size once in orbit. The cells are made from purified crystal ingots of silicon that directly convert light to electricity for immediate use through a process called photovoltaics.

Gimbals are used to rotate the arrays so that they face the sun to provide maximum power to the space station. After the conversion process, the PVMs also use the electricity to recharge onboard batteries for continuous sources of electricity while the station is in the Earth's shadow. Once complete, the station power system, consisting of U.S. and Russian hardware and four photovoltaic modules, will use between 80 – 100 kilowatts of power or about as much as 42 average houses (defined as 2,800 square feet of floor space using 2 kilowatts each). Some of the electricity is needed to operate space station systems, but once that is figured in, the addition of the S6 will nearly double the amount of power available to perform scientific experiments on the station – from 15 kilowatts to 30 kilowatts.

### Solar Array Wings (SAWs)

There are two SAWs on the S6 module, each deployed in the opposite direction of the other. Each SAW is made up of two solar blankets mounted to a common mast. Before deployment, each panel is folded accordion style into a Solar Array Blanket Box (SABB) measuring 20 inches high and 15 feet in length. Each blanket is only about 20 inches thick while in this stored position. The mast consists of interlocking battens that are stowed for launch inside a Mast Canister Assembly (MCA). When deployed by the astronauts, the SAW unfolds like an erector set. Like a human torso, it has two arms when mounted on S6, and they are rotated outwards by astronauts during a spacewalk so they can be fully deployed.

Because these blankets were stored for such a long time, extensive testing was conducted to ensure they would unfold properly in orbit so the blankets would not stick together. When fully deployed, the SAW extends 115 feet and spans 38 feet across and extends to each side of the Integrated Equipment Assembly. Since the second SAW is deployed in the opposite direction, the total wing span is more than 240 feet.

Each SAW weighs more than 2,400 pounds and uses 32,800 solar array cells, each measuring 8 centimeters square with 4,100 diodes. The individual cells were made by Boeing's Spectrolab and Aviation Systems Engineering Co. There are 400 solar array cells to a string and there are 82 strings per wing. Each SAW is capable of generating 32.8 kilowatts, or about 10.5 to 15 kilowatts of usable power. There are two SAWs on the S6 module capable of delivering a combined 21 to 30 kilowatts of usable power per PVM with a total of four PVMs on the station.

The solar arrays produce more power than can be made available to the station's systems and experiments. Because all or part of the solar arrays are eclipsed by the Earth or station structure at times, batteries are used to store electricity for use during those periods. About 60 percent of the electricity generated is used to recharge the batteries. During long eclipse periods, power availability is limited to about 10.5 kilowatts from each SAW, or 30 kilowatts per PVM. During shorter eclipse periods more power is available to station systems and experiments. Circuit breakers also regulate the flow of electricity to prevent overheating of the Utility Transfer Assembly (UTA) that allows power to flow through the rotating SARJ.

### Solar Alpha Rotary Joint (SARJ)

When the S6 truss is attached to the S5 short spacer, it will be positioned outboard of the starboard SARJ, which is designed to continuously rotate to keep the S4 and S6 solar array wings oriented toward the sun as the station orbits the Earth. Located between S3 and S4, the starboard SARJ is a 10.5-foot diameter rotary joint that weighs approximately 2,500 pounds. The SARJ can spin 360 degrees using bearing assemblies and a servo control system to turn. Due to vibrations and damage found on its race ring, the starboard SARJ has been rotated only when needed. STS-126 astronauts cleaned and lubricated the race ring, and preliminary results show the joint is moving more freely. The race ring has a triangular cross-section on which 12 bearings roll. All of the power flows through the Utility Transfer Assembly (UTA) in the SARJ. Roll ring assemblies allow transmission of data and power across the rotating interface so it never has to unwind.

### Beta Gimbal Assembly (BGA)

The solar array wings also are oriented by the BGA, which can change the pitch of the wings by spinning the solar array. The BGA measures 3 x 3 x 3 feet and provides a structural link to the Integrated Equipment Assembly (IEA). The BGA's most visual functions are to deploy and retract the SAW and rotate it about its longitudinal axis. The BGA consists of three major components: the Bearing, Motor and Roll Ring Module (BMRRM), the Electronics Control Unit (ECU) and the Beta Gimbal Transition Structure, mounted on the BGA platform. The Sequential Shunt Unit (SSU) serves to manage and distribute the power generated from the arrays and is also mounted on each BGA platform.

Both the SARJ and BGA are pointing mechanisms and mechanical devices used to point the arrays toward the sun. They can follow an angle target and rotate to that target in the direction toward the sun. Controllers in orbit continuously update those targets so they keep moving as the station orbits the Earth every 90 minutes, maintaining the same orientation toward the sun at the same orbital rate. The SARJ mechanism rotates 360 degrees every orbit, or about 4 degrees per minute, whereas the BGA moves only about four or five degrees per day.

### S6 Integrated Equipment Assembly (IEA)

The IEA has many components: 12 battery subassembly Orbital Replacement Units (ORUs), Battery Charge/Discharge Units (BCDU) ORUs, two Direct Current Switching Units (DCSUs), two Direct Current to Direct Current

Converter Units (DDCUs), and two Photovoltaic Controller Units (PVCUs). The IEA integrates the Thermal Control Subsystem that consists of one Photovoltaic Radiator (PVR) ORU and two Pump Flow Control Subassembly (PFCS) ORUs, which are used to transfer and dissipate heat generated by the IEA ORU boxes.

In addition, the IEA provides accommodation for ammonia servicing of the outboard PV modules as well as pass through of power and data to and from the outboard truss elements.

The IEA measures 16 x 16 x 16 feet, weighs nearly 17,000 pounds and is designed to condition and store the electrical power collected by the photovoltaic arrays for use aboard the station. The IEA integrates the energy storage subsystem, the electrical distribution equipment, the thermal control system and structural framework. The IEA consists of three major elements:

1. The power system electronics consisting of the Direct Current Switching Unit (DCSU) used for primary power distribution; the Direct Current to Direct Current Converter Unit (DDCU) used to produce regulated secondary power; the Battery Charge/Discharge Unit (BCDU) used to control the charging and discharging of the storage batteries; and the batteries used to store power.

2. The Photovoltaic Thermal Control System (PVTCS) consisting of: the coldplate subassemblies used to transfer heat from electronic boxes to the coolant; the Pump Flow Control Subassembly (PFCS) used to pump and control the flow of ammonia coolant; and the Photovoltaic Radiator (PVR) used to dissipate the heat into deep space. Ammonia, unlike other chemical coolants, has significantly greater heat transfer properties.

3. The computers used to control the S6 module ORUs consisting of two Photovoltaic Controller Unit (PVCU) Multiplexer/Demultiplexers (MDMs). The IEA power system is divided into two independent and nearly identical channels. Each channel is capable of control, storage and distribution of power to the station. The two SAWs are attached to the outboard end of the IEA.

### Direct Current Switching Unit (DCSU)

Power received from each SAW is fed directly into the appropriate DCSU, a high-power, multi-path remotely controlled unit used for primary and secondary power distribution, protection and fault isolation within the IEA. During periods of sunlight, the DCSU routes primary power directly to the station from its SAW and also routes power to the power storage system for battery charging. During periods of eclipse, the DCSU routes power from the power storage system to the station. The DCSU measures 25″ by 40″ by 14″ and weighs 218 pounds.

### Direct Current to Direct Current Converter Unit (DDCU)

Primary power from the DCSU also is distributed to the DDCU, a power processing system that conditions the coarsely regulated power from the SAW and BCDUs to 124.5 +/- 1.5 direct current volts. It has a maximum power output of 6.25 kW. This power is used for all S6 operations employing secondary power. By transmitting power at higher voltages and stepping it down to lower voltages where the power is to be used, much like municipal power systems, the station can use smaller wires to transmit this electrical power and thus reduce launch loads. The converters also isolate the secondary system from the primary system and maintain uniform power quality throughout the station. The DDCU measures 27.25″ by 23″ by 12″ and weighs 129 pounds.

Primary power from the DCSU also is distributed to the three power storage systems within each channel of the IEA. The power storage system consists of a Battery Charge/Discharge Unit (BCDU) and two battery subassembly ORUs. The BCDU serves a dual function of charging the batteries during solar collection periods and providing conditioned battery power to the primary power busses via the DCSU during eclipse periods. The BCDU has a battery charging capability of 8.4 kW and a discharge capability of 6.6 kW. The BCDU also includes provisions for battery status monitoring and protection from power circuit faults. Commanding of the BCDU is done from the PVCU. The BCDU measures 28″ by 40″ by 12″ and weighs 235 pounds.

Each battery subassembly ORU consists of 38 lightweight nickel hydrogen cells and associated electrical and mechanical equipment. Two battery subassembly ORUs connected in series are capable of storing 8 kilowatt-hours (kWh) of electrical power. This power is fed to the station via the BCDU and DCSU, respectively. The batteries have a design life of 6.5 years and can exceed 38,000 charge/discharge cycles at 35 percent depth of discharge. Each battery measures 41″ by 37″ by 19″ and weighs 372 pounds.

### Photovoltaic Thermal Control System (PVTCS)

To maintain the IEA electronics and batteries at safe operating temperatures in the harsh space environment, a PVTCS is used. The PVTCS consists of ammonia coolant, 11 coldplates, two Pump Flow Control Subassemblies (PFCS) and one Photovoltaic Radiator (PVR).

The coldplate subassemblies are an integral part of the IEA structural framework. Heat is transferred from the IEA Orbital Replacement Unit (ORU) electronic boxes to the coldplates via fine interweaving fins on both the coldplate and the electronic boxes. The fins add lateral structural stiffness to the coldplates in addition to increasing the available heat transfer area.

### Pump Flow Control Subassemblies (PFCS)

The PFCS is the heart of the thermal system, consisting of all the pumping capacity, valves and controls required to pump the heat transfer fluid to the heat exchangers and radiator, and regulate the temperature of the thermal control system ammonia coolant. The PVTCS is designed to dissipate an average of 6,000 watts of heat, and communicates with the PVCUs. Each PFCS consumes 275 watts during normal operations and measures approximately 40 by 29 by 19 inches, weighing 235 pounds.

### Photovoltaic Radiator (PVR)

The PVR is deployable in orbit and is comprised of two separate flow paths through seven panels. Each flow path is independent and is connected to one of the two PFCSs on the IEA. In total, the PVR can reject up to 14 kW of heat into deep space. The PVR weighs 1,633 pounds and, when deployed, measures 44 by 12 by 7 feet.

# NASA Press Kit STS-119 Spacewalk Overview

***Editor's note...***
The following mission overview was taken from NASA's STS-119 press kit.

The four spacewalks of the STS-119 mission will feature a variety of tasks. The highlight is the installation of the final pair of solar arrays that will bring the station up to full power (and balance it out, appearance wise). To prepare for the next mission to the station, STS-127, the astronauts will move the Crew and Equipment Translation Aid carts out of the way of the mobile transporter, much as was done during the STS-126 mission.

Mission Specialists Steve Swanson, Richard Arnold, and Joseph Acaba will spend a combined total of 26 hours outside the station on flight days 5, 7, 9 and 11. Swanson, the lead spacewalker for the mission, will suit up for the first, second and fourth spacewalks in a spacesuit marked with solid red stripes. He is a veteran spacewalker with two extravehicular activities, or EVAs, performed during the STS-117 flight in 2007.

Arnold and Acaba will perform their first spacewalks. Arnold will participate in the first, third and fourth spacewalks and wear an all white spacesuit, while Acaba will wear a spacesuit with broken red stripes for spacewalks two and three.

On each EVA day, a spacewalker inside the station will act as the intravehicular officer, or spacewalk choreographer. And Mission Specialist John Phillips will work with the spacewalkers from the inside to operate the station's robotic arm as needed.

Preparations will start the night before each spacewalk, when the astronauts spend time in the station's Quest airlock. This practice is called the campout prebreathe protocol and is used to purge nitrogen from the spacewalkers' systems and prevent decompression sickness, also known as "the bends."

During the campout, the two astronauts performing the spacewalk will isolate themselves inside the airlock while the air pressure is lowered to 10.2 pounds per square inch, or psi. The station is kept at the near-sealevel pressure of 14.7 psi. The morning of the spacewalk, the astronauts will wear oxygen masks while the airlock's pressure is raised back to 14.7 psi for an hour and the hatch between the airlock and the rest of the station is opened. That allows the spacewalkers to perform their morning routines before returning to the airlock, where the air pressure is lowered again. Approximately 50 minutes after the spacewalkers don their spacesuits, the prebreathe protocol will be complete. The procedure enables spacewalks to begin earlier in the crew's day than was possible before the protocol was adopted.

**EVA-1 Duration: 6 hours, 30 minutes Crew: Swanson and Arnold**

- Install final starboard truss element (S6)
- Prepare truss element for solar array deploy

The first spacewalk of the mission will be devoted to installing the station's new truss segment and preparing the segment's solar arrays for unfolding on the eighth day of the mission. Swanson and Arnold will move to the S5 – or Starboard 5 – segment of the truss and make sure that the station's robotic arm has the new S6 truss segment in the correct position for its installation. It should be about 150 centimeters (4.9 feet) from the end of the S5 truss.

From the robotic arm workstation inside the Destiny laboratory, Phillips then will move the segment to a point 30 centimeters (11.8 inches) away from the end of the S5 truss, while Swanson and Arnold monitor clearances to ensure proper alignment. On their "go," Phillips will move the segment to 15 centimeters (about 6 inches) for another check before making contact.

Assuming everything is correctly aligned, Arnold will engage a capture latch to allow the station's truss to support the new segment, rather than the robotic arm. Then Swanson will tighten the four bolts that attach the segment to the station, and Arnold will attach four S6 grounding straps to S5.

With S6 safely attached to S5, Swanson and Arnold can begin hooking up the four connections that will allow power and data to pass from one segment to the other. After that, Swanson and Arnold split up. Arnold will release the restraints holding the blanket box that contains the solar array blankets, so that the arrays can be unfolded later.

Swanson, meanwhile, will have two tasks. First he'll prepare the S6 radiator panels to be unfolded. He'll remove the six cinches that keep the panels folded together, and remove two pins that prevent them from unfolding. Afterward, flight controllers at the Mission Control Center in Houston will be able to command the radiator to unfold.

Swanson then will move to the beta gimbal assembly – or BGA – which allows the solar array wings to twist as they track the sun. The BGA is kept from rotating during launch by a keel fastener. Swanson will remove the fastener so he can rotate the BGA into place for the unfolding on the solar array wings. After he's done, he'll reinstall the fastener and remove some launch restraints on the BGA.

Swanson and Arnold then will reunite and rotate the blanket boxes into position for the unfolding of the arrays within them. Swanson will work on the two boxes on the bottom, while Arnold works on the two on the top. Their last tasks will be to remove thermal covers from the system's electronic control and sequential control units and jettison them behind the station to burn up in the Earth's atmosphere.

**EVA-2 Duration: 6 hours, 30 minutes Crew: Swanson and Acaba**

- P6 battery prep
- P3 nadir Unpressurized Cargo Carrier Attachment System and S3 outboard, zenith Payload Attachment System deploy
- Radiator beam valve module thermal cover repair
- P1/P3 fluid jumper install
- Flex hose rotary coupler clamp release
- Tool stanchion relocation
- Foot restraint retrieval

Swanson and Acaba's first task during this spacewalk will be to loosen two bolts on the battery on the P6 – or Port 6 – arrays. The battery will be replaced during the STS-127 mission.

From there, they'll continue working on the port side of the station's truss, on the bottom of the P3 segment, to prepare an unpressurized cargo carrier attachment system for use. The system allows cargo to be attached to the station's truss. To do so, the spacewalkers will first remove brackets and pins holding the latch in place, move the latch into position and then reinstall the brackets and pins.

Following that task, Swanson will work on repairing a thermal cover over a quick disconnect on the first port segment's radiator beam valve module. Acaba, meanwhile, will work between the first and third port segments to install two fluid jumpers, by disconnecting them from the panels they're currently connected to and reconnecting them on new panels. The two spacewalkers then will reunite at the flex hose rotary coupler on P1 to release clamps holding the hoses down. This prepares the coupler, which transfers liquid ammonia across the joints that allow the station's radiators to rotate, to be replaced at a later date.

After that work is complete, Swanson and Acaba will move to the starboard side of the station's truss to prepare a payload attachment system for use on the top of the outboard side of the S3 segment, in a process similar to preparing the unpressurized cargo carrier attachment system for use. Both systems are used to attach equipment to the station's truss.

The final tasks of the spacewalk will be for Swanson to relocate a tool stanchion from the station's zenith truss segment to a worksite on the exterior of the Destiny laboratory, and for Acaba to retrieve a foot restraint on the zenith truss and bring it into the station's airlock.

**EVA-3 Duration: 6 hours, 30 minutes Crew: Arnold and Acaba**

- Crew and Equipment Translation Aid cart relocation
- Dextre thermal cover maintenance/removal
- Robotic arm latching end effector lubrication
- S1/S3 bus bolt controller connector swap
- S3 fluid jumper installation
- S1 flex hose rotary coupler clamp release
- P1 and S0 remote power control module replacement

Arnold and Acaba will begin the mission's third spacewalk by moving one of the station's two Crew and Equipment and Translation Aid – or CETA – carts. The carts were moved to the port side of the station's truss during the previous mission to give the robotic arm's mobile transporter the best possible access to the starboard truss for the installation of the new truss segment and solar arrays. With that work done, one of the carts will be moved back to the station's port side, leaving a cart for use on either side of the truss.

Arnold will prepare the cart to be moved from P1 to S1 by releasing its brakes and wheel bogies. Acaba will carry it to its new home on S1 aboard the station's robotic arm. Arnold then will move to the site and be ready to help Arnold reinstall the cart.

Arnold then will take his turn on the station's robotic arm, which will maneuver him into place to work on the station's special purpose dexterous manipulator – also known as Dextre – on the exterior of the Destiny laboratory. Arnold will be re-securing two thermal covers on Dextre's orbital replacement unit tool changeout mechanism and removing a thermal cover on one of its electrical platforms.

When he's done with that, he'll climb off the robotic arm to lubricate the latching snares on its end effector, the mechanism that allows the arm to hold on to grapple fixtures or equipment. During the previous shuttle mission, the same lubrication was performed on the other end of the robotic arm – the arm has two end effectors, which allows it to move end-over-end to various worksites on the station. The snares have been experiencing some sticky spots that caused kinks in them, and during the previous mission, the lubrication was able to help clear up that problem. Arnold will use a grease gun to apply the lubrication and use needlenose pliers to maneuver the snares.

While Arnold is working on Dextre and the robotic arm, Acaba will perform several tasks on the starboard truss, mirroring some of the work he and Arnold did on the port side of the truss during the second spacewalk. He'll install fluid jumpers between the S1 and S3 truss segments and release clamps on the S1 flex hose rotary coupler. He'll also swap a bolt bus controller connector on the truss' segment-tosegment attach system.

Arnold and Acaba will finish the spacewalk by replacing failed remote power control modules on the S0 and P1 truss segments.

**EVA-4 Duration: 6 hours, 30 minutes Crew: Swanson and Arnold**

- Global Positioning System (GPS) antenna installation
- Z1 patch panel connector swap
- S1/P1 radiator photography
- Wireless Video System installation
- S3 outboard, zenith and inboard, nadir PAS deploy

Swanson and Arnold will work separately for the first half of the mission's final scheduled spacewalk. Swanson will begin by installing a GPS antenna on the exterior of the Japanese logistics module. The antenna will be the second of two to be installed (the first was installed during the STS-126 mission) and will be used to guide the Japanese H-II Transfer Vehicle to the station later in the year. After that, he'll swap connectors on a patch panel on the station's zenith truss segment.

Meanwhile, Arnold will photograph the radiators on the first port and starboard truss segments, using both regular and infrared cameras. In September, ground controllers noticed damage to one panel of the starboard radiator, and the photos will help them determine how the damage is affecting its operation.

After that, Swanson and Arnold will work together. First they'll install a wireless video system external transceiver assembly, or WETA, which supports the transmission of video from spacewalkers' helmet cameras, on the S3 truss segment. To do so, Swanson will remove a dummy box currently in the location, and then attach the WETA to a stanchion. Arnold will connect three cables to the assembly.

Afterward, Swanson and Arnold will prepare two more payload attachment systems on the S3 truss segment – one on the outboard side of the bottom of the segment, and one on the inboard side of the top of the segment. They will use the same process employed during the mission's second spacewalk.

# NASA Mission Priorities

***Editor's note...***
The following mission overview was taken from NASA's STS-119 press kit.

1. Dock Discovery to Pressurized Mating Adapter (PMA)-2 port and perform mandatory safety briefing for all crew members

2. Rotate Expedition 18 Flight Engineer Sandra Magnus with Expedition 18/19 Flight Engineer Koichi Wakata

3. Configure International Space Station for Starboard 6 (S6) truss installation 4. Perform robotic operations in support of S6 unberthing and installation

5. Perform S6 installation and deployment tasks

6. Transfer mandatory quantities of water from Discovery to space station

7. Transfer and stow critical cargo items to station

8. Deploy S6 photovoltaic radiator

9. Configure station, S3/S4, and deploy S6 solar array wings

10. Configure station for post-S6 installation

11. Verify S6 1B and 3B solar array wing positioning capability to support docking and undocking operations for visiting vehicles

12. Relocate Crew and Equipment Translation Aid (CETA) cart

13. Prepare P6 battery for Flight 2J/A

14. Deploy S3 upper outboard Payload Attachment System (PAS)

15. Deploy P3 nadir Unpressurized Cargo Carrier Attachment System (UCCAS) site 16. Transfer remaining cargo items

17. Perform station payload research operations tasks, sortie experiments and short-duration bioastronautics investigations

18. Transfer 25 pounds of oxygen from Discovery to the space station airlock high-pressure gas tank

19. Transfer required nitrogen from Discovery to the station

20. Perform the following EVA tasks:

    - Release S6 Integrated Equipment Assembly (IEA) micrometeoroid orbital debris cover

    - Remove and replace S0-1A-D Remote Power Control Module (RPCM)

    - Remove and replace P1-1A-A RPCM

- Lubricate Canadarm2 latching end-effector B snares

- Retrieve Power and Data Grapple Fixture (PDGF) on P6

- Install stand with PDGF and cable harness on Zarya

- Install Video Signal Conditioner (VSC) and VSC thermal cover. Connect fiber optic cable to VSC and route to S0 Video Switch Unit (VSU)

- Reconfigure Z1 patch panel

- Disconnect P1/P3 Segment-to-Segment Attach System (SSAS) umbilicals and install caps

- Disconnect S1/S3 SSAS umbilicals and install caps. Roll up blanket on the Special Purpose Dexterous Manipulator (SPDM) to cover aluminum ground tabs

- Remove SPDM Electronics Platform 1 thermal cover

- Retrieve Articulating Portable Foot Restraint (APFR) No. 5 and relocate tool stanchion to CETA cart

- Reinstall APFR No. 5

# STS-119: Quick-Look Mission Data

| Position/Age | Astronaut/Flights | Family/TIS | DOB/Seat |
|---|---|---|---|
| **Commander** | AF Col. Lee J. Archambault | M/3 | 08/25/60 |
| 48 | 1: STS-117 | 14.0 * | Up-1/Up-1 |
| **Pilot** | Navy Cmdr. Dominic A. Antonelli | M/2 | 08/23/67 |
| 41 | 0: Rookie | 0.0 | Up-2/Up-2 |
| **MS1/EV3** | Joseph M. Acaba | ?/3 | 05/17/67 |
| 41 | 0: Rookie | 0.0 | Up-3/Up-3 |
| **MS2/FE/EV1** | Steven R. Swanson, Ph.D. | M/3 | 12/03/60 |
| 48 | 1: STS-117 | 14.0 | Up-4/Up-4 |
| **MS3/EV2** | Richard R. Arnold II | M/2 | 11/26/63 |
| 45 | 0: Rookie | 0.0 | Dn-5/Dn-5 |
| **MS4** | John L. Phillips, Ph.D. | M/2 | 04/15/51 |
| 57 | 2: STS-100,ISS-11 | 191.0 | Dn-6/Dn-6 |
| **MS5 (up)** | Koichi Wakata, Ph.D. | M/1 | 08/01/63 |
| 45 | 2: STS-72,92 | 22.0 | Dn-7 (up) |
| | | | |
| **ISS-18 CDR** | AF Col. Michael Fincke | M/3 | 03/14/67 |
| 42 | 2: TMA-4,TMA-13 | 334.0 | N/A |
| **ISS-18 FE1** | RSA Col., Yury Lonchakov | M/1 | 03/04/65 |
| 44 | 3: STS-100; TMA-1; TMA-13 | 169.0 | N/A |
| **FE2/MS5 (dn)** | Sandra Magnus, Ph.D. | S/0 | 10/30/64 |
| 44 | 2: STS-112,126/ISS-18 | 123.3 | Dn-7 (dn) |

| Shuttle Hardware and Flight Data | |
|---|---|
| STS Mission | STS-119 (flight 125) |
| Orbiter | Discovery 36th flight) |
| Payload | P6 solar array |
| Launch | 08:20:10 PM 03.11.09 |
| Pad/MLP | LC-39A/MLP-1 |
| Prime TAL | Zaragoza |
| Landing | 03:27:00 PM 03.25.09 |
| Landing Site | Kennedy Space Center |
| Duration | 13/18:07 |
| | |
| Discovery | 310/08:50:01 |
| STS Program | 1182/16:22:13 |
| MECO Ha/Hp | 135.7 X 35.6 sm |
| OMS Ha/Hp | 141.5 X 120.8 sm |
| ISS | 210 sm |
| Period | 91.6 minutes |
| Inclination | 51.6 |
| Velocity | 17,188 mph |
| EOM Miles | 5,744,666 |
| EOM Orbits | 217 |
| SSMEs | 2048 / 2051 / 2058 |
| SRB | Bi135/RSRM 103 |
| ET | 127 |
| Software | OI-33 |
| Left OMS | LP01/39 |
| Right OMS | RP03/37 |
| Forward RCS | FRC3/36 |
| OBSS | TBD |
| RMS | 202 |
| Cryo/GN2 | 5/6 |
| Spacesuits | TBD |
| Launch WGT | 266,448 (up)/200,986 (dn) |

**STS-119**

**International Space Station**

| Flight Plan | ET |
|---|---|
| Docking | |
| 3/13/09 | 06:27 PM |
| EVA-1 | |
| 3/15/09 | 02:50 PM |
| EVA-2 | |
| 3/17/09 | 02:20 PM |
| EVA-3 | |
| 3/19/09 | 01:20 PM |
| EVA-4 | |
| 3/21/09 | 12:50 PM |
| Undocking | |
| 3/23/09 | 10:23 AM |

| Flight Control Personnel | |
|---|---|
| Mike Leinbach | Launch director |
| Steve Payne | NTD |
| Laurie Sally | OTC |
| Richard Jones | Ascent/Entry |
| Paul Dye | Orbit 1 FD (ld) |
| Mike Sarafin | Orbit 2 FD |
| Norm Knight | Planning |
| Kwatsi Alibaruho | ISS Orbit 1 FD (ld) |
| Heather Rarick | ISS Orbit 2 FD |
| David Korth | ISS Orbit 3 FD |
| Mike Moses | MMT (launch) |
| Candria Thomas | Countdown PAO |
| TBD | Ascent PAO |

| This will be the... | |
|---|---|
| 125th | Shuttle mission |
| 12th | Post-Columbia mission |
| 100th | Post-Challenger mission |
| 36th | Flight of Discovery |
| 94th | Day launch |
| 72nd | Launch off pad 39A |
| 54th | Day launch off pad 39A |
| TBD | 51.6-degree inclination |
| 70th | Planned KSC landing |
| 23rd | Night landing |
| 17th | Night landing at KSC |
| 23.13 | Years since STS-51L |
| 6.11 | Years since STS-107 |

* Ages as of launch date *Days in space as of: 3/7/09

Compiled by William Harwood

# STS-119: 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 | 310/08:50:01 | 35 | STS-124: 05/31/08 |
| Atlantis | 258/07:07:06 | 29 | STS-122: 02/07/08 |
| Endeavour | 150/22:48:22 | 22 | STS-126: 11/14/08 |
| **Total** | **1182/16:22:13** | **124** | * Vehicle lost |

| Launches | LC-39A | LC-39B | Total |
|---|---|---|---|
| Night | 18 | 13 | 31 |
| Daylight | 53 | 40 | 93 |
| Total | 72 | 53 | 124 |
| Most Recent | 11/14/08 | 12/9/06 | |

| Landings | KSC | EAFB | WSSH | Total |
|---|---|---|---|---|
| Night | 16 | 6 | 0 | 22 |
| Daylight | 53 | 46 | 1 | 100 |
| Total | 69 | 52 | 1 | 122 |
| Most Recent | 6/14/08 | 11/30/08 | 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 | TBD | TBD | 3 |

| Demographics | 126 | 119 |
|---|---|---|
| Total Fliers | 489 | 492 |
| Nations | 36 | 36 |
| Male | 439 | 442 |
| Female | 50 | 50 |
| Total Tickets | 1,075 | 1,082 |
| United States | 312 | 315 |
| United States men | 271 | 274 |
| United States Women | 41 | 41 |
| USSR | 72 | 72 |
| USSR Men | 70 | 70 |
| USSR Women | 2 | 2 |
| CIS | 31 | 31 |
| CIS Men | 30 | 30 |
| 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 | 14 | 14 |
| Women/5 | 6 | 6 |
| Men/4 | 57 | 57 |
| Women/4 | 6 | 6 |
| Men/3 | 67 | 69 |
| Women/3 | 6 | 6 |
| All/2 | 129 | 129 |
| All/1 | 196 | 197 |

## 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 |

## 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 |

# STS-119 NASA Crew Thumbnails

| Position/Age | Astronaut/Flights/Education | Fam/TS | DOB/Seat | Home/BKG | Hobbies/notes |
|---|---|---|---|---|---|
| **Commander** | AF Col. Lee J. Archambault | M/3 | 08/25/60 | Oak Park, Ill. | Biking, golf, ice hockey; |
| Age: 48 | 1: STS-117 | 14.0 * | Up-1/Up-1 | AF test pilot | >4,250 hours in 30 aircraft |
| | Master's, aeronautical engineering | | | F-117A/F-111 | ` |
| **Pilot** | Navy Cmdr. Dominic A. Antonelli | M/2 | 08/23/67 | Detroit, Mich. | Snow boarding, NASCAR |
| 41 | 0: Rookie | 0.0 | Up-2/Up-2 | Navy test pilot | >3,200 hours/41 aircraft |
| | Master's, aeronautics and astronautics | | | F/A-18C | 273 carrier landings |
| **MS1/EV3** | Joseph M. Acaba | ?/3 | 05/17/67 | Inglewood, CA | Outdoor activities; camping, |
| 41 | 0: Rookie | 0.0 | Up-3/Up-3 | Teacher | hiking, mountain biking, |
| | Master's, geology | | | Peace Corps | kayaking, scuba diving |
| **MS2/FE/EV1** | Steven R. Swanson, Ph.D. | M/3 | 12/03/60 | Syracuse, NY | Mountain biking, running, |
| 48 | 1: STS-117 | 14.0 | Up-4/Up-4 | STA simulator | basketball, skiing, weights, |
| | Ph.D., computer science | | | Reactor officer | wood working, family |
| **MS3/EV2** | Richard R. Arnold II | M/2 | 11/26/63 | Bowie, MD | Running, fishing, reading, |
| 45 | 0: Rookie | 0.0 | Dn-5/Dn-5 | Teacher | kayaking, biking, guitar, |
| | Master's, marine environmental science | | | Woods Hole | paleontology, ornithology |
| **MS4** | John L. Phillips, Ph.D. | M/2 | 04/15/51 | Scottsdale, AZ | Skiing, swimming, |
| 57 | 2: STS-100,ISS-11 | 191.0 | Dn-6/Dn-6 | Naval Academy | kayaking, hiking and |
| | Ph.D. in space physics, geophysics | | | Los Alamos | family recreation |
| **MS5 (up)** | Koichi Wakata, Ph.D. | M/1 | 08/01/63 | Saitama, Japan | Flying, hang-gliding, |
| 45 | 2: STS-72,92 | 22.0 | Dn-7 (up) | JAL engineer | baseball, tennis, snow |
| | Ph.D., materials science/engineering | | | 2100 hours flying | skiing |
| **ISS-18 CDR** | AF Col. Michael Fincke | M/3 | 03/14/67 | Emsworth, PA | Travel, geology, astronomy, |
| 42 | 2: TMA-4,TMA-13 | 334.1 | N/A | MIT, Stanford | learning languages, |
| | Master's, aeronautics and astronautics | | | AF test engineer | reading |
| **ISS-18 FE1** | RSA Col., Yury Lonchakov | M/1 | 03/04/65 | Balkhash, Russia | Books, tourism, auto- |
| 44 | 3: STS-100; TMA-1; TMA-13 | 169.1 | N/A | Military test pilot | tourism, downhill skiing, |
| | Pilot engineer | | | >1400 hours | sports |
| **FE2/MS5 (dn)** | Sandra Magnus, Ph.D. | S/0 | 10/30/64 | Belleville, Ill. | Soccer, reading, travel, |
| 44 | 2: STS-112,126/ISS-18 | 123.4 | Dn-7 (dn) | Stealth research | water sports |
| | Ph.D., materials science | | | 'Russian Crusader' | |

Acaba Antonelli Phillips Swanson Arnold Archambault Wakata

Wakata Fincke Magnus Lonchakov Chamitoff

*Age, days in space as of: 03/07/09

Compiled by William Harwood

# Current Space Demographics (post STS-126)

| Post STS-126 | |
|---|---|
| **Total Fliers** | 489 |
| Nations | 36 |
| Men | 439 |
| Women | 50 |
| Total Tickets | 1075 |
| | |
| **United States** | 312 |
| US Men | 271 |
| US Women | 41 |
| | |
| **Soviet Union** | 72 |
| USSR Men | 70 |
| USSR Women | 2 |
| **CIS** | 31 |
| CIS Men | 30 |
| 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 | 14 |
| Women with 5 flights | 6 |
| Men with 4 flights | 57 |
| Women with 4 flights | 6 |
| Men with 3 flights | 67 |
| Women with 3 flights | 6 |
| All with 2 flights | 129 |
| All with 1 flight | 196 |
| | |
| **TOTAL** | 489 |
| | |
| **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 | 31 |
| 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 | 312 |
| 36 | USSR | 72 |
| | | |
| | **TOTAL** | 489 |

| Rank | Name | Days/Flts |
|---|---|---|
| **1** | **Sergei Krikalev** | 803/6 |
| 20 | Peggy Whitson | 377/2 |

| ISS Crew | Launch | Land | Duration |
|---|---|---|---|
| ISS-1 | 10/31/00 | 03/18/01 | 136/17:09 |
| | Shepherd | Gidzenko | Krikalev |
| ISS-2 | 03/08/01 | 08/20/01 | 147/16:43 |
| | Usachev | Helms | Voss |
| ISS-3 | 08/10/01 | 12/15/01 | 117/02:56 |
| | Culbertson | Dezhurov | Tyurin |
| ISS-4 | 12/05/01 | 06/15/02 | 181/00:44 |
| | Onufrienko | Bursch | Walz |
| ISS-5 | 06/05/02 | 12/02/02 | 171/03:33 |
| | Korzun | Whitson | Treschev |
| ISS-6 | 11/23/02 | 05/03/03 | 161/01:17 |
| | Bowersox | Budarin | Pettit |
| ISS-7 | 04/25/03 | 10/27/03 | 184/21:47 |
| | Malenchenko | Lu | N/A |
| ISS-8 | 10/18/03 | 04/29/04 | 194/18:35 |
| | Foale | Kaleri | N/A |
| ISS-9 | 04/18/04 | 10/23/04 | 187/21:17 |
| | Padalka | Fincke | N/A |
| ISS-10 | 10/13/04 | 04/24/05 | 192/19:02 |
| | Chiao | Sharipov | N/A |
| ISS-11 | 04/14/05 | 10/10/05 | 179/00:23 |
| | Krikalev | Phillips | N/A |
| ISS-12 | 10/01/05 | 04/08/06 | 189/19:53 |
| | McArthur | Tokarev | N/A |
| ISS-13 | 03/30/06 | 09/28/06 | 182/22:44 |
| | Vinogradov | J Williams | Reiter |
| ISS-14 | 09/18/06 | 04/20/07 | 215/08:23 |
| | Lopez-Alegria | Tyurin | Various |
| ISS-15 | 04/07/07 | 10/21/07 | 196/17:5 |
| | Yurchikhin | Kotov | Various |
| ISS-16 | 10/10/07 | 04/19/08 | 191/19:7 |
| | Whitson | Malenchenko | Various |
| ISS-17 | 04/08/08 | 10/24/08 | 198/16:20 |
| | Volkov | Kononenko | Various |
| ISS-18 | 10/12/08 | TBD | TBD |
| | Fincke | Lonchakov | Various |

# Projected Space Demographics (post STS-119)

| Post STS-119 | |
|---|---|
| **Total Fliers** | **492** |
| Nations | 36 |
| Men | 442 |
| Women | 50 |
| Total Tickets | 1082 |
| | |
| **United States** | **315** |
| US Men | 274 |
| US Women | 41 |
| | |
| **Soviet Union** | **72** |
| USSR Men | 70 |
| USSR Women | 2 |
| **CIS** | **31** |
| CIS Men | 30 |
| 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 | 14 |
| Women with 5 flights | 6 |
| Men with 4 flights | 57 |
| Women with 4 flights | 6 |
| Men with 3 flights | 69 |
| Women with 3 flights | 6 |
| All with 2 flights | 129 |
| All with 1 flight | 197 |
| | |
| **TOTAL** | **492** |
| | |
| **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 | 31 |
| 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 | 315 |
| 36 | USSR | 72 |
| | | |
| | **TOTAL** | **492** |

| Rank | Name | Days/Flts |
|---|---|---|
| **1** | **Sergei Krikalev** | 803/6 |
| 20 | Peggy Whitson | 377/2 |

| ISS Crew | Launch | Land | Duration |
|---|---|---|---|
| ISS-1 | 10/31/00 | 03/18/01 | 136/17:09 |
| | Shepherd | Gidzenko | Krikalev |
| ISS-2 | 03/08/01 | 08/20/01 | 147/16:43 |
| | Usachev | Helms | Voss |
| ISS-3 | 08/10/01 | 12/15/01 | 117/02:56 |
| | Culbertson | Dezhurov | Tyurin |
| ISS-4 | 12/05/01 | 06/15/02 | 181/00:44 |
| | Onufrienko | Bursch | Walz |
| ISS-5 | 06/05/02 | 12/02/02 | 171/03:33 |
| | Korzun | Whitson | Treschev |
| ISS-6 | 11/23/02 | 05/03/03 | 161/01:17 |
| | Bowersox | Budarin | Pettit |
| ISS-7 | 04/25/03 | 10/27/03 | 184/21:47 |
| | Malenchenko | Lu | N/A |
| ISS-8 | 10/18/03 | 04/29/04 | 194/18:35 |
| | Foale | Kaleri | N/A |
| ISS-9 | 04/18/04 | 10/23/04 | 187/21:17 |
| | Padalka | Fincke | N/A |
| ISS-10 | 10/13/04 | 04/24/05 | 192/19:02 |
| | Chiao | Sharipov | N/A |
| ISS-11 | 04/14/05 | 10/10/05 | 179/00:23 |
| | Krikalev | Phillips | N/A |
| ISS-12 | 10/01/05 | 04/08/06 | 189/19:53 |
| | McArthur | Tokarev | N/A |
| ISS-13 | 03/30/06 | 09/28/06 | 182/22:44 |
| | Vinogradov | J Williams | Reiter |
| ISS-14 | 09/18/06 | 04/20/07 | 215/08:23 |
| | Lopez-Alegria | Tyurin | Various |
| ISS-15 | 04/07/07 | 10/21/07 | 196/17:5 |
| | Yurchikhin | Kotov | Various |
| ISS-16 | 10/10/07 | 04/19/08 | 191/19:7 |
| | Whitson | Malenchenko | Various |
| ISS-17 | 04/08/08 | 10/24/08 | 198/16:20 |
| | Volkov | Kononenko | Various |
| ISS-18 | 10/12/08 | TBD | TBD |
| | Fincke | Lonchakov | Various |

# 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-119/ISS-18 NASA Crew Biographies

## 1. STS-119 Commander: Air Force Col. Lee J. Archambault, 48

**PERSONAL DATA**: Born August 25, 19 60 in Oak Park, Illinois, but considers Bellwood, Illinois to be his hometown. Married to the former Kelly Renee Raup. They have three children. Recreational interests include bicycling, weightlifting, golf, and ice hockey. His parents, Lee and Mary Ann Archambault, reside in Addison, Illinois. Her parents, Linda Post and Henry Raup reside in Royal, Illinois and Tavares, Florida, respectively.

**EDUCATION**: Graduated from Proviso West High School, Hillside, Illinois in 1978. Earned Bachelor of Science and Master of Science degrees in Aeronautical/ Astronautical Engineering from the University of Illinois-Urbana, in 1982 and 1984, respectively.

**ORGANIZATIONS**: Order of Daedalians (fraternity of military pilots), University of Illinois Alumni Association, University of Illinois Aeronautical/Astronautical Engineering Department Academic Advisory Committee.

**AWARDS**: Military decorations include the Distinguished Flying Cross, Meritorious Service Medal (2 nd Oak Leaf Cluster), Air Medal (2 nd Oak Leaf Cluster), Aerial Achievement Medal (4 th Oak Leaf Cluster), Commendation Medal (1 st Oak Leaf Cluster), Air Force Achievement Medal, Combat Readiness Medal, Southwest Asia Service Medal, Kuwaiti Liberation Medal, and various other service awards.

**SPECIAL HONORS:** Distinguished Graduate and Liethen-Tittle Award (top graduate) from the U.S. Air Force Test Pilot School. Distinguished Graduate from the U.S. Air Force Officer Training School. Graduated with Honors from the University of Illinois. University of Illinois Aeronautical/Astronautical Engineering Outstanding Recent Alumnus. Proviso West High School Hall of Fame inductee.

**EXPERIENCE**: Archambault received his commission as a Second Lieutenant in the United States Air Force from the Air Force Officer Training School at Lackland Air Force Base (AFB), Texas, in January 1985. Upon completion, he attended the Euro-Nato Joint Jet Pilot Training Program at Sheppard AFB, Texas, and earned his pilot wings in April 1986. He then reported to Cannon AFB, New Mexico, where he served as a combat ready F-111D pilot in the 27 th Tactical Fighter Wing until April 1990. In May 1990, he transitioned to the F-117A Stealth Fighter in the 37 th Tactical Fighter Wing at Nellis AFB/Tonopah Test Range, Nevada. From November 1990 through April 1991, he deployed to Saudi Arabia in support of Operation Desert Shield/Desert Storm and flew twenty-two combat missions in the F-117A during the Gulf War. He served a second F-117A tour in Saudi Arabia from August 1991 through December 1991 in support of post-Desert Storm peacekeeping efforts. In August 1992, Archambault was reassigned to Holloman AFB, New Mexico, where he served as an F-117A instructor pilot and operational test pilot for the 57 th Wing. Archambault attended the U.S. Air Force Test Pilot School at Edwards AFB, California, from July 1994 until June 1995. In July 1995, he was assigned to the 46 th Test Wing at the Air Force Development Test Center, Eglin AFB, Florida. There, he performed weapons developmental flight tests in all models of the F-16. Archambault was the assistant operations officer for the 39 th Flight Test Squadron when he was selected for the astronaut program.

He has logged over 4250 flight hours in more than 30 different aircraft.

**NASA EXPERIENCE**: Selected as a pilot by NASA in June 1998, he reported for training in August 1998. Astronaut Candidate 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. In June 1999, Archambault was assigned to the Astronaut Office Shuttle Operations Branch, where he worked on flight instrument upgrades that were incorporated into the Shuttle in 2003. In September 2001, he was assigned within the Shuttle Branch to serve as an Astronaut Support Person supporting launch and landing operations at the Kennedy Space Center, and was the lead in this role for STS-111 and STS-114. In October 2004, he was assigned as CAPCOM.

Archambault was the pilot on STS-117 (June 8-22, 2007) and has logged a total of 14 days in space. Archambault is assigned to command the STS-119 mission, targeted for launch in February 2009. The flight will deliver the final pair of power-generating solar array wings and truss element to the International Space Station.

**SPACE FLIGHT EXPERIENCE**: STS-117 Atlantis (June 8-22, 2007) was the 118 th Shuttle mission and the 21st mission to visit the international Space Station. The successful construction and repair mission involved multiple EVAs by 5 astronauts. 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.

**NOVEMBER 2008**

## 2. STS-119 Pilot: Navy Cmdr. Dominic A. Antonelli, 41

**PERSONAL DATA**: Born in Detroit, Michigan. Raised in Indiana and North Carolina. Married with two children. Interests include snow boarding and NASCAR.

**EDUCATION**: Graduated from Douglas Byrd High School, Fayetteville, North Carolina; B.S., Aeronautics & Astronautics, Massachusetts Institute of Technology; M.S., Aeronautics & Astronautics, University of Washington.

**SPECIAL HONORS**: Navy Commendation Medal, Navy Achievement Medals (2), Unit Battle Efficiency Awards (2), CVW-9 Landing Signal Officer of the Year, NASA Return-to-Flight Award, NASA Superior Accomplishment Award, NASA Exceptional Achievement Medal and various service awards.

**EXPERIENCE**: Antonelli served as a fleet Naval Aviator and Landing Signal Officer aboard the aircraft carrier USS Nimitz with the Blue Diamonds, Strike Fighter Squadron 146, flying F/A-18C Hornets in support of Operation Southern Watch.

Antonelli has accumulated over 3,200 hours in 41 different kinds of aircraft and has completed 273 carrier arrested landings. He is a Distinguished Graduate of the U.S. Air Force Test Pilot School (Navy Exchange Pilot).

**NASA EXPERIENCE**: Selected as a pilot by NASA in July 2000, Antonelli served in various technical assignments until his assignment to space flight. He is assigned as pilot on the STS-119 mission, targeted for launch in February 2009. The flight will deliver the final pair of power-generating solar array wings and truss element to the International Space Station.

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## 3. STS-119 MS-1/EV-3: Joseph M. Acaba, 41

**PERSONAL DATA**: Born in 1967 in Inglewood, California and raised in Anaheim, California where his parents Ralph and Elsie still reside. Enjoys outdoor activities such as camping, hiking, mountain biking, kayaking, and scuba diving. Also enjoys reading, especially science fiction.

**EDUCATION**: Esperanza High School, Anaheim, California, 1985

B.S., Geology, University of California-Santa Barbara, 1990

M.S., Geology, University of Arizona, 1992

**ORGANIZATIONS**: International Technology Education Association and Florida Association of Science Teachers.

**EXPERIENCE**: Unites States Marine Corps, Reserves. Worked as a hydro-geologist in Los Angeles, California. Primarily worked on Superfund sites and was involved the assessment and remediation of groundwater contaminants. Spent 2 years in the United States Peace Corps as an Environmental Education Awareness Promoter in the Dominican Republic. Served as the Island Manager of the Caribbean Marine Research Center at Lee Stocking Island in the Exumas, Bahamas. Shoreline Revegetation Coordinator in Vero Beach, Florida, planning, designing, and implementing a mangrove revegetation project. One year of high school experience at Melbourne High School, Florida and four years of middle school experience as a math and science teacher at Dunnellon Middle School, Florida.

**NASA EXPERIENC**E: Selected as a Mission Specialist 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. Upon completion of his training, Acaba was assigned to the Hardware Integration Team in the Space Station Branch working technical issues with European Space Agency ( ESA) hardware. Currently he is assigned as a mission specialist on the STS-119 mission, targeted for launch in February 2009. The flight will deliver the final pair of power-generating solar array wings and truss element to the International Space Station.

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## 4. STS-119 MS-2/FE/EV-1: Steven R. Swanson, Ph.D., 48

**PERSONAL DATA**: Born in Syracuse, New York, but considers Steamboat Springs, Colorado to be his hometown. Married to the former Mary Drake Young of Steamboat Springs, Colorado. They have three children. He enjoys mountain biking, basketball, skiing, weight lifting, trail running, woodworking and spending time with his family. His parents, Stanley and June Swanson, reside in Boise, Idaho. Her parents, Chan and Martha Young, reside in Steamboat Springs, Colorado.

**EDUCATION**: Graduated from Steamboat Springs High School in Steamboat Springs, Colorado, in 1979; received a bachelor of science degree in engineering physics from the University of Colorado in 1983, and a master of applied science in computer systems from Florida Atlantic University in 1986, and a doctorate in computer science from Texas A&M University in 1998.

**SPECIAL HONORS**: Recipient of the NASA Exceptional Achievement Medal, the JSC Certificate of Accommodation, Flight Simulation Engineering Award, and Phi Kappa Phi Honor Society

**EXPERIENCE**: Prior to coming to NASA, Steve worked for GTE in Phoenix, Arizona as a software engineer working on the real-time software of telephone system multiplexer/demultiplexers.

**NASA EXPERIENCE**: In 1987, Steve joined NASA as a systems engineer in the Aircraft Operations Division of JSC working on the Shuttle Training Aircraft. The Shuttle Training Aircraft (STA) is a complex airborne shuttle simulator, which models the flight characteristics of the Shuttle from 35,000 ft. to main gear touchdown. In 1989, Steve also became a flight simulation engineer on the STA. During his time with the STA, Steve worked on the improvement of the STA's navigation and control systems and the incorporation of a real-time wind determination algorithm.

In May of 1998, Steve was selected as mission specialist and started training in August of 1998. After completing Astronaut Candidate training, which included intensive instruction in Shuttle and International Space Station systems, Steve was assigned to the Astronaut Office Space Station Operations Branch. Steve has also worked in the Astronaut Office Robotics Branch and as a CAPCOM (spacecraft communicator) for ISS and Shuttle missions. He also completed the advance training for EVA, the Shuttle and ISS robotic arms, and Shuttle rendezvous. In 2007 Steve flew on STS-117 logging 336 hours in space including almost 14 EVA hours. He is currently assigned as a mission specialist on the STS-119 mission, targeted for launch in February 2009. The flight will deliver the final pair of power-generating solar array wings and truss element to the International Space Station.

**SPACE FLIGHT EXPERIENCE**: STS-117 Atlantis (June 8-22, 2007) was the 118 th 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 of astronauts. Steve accumulated 13 hours and 37 minutes of EVA in 2 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.

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## 5. STS-119 MS-3/EV-2: Richard R. Arnold II, 45

**PERSONAL DATA**: Born in Cheverly and raised in Bowie, Maryland. Married to Eloise Miller Arnold of Bowie, Maryland. They have two daughters. Enjoys running, fishing, reading, kayaking, bicycling, ornithology, paleontology and guitar.

**EDUCATION**: B.S., Frostburg State University, Maryland, 1985. Completed teacher certification program at Frostburg State University, Maryland, 1988. M.S., Marine, Estuarine & Environmental Science, University of Maryland, 1992.

**ORGANIZATIONS**: National Science Teachers Association, International Technology Education Association, and the National Council of Teachers of Mathematics.

**SPECIAL HONORS**: Recipient of various grants for extended studies in marine science.

**EXPERIENCE**: Arnold began working at the United States Naval Academy in 1987 as an Oceanographic Technician. Upon completing his teacher certification program, he accepted a position as a science teacher at John Hanson Middle School in Waldorf, Maryland. During his tenure, he completed a Masters program while conducting research in biostratigraphy at the Horn Point Environmental Laboratory in Cambridge, Maryland. Upon martriculation, Arnold spent another year working in the Marine Sciences including time at the Cape Cod National Seashore and aboard a sail training/oceanographic vessel headquartered in Woods Hole, Massachusetts. In 1993, Arnold joined the faculty at the Casablanca American School in Casablanca, Morocco, teaching college prepatory Biology and Marine Environmental Science. During that time, he began presenting workshops at various international education conferences focusing on science teaching methodologies. In 1996, he and his family moved to Riyadh, Saudi Arabia, where he was employed as a middle and high school science teacher and Science Department Chair at the American International School. In 2001, Arnold was hired by International School Services to teach middle school mathematics and science at the International School of Kuala Kencana in West Papua, Indonesia. In 2003, he accepted a similar teaching position at the American International School of Bucharest in Bucharest, Romania.

**NASA EXPERIENCE**: Selected as a Mission Specialist 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. Upon completion of his training, Arnold was assigned to the Hardware Integration Team in the Space Station Branch working technical issues with JAXA hardware. In August 2007, he completed aquanaut training and served as a mission specialist on a joint NASA-NOAA-NEEMO NASA Extreme Environment Mission where he lived and worked in and around Aquarius - the world's only undersea laboratory. During the 10 day mission, the crew of NEEMO XIII conducted experiments and operations in a simulated lunar outpost in support of our nation's visions for a return to Moon and the future exploration of Mars. Currently he is assigned as a mission specialist to the STS-119 mission, targeted for launch February 2009. The flight will deliver the final pair of power-generating solar array wings and truss element to the International Space Station.

**NOVEMBER 2008**

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## 6. STS-119 MS-4: John L. Phillips, Ph.D., 57

**PERSONAL DATA**: Born April 15, 1951 in Fort Belvoir, Virginia, but considers Scottsdale, Arizona to be his hometown. Married to the former Laura Jean Doell of Scotia, New York. They have two children. Enjoys skiing, swimming, kayaking, hiking, and family recreation.

**EDUCATION**: Graduated from Scottsdale High School, Scottsdale, Arizona, in 1966; received a bachelor of science degree in mathematics and Russian from the U.S. Naval Academy in 1972; a master of science degree in aeronautical systems from the University of West Florida in 1974; a master of science degree and a doctorate in geophysics and space physics from the University of California, Los Angeles (UCLA) in 1984 and 1987 respectively.

**SPECIAL HONORS**: National Merit Scholar; graduated second of 906 in the class of 1972 at U.S. Naval Academy; awarded the NASA Space Flight Medal, NASA Distinguished Service Medal, the Gagarin Medal, the Komarov Diploma, the Los Alamos National Laboratory Distinguished Performance Award, and various military awards.

**EXPERIENCE**: Phillips received a navy commission upon graduation from the U.S. Naval Academy in 1972 and was designated a Naval Aviator in November 1974. He trained in the A-7 Corsair Aircraft and made overseas deployments with Attack Squadron 155 aboard the USS Oriskany and USS Roosevelt. Subsequent tours of duty included navy recruiting in Albany, New York, and flying the CT-39 Sabreliner Aircraft at Naval Air Station North Island, California.

After leaving the Navy in 1982, Phillips enrolled as a graduate student at UCLA. While at UCLA he carried out research involving observations by the NASA Pioneer Venus Spacecraft. Upon completing his doctorate in 1987, he was awarded an Oppenheimer Postdoctoral Fellowship at Los Alamos National Laboratory in New Mexico. He accepted a career position at Los Alamos in 1989. While there, Phillips performed research on the sun and the space environment. From 1993 through 1996 he was Principal Investigator for the Solar Wind Plasma Experiment aboard the Ulysses Spacecraft as it executed a unique trajectory over the poles of the sun. He has authored 156 scientific papers dealing with the plasma environments of the sun, earth, other planets, comets and spacecraft.

Phillips has logged over 4,400 flight hours and 250 carrier landings. He served as a Navy reservist from 1982 to 2002, as an A-7 pilot and in various non-flying assignments. He retired in 2002 with the rank of Captain, USNR.

**NASA EXPERIENCE**: Selected by NASA in April 1996, Phillips reported to the Johnson Space Center in August 1996. After completing astronaut candidate training, he held various jobs in the Astronaut Office, including systems engineering and CAPCOM for the International Space Station, as well as the Robotics Branch of the Astronaut Office, supporting robotic operations on present and future missions. .He flew aboard STS-100 in 2001, logging nearly 12 days and 5 million miles in space. He served as a backup to ISS Expedition-7, completing that assignment in February 2003. He served a six-month tour of duty aboard the International Space Station in 2005. Twice flown, Phillips has logged over 190 days in space. He is currently assigned as a mission specialist on the STS-119 mission, targeted for launch in February 2009. The flight will deliver the final pair of power-generating solar array wings and truss element to the International Space Station.

**SPACE FLIGHT EXPERIENCE**: STS-100 Endeavour (April 19 to May 1, 2001). During the 12-day, 187 orbit mission, the crew successfully delivered and installed the Canadarm-2 Robotic Arm. They also delivered experiments and supplies aboard the Multi-Purpose Logistics Module Raffaello on its maiden flight. Phillips was the Ascent/Entry Flight engineer and was the intravehicular activity coordinator during two space walks.

Phillips was the NASA Science Officer and Flight Engineer on ISS Expedition-11 which launched from the Baikonur Cosmodrome in Kazakhstan on April 14, 2005 aboard Soyuz TMA-6 and docked with the ISS on April 16, 2005. During their six-month stay aboard the station the crew continued station maintenance, worked with scientific experiments, performed a spacewalk in Russian spacesuits from the Pirs Airlock, and hosted the "return to flight" visit of the Space Shuttle Discovery ( STS-114). The Expedition-11 crew landed in Kazakhstan on October 10, 2005. In completing his second mission Phillips logged 179 days and 23 minutes in space including an EVA totaling 4 hours and 58 minutes.

**NOVEMBER 2008**

## 7. STS-119 MS-5/ISS-18 FE-2 (launch): Koichi Wakata, Ph.D., 45

**PERSONAL DATA**: Born in 1963, in Saitama, Japan. Married and has one child. Enjoys flying, hang-gliding, baseball, tennis, and snow skiing.

**EDUCATION**: Graduated from Urawa High School, Saitama, in 1982; received a Bachelor of Science degree in Aeronautical Engineering in 1987, a Master of Science degree in Applied Mechanics in 1989, and a Doctorate in Aerospace Engineering in 2004, all from Kyushu University.

**ORGANIZATIONS**: Member of the Japan Society for Aeronautical and Space Sciences, the American Institute of Aeronautics and Astronautics, the Robotics Society of Japan, and the Japanese Society for Biological Sciences in Space.

**SPECIAL HONORS**: Minister of State for Science and Technology Commendation (1996). Special awards from Saitama Prefecture and Omiya City (1996). National Space Development Agency of Japan Outstanding Service Award (1996). Diplome pilote-cosmonaute de l' URSS V.M. Komarov (1997, 2001). NASA Exceptional Service Medal (2001). Japan Society for Biological Sciences in Space Distinguished Service Award (2001). Foreign Minister's Certificate of Commendation (2004).

**EXPERIENCE**: Dr. Wakata joined Japan Airlines (JAL) in April 1989. He was assigned to the Base Maintenance Department, Narita, Chiba, where he was designated as a structural engineer. From July 1991 to May 1992, he was assigned to the Airframe Group, Systems Engineering Office, Engineering Department of JAL. During his tenure with JAL, Dr. Wakata was involved in multiple research and engineering projects in the fields of structural integrity of transport aircraft, fatigue fracture, corrosion prevention, and the environmental effects on fuselage polished aluminum skin on B-747 aircraft. He was selected as an astronaut candidate by the National Space Development Agency of Japan (NASDA) in June 1992. A multi-engine and instrument rated pilot, Dr. Wakata has logged over 2100 hours in a variety of aircraft.

**NASA/JAXA EXPERIENCE**: Dr. Wakata reported to the Johnson Space Center in August 1992. He completed one year of training and was qualified for assignment as a Mission Specialist on the Space Shuttle. Dr. Wakata's technical assignments to date include: payload science support for the Astronaut Office Mission Development Branch (April 1993 to February 1995), Space Shuttle flight software verification testing in the Shuttle Avionics Integration Laboratory (SAIL) (April to October 1994), Space Shuttle and Space Station Robotics for the Astronaut Office Robotics Branch (March 1996 to July 2006), and Extravehicular Activities (EVA) development for the Astronaut Office EVA Branch (May 2001 to April 2006). During the STS-85 mission (August 7-19, 1997), Dr. Wakata was the NASDA Assistant Payload Operations Director for the Manipulator Flight Demonstration, a robotic arm experiment for the Japanese Experiment Module of the International Space Station (ISS). He operated the robotic arm system on NASDA's Engineering Test Satellite VII in the tele-operation robotics experiments in 1999. Since December 2000, h e has been a NASA robotics instructor astronaut. Dr. Wakata has been training for a long-duration expedition on the ISS since October 2001. In July 2006, he served as the commander of the 10 th NASA Extreme Environment Mission Operations (NEEMO) mission, a seven-day undersea expedition at the National Oceanic & Atmospheric Administration's Aquarius habitat located off the coast of Florida. In August 2006, he started flight engineer training for Russian Soyuz spacecraft. In February 2007, Dr. Wakata was assigned as a flight engineer to ISS Expedition 18. He will launch with the crew of STS-119 and will become the first resident station crew member from the Japanese Aerospace Exploration Agency (JAXA). He will return to Earth with the crew of STS-127.

**SPACE FLIGHT EXPERIENCE**: STS-72, Endeavour (January 11-20, 1996): Dr. Wakata flew as the first Japanese Mission Specialist on this 9-day mission during which the six-member crew retrieved the Space Flyer Unit (launched from Japan ten months earlier), deployed and retrieved the OAST-Flyer, and conducted two spacewalks to demonstrate and evaluate techniques to be used in the assembly of the International Space Station. The STS-72 mission was completed in 142 orbits, traveling 3.7 million miles in 8 days, 22 hours, and 40 seconds.

STS -92, Discovery (October 11-24, 2000): Dr. Wakata became the first Japanese astronaut to work on the ISS assembly on this 13-day mission during which the seven-member crew attached the Z1 Truss and Pressurized Mating Adapter 3 to the ISS using Discovery's robotic arm and performed four space walks to configure these elements. This expansion of the ISS opened the door for future assembly missions and prepared the station for its first resident crew. The STS-92 mission was accomplished in 202 orbits, traveling 5.3 million miles in 12 days, 21 hours, 40 minutes, and 25 seconds.

Dr. Wakata has logged a total of 21 days, 19 hours, 41 minutes, and 5 seconds in space.

**NOVEMBER 2008**

## 8. ISS-18 Commander: Michael Fincke

**PERSONAL DATA**: Born March 14, 1967 in Pittsburgh, Pennsylvania, but considers Emsworth, Pennsylvania to be his hometown. Married to the former Renita Saikia of Houston, Texas. They have three children. In addition to time with his family, Mike enjoys travel, Geology, Astronomy, learning new languages, and reading. He is conversant in Japanese and Russian. His parents, Edward and Alma Fincke reside in Emsworth, Pennsylvania. Renita's parents, Rupesh and Probha Saikia formerly of Assam, India reside in Houston, Texas.

**EDUCATION**: Graduated from Sewickley Academy, Sewickley, Pennsylvania in 1985. He attended the Massachusetts Institute of Technology (MIT) on an Air Force ROTC scholarship and graduated in 1989 with a bachelor of science in Aeronautics and Astronautics as well as a bachelor of science in Earth, Atmospheric and Planetary Sciences. This was followed by a master of science in Aeronautics and Astronautics from Stanford University in 1990. He was awarded associates of science degree in Earth Sciences (Geology) from El Camino College in Torrance, California in 1993 and then a second master of science in Physical Sciences (Planetary Geology) from the University of Houston, Clear Lake in 2001.

**ORGANIZATIONS**: Geological Society of America (GSA), British Interplanetary Society.

**SPECIAL HONORS**: In addition to a NASA Distinguished Service Medal and a NASA Spaceflight Medal, Colonel Fincke is a recipient of the first ISS Leadership Award as well as a United States Air Force Meritorious Service Medal, three Commendation Medals, two Achievement Medals, and various unit and service awards. He is a Distinguished Graduate from the United States Air Force ROTC, Squadron Officer School, and Test Pilot School Programs and the recipient of the United States Air Force Test Pilot School Colonel Ray Jones Award as the top Flight Test Engineer/ Flight Test Navigator in class 93B.

**EXPERIENCE**: Colonel Mike Fincke graduated from MIT in 1989, and immediately attended a summer exchange program with the Moscow Aviation Institute in the former Soviet Union, where he studied Cosmonautics. Upon graduation from Stanford University in 1990, he entered the United States Air Force. After "washing-out" of pilot training in 1991, he was reassigned to the Air Force Space and Missiles Systems Center, Los Angeles Air Force Base, California. There he served as a Space Systems Engineer and a Space Test Engineer. In 1994, upon completion of the United States Air Force Test Pilot School Flight Test Engineer Program, Edwards Air Force Base, California, he joined the 39th Flight Test Squadron, Eglin Air Force Base, Florida, where he served as a Flight Test Engineer working on a variety of flight test programs, flying in F-16 and F-15 aircraft. In January of 1996, he reported to the Gifu Test Center, Gifu Air Base, Japan where he was the United States Flight Test Liaison to the Japanese/United States XF-2 fighter program. Colonel Fincke has over 825 flight hours in more than 30 different aircraft types.

**NASA EXPERIENCE**: Selected by NASA in April 1996, Colonel Fincke reported to the Johnson Space Center in August 1996. Having completed two years of training and evaluation, he was assigned technical duties in the Astronaut Office Station Operations Branch serving as an International Space Station Spacecraft Communicator (ISS CAPCOM), a member of the Crew Test Support Team in Russia and as the ISS crew procedures team lead. He also served as back-up crewmember for ISS Expedition-4 and Expedition-6 and is qualified to fly as a left-seat Flight Engineer (co-pilot) on the Russian Soyuz TM and TMA spacecraft. He was the Commander of the second NASA Extreme Environment Mission Operations (NEEMO 2) mission living and working underwater for 7 days in May of 2002.

Having served as the back-up Commander for ISS Expeditions -13 and -16, Colonel Fincke has been named to lead the Expedition-18 crew, starting with a Soyuz launch in October 2008 and supplemented by several Shuttle launches in 2008 and 2009.

**SPACE FLIGHT EXPERIENCE**: ISS Expedition-9 (April 18 to Oct 23, 2004). Expedition-9 was launched from the Baikonur Cosmodrome, Kazakhstan aboard the Soyuz TMA-4 spacecraft, docking with the International Space Station on April 21, 2004. As the NASA Space Station science officer and flight engineer, Colonel Fincke spent six-months aboard the ISS continuing ISS science operations, maintaining Station systems, and performing four spacewalks. The Expedition-9 mission concluded with undocking from the station and safe landing back in Kazakhstan on October 23, 2004. Colonel Fincke completed his first mission in 187 days, 21 hours and 17 minutes, and logged a total of 15 hours, 45 minutes and 22 seconds of EVA time in four spacewalks.

**APRIL 2008**

## 9. ISS-18 FE-1: Yury Lonchakov

**PERSONAL DATA**: Born March 4, 1965, in Balkhash, Dzhezkazkansk Region. His parents, Lonchakov Valentin Gavrilovich and Galina Vasilyevna, reside in Aktyubinsk, Kazakhstan. He is married to Lonchakova (Dolmatova) Tatyana Alexeevna. They have one son. His hobbies include books, tourism, auto-tourism, downhill skiing, sport games.

**EDUCATION**: In 1982 Lonchakov finished high school in Aktyubinsk and entered the Orenburg Air Force Pilot School from which he graduated with honors in 1986 as pilot-engineer. In 1995 Lonchakov entered the Zhukovski Air Force Academy from which he graduated with honors in 1998 as pilot-engineer-researcher.

**EXPERIENCE**: After graduation from the pilot school he served as a second crew commander, crew commander, squadron senior pilot, aviation brigade commander in the Navy. He flew Yak-52, L-39, Su-24, A-50, L-29, Tu-134 and Tu-16 aircraft.

Lonchakov has logged over 1400 hours of flight time. He is a Class 1 Air Force pilot. He is a paratroop training instructor and has made 526 jumps.

Lonchakov was selected as a test-cosmonaut candidate of the Gagarin Cosmonaut Training Center Cosmonaut Office in December of 1997. Over two space flight missions he has logged 22 days, 16 hours and 23 minutes in space.

**SPACE FLIGHT EXPERIENCE**: STS-100 Endeavour (April 19 to May 1, 2001) was the 9th mission to the International Space Station during which the crew successfully delivered and installed the Canadarm2 Robotic Arm supplied by the Canadian Space Agency. They also delivered more than 6,000 pounds of supplies and equipment from the Italian-built Raffaello Multi-Purpose Logistics Module. In completing his first space flight, Lonchakov traveled 4.9 million miles in 186 Earth orbits, logging 283 hours and 30 minutes in space.

Soyuz TMA-1 (October 30 to November 10, 2002) was delivered to the International Space Station by Cosmonauts Sergei Zaletin and Lonchakov along with European Space Agency astronaut Frank De Winne. They returned on the Soyuz TM-34 at the end of the Soyuz taxi flight. Lonchakov logged 10 days, 20 hours and 53 minutes in space.

In October 2008, Lonchakov will command a Soyuz spacecraft that will launch Expedition 18 to the International Space Station. NASA astronaut and Expedition 18 commander E. Michael Fincke and American spaceflight participant Richard Garriott will fly with Lonchakov. Garriott will return to Earth with the Expedition 17 crew. Lonchakov and Fincke are scheduled to return in March 2009.

**JULY 2008**

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## 10. ISS-18 FE-2/STS-119 MS-5 (entry): Sandra Magnus, Ph.D., 44

**PERSONAL DATA**: Born October 30, 1964 in Belleville, Illinois. Enjoys soccer, reading, travel, water activities.

**EDUCATION**: Graduated from Belleville West High School, Belleville, Illinois, in 1982; received a bachelor degree in physics and a master degree in electrical engineering from the University of Missouri-Rolla in 1986 and 1990, respectively, and a doctorate from the School of Material Science and Engineering at the Georgia Institute of Technology in 1996.

**ORGANIZATIONS**: ASM/ TMS (Metallurgical/Material Society), AAAS.

**SPECIAL HONORS**: Outstanding Graduate Teaching Assistant Award (1994 and 1996), Saturn Team Award (1994), Performance Bonus Award (1989), NASA Space Flight Medal (2002).

**EXPERIENCE**: During 1986 to 1991, Magnus worked for McDonnell Douglas Aircraft Company as a stealth engineer where she worked on internal research and development studying the effectiveness of RADAR signature reduction techniques. She was also assigned to the Navy's A-12 Attack Aircraft program primarily working on the propulsion system until the program was cancelled. From 1991 to 1996, Magnus completed her thesis work which was supported by NASA-Lewis Research Center through a Graduate Student Fellowship and involved investigations on materials of interest for "Scandate" thermionic cathodes.

**NASA EXPERIENCE**: Selected by NASA in April 1996, Dr. Magnus reported to the Johnson Space Center in August 1996. She completed two years of training and evaluation and is qualified for flight assignment as a mission specialist. From January 1997 through May 1998 Dr. Magnus worked in the Astronaut Office Payloads/Habitability Branch. Her duties involved working with ESA, NASDA and Brazil on science freezers, glove boxes and other facility type payloads. In May 1998, Dr. Magnus was assigned as a "Russian Crusader" which involved traveling to Russia in support of hardware testing and operational products development. In August 2000, she served as a CAPCOM for the International Space Station. In August 2001, she was assigned to STS-112. In October 2002, Dr. Magnus flew aboard STS-112. In completing her first space flight she logged a total of 10 days, 19 hours, and 58 minutes in space. Following STS-112, Dr. Magnus was assigned to work with the Canadian Space Agency to prepare the Special Dexterous Manipulator robot for installation on the ISS. She was also involved in return to flight activities. In July 2005, Dr. Magnus was assigned to the ISS Expedition Corps to begin training for a future space station long duration mission. Currently she is assigned to serve aboard the International Space Station as a flight engineer and NASA science officer on Expedition 18. She will fly to the station with the crew of STS-119, targeted for launch in November 2008, and return to Earth with the crew of STS-119.

**SPACE FLIGHT EXPERIEN**CE: STS-112 Atlantis (October 7-18, 2002) launched from and returned to land at the Kennedy Space Center, Florida. STS-112 was an International Space Station assembly mission during which the crew conducted joint operations with the Expedition-5 by delivering and installing the S-One Truss (the third piece of the station's 11-piece Integrated Truss Structure). Dr. Magnus operated the space station's robotic arm during the three spacewalks required to outfit and activate the new component. The crew also transferred cargo between the two vehicles and used the shuttle's thruster jets during two maneuvers to raise the station's orbit. STS-112 was the first shuttle mission to use a camera on the External Tank, providing a live view of the launch to flight controllers and NASA TV viewers. The mission was accomplished in 170 orbits, traveling 4.5 million miles in 10 days, 19 hours, and 58 minutes.

**JUNE 2008**

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# STS-119 Crew Photographs

CDR Lee Archambault

PLT Dominic Antonelli

MS1/EV3 Joseph Acaba

MS2/FE/EV1 Steve Swanson

MS3/EV2 Richard Arnold

MS4 John Phillips

MS5/ISS-18 Soichi Wakata

MS5/ISS-18 Sandy Magnus

# ISS-18 Crew Photographs

ISS-18 CDR Michael Fincke

ISS-18 FE Yury Lonchakov

ISS-18 FE: Sandra Magnus

# STS-119 Launch Windows

**Updated: 03/05/09**

To reach the international space station, the shuttle must take off within about five minutes of the moment Earth's rotation carries the launch pad into the plane of the station's orbit. To optimize ascent performance, NASA targets the middle of that 10-minute window for launch. All times in Eastern and subject to change.

| Date | Window Open | Launch | Window Close | ISS Docking |
|---|---|---|---|---|
| 03/08/09 | 10:25:53 PM | 10:30:53 PM | 10:35:53 PM | Flight Day 3 |
| | | | 10:39:06 PM | FD 4 |
| 03/09/09 | 10:03:20 PM | 10:08:20 PM | 10:13:20 PM | FD 3 |
| 03/10/09 | 09:37:39 PM | 09:42:39 PM | 09:47:39 PM | FD 3 |
| | | | 09:50:51 PM | FD 4 |
| 03/11/09 | 09:15:10 PM | 09:20:10 PM | 09:25:10 PM | FD 3 |
| 03/12/09 | 08:49:27 PM | 08:54:27 PM | 08:59:27 PM | FD 3 |
| | | | 09:02:36 PM | FD 4 |
| 03/13/09 | 08:26:53 PM | 08:31:53 PM | 08:36:53 PM | FD 3 |
| 03/14/09 | 08:01:12 PM | 08:06:12 PM | 08:11:12 PM | FD 3 |
| | | | 08:14:22 PM | FD 4 |
| 03/15/09 | 07:38:38 PM | 07:43:38 PM | 07:48:38 PM | FD 3 |
| 03/16/09 | 07:16:05 PM | 07:21:05 PM | 07:26:05 PM | FD 4 |

# STS-119 Launch and Flight Control Personnel

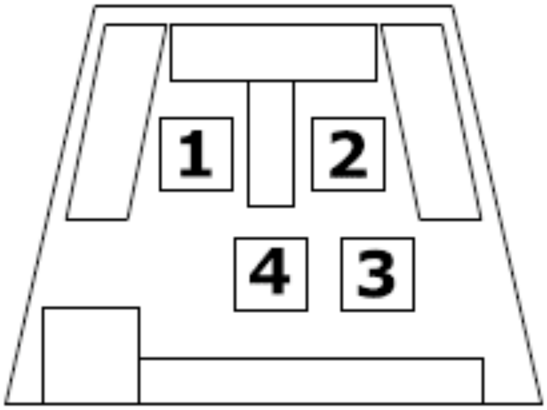
| KSC/LCC | Launch Ops | LCC PAO | Backup |
|---|---|---|---|
| LD (STS-119) | Mike Leinbach | Candrea Thomas | Allard Beutel |
| NTD | Steve Payne | | |
| OTC | John Kracsun | | |

| JSC/MCC | Flight Ops | MCC PAO | STS CAPCOM |
|---|---|---|---|
| **STS-119** | | | |
| Ascent FD | Richard Jones | Kylie Clem | George Zamka |
| Weather | | | Alan Poindexter |
| Orbit 1 FD (ld) | Paul Dye | Nicole Clutier | George Zamka |
| Orbit 2 (1-12) | Mike Sarafin | Brandi Dean | Greg Johnson |
| Orbit 2 (13-EOM) | Tony Ceccacci | | |
| Orbit 3 (1-8) | Norm Knight | Josh Byerley | Shannon Lucid |
| Orbit 3 (9-EOM) | Bryan Lunney | | |
| Entry FD | Richard Jones | Kylie Clem | George Zamka |
| Weather | | | Alan Poindexter |
| Team 4 | Tony Ceccacci | | |

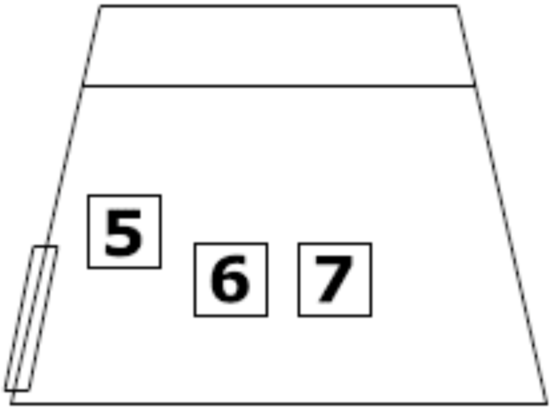
| ISS MCC | Flight Director | Partner FD | ISS CAPCOM |
|---|---|---|---|
| Orbit 1 | Kwatsi Alibaruho | N/A | Rick Davis |
| Orbit 2 (ld) | Heather Rarick | N/A | Lucia McCullough |
| Orbit 3 | David Korth | N/A | Jay Marchchke |
| Team 4 | Bob Dempsey | | |

| Flight Support | Prime | Backup | Backup |
|---|---|---|---|
| Shuttle Program | John Shannon | | |
| ISS Program | Mike Suffredini | | |
| MMT (JSC) | LeRoy Cain | | |
| MMT (KSC) | Mike Moses | | |
| Weather Coordinator | Dom Gorie | | |
| Launch STA | Steve Lindsey | | |
| Entry STA (KSC) | Steve Lindsey | | |
| Entry STA (EAFB) | Dom Gorie | | |
| TAL Zaragoza | Scott Altman | | |
| TAL Istres | Mark Kelly | | |
| TAL Moron | Greg C. Johnosn | | |
| JSC PAO at KSC | Laura Rochon | | |
| HQ PAO at KSC | Mike Curie | | |
| Astro Support | Ken Ham | Barry Wilmore | |
| Family Support | Ron Garan | Mike Massimino | Mike Foreman |

| Crew | Name | Launch Seat/Bailout | | Entry Seat/Bailout | |
|---|---|---|---|---|---|
| Commander | Lee Archambault | Up-1 | 7 | Up-1 | 7 |
| Pilot | Dominic Antonelli | Up-2 | 6 | Up-2 | 6 |
| MS1/EV3 | Joseph Acaba | Up-3 | 5 | Up-3 | 5 |
| MS2/EV1/FE | Steven Swanson | Up-4 | 4 | Up-4 | 4 |
| MS3/EV2 | Richard Arnold | Down-5 | 1 | Down-5 | 1 |
| MS4 | John Phillips | Down-6 | 3 | Down-6 | 3 |
| MS5 | Koichi Wakata | Down-7 | 2 | N/A | |
| MS5 | Sandra Magnus | N/A | | Down-7 | 2 |



Upper Deck

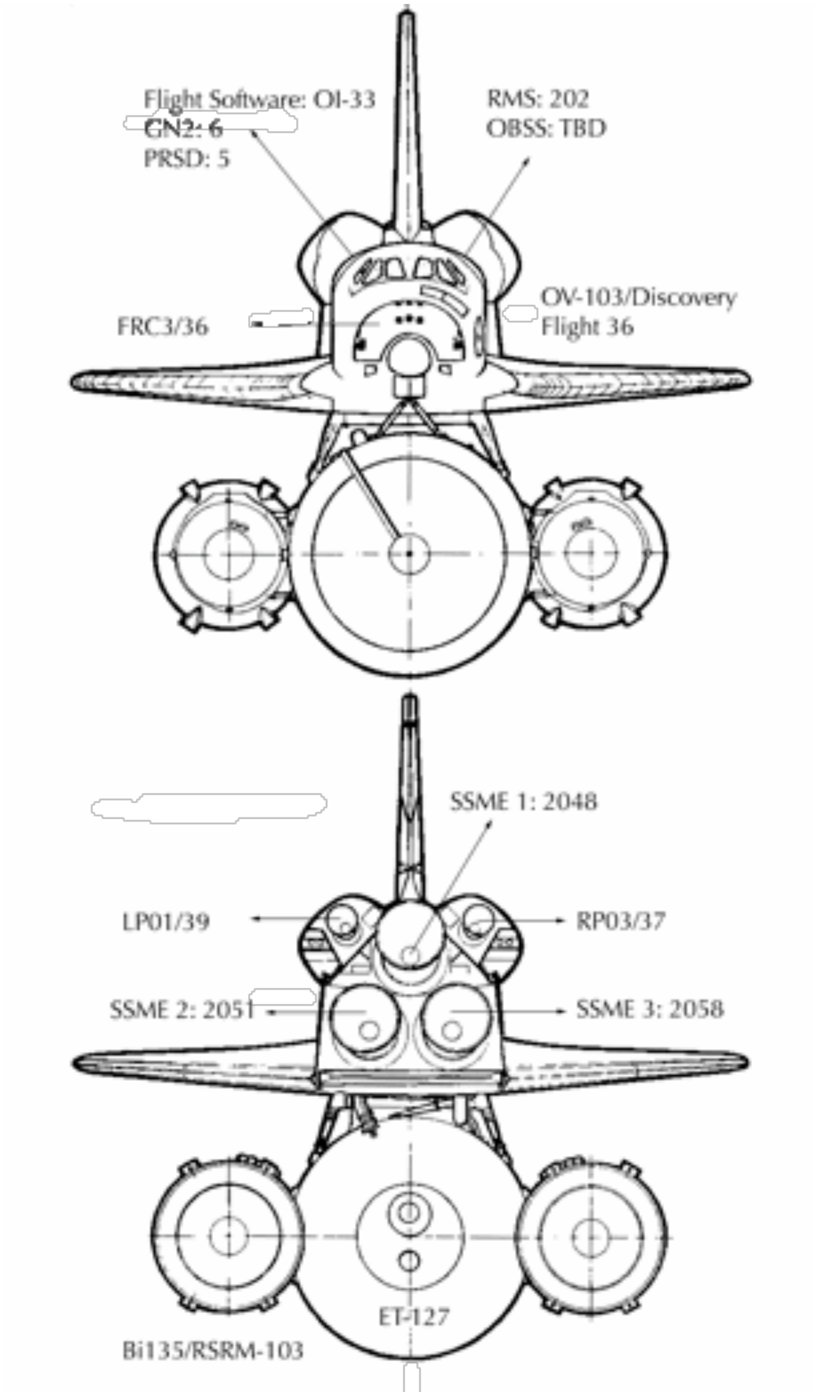


Lower Deck

| EVAs | Crew | Suit Markings | IV | Notes |
|---|---|---|---|---|
| EVA-1 | Swanson | Red stripes | Acaba | |
| | Arnold | No stripes | | |
| EVA-2 | Swanson | | Arnold | |
| | Acaba | Broken stripes | | |
| EVA-3 | Arnold | | Swanson | |
| | Acaba | | | |
| EVA-4 | Swanson | | Acaba | |
| | Arnold | | | |

| Crew Tasks | Prime | Backup |
|---|---|---|
| ET Still photos | Armold | |
| ET Video | Acaba | |
| SRMS FD-2 inspection | Antonelli | Acaba |
| SRMS focused inspect. | Antonelli | Acaba |
| SRMS late inspection | Antonelli | Acaba |
| SSRMS FD-4 install | Phillips | Wakata |
| SSRMS FD-5 focused in. | Phillips | Wakata |
| Cargo transfer | Arnold | Acaba |
| PVR deploy | Antonelli | Wakata |
| SAW deploy | Phillips | Wakata |

# STS-119 Flight Hardware/Software[1]



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[1] Graphic from The Space Shuttle Operator's Manual, 1982, Ballentine Books

# Space Shuttle Discovery Flight History

| 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 |
| **Vehicle Total** | | | **310** | **08** | **50** | **01** | | |

**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.

**Space Shuttle Discovery**

# STS-119 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 |
|---|---|
| **Sun 03/08/09** | |
| 06:30 PM | Call to stations |
| 07:00 PM | Countdown begins |
| **Mon 03/09/09** | |
| 05:00 AM | Fuel cell reactant load preps |
| 10:30 AM | MEC/SRB power up |
| 11:00 AM | Clear crew module |
| 11:00 AM | Begin 4-hour built-in hold |
| 11:00 AM | Clear blast danger area |
| 11:45 AM | Orbiter pyro-initiator controller test |
| 11:55 AM | SRB PIC test |
| 12:55 PM | Master events controller pre-flight BITE test |
| 03:00 PM | Resume countdown |
| 04:30 PM | Fuel cell oxygen loading begins |
| 07:00 PM | Fuel cell oxygen load complete |
| 07:00 PM | Fuel cell hydrogen loading begins |
| 09:30 PM | Fuel cell hydrogen loading complete |
| 10:30 PM | Pad open; ingress white room |
| 11:00 PM | Begin 8-hour built-in hold |
| 11:00 PM | Begin PRSD offload |
| 11:00 PM | Crew module clean and vacuum |
| **Tue 03/10/09** | |
| 03:00 AM | PRSD offload complete |
| 03:30 AM | OMBUU demate |
| 07:00 AM | Countdown resumes |
| 07:00 AM | Main engine preps |
| 07:00 AM | MECs 1 and 2 on; avionics system checkout |
| 08:00 AM | Remove OMS engine covers, throat plugs |
| 08:30 AM | Deflate RSS dock seals; tile inspection |
| 09:00 AM | Tile inspection |
| 01:00 PM | TSM prepped for fueling |
| 03:00 PM | Begin 13-hour 55-minute hold |
| 04:40 PM | ASP crew module inspection |
| 05:00 PM | OIS communications check |

| EDT | EVENT |
|---|---|
| 07:30 PM | Debris inspection |
| 07:30 PM | JSC flight control team on station |
| 07:30 PM | Crew weather briefing |
| 08:00 PM | Comm activation |
| 08:30 PM | Crew module voice checks |
| 08:30 PM | Flight crew equipment late stow |
| **Wed 03/11/09** | |
| 12:30 AM | RSS to park position |
| 01:30 AM | Final TPS, debris inspection |
| 02:00 AM | Ascent switch list |
| 04:55 AM | Resume countdown |
| 04:55 AM | ASP cockpit config |
| 05:15 AM | Pad clear of non-essential personnel |
| 05:15 AM | APU bite test |
| 06:05 AM | Fuel cell activation |
| 06:55 AM | Booster joint heater activation |
| 07:25 AM | MEC pre-flight bite test |
| 07:40 AM | Tanking weather update |
| 08:25 AM | Final fueling preps; launch area clear |
| 08:55 AM | Red crew assembled |
| 09:40 AM | Fuel cell integrity checks complete |
| 09:55 AM | Begin 2-hour built-in hold (T-minus 6 hours) |
| 10:05 AM | Safe-and-arm PIC test |
| 10:55 AM | External tank ready for loading |
| 11:18 AM | Mission management team tanking meeting |
| 11:55 AM | Resume countdown (T-minus 6 hours) |
| 11:55 AM | LO2, LH2 transfer line chilldown |
| 12:05 PM | Main propulsion system chill down |
| 12:05 PM | LH2 slow fill |
| 12:35 PM | LO2 slow fill |
| 12:40 PM | Hydrogen ECO sensors go wet |
| 12:45 PM | LO2 fast fill |
| 12:48 PM | Crew medical checks |
| 12:55 PM | LH2 fast fill |
| 02:50 PM | LH2 topping |
| 02:55 PM | LH2 replenish |
| 02:55 PM | LO2 replenish |
| 02:55 PM | Begin 2-hour 30-minute built-in hold (T-minus 3 hours) |
| 02:55 PM | Closeout crew to white room |
| 02:55 PM | External tank in stable replenish mode |
| 03:10 PM | Astronaut support personnel comm checks |
| 03:40 PM | Pre-ingress switch reconfig |
| 04:30 PM | NASA TV coverage begins |
| 04:55 PM | Final crew weather briefing |
| 05:00 PM | Crew suit up begins |

| EDT | EVENT |
|---|---|
| 05:25 PM | Resume countdown (T-minus 3 hours) |
| 05:30 PM | Crew departs O&C building |
| 06:00 PM | Crew ingress |
| 06:50 PM | Astronaut comm checks |
| 07:15 PM | Hatch closure |
| 07:45 PM | White room closeout |
| 08:05 PM | Begin 10-minute built-in hold (T-minus 20m) |
| 08:15 PM | NASA test director countdown briefing |
| 08:15 PM | Resume countdown (T-minus 20m) |
| 08:16 PM | Backup flight computer to OPS 1 |
| 08:20 PM | KSC area clear to launch |
| 08:26 PM | Begin final built-in hold (T-minus 9m) |
| 08:56 PM | NTD launch status verification |
| 09:11:10 PM | Resume countdown (T-minus 9m) |
| 09:12:40 PM | Orbiter access arm retraction |
| 09:15:10 PM | Launch window opens |
| 09:15:10 PM | Hydraulic power system (APU) start |
| 09:15:15 PM | Terminate LO2 replenish |
| 09:16:10 PM | Purge sequence 4 hydraulic test |
| 09:16:10 PM | IMUs to inertial |
| 09:16:15 PM | Aerosurface profile |
| 09:16:40 PM | Main engine steering test |
| 09:17:15 PM | LO2 tank pressurization |
| 09:17:35 PM | Fuel cells to internal reactants |
| 09:17:40 PM | Clear caution-and-warning memory |
| 09:18:10 PM | Crew closes visors |
| 09:18:13 PM | LH2 tank pressurization |
| 09:19:20 PM | SRB joint heater deactivation |
| 09:19:39 PM | Shuttle GPCs take control of countdown |
| 09:19:49 PM | SRB steering test |
| 09:20:03 PM | Main engine start (T-6.6 seconds) |
| 09:20:10 PM | SRB ignition (LAUNCH) |

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# STS-119 Weather Guidelines[2]

**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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[2] 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-119 Ascent Events Summary

| Flight Data | EST | L-MM:SS | Terminal Countdown |
|---|---|---|---|
| STS-119 | 8:26:10 PM | L-45:00 | **T-9 hold begins** |
| 11-Mar-09 | 9:11:10 PM | L-09:00 | Resume countdown |
| 09:20:10 PM | 9:12:40 PM | L-07:30 | Orbiter access arm retraction |
| Win Close | 9:15:10 PM | L-05:00 | Auxilliary power unit start |
| 09:25:10 PM | 9:15:15 PM | L-04:55 | Liquid oxygen drainback begins |
| -107:05:44 | 9:16:15 PM | L-03:55 | Purge sequence 4 hydraulic test |
|  | 9:17:15 PM | L-02:55 | Oxygen tank at flight pressure |
| SLF Max Wind: | 9:17:15 PM | L-02:55 | Gaseous oxygen vent arm retraction |
| TBD | 9:17:35 PM | L-02:35 | Fuel cells to internal |
| Wind Direction: | 9:18:13 PM | L-01:57 | Hydrogen tank at flight pressure |
| TBD | 9:19:20 PM | L-00:50 | Orbiter to internal power |
| SLF Crosswind: | 9:19:39 PM | L-00:31 | Shuttle computers control countdown |
| **TBD** | 9:19:49 PM | L-00:21 | Booster steering test |
| **TBD** | 9:20:03 PM | L-00:06.6 | Main engine ignition |

| Abort Data |  | L+MM:SS | Ascent Events Timeline | FPS | MPH |
|---|---|---|---|---|---|
| **0:02:24** | **9:20:10 PM** | **T+0:00** | **LAUNCH** |  |  |
| **RTLS** | 9:20:20 PM | T+00:10 | START ROLL MANEUVER | 1,350 | 921 |
| **ONLY** | 9:20:28 PM | T+00:18 | END ROLL MANEUVER | 1,490 | 1,016 |
|  | 9:20:44 PM | T+00:34 | START THROTTLE DOWN (72%) | 1,820 | 1,241 |
|  | 9:20:56 PM | T+00:46 | START THROTTLE UP (104.5%) | 2,070 | 1,411 |
|  | 9:21:10 PM | T+01:00 | MAX Q (731 psf) | 2,390 | 1,630 |
|  | 9:22:14 PM | T+02:04 | SRB STAGING | 5,360 | 3,655 |
|  | 9:22:24 PM | T+02:14 | START OMS ASSIST (x:xx duration) | 5,560 | 3,791 |
|  | 9:22:34 PM | T+02:24 | **2 ENGINE TAL MORON (104.5%, 2s)** | 5,800 | 3,955 |
| **0:02:20** | 9:22:39 PM | T+02:29 | 2 ENGINE TAL ZARAGOZA (104.5%, 2s) | 5,900 | 4,023 |
| **TAL** | 9:22:50 PM | T+02:40 | 2 ENGINE TAL ISTRES (104.5%, 2s) | 6,100 | 4,159 |
|  | 9:23:58 PM | T+03:48 | NEGATIVE RETURN (KSC) (104.5%, 3s) | 8,000 | 5,455 |
|  | 9:24:54 PM | T+04:44 | **PRESS TO ATO (104.5%, 2s, 160 u/s)** | 10,200 | 6,955 |
| **0:01:48** | 9:25:32 PM | T+05:22 | DROOP ZARAGOZA (109%,0s) | 12,000 | 8,183 |
| **ATO** | 9:25:35 PM | T+05:25 | SINGLE ENGINE OPS-3 ZARAGOZA (109%,0s,2EO SIMO) | 12,100 | 8,251 |
|  | 9:25:56 PM | T+05:46 | ROLL TO HEADSUP | 13,200 | 9,001 |
|  | 9:26:13 PM | T+06:03 | SINGLE ENGINE TAL ZARAGOZA (104.5%,2s,2EO SIMO) | 14,300 | 9,751 |
|  | 9:26:42 PM | T+06:32 | **PRESS TO MECO (104.5%, 2s, 160 u/s)** | 16,100 | 10,978 |
|  | 9:26:42 PM | T+06:32 | SINGLE ENGINE TAL MORON (109%,0s,2EO SEQ,1st EO @ VI) | 16,300 | 11,115 |
|  | 9:26:42 PM | T+06:32 | SINGLE ENGINE TAL ISTRES (109%,0s,2EO SEQ,1st EO @ VI) | 16,900 | 11,524 |
|  | 9:27:15 PM | T+07:05 | SINGLE ENGINE PRESS-TO-MECO (104.5%, 2s, 597 u/s) | 18,600 | 12,683 |
|  | 9:27:30 PM | T+07:20 | 3G LIMITING | 19,950 | 13,603 |
|  | 9:27:31 PM | T+07:21 | NEGATIVE MORON (2@67%) | 20,000 | 13,638 |
|  | 9:27:51 PM | T+07:41 | LAST 2 ENG PRE-MECO TAL ZARAGOZA (67%) | 21,800 | 14,865 |
|  | 9:27:51 PM | T+07:41 | NEGATIVE ISTRES (2@67%) | 21,800 | 14,865 |
| **MECO Ha/Hp** | 9:27:57 PM | T+07:47 | LAST SINGLE ENG PRE-MECO TAL ZARAGOZA (104.5%) | 22,500 | 15,342 |
| **135.7 X 35.6 sm** | 9:28:02 PM | T+07:52 | 23K | 23,000 | 15,683 |
|  | 9:28:02 PM | T+07:52 | LAST 3 ENG PRE-MECO TAL ZARAGOZA (67%) | 23,000 | 15,683 |
| **OMS-2 Ha/Hp** | 9:28:28 PM | T+08:18 | LAST TAL DIEGO GARCIA | 25,300 | 17,252 |
| **141.5 X 120.8** | 9:28:33 PM | T+08:23 | **MECO COMMANDED** | 25,780 | 17,579 |
|  | 9:28:39 PM | T+08:29 | ZERO THRUST | 25,819 | 17,605 |
|  |  |  | **Compiled by William Harwood** | **Inertial Velocity** |  |

# STS-119 Predicted Trajectory Data

| Time (EDT) | T+ MM:SS | Thrust Level | Altitude Feet | Mach Number | Velocity MPH | Vi FPS | Vi MPH | Acc Gs | Range (sm) |
|---|---|---|---|---|---|---|---|---|---|
| 09:20:10 PM | 00:00 | 100.0 | -23 | 0.0 | 0.0 | 1,341.0 | 914.4 | 0.3 | 0.0 |
| 09:20:20 PM | 00:10 | 104.5 | 775 | 0.2 | 124.8 | 1,353.0 | 922.6 | 1.7 | 0.0 |
| 09:20:30 PM | 00:20 | 104.5 | 3,972 | 0.4 | 306.8 | 1,526.0 | 1,040.5 | 1.9 | 0.1 |
| 09:20:40 PM | 00:30 | 104.5 | 9,142 | 0.7 | 492.3 | 1,732.0 | 1,181.0 | 1.8 | 0.5 |
| 09:20:50 PM | 00:40 | 72.0 | 17,102 | 0.9 | 671.0 | 1,957.0 | 1,334.4 | 1.7 | 1.2 |
| 09:21:00 PM | 00:50 | 104.0 | 25,880 | 1.1 | 814.8 | 2,152.0 | 1,467.4 | 1.8 | 2.1 |
| 09:21:10 PM | 01:00 | 104.5 | 36,192 | 1.4 | 995.5 | 2,389.0 | 1,629.0 | 2.0 | 3.4 |
| 09:21:20 PM | 01:10 | 104.5 | 49,886 | 1.9 | 1,260.8 | 2,752.0 | 1,876.5 | 2.3 | 5.1 |
| 09:21:30 PM | 01:20 | 104.5 | 64,770 | 2.4 | 1,579.2 | 3,220.0 | 2,195.7 | 2.5 | 7.3 |
| 09:21:40 PM | 01:30 | 104.5 | 83,626 | 2.9 | 1,974.0 | 3,816.0 | 2,602.1 | 2.5 | 10.5 |
| 09:21:50 PM | 01:40 | 104.5 | 102,647 | 3.4 | 2,353.2 | 4,385.0 | 2,990.0 | 2.5 | 14.4 |
| 09:22:00 PM | 01:50 | 104.5 | 125,237 | 3.9 | 2,768.4 | 5,007.0 | 3,414.2 | 2.2 | 19.8 |
| 09:22:10 PM | 02:00 | 104.5 | 146,373 | 3.9 | 2,962.1 | 5,307.0 | 3,618.7 | 1.0 | 25.5 |
| 09:22:20 PM | 02:10 | 104.5 | 167,916 | 4.0 | 3,060.3 | 5,468.0 | 3,728.5 | 1.0 | 31.9 |
| 09:22:30 PM | 02:20 | 104.5 | 187,000 | 4.2 | 3,174.8 | 5,653.0 | 3,854.7 | 1.0 | 38.4 |
| 09:22:40 PM | 02:30 | 104.5 | 206,699 | 4.5 | 3,317.3 | 5,878.0 | 4,008.1 | 1.0 | 45.9 |
| 09:22:50 PM | 02:40 | 104.5 | 223,427 | 4.9 | 3,459.2 | 6,099.0 | 4,158.8 | 1.1 | 53.2 |
| 09:23:00 PM | 02:50 | 104.5 | 239,045 | 5.4 | 3,613.3 | 6,334.0 | 4,319.0 | 1.1 | 60.9 |
| 09:23:10 PM | 03:00 | 104.5 | 254,960 | 5.9 | 3,794.7 | 6,609.0 | 4,506.5 | 1.1 | 69.8 |
| 09:23:20 PM | 03:10 | 104.5 | 268,301 | 6.3 | 3,971.3 | 6,873.0 | 4,686.6 | 1.1 | 78.5 |
| 09:23:30 PM | 03:20 | 104.5 | 281,761 | 6.8 | 4,177.9 | 7,181.0 | 4,896.6 | 1.2 | 88.5 |
| 09:23:40 PM | 03:30 | 104.5 | 292,917 | 7.2 | 4,377.0 | 7,475.0 | 5,097.0 | 1.2 | 98.1 |
| 09:23:50 PM | 03:40 | 104.5 | 303,066 | 7.5 | 4,585.6 | 7,782.0 | 5,306.4 | 1.2 | 108.2 |
| 09:24:00 PM | 03:50 | 104.5 | 313,093 | 7.7 | 4,824.3 | 8,132.0 | 5,545.0 | 1.3 | 119.9 |
| 09:24:10 PM | 04:00 | 104.5 | 321,212 | 7.9 | 5,051.4 | 8,465.0 | 5,772.1 | 1.3 | 131.1 |
| 09:24:20 PM | 04:10 | 104.5 | 329,082 | 8.1 | 5,313.2 | 8,848.0 | 6,033.3 | 1.3 | 144.0 |
| 09:24:30 PM | 04:20 | 104.5 | 335,298 | 8.3 | 5,562.1 | 9,211.0 | 6,280.8 | 1.4 | 156.4 |
| 09:24:40 PM | 04:30 | 104.5 | 341,140 | 8.6 | 5,847.8 | 9,628.0 | 6,565.1 | 1.4 | 170.6 |
| 09:24:50 PM | 04:40 | 104.5 | 345,575 | 8.9 | 6,119.2 | 10,023.0 | 6,834.5 | 1.5 | 184.3 |
| 09:25:00 PM | 04:50 | 104.5 | 349,211 | 9.2 | 6,402.2 | 10,435.0 | 7,115.4 | 1.5 | 198.5 |
| 09:25:10 PM | 05:00 | 104.5 | 352,326 | 9.5 | 6,726.1 | 10,907.0 | 7,437.3 | 1.6 | 215.0 |
| 09:25:20 PM | 05:10 | 104.5 | 354,400 | 9.9 | 7,033.6 | 11,354.0 | 7,742.1 | 1.6 | 230.6 |
| 09:25:30 PM | 05:20 | 104.5 | 355,896 | 10.4 | 7,386.8 | 11,868.0 | 8,092.5 | 1.7 | 248.7 |
| 09:25:40 PM | 05:30 | 104.5 | 356,586 | 10.8 | 7,722.3 | 12,356.0 | 8,425.3 | 1.7 | 265.9 |
| 09:25:50 PM | 05:40 | 104.5 | 356,686 | 11.3 | 8,072.1 | 12,865.0 | 8,772.4 | 1.8 | 283.9 |
| 09:26:00 PM | 05:50 | 104.5 | 356,171 | 11.9 | 8,474.4 | 13,451.0 | 9,172.0 | 1.9 | 304.6 |
| 09:26:10 PM | 06:00 | 104.5 | 355,212 | 12.4 | 8,856.9 | 14,007.0 | 9,551.1 | 1.9 | 324.4 |
| 09:26:20 PM | 06:10 | 104.5 | 353,780 | 13.1 | 9,296.1 | 14,646.0 | 9,986.8 | 2.0 | 347.1 |
| 09:26:30 PM | 06:20 | 104.5 | 352,259 | 13.8 | 9,714.7 | 15,256.0 | 10,402.7 | 2.1 | 368.7 |
| 09:26:40 PM | 06:30 | 104.5 | 350,330 | 14.5 | 10,203.6 | 15,968.0 | 10,888.2 | 2.2 | 393.7 |
| 09:26:50 PM | 06:40 | 104.5 | 348,308 | 15.3 | 10,672.8 | 16,651.0 | 11,354.0 | 2.4 | 417.5 |
| 09:27:00 PM | 06:50 | 104.5 | 346,125 | 16.1 | 11,166.5 | 17,370.0 | 11,844.2 | 2.5 | 442.3 |
| 09:27:10 PM | 07:00 | 104.5 | 343,666 | 17.1 | 11,741.3 | 18,208.0 | 12,415.7 | 2.6 | 471.0 |
| 09:27:20 PM | 07:10 | 104.5 | 341,518 | 18.0 | 12,296.3 | 19,017.0 | 12,967.3 | 2.8 | 498.4 |
| 09:27:30 PM | 07:20 | 104.5 | 339,410 | 19.1 | 12,946.8 | 19,965.0 | 13,613.7 | 3.0 | 530.0 |
| 09:27:40 PM | 07:30 | 98.0 | 337,892 | 20.1 | 13,559.2 | 20,858.0 | 14,222.6 | 3.0 | 560.2 |
| 09:27:50 PM | 07:40 | 92.0 | 336,868 | 21.1 | 14,171.5 | 21,752.0 | 14,832.2 | 3.0 | 591.8 |
| 09:28:00 PM | 07:50 | 86.0 | 336,408 | 22.1 | 14,846.6 | 22,736.0 | 15,503.2 | 3.0 | 628.1 |

| Time (EDT) | T+ MM:SS | Thrust Level | Altitude Feet | Mach Number | Velocity MPH | Vi FPS | Vi MPH | Acc Gs | Range (sm) |
|---|---|---|---|---|---|---|---|---|---|
| 09:28:10 PM | 08:00 | 80.0 | 336,728 | 23.0 | 15,460.2 | 23,632.0 | 16,114.2 | 2.9 | 662.6 |
| 09:28:20 PM | 08:10 | 75.0 | 338,057 | 23.9 | 16,133.9 | 24,615.0 | 16,784.5 | 3.0 | 702.2 |
| 09:28:30 PM | 08:20 | 67.0 | 340,347 | 24.7 | 16,750.4 | 25,516.0 | 17,398.8 | 2.8 | 740.9 |
| 09:28:40 PM | 08:30 | 67.0 | 343,475 | 24.7 | 16,957.0 | 25,817.0 | 17,604.1 | 0.0 | 780.7 |
| 09:28:41 PM | 08:31 | 67.0 | 343,785 | 24.7 | 16,957.0 | 25,818.0 | 17,604.8 | 0.0 | 784.6 |
| 09:28:42 PM | 08:32 | 67.0 | 344,096 | 24.7 | 16,957.0 | 25,818.0 | 17,604.8 | 0.0 | 788.4 |
| 09:28:43 PM | 08:33 | 67.0 | 344,406 | 24.6 | 16,957.0 | 25,818.0 | 17,604.8 | 0.0 | 792.3 |
| 09:28:44 PM | 08:34 | 67.0 | 344,652 | 24.6 | 16,957.0 | 25,818.0 | 17,604.8 | 0.0 | 795.3 |

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# STS-119 Flight Plan

***Editor's Note...***
Current as of 03/06/09

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 | EVENT |
|---|---|---|---|---|
| | | | | **Flight Day 1** |
| **03/11/09** | | | | |
| Wed 09:20 PM | 00 | 00 | 00 | Launch |
| Wed 09:57 PM | 00 | 00 | 37 | OMS-2 rocket firing |
| Wed 10:10 PM | 00 | 00 | 50 | Post insertion timeline begins |
| Wed 11:50 PM | 00 | 02 | 30 | Laptop computer setup (part 1) |
| Wed 11:50 PM | 00 | 02 | 30 | GIRA installation |
| Thu 12:00 AM | 00 | 02 | 40 | SRMS powerup |
| **03/12/09** | | | | |
| Thu 12:54 AM | 00 | 03 | 34 | NC1 rendezvous rocket firing |
| Thu 01:00 AM | 00 | 03 | 40 | SRMS checkout |
| Thu 01:05 AM | 00 | 03 | 45 | SEE setup |
| Thu 01:15 AM | 00 | 03 | 55 | Group B computer powerdown |
| Thu 01:30 AM | 00 | 04 | 10 | Wing leading edge sensors activated |
| Thu 01:30 AM | 00 | 04 | 10 | ET photo |
| Thu 01:40 AM | 00 | 04 | 20 | ET video downlink |
| Thu 01:50 AM | 00 | 04 | 30 | TPS imagery downlink |
| Thu 03:50 AM | 00 | 06 | 30 | Crew sleep begins |
| | | | | **Flight Day 2** |
| Thu 11:50 AM | 00 | 14 | 30 | Crew wakeup |
| Thu 02:14 PM | 00 | 16 | 54 | NC-2 rendezvous rocket firing |
| Thu 02:30 PM | 00 | 17 | 10 | SRMS unberths OBSS |
| Thu 03:00 PM | 00 | 17 | 40 | PGSC setup (part 2) |
| Thu 03:10 PM | 00 | 17 | 50 | Spacesuit checkout preps |
| Thu 03:40 PM | 00 | 18 | 20 | Spacesuit checkout |
| Thu 04:00 PM | 00 | 18 | 40 | OBSS starboard wing survey |
| Thu 05:50 PM | 00 | 20 | 30 | Ergometer setup |
| Thu 05:55 PM | 00 | 20 | 35 | OBSS nose cap survey |
| Thu 06:45 PM | 00 | 21 | 25 | Crew meals begin |
| Thu 07:45 PM | 00 | 22 | 25 | OBSS port wing survey |
| Thu 07:45 PM | 00 | 22 | 25 | Spacesuit prepped for transfer to station |
| Thu 09:45 PM | 01 | 00 | 25 | SRMS berths OBSS |
| Thu 09:55 PM | 01 | 00 | 35 | Centerline camera setup |
| Thu 10:00 PM | 01 | 00 | 40 | LDRI downlink |
| Thu 10:25 PM | 01 | 01 | 05 | Orbiter docking system ring extension |
| Thu 10:55 PM | 01 | 01 | 35 | Rendezvous tools checkout |
| Thu 11:25 PM | 01 | 02 | 05 | OMS pod survey |

| DATE/ET | DD | HH | MM | EVENT |
|---|---|---|---|---|
| **03/13/09** | | | | |
| Fri 01:21 AM | 01 | 04 | 01 | NC-3 rendezvous rocket firing |
| Fri 03:20 AM | 01 | 06 | 00 | Crew sleep begins |
| | | | | **Flight Day 3** |
| Fri 10:30 AM | 01 | 13 | 10 | ISS crew wakeup |
| Fri 11:20 AM | 01 | 14 | 00 | STS crew wakeup |
| Fri 12:00 PM | 01 | 14 | 40 | ISS daily planning conference |
| Fri 12:35 PM | 01 | 15 | 15 | Group B computer powerup |
| Fri 12:50 PM | 01 | 15 | 30 | Rendezvous timeline begins |
| Fri 02:17 PM | 01 | 16 | 57 | NC-4 rendezvous rocket firing |
| Fri 03:05 PM | 01 | 17 | 45 | Spacesuits removed from airlock |
| Fri 03:49 PM | 01 | 18 | 29 | TI burn |
| Fri 06:15 PM | 01 | 20 | 55 | Docking port prepped |
| Fri 06:27 PM | 01 | 21 | 07 | DOCKING |
| Fri 06:55 PM | 01 | 21 | 35 | Leak checks |
| Fri 07:25 PM | 01 | 22 | 05 | Orbiter docking system prepped for ingress |
| Fri 07:25 PM | 01 | 22 | 05 | Group B computer powerdown |
| Fri 07:40 PM | 01 | 22 | 20 | Post docking laptop reconfig |
| Fri 07:45 PM | 01 | 22 | 25 | Hatch open |
| Fri 08:15 PM | 01 | 22 | 55 | Welcome aboard! |
| Fri 08:20 PM | 01 | 23 | 00 | Safety briefing |
| Fri 08:45 PM | 01 | 23 | 25 | Soyuz seatliner transfer/installation |
| Fri 08:45 PM | 01 | 23 | 25 | Spacesuits transferred to ISS |
| Fri 10:05 PM | 02 | 00 | 45 | REBA checkout |
| Fri 10:20 PM | 02 | 01 | 00 | Playback ops |
| Fri 11:40 PM | 02 | 02 | 20 | ISS evening planning conference |
| **03/14/09** | | | | |
| Sat 01:50 AM | 02 | 04 | 30 | ISS crew sleep begins |
| Sat 02:20 AM | 02 | 05 | 00 | STS crew sleep begins |
| | | | | **Flight Day 4** |
| Sat 10:20 AM | 02 | 13 | 00 | STS/ISS crew wakeup |
| Sat 11:50 AM | 02 | 14 | 30 | ISS daily planning conference |
| Sat 12:45 PM | 02 | 15 | 25 | SRMS powerup |
| Sat 01:15 PM | 02 | 15 | 55 | SSRMS S6 grapple/unberth |
| Sat 02:30 PM | 02 | 17 | 10 | SSRMS moves S6 to handoff position |
| Sat 02:50 PM | 02 | 17 | 30 | Equipment lock preps |
| Sat 03:20 PM | 02 | 18 | 00 | SRMS grapples S6 |
| Sat 03:35 PM | 02 | 18 | 15 | EVA-1: Tools configured |
| Sat 03:40 PM | 02 | 18 | 20 | SSRMS ungrapples S6 |
| Sat 03:55 PM | 02 | 18 | 35 | SSRMS maneuvers XLAT |
| Sat 04:20 PM | 02 | 19 | 00 | SOKOL suit leak check/dry |
| Sat 04:35 PM | 02 | 19 | 15 | PAO event |
| Sat 04:55 PM | 02 | 19 | 35 | Crew meals begin |
| Sat 05:55 PM | 02 | 20 | 35 | EVA-1: Tool audit |
| Sat 06:20 PM | 02 | 21 | 00 | SRMS moves S6 to handoff position |
| Sat 07:35 PM | 02 | 22 | 15 | SSRMS grapples S6 |

| DATE/ET | DD | HH | MM | EVENT |
|---|---|---|---|---|
| Sat 08:05 PM | 02 | 22 | 45 | SRMS ungrapples S6 |
| Sat 08:20 PM | 02 | 23 | 00 | SSRMS to overnight park position |
| Sat 10:05 PM | 03 | 00 | 45 | ISS evening planning conference |
| Sat 10:20 PM | 03 | 01 | 00 | EVA-1: Procedures review |
| **03/15/09** | | | | |
| Sun 12:15 AM | 03 | 02 | 55 | EVA-1: Mask pre-breathe |
| Sun 01:00 AM | 03 | 03 | 40 | EVA-1: Airlock depress to 10.2 psi |
| Sun 01:20 AM | 03 | 04 | 00 | ISS crew sleep begins |
| Sun 01:50 AM | 03 | 04 | 30 | STS crew sleep begins |
| | | | | **Flight Day 5** |
| Sun 09:50 AM | 03 | 12 | 30 | Crew wakeup |
| Sun 10:25 AM | 03 | 13 | 05 | EVA-1: 14.7 psi repress/hygiene break |
| Sun 11:15 AM | 03 | 13 | 55 | EVA-1: Airlock depress to 10.2 psi |
| Sun 11:20 AM | 03 | 14 | 00 | ISS daily planning conference |
| Sun 11:35 AM | 03 | 14 | 15 | EVA-1: Campout EVA preps |
| Sun 12:45 PM | 03 | 15 | 25 | SSRMS moves S6 to pre-install |
| Sun 01:05 PM | 03 | 15 | 45 | EVA-1: Spacesuit purge |
| Sun 01:20 PM | 03 | 16 | 00 | EVA-1: Spacesuit prebreathe |
| Sun 02:20 PM | 03 | 17 | 00 | EVA-1: Crew lock depressurization |
| Sun 02:50 PM | 03 | 17 | 30 | EVA-1: Spacesuits to battery power |
| Sun 02:55 PM | 03 | 17 | 35 | EVA-1: Airlock egress |
| Sun 03:25 PM | 03 | 18 | 05 | EVA-1: Setup |
| Sun 03:40 PM | 03 | 18 | 20 | EVA-1: S6 attach |
| Sun 04:45 PM | 03 | 19 | 25 | EVA-1: S6 umbilical connect |
| Sun 04:45 PM | 03 | 19 | 25 | SSRMS releases S6 |
| Sun 05:40 PM | 03 | 20 | 20 | EVA-1/EV-2: Blanket box launch lock release |
| Sun 05:40 PM | 03 | 20 | 20 | EVA-1/EV-1: PVR cinch/winch |
| Sun 06:25 PM | 03 | 21 | 05 | EVA-1/EV-1: Keel pin stow |
| Sun 06:40 PM | 03 | 21 | 20 | EVA-1/EV-1: BGA release |
| Sun 07:10 PM | 03 | 21 | 50 | EVA-1: Unstow blanket boxes |
| Sun 08:10 PM | 03 | 22 | 50 | EVA-1: SSU/ECU |
| Sun 08:20 PM | 03 | 23 | 00 | EVA-1: Cleanup and ingress |
| Sun 09:20 PM | 04 | 00 | 00 | EVA-1: Airlock pressurization |
| Sun 09:35 PM | 04 | 00 | 15 | Spacesuit servicing |
| Sun 10:35 PM | 04 | 01 | 15 | ISS evening planning conference |
| Sun 10:50 PM | 04 | 01 | 30 | SSRMS walkoff node 2 |
| **03/16/09** | | | | |
| Mon 12:50 AM | 04 | 03 | 30 | ISS crew sleep begins |
| Mon 01:20 AM | 04 | 04 | 00 | STS crew sleep begins |
| | | | | **Flight Day 6** |
| Mon 09:20 AM | 04 | 12 | 00 | Crew wakeup |
| Mon 11:15 AM | 04 | 13 | 55 | ISS daily planning conference |
| Mon 11:25 AM | 04 | 14 | 05 | F1 DOUG review |
| Mon 12:30 PM | 04 | 15 | 10 | SSRMS grapples OBSS |
| Mon 12:50 PM | 04 | 15 | 30 | SSRMS unberths OBSS |

| DATE/ET | DD | HH | MM | EVENT |
|---|---|---|---|---|
| Mon 01:05 PM | 04 | 15 | 45 | Spacesuit swap |
| Mon 01:20 PM | 04 | 16 | 00 | SSRMS moves OBSS to handoff position |
| Mon 01:50 PM | 04 | 16 | 30 | SRMS grapples OBSS |
| Mon 02:10 PM | 04 | 16 | 50 | SSRMS ungrapples OBSS |
| Mon 03:00 PM | 04 | 17 | 40 | Focused inspection (if needed) |
| Mon 03:00 PM | 04 | 17 | 40 | Crew meals begin |
| Mon 03:35 PM | 04 | 18 | 15 | PAO event |
| Mon 04:55 PM | 04 | 19 | 35 | Glacier transfer |
| Mon 06:00 PM | 04 | 20 | 40 | Equipment lock preps |
| Mon 06:35 PM | 04 | 21 | 15 | SSRMS grapples OBSS |
| Mon 06:40 PM | 04 | 21 | 20 | Tool configuration |
| Mon 06:50 PM | 04 | 21 | 30 | SRMS ungrapples OBSS |
| Mon 07:05 PM | 04 | 21 | 45 | SSRMS berths OBSS |
| Mon 07:40 PM | 04 | 22 | 20 | EVA-2: Tool audit |
| Mon 08:10 PM | 04 | 22 | 50 | SSRMS walkoff PDGF-1 |
| Mon 09:20 PM | 05 | 00 | 00 | EVA-2: Procedures review |
| Mon 09:55 PM | 05 | 00 | 35 | SSRMS maneuvers XLAT |
| Mon 10:25 PM | 05 | 01 | 05 | ISS evening planning conference |
| Mon 11:45 PM | 05 | 02 | 25 | EVA-2: Mask pre-breathe |
| **03/17/09** | | | | |
| Tue 12:30 AM | 05 | 03 | 10 | EVA-2: Airlock depress to 10.2 psi |
| Tue 12:50 AM | 05 | 03 | 30 | ISS crew sleep begins |
| Tue 01:20 AM | 05 | 04 | 00 | STS crew sleep begins |
| | | | | **Flight Day 7** |
| Tue 09:20 AM | 05 | 12 | 00 | Crew wakeup |
| Tue 09:55 AM | 05 | 12 | 35 | EVA-2: 14.7 psi repress/hygiene break |
| Tue 10:45 AM | 05 | 13 | 25 | EVA-2: Airlock depress to 10.2 psi |
| Tue 10:50 AM | 05 | 13 | 30 | ISS daily planning conference |
| Tue 11:05 AM | 05 | 13 | 45 | EVA-2: Campout EVA preps |
| Tue 12:35 PM | 05 | 15 | 15 | EVA-2: Spacesuit purge |
| Tue 12:50 PM | 05 | 15 | 30 | EVA-2: Spacesuit prebreathe |
| Tue 01:40 PM | 05 | 16 | 20 | EVA-2: Crew lock depressurization |
| Tue 02:20 PM | 05 | 17 | 00 | EVA-2: Spacesuits to battery power |
| Tue 02:25 PM | 05 | 17 | 05 | EVA-2: Airlock egress |
| Tue 02:40 PM | 05 | 17 | 20 | EVA-2: Setup |
| Tue 03:10 PM | 05 | 17 | 50 | EVA-2: S6 battery R&R preps |
| Tue 04:20 PM | 05 | 19 | 00 | EVA-2: P3 nadir UCCAS deploy |
| Tue 05:35 PM | 05 | 20 | 15 | EVA-2/EV-2: P1/P3 fluid jumper |
| Tue 05:35 PM | 05 | 20 | 15 | EVA-2/EV-1: P1/P3 SSAS and RBVM MLI |
| Tue 05:50 PM | 05 | 20 | 30 | EVA-2/EV-1: P1 FHRC P-clamps |
| Tue 06:05 PM | 05 | 20 | 45 | EVA-2/EV-2: P1 FHRC P-clamps |
| Tue 06:40 PM | 05 | 21 | 20 | EVA-2: S2 PAS deploys |
| Tue 07:40 PM | 05 | 22 | 20 | EVA-2/EV-2: Tool stanchion relocate |
| Tue 07:40 PM | 05 | 22 | 20 | EVA-2/EV-1: APFR retrieval |
| Tue 08:05 PM | 05 | 22 | 45 | EVA-2: Cleanup and airlock ingress |
| Tue 08:50 PM | 05 | 23 | 30 | EVA-2: Airlock repressurization |
| Tue 09:05 PM | 05 | 23 | 45 | Spacesuit servicing |
| Tue 10:45 PM | 06 | 01 | 25 | Evening planning conference |

| DATE/ET | DD | HH | MM | EVENT |
|---|---|---|---|---|
| **03/18/09** | | | | |
| Wed 12:20 AM | 06 | 03 | 00 | ISS crew sleep begins |
| Wed 12:50 AM | 06 | 03 | 30 | STS crew sleep begins |
| | | | | **Flight Day 8** |
| Wed 08:50 AM | 06 | 11 | 30 | Crew wakeup |
| Wed 10:20 AM | 06 | 13 | 00 | ISS daily planning conference |
| Wed 10:50 AM | 06 | 13 | 30 | Maneuver to solar array deploy attitude |
| Wed 11:35 AM | 06 | 14 | 15 | 1B to 49 percent |
| Wed 12:20 PM | 06 | 15 | 00 | 1B to 100 percent |
| Wed 01:05 PM | 06 | 15 | 45 | 3B to 49 percent |
| Wed 01:50 PM | 06 | 16 | 30 | 3B to 100 percent |
| Wed 02:05 PM | 06 | 16 | 45 | Spacesuit component swap |
| Wed 02:35 PM | 06 | 17 | 15 | Crew meals begin |
| Wed 03:35 PM | 06 | 18 | 15 | Equipment lock preps |
| Wed 04:20 PM | 06 | 19 | 00 | Tool configuration |
| Wed 05:05 PM | 06 | 19 | 45 | APFR heat shield/SPDM setup/DPART prep |
| Wed 07:05 PM | 06 | 21 | 45 | PAO event |
| Wed 08:50 PM | 06 | 23 | 30 | EVA-3: Procedures review |
| Wed 09:50 PM | 07 | 00 | 30 | Evening planning conference |
| Wed 10:45 PM | 07 | 01 | 25 | EVA-3: Mask pre-breathe |
| Wed 11:30 PM | 07 | 02 | 10 | EVA-3: Airlock depress to 10.2 psi |
| Wed 11:50 PM | 07 | 02 | 30 | ISS crew sleep begins |
| Thu 12:20 AM | 07 | 03 | 00 | STS crew sleep begins |
| | | | | **Flight Day 9** |
| **03/19/09** | | | | |
| Thu 08:20 AM | 07 | 11 | 00 | Crew wakeup |
| Thu 08:55 AM | 07 | 11 | 35 | EVA-3: 14.7 psi repress/hygiene break |
| Thu 09:45 AM | 07 | 12 | 25 | EVA-3: Airlock depress to 10.2 psi |
| Thu 10:05 AM | 07 | 12 | 45 | EVA-3: Campout EVA preps |
| Thu 10:20 AM | 07 | 13 | 00 | ISS daily planning conference |
| Thu 11:35 AM | 07 | 14 | 15 | EVA-3: Spacesuit purge |
| Thu 11:50 AM | 07 | 14 | 30 | EVA-3: Spacesuit prebreathe |
| Thu 12:50 PM | 07 | 15 | 30 | EVA-3: Crew lock depressurization |
| Thu 01:20 PM | 07 | 16 | 00 | EVA-3: Spacesuits to battery power |
| Thu 01:25 PM | 07 | 16 | 05 | EVA-3: Airlock egress |
| Thu 01:50 PM | 07 | 16 | 30 | EVA-3: Setup |
| Thu 02:10 PM | 07 | 16 | 50 | EVA-3: CETA relocate |
| Thu 03:10 PM | 07 | 17 | 50 | EVA-3/EV-1: SPDM tasks |
| Thu 03:10 PM | 07 | 17 | 50 | EVA-3/EV-2: S1 tasks |
| Thu 04:40 PM | 07 | 19 | 20 | EVA-3/EV-1: LEE B lube |
| Thu 05:20 PM | 07 | 20 | 00 | EVA-3/EV-2: S0 1A-D PRCM R&R |
| Thu 06:25 PM | 07 | 21 | 05 | SSRMS stow |
| Thu 06:40 PM | 07 | 21 | 20 | SPDM stow |
| Thu 06:55 PM | 07 | 21 | 35 | EVA-3/EV-1: Cleanup and ingress |
| Thu 07:20 PM | 07 | 22 | 00 | EVA-3/EV-2: Cleanup and ingress |
| Thu 07:50 PM | 07 | 22 | 30 | EVA-3: Airlock repressurization |
| Thu 08:05 PM | 07 | 22 | 45 | Spacesuit servicing |

| DATE/ET | DD | HH | MM | EVENT |
|---|---|---|---|---|
| Thu 09:35 PM | 08 | 00 | 15 | Evening planning conference |
| Thu 11:20 PM | 08 | 02 | 00 | ISS crew sleep begins |
| Thu 11:50 PM | 08 | 02 | 30 | STS crew sleep begins |
| | | | | **Flight Day 10** |
| **03/20/09** | | | | |
| Fri 07:50 AM | 08 | 10 | 30 | Crew wakeup |
| Fri 09:50 AM | 08 | 12 | 30 | ISS daily planning conference |
| Fri 11:05 AM | 08 | 13 | 45 | Spacesuit swap |
| Fri 11:50 AM | 08 | 14 | 30 | Equipment lock preps |
| Fri 12:20 PM | 08 | 15 | 00 | Tools configured |
| Fri 01:20 PM | 08 | 16 | 00 | Tool audit |
| Fri 01:45 PM | 08 | 16 | 25 | EVA-4: Procedures review |
| Fri 02:45 PM | 08 | 17 | 25 | Crew news conference |
| Fri 03:25 PM | 08 | 18 | 05 | Crew photo |
| Fri 03:45 PM | 08 | 18 | 25 | Joint crew meal |
| Fri 04:45 PM | 08 | 19 | 25 | Crew off duty time begins |
| Fri 08:20 PM | 08 | 23 | 00 | ISS evening planning conference |
| Fri 10:15 PM | 09 | 00 | 55 | EVA-4: Mask pre-breathe |
| Fri 11:00 PM | 09 | 01 | 40 | EVA-4: Airlock depress to 10.2 psi |
| Fri 11:20 PM | 09 | 02 | 00 | ISS crew sleep begins |
| Fri 11:50 PM | 09 | 02 | 30 | STS crew sleep begins |
| | | | | **Flight Day 11** |
| **03/21/09** | | | | |
| Sat 07:50 AM | 09 | 10 | 30 | Crew wakeup |
| Sat 08:25 AM | 09 | 11 | 05 | EVA-4: 14.7 psi repress/hygiene break |
| Sat 08:50 AM | 09 | 11 | 30 | EVA-4: Airlock depress to 10.2 psi |
| Sat 09:20 AM | 09 | 12 | 00 | ISS daily planning conference |
| Sat 09:35 AM | 09 | 12 | 15 | EVA-4: Campout EVA preps |
| Sat 11:05 AM | 09 | 13 | 45 | EVA-4: Spacesuit purge |
| Sat 11:20 AM | 09 | 14 | 00 | EVA-4: Spacesuit prebreathe |
| Sat 12:20 PM | 09 | 15 | 00 | EVA-4: Crew lock depressurization |
| Sat 12:50 PM | 09 | 15 | 30 | EVA-4: Spacesuits to battery power |
| Sat 12:55 PM | 09 | 15 | 35 | EVA-4: Airlock egress |
| Sat 01:15 PM | 09 | 15 | 55 | EVA-4/EV-1: JLP GPS antenna B install |
| Sat 01:15 PM | 09 | 15 | 55 | EVA-4/EV-2: S1/P1 radiator imaging |
| Sat 02:15 PM | 09 | 16 | 55 | EVA-4/EV-1: Z1 patch panel reconfig |
| Sat 02:45 PM | 09 | 17 | 25 | EVA-4: S3 task setup |
| Sat 03:15 PM | 09 | 17 | 55 | EVA-4: CP1 WETA install |
| Sat 03:55 PM | 09 | 18 | 35 | EVA-4: S3 outboard/nadir PAS |
| Sat 05:10 PM | 09 | 19 | 50 | EVA-4: S3 inboard/zenith PAS |
| Sat 06:35 PM | 09 | 21 | 15 | EVA-4: Cleanup and airlock ingress |
| Sat 07:20 PM | 09 | 22 | 00 | EVA-4: Airlock repressurization |
| Sat 07:35 PM | 09 | 22 | 15 | Spacesuit servicing |
| Sat 09:05 PM | 09 | 23 | 45 | Evening planning conference |
| Sat 10:50 PM | 10 | 01 | 30 | ISS crew sleep begins |
| Sat 11:20 PM | 10 | 02 | 00 | STS crew sleep begins |

| DATE/ET | DD | HH | MM | EVENT |
|---|---|---|---|---|
| | | | | **Flight Day 12** |
| **03/22/09** | | | | |
| Sun 07:20 AM | 10 | 10 | 00 | Crew wakeup |
| Sun 08:50 AM | 10 | 11 | 30 | ISS daily planning conference |
| Sun 10:15 AM | 10 | 12 | 55 | Oxygen system teardown |
| Sun 10:20 AM | 10 | 13 | 00 | Rendezvous tools checkout |
| Sun 11:35 AM | 10 | 14 | 15 | Post-EVA reconfig |
| Sun 02:05 PM | 10 | 16 | 45 | Crew meals begin |
| Sun 03:05 PM | 10 | 17 | 45 | Shuttle crew off duty |
| Sun 03:50 PM | 10 | 18 | 30 | PAO event (ISS crew) |
| Sun 07:20 PM | 10 | 22 | 00 | Farewell ceremony |
| Sun 07:35 PM | 10 | 22 | 15 | Hatches closed |
| Sun 08:05 PM | 10 | 22 | 45 | Orbiter docking system leak checks |
| Sun 08:10 PM | 10 | 22 | 50 | Centerline camera setup |
| Sun 08:35 PM | 10 | 23 | 15 | Evening planning conference |
| Sun 10:50 PM | 11 | 01 | 30 | ISS crew sleep begins |
| Sun 11:20 PM | 11 | 02 | 00 | STS crew sleep begins |
| | | | | **Flight Day 13** |
| **03/23/09** | | | | |
| Mon 07:20 AM | 11 | 10 | 00 | Crew wakeup |
| Mon 08:50 AM | 11 | 11 | 30 | Group B computer powerup |
| Mon 09:20 AM | 11 | 12 | 00 | ISS daily planning conference |
| Mon 09:40 AM | 11 | 12 | 20 | Undocking timeline begins |
| Mon 10:23 AM | 11 | 13 | 03 | UNDOCKING |
| Mon 10:30 AM | 11 | 13 | 10 | PMA-2 depressurization |
| Mon 11:38 AM | 11 | 14 | 18 | Separation burn 1 |
| Mon 12:06 PM | 11 | 14 | 46 | Separation burn 2 |
| Mon 12:10 PM | 11 | 14 | 50 | Post undocking computer reconfig |
| Mon 12:25 PM | 11 | 15 | 05 | Group B computer powerdown |
| Mon 12:45 PM | 11 | 15 | 25 | Crew meal |
| Mon 01:45 PM | 11 | 16 | 25 | OBSS unberth |
| Mon 03:00 PM | 11 | 17 | 40 | EVA unpack and stow |
| Mon 03:00 PM | 11 | 17 | 40 | OBSS starboard wing survey |
| Mon 03:30 PM | 11 | 18 | 10 | Post ISS EVA entry preps |
| Mon 04:40 PM | 11 | 19 | 20 | OBSS nose cap survey |
| Mon 05:30 PM | 11 | 20 | 10 | OBSS port wing survey |
| Mon 07:15 PM | 11 | 21 | 55 | OBSS berthing |
| Mon 07:15 PM | 11 | 21 | 55 | LDRI downlink |
| Mon 11:20 PM | 12 | 02 | 00 | Crew sleep begins |
| | | | | **Flight Day 14** |
| **03/24/09** | | | | |
| Tue 07:20 AM | 12 | 10 | 00 | Crew wakeup |
| Tue 10:20 AM | 12 | 13 | 00 | SRMS powerdown |
| Tue 10:35 AM | 12 | 13 | 15 | Cabin stow begins |
| Tue 12:15 PM | 12 | 14 | 55 | FCS checkout |
| Tue 01:25 PM | 12 | 16 | 05 | RCS hotfire |

| DATE/ET | DD | HH | MM | EVENT |
|---|---|---|---|---|
| Tue 02:00 PM | 12 | 16 | 40 | PAO event |
| Tue 02:20 PM | 12 | 17 | 00 | Deorbit review |
| Tue 02:50 PM | 12 | 17 | 30 | Crew meal |
| Tue 03:50 PM | 12 | 18 | 30 | Cabin stow resumes |
| Tue 04:25 PM | 12 | 19 | 05 | Landing comm checks |
| Tue 05:50 PM | 12 | 20 | 30 | Ergometer stow |
| Tue 06:20 PM | 12 | 21 | 00 | Recumbent seat setup |
| Tue 07:05 PM | 12 | 21 | 45 | PILOT operations |
| Tue 07:20 PM | 12 | 22 | 00 | Launch/entry suit checkout |
| Tue 08:05 PM | 12 | 22 | 45 | Wing leading edge sensor system deactivation |
| Tue 08:25 PM | 12 | 23 | 05 | PGSC stow (part 1) |
| Tue 08:45 PM | 12 | 23 | 25 | KU antenna stow |
| Tue 11:20 PM | 13 | 02 | 00 | Crew sleep begins |
|  |  |  |  | **Flight Day 15** |
| **03/25/09** |  |  |  |  |
| Wed 07:20 AM | 13 | 10 | 00 | Crew wakeup |
| Wed 09:25 AM | 13 | 12 | 05 | Group B computer powerup |
| Wed 09:40 AM | 13 | 12 | 20 | IMU alignment |
| Wed 10:25 AM | 13 | 13 | 05 | Deorbit timeline begins |
| Wed 02:24 PM | 13 | 17 | 04 | Deorbit ignition (rev. 217) |
| Wed 03:27 PM | 13 | 18 | 07 | Landing |

# STS-119 Television Schedule

**Editor's note:**
NASA's daily video highlights reel will be replayed on the hour during crew sleep periods. The timing 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 |
|---|---|---|---|---|
| TUESDAY, MARCH 10 | | | | |
| | STS-119 COUNTDOWN STATUS BRIEFING | | 10:00 AM | 14:00 |
| | VIDEO FILE | | 11:00 AM | 15:00 |
| | STS-119 WEBCAST UPDATE | | 11:30 AM | 15:30 |
| | ISS EXPEDITION 18 SPACEWALK COVERAGE | | 12:00 PM | 16:00 |
| WEDNESDAY, MARCH 11 FD 1/FD 2 | | | | |
| | LAUNCH PAD 39-A GANTRY RETRACTION | | 01:00 AM | 05:00 |
| | EXPEDITION 19 CREW DEPARTURE CEREMONY VIDEO FILE | | 12:00 PM | 16:00 |
| | EXPEDITION 19 PREFLIGHT BRIEFING | | 02:00 PM | 18:00 |
| | DISCOVERY LAUNCH COVERAGE BEGINS | | 04:00 PM | 20:00 |
| | LAUNCH | 00/00:00 | 09:20 PM | 01:20 |
| | MECO | 00/00:08 | 09:28 PM | 01:28 |
| 1 | LAUNCH REPLAYS | 00/00:13 | 09:33 PM | 01:33 |
| 1 | ADDITIONAL LAUNCH REPLAYS FROM KSC | 00/00:45 | 10:05 PM | 02:05 |
| 1 | POST LAUNCH NEWS CONFERENCE | 00/01:10 | 10:30 PM | 02:30 |
| 1 | PAYLOAD BAY DOOR OPENING | 00/01:25 | 10:45 PM | 02:45 |
| THURSDAY, MARCH 12 FD 2/FD 3 | | | | |
| 3 | RMS CHECKOUT | 00/03:40 | 01:00 AM | 05:00 |
| 3 | ASCENT FLIGHT CONTROL TEAM VIDEO REPLAY | 00/03:40 | 01:00 AM | 05:00 |
| 4 | LAUNCH ENGINEERING REPLAYS FROM KSC | 00/04:40 | 02:00 AM | 06:00 |
| 5 | DISCOVERY CREW SLEEP BEGINS | 00/06:30 | 03:50 AM | 07:50 |
| 5 | FLIGHT DAY 1 HIGHLIGHTS | 00/06:40 | 04:00 AM | 08:00 |
| 10 | DISCOVERY CREW WAKE UP (FD 2) | 00/14:30 | 11:50 AM | 15:50 |
| 11 | VIDEO FILE | 00/14:55 | 12:15 PM | 16:15 |
| 12 | OBSS UNBERTH | 00/17:10 | 02:30 PM | 18:30 |
| 13 | EMU CHECKOUT | 00/18:20 | 03:40 PM | 19:40 |
| 13 | TPS SURVEY BEGINS | 00/18:40 | 04:00 PM | 20:00 |
| 15 | POST-MMT BRIEFING | 00/19:40 | 05:00 PM | 21:00 |
| 17 | MISSION STATUS BRIEFING | 00/23:40 | 09:00 PM | 01:00 |
| 17 | CENTERLINE CAMERA INSTALLATION | 01/00:20 | 09:40 PM | 01:40 |
| 17 | OBSS BERTH | 01/00:25 | 09:45 PM | 01:45 |

| ORBIT | EVENT | MET | EDT | GMT |
|---|---|---|---|---|
| 17 | OMS POD SURVEY | 01/00:30 | 09:50 PM | 01:50 |
| 18 | ODS RING EXTENSION | 01/01:50 | 11:10 PM | 03:10 |
| 19 | RENDEZVOUS TOOL CHECKOUT | 01/02:25 | 11:45 PM | 03:45 |
| 19 | CREW CHOICE DOWNLINK OPPORTUNITY | 01/02:40 | 12:00 AM | 04:00 |
| | FRIDAY, MARCH 13 FD 3/FD 4 | | | |
| 21 | DISCOVERY CREW SLEEP BEGINS | 01/06:00 | 03:20 AM | 07:20 |
| 21 | FLIGHT DAY 2 HIGHLIGHTS | 01/06:40 | 04:00 AM | 08:00 |
| 26 | DISCOVERY CREW WAKE UP (FD 3) | 01/14:00 | 11:20 AM | 15:20 |
| 27 | VIDEO FILE | 01/14:40 | 12:00 PM | 16:00 |
| 27 | RENDEZVOUS OPERATIONS BEGIN | 01/15:30 | 12:50 PM | 16:50 |
| 30 | DISCOVERY RPM DOCUMENTATION BEGINS | 01/20:00 | 05:20 PM | 21:20 |
| 31 | DISCOVERY/ISS DOCKING | 01/21:07 | 06:27 PM | 22:27 |
| 32 | DISCOVERY/ISS CREW HATCH OPENING | 01/22:55 | 08:15 PM | 00:15 |
| 32 | DISCOVERY/ISS TRANSFERS BEGIN | 01/23:25 | 08:45 PM | 00:45 |
| 32 | MAGNUS/WAKATA SOYUZ SEATLINER SWAP | 01/23:25 | 08:45 PM | 00:45 |
| 33 | MISSION STATUS/POST-MMT BRIEFING | 01/23:40 | 09:00 PM | 01:00 |
| 33 | VTR PLAYBACK OF DISCOVERY/ISS DOCKING | 02/00:55 | 10:15 PM | 02:15 |
| 34 | CREW SHUTTLE HDTV DOWNLINK TEST | 02/01:25 | 10:45 PM | 02:45 |
| 34 | CREW CHOICE DOWNLINK OPPORTUNITY | 02/01:40 | 11:00 PM | 03:00 |
| | SATURDAY, MARCH 14 FD 4/FD 5 | | | |
| 36 | ISS CREW SLEEP BEGINS | 02/04:30 | 01:50 AM | 05:50 |
| 36 | DISCOVERY CREW SLEEP BEGINS | 02/05:00 | 02:20 AM | 06:20 |
| 36 | FLIGHT DAY 3 HIGHLIGHTS | 02/05:40 | 03:00 AM | 07:00 |
| 39 | HD FLIGHT DAY 3 CREW HIGHLIGHTS | 02/09:40 | 07:00 AM | 11:00 |
| 41 | DISCOVERY/ISS CREW WAKE UP (FD 4) | 02/13:00 | 10:20 AM | 14:20 |
| 43 | SSRMS GRAPPLE & UNBERTH S6 TRUSS | 02/15:35 | 12:55 PM | 16:55 |
| 45 | SSRMS HANDOFF S6 TRUSS TO SRMS | 02/18:20 | 03:40 PM | 19:40 |
| 45 | U.S. PAO EVENT | 02/19:15 | 04:35 PM | 20:35 |
| 46 | MT TRANSLATION TO WS-1 | 02/20:00 | 05:20 PM | 21:20 |
| 46 | POST-MMT BRIEFING | 02/20:10 | 05:30 PM | 21:30 |
| 47 | EVA # 1 EQUIPMENT PREPARATION | 02/21:05 | 06:25 PM | 22:25 |
| 47 | SRMS HANDOFF S6 TRUSS TO SSRMS | 02/22:20 | 07:40 PM | 23:40 |
| 47 | MISSION STATUS BRIEFING | 02/22:40 | 08:00 PM | 00:00 |
| 49 | EVA # 1 CREW PROCEDURE REVIEW | 03/01:00 | 10:20 PM | 02:20 |
| 50 | CREW CHOICE DOWNLINK OPPORTUNITY | 03/02:40 | 12:00 AM | 04:00 |
| 50 | EVA # 1 CAMPOUT BEGINS | 03/02:55 | 12:15 AM | 04:15 |
| | SUNDAY, MARCH 15 FD 5/FD 6 | | | |
| 51 | ISS CREW SLEEP BEGINS | 03/04:00 | 01:20 AM | 05:20 |
| 51 | DISCOVERY CREW SLEEP BEGINS | 03/04:30 | 01:50 AM | 05:50 |
| 52 | FLIGHT DAY 4 HIGHLIGHTS | 03/04:40 | 02:00 AM | 06:00 |
| 55 | HD FLIGHT DAY 4 CREW HIGHLIGHTS | 03/09:40 | 07:00 AM | 11:00 |
| 57 | DISCOVERY/ISS CREW WAKE UP (FD 5) | 03/12:30 | 09:50 AM | 13:50 |
| 57 | EVA # 1 PREPARATIONS RESUME | 03/13:05 | 10:25 AM | 14:25 |
| 59 | SSRMS MANEUVERS S6 TO PRE-INSTALL | 03/15:25 | 12:45 PM | 16:45 |
| 60 | EVA # 1 BEGINS (Swanson and Arnold) | 03/17:30 | 02:50 PM | 18:50 |
| 61 | INSTALLATION OF S6 TRUSS TO S5 TRUSS | 03/18:20 | 03:40 PM | 19:40 |
| 61 | CONNECTION OF S5/S6 UMBILICALS | 03/19:25 | 04:45 PM | 20:45 |
| 62 | SABB LAUNCH RESTRAINT RELEASE | 03/20:20 | 05:40 PM | 21:40 |
| 62 | S6 BGA RELEASE | 03/21:20 | 06:40 PM | 22:40 |

| ORBIT | EVENT | MET | EDT | GMT |
|---|---|---|---|---|
| 63 | SABB UNSTOW | 03/21:50 | 07:10 PM | 23:10 |
| 63 | S6 PHOTOVOLTAIC RADIATOR DEPLOYMENT | 03/22:45 | 08:05 PM | 00:05 |
| 63 | REMOVAL AND STOWAGE OF SSU & ECU COVERS | 03/22:50 | 08:10 PM | 00:10 |
| 64 | EVA # 1 ENDS/MT MOVE FROM WS-1 TO WS-4 | 04/00:00 | 09:20 PM | 01:20 |
| 65 | MISSION STATUS BRIEFING | 04/00:40 | 10:00 PM | 02:00 |
| 65 | SSRMS WALKOFF TO HARMONY PDGF | 04/01:30 | 10:50 PM | 02:50 |
| 65 | CREW CHOICE DOWNLINK OPPORTUNITY | 04/01:45 | 11:05 PM | 03:05 |
| 67 | ISS CREW SLEEP BEGINS | 04/03:30 | 12:50 AM | 04:50 |
| MONDAY, MARCH 16 FD 6/FD 7 | | | | |
| 67 | DISCOVERY CREW SLEEP BEGINS | 04/04:00 | 01:20 AM | 05:20 |
| 67 | FLIGHT DAY 5 HIGHLIGHTS | 04/04:40 | 02:00 AM | 06:00 |
| 70 | HD FLIGHT DAY 5 CREW HIGHLIGHTS | 04/09:40 | 07:00 AM | 11:00 |
| 72 | DISCOVERY/ISS CREW WAKE UP (FD 6) | 04/12:00 | 09:20 AM | 13:20 |
| 73 | VIDEO FILE | 04/12:40 | 10:00 AM | 14:00 |
| 74 | SSRMS UNBERTH OF OBSS | 04/15:45 | 01:05 PM | 17:05 |
| 75 | DISCOVERY/ISS TRANSFERS RESUME | 04/16:25 | 01:45 PM | 17:45 |
| 75 | SSRMS HANDOFF OBSS TO SRMS | 04/16:30 | 01:50 PM | 17:50 |
| 76 | SRMS/OBSS FOCUSED INSPECTION (IF NEEDED) | 04/17:40 | 03:00 PM | 19:00 |
| 76 | U.S. PAO EVENT | 04/18:15 | 03:35 PM | 19:35 |
| 78 | SSRMS GRAPPLE OBSS FROM SRMS | 04/21:15 | 06:35 PM | 22:35 |
| 78 | SSRMS BERTHS OBSS IN DISCOVERY | 04/21:45 | 07:05 PM | 23:05 |
| 79 | MISSION STATUS BRIEFING | 04/22:10 | 07:30 PM | 23:30 |
| 79 | SSRMS WALKOFF TO MBS FROM HARMONY | 04/22:50 | 08:10 PM | 00:10 |
| 80 | EVA # 2 PROCEDURE REVIEW | 05/00:00 | 09:20 PM | 01:20 |
| 81 | MT TRANSLATION FROM WS-4 TO WS-1 | 05/01:50 | 11:10 PM | 03:10 |
| 81 | CREW CHOICE DOWNLINK OPPORTUNITY | 05/02:05 | 11:25 PM | 03:25 |
| 82 | EVA # 2 CAMPOUT BEGINS | 05/02:25 | 11:45 PM | 03:45 |
| 82 | ISS CREW SLEEP BEGINS | 05/03:30 | 12:50 AM | 04:50 |
| TUESDAY, MARCH 17 FD 7/FD 8 | | | | |
| 83 | DISCOVERY CREW SLEEP BEGINS | 05/04:00 | 01:20 AM | 05:20 |
| 83 | FLIGHT DAY 6 HIGHLIGHTS | 05/04:40 | 02:00 AM | 06:00 |
| 86 | HD FLIGHT DAY 6 CREW HIGHLIGHTS | 05/09:40 | 07:00 AM | 11:00 |
| 87 | VIDEO FILE | 05/11:10 | 08:30 AM | 12:30 |
| 88 | DISCOVERY/ISS CREW WAKE UP (FD 7) | 05/12:00 | 09:20 AM | 13:20 |
| 88 | EVA # 2 PREPARATIONS RESUME | 05/12:35 | 09:55 AM | 13:55 |
| 90 | URINE PROCESSOR DA REPLACEMENT | 05/15:30 | 12:50 PM | 16:50 |
| 91 | EVA # 2 BEGINS (Swanson and Acaba) | 05/17:00 | 02:20 PM | 18:20 |
| 92 | P6 BATTERY REMOVAL/REPLACEMENT PREP | 05/17:50 | 03:10 PM | 19:10 |
| 92 | P3 NADIR UCCAS DEPLOY | 05/19:00 | 04:20 PM | 20:20 |
| 93 | P1/P3 FLUID JUMPER CONNECTIONS | 05/20:15 | 05:35 PM | 21:35 |
| 94 | S3 PAYLOAD ATTACHMENT SYSTEM DEPLOY | 05/21:20 | 06:40 PM | 22:40 |
| 95 | EVA #2 ENDS | 05/23:30 | 08:50 PM | 00:50 |
| 96 | MISSION STATUS BRIEFING | 06/00:10 | 09:30 PM | 01:30 |
| 96 | CREW CHOICE DOWNLINK OPPORTUNITY | 06/01:05 | 10:25 PM | 02:25 |
| 98 | ISS CREW SLEEP BEGINS | 06/03:00 | 12:20 AM | 04:20 |
| 98 | DISCOVERY CREW SLEEP BEGINS | 06/03:30 | 12:50 AM | 04:50 |
| WEDNESDAY, MARCH 18 FD 8/FD 9 | | | | |
| 98 | FLIGHT DAY 7 HIGHLIGHTS | 06/03:40 | 01:00 AM | 05:00 |

| ORBIT | EVENT | MET | EDT | GMT |
|---|---|---|---|---|
| 101 | S6 1B SOLAR ARRAY DEPLOY ONE BAY | 06/07:50 | 05:10 AM | 09:10 |
| 102 | S6 3B SOLAR ARRAY DEPLOY ONE BAY | 06/09:00 | 06:20 AM | 10:20 |
| 103 | HD FLIGHT DAY 7 CREW HIGHLIGHTS | 06/09:40 | 07:00 AM | 11:00 |
| 103 | DISCOVERY/ISS CREW WAKE UP (FD 8) | 06/11:30 | 08:50 AM | 12:50 |
| 104 | VIDEO FILE | 06/11:55 | 09:15 AM | 13:15 |
| 105 | S6 SOLAR ARRAY DEPLOYMENT RESUMES | 06/14:15 | 11:35 AM | 15:35 |
| 110 | U.S. PAO EVENT | 06/21:45 | 07:05 PM | 23:05 |
| 111 | MISSION STATUS BRIEFING | 06/22:10 | 07:30 PM | 23:30 |
| 111 | CREW CHOICE DOWNLINK OPPORTUNITY | 06/23:00 | 08:20 PM | 00:20 |
| 111 | EVA # 3 CREW PROCEDURE REVIEW | 06/23:30 | 08:50 PM | 00:50 |
| 112 | MT TRANSLATION FROM WS-1 TO WS-4 | 07/01:00 | 10:20 PM | 02:20 |
| 112 | EVA # 3 CAMPOUT BEGINS | 07/01:25 | 10:45 PM | 02:45 |
| 113 | ISS CREW SLEEP BEGINS | 07/02:30 | 11:50 PM | 03:50 |
| 113 | DISCOVERY CREW SLEEP BEGINS | 07/03:00 | 12:20 AM | 04:20 |

THURSDAY, MARCH 19 FD 9/ FD 10

| ORBIT | EVENT | MET | EDT | GMT |
|---|---|---|---|---|
| 114 | FLIGHT DAY 8 HIGHLIGHTS | 07/03:40 | 01:00 AM | 05:00 |
| 118 | HD FLIGHT DAY 8 CREW HIGHLIGHTS | 07/09:40 | 07:00 AM | 11:00 |
| 119 | DISCOVERY/ISS CREW WAKE UP (FD 9) | 07/11:00 | 08:20 AM | 12:20 |
| 119 | EVA # 3 PREPARATIONS RESUME | 07/11:35 | 08:55 AM | 12:55 |
| 119 | VIDEO FILE | 07/11:40 | 09:00 AM | 13:00 |
| 122 | EVA # 3 BEGINS (Acaba and Arnold) | 07/16:00 | 01:20 PM | 17:20 |
| 123 | EVA # 3 CETA CART RELOCATION | 07/16:50 | 02:10 PM | 18:10 |
| 123 | S1 TRUSS CONNECTOR & FLUID JUMPER TASKS | 07/17:50 | 03:10 PM | 19:10 |
| 124 | SSRMS LEE-B SNARE REPAIR & LUBRICATION | 07/19:20 | 04:40 PM | 20:40 |
| 126 | EVA # 3 ENDS | 07/22:30 | 07:50 PM | 23:50 |
| 127 | MISSION STATUS BRIEFING | 07/23:10 | 08:30 PM | 00:30 |
| 128 | CREW CHOICE DOWNLINK OPPORTUNITY | 08/00:35 | 09:55 PM | 01:55 |
| 129 | ISS CREW SLEEP BEGINS | 08/02:00 | 11:20 PM | 03:20 |
| 129 | DISCOVERY CREW SLEEP BEGINS | 08/02:30 | 11:50 PM | 03:50 |
| 129 | FLIGHT DAY 9 HIGHLIGHTS | 08/02:40 | 12:00 AM | 04:00 |

FRIDAY, MARCH 20 FD 10/FD 11

| ORBIT | EVENT | MET | EDT | GMT |
|---|---|---|---|---|
| 133 | HD FLIGHT DAY 9 CREW HIGHLIGHTS | 08/09:40 | 07:00 AM | 11:00 |
| 134 | DISCOVERY/ISS CREW WAKE UP (FD 10) | 08/10:30 | 07:50 AM | 11:50 |
| 135 | VIDEO FILE | 08/11:40 | 09:00 AM | 13:00 |
| 138 | EVA # 4 CREW PROCEDURE REVIEW | 08/16:25 | 01:45 PM | 17:45 |
| 138 | JOINT CREW NEWS CONFERENCE | 08/17:25 | 02:45 PM | 18:45 |
| 139 | JOINT CREW NEWS CONFERENCE REPLAY | 08/18:40 | 04:00 PM | 20:00 |
| 140 | DISCOVERY/ISS CREW OFF DUTY PERIOD | 08/19:25 | 04:45 PM | 20:45 |
| 141 | JAXA PAO EVENT | 08/21:20 | 06:40 PM | 22:40 |
| 142 | MISSION STATUS BRIEFING | 08/21:55 | 07:15 PM | 23:15 |
| 143 | JAXA PAO EVENT REPLAY WITH ENGLISH | 08/23:10 | 08:30 PM | 00:30 |
| 144 | EVA # 4 CAMPOUT BEGINS | 09/00:55 | 10:15 PM | 02:15 |
| 144 | ISS CREW SLEEP BEGINS | 09/02:00 | 11:20 PM | 03:20 |
| 145 | DISCOVERY CREW SLEEP BEGINS | 09/02:30 | 11:50 PM | 03:50 |
| 145 | FLIGHT DAY 10 HIGHLIGHTS | 09/02:40 | 12:00 AM | 04:00 |

SATURDAY, MARCH 21 FD 11/FD 12

| ORBIT | EVENT | MET | EDT | GMT |
|---|---|---|---|---|
| 149 | HD FLIGHT DAY 10 CREW HIGHLIGHTS | 09/09:40 | 07:00 AM | 11:00 |
| 150 | DISCOVERY/ISS CREW WAKE UP (FD 11) | 09/10:30 | 07:50 AM | 11:50 |
| 150 | EVA # 4 PREPARATIONS RESUME | 09/11:05 | 08:25 AM | 12:25 |

| ORBIT | EVENT | MET | EDT | GMT |
|---|---|---|---|---|
| 152 | DISCOVERY/ISS TRANSFERS RESUME | 09/13:55 | 11:15 AM | 15:15 |
| 153 | EVA # 4 BEGINS (Swanson & Arnold) | 09/15:30 | 12:50 PM | 16:50 |
| 154 | JLP GPS ANTENNA B INSTALLATION | 09/15:55 | 01:15 PM | 17:15 |
| 154 | Z1 PATCH PANEL RECONFIGURATION | 09/16:55 | 02:15 PM | 18:15 |
| 155 | P3 WIRELESS TV ANTENNA INSTALLATION | 09/17:55 | 03:15 PM | 19:15 |
| 155 | S3 TRUSS OUTBOARD/NADIR PAS DEPLOYMENT | 09/18:35 | 03:55 PM | 19:55 |
| 156 | S3 TRUSS INBOARD/ZENITH PAS DEPLOYMENT | 09/19:50 | 05:10 PM | 21:10 |
| 157 | EVA # 4 ENDS | 09/22:00 | 07:20 PM | 23:20 |
| 158 | MISSION STATUS BRIEFING | 09/22:40 | 08:00 PM | 00:00 |
| 158 | CREW CHOICE DOWNLINK OPPORTUNITY | 09/23:35 | 08:55 PM | 00:55 |
| 160 | ISS CREW SLEEP BEGINS | 10/01:30 | 10:50 PM | 02:50 |
| 160 | DISCOVERY CREW SLEEP BEGINS | 10/02:00 | 11:20 PM | 03:20 |
| 161 | FLIGHT DAY 11 HIGHLIGHTS | 10/02:40 | 12:00 AM | 04:00 |
| SUNDAY, MARCH 22 FD 12/FD 13 | | | | |
| 165 | HD FLIGHT DAY 11 CREW HIGHLIGHTS | 10/09:40 | 07:00 AM | 11:00 |
| 165 | DISCOVERY/ISS CREW WAKE UP (FD 12) | 10/10:00 | 07:20 AM | 11:20 |
| 167 | RENDEZVOUS TOOL CHECKOUT | 10/13:00 | 10:20 AM | 14:20 |
| 168 | POST EVA RECONFIGURATION AND TRANSFERS | 10/14:15 | 11:35 AM | 15:35 |
| 170 | DISCOVERY CREW OFF DUTY PERIOD | 10/17:45 | 03:05 PM | 19:05 |
| 171 | U.S. PAO EVENT | 10/18:30 | 03:50 PM | 19:50 |
| 172 | MISSION STATUS BRIEFING | 10/20:10 | 05:30 PM | 21:30 |
| 173 | FAREWELL AND HATCH CLOSURE | 10/22:00 | 07:20 PM | 23:20 |
| 173 | ODS HATCH LEAK CHECK | 10/22:45 | 08:05 PM | 00:05 |
| 174 | CENTERLINE CAMERA INSTALLATION | 10/22:55 | 08:15 PM | 00:15 |
| 175 | CREW CHOICE DOWNLINK OPPORTUNITY | 11/00:35 | 09:55 PM | 01:55 |
| 175 | ISS CREW SLEEP BEGINS | 11/01:30 | 10:50 PM | 02:50 |
| 176 | DISCOVERY CREW SLEEP BEGINS | 11/02:00 | 11:20 PM | 03:20 |
| 176 | FLIGHT DAY 12 HIGHLIGHTS | 11/02:40 | 12:00 AM | 04:00 |
| MONDAY, MARCH 23 FD 13/FD 14 | | | | |
| 181 | HD FLIGHT DAY 12 CREW HIGHLIGHTS | 11/09:40 | 07:00 AM | 11:00 |
| 181 | DISCOVERY/ISS CREW WAKE UP (FD 13) | 11/10:00 | 07:20 AM | 11:20 |
| 183 | DISCOVERY UNDOCKS FROM ISS | 11/13:03 | 10:23 AM | 14:23 |
| 183 | DISCOVERY FLYAROUND BEGINS | 11/13:28 | 10:48 AM | 14:48 |
| 184 | DISCOVERY FINAL SEPARATION FROM ISS | 11/14:46 | 12:06 PM | 16:06 |
| 185 | OBSS UNBERTH | 11/16:25 | 01:45 PM | 17:45 |
| 186 | VTR PLAYBACK OF UNDOCKING AND FLYAROUND | 11/16:40 | 02:00 PM | 18:00 |
| 186 | EXPEDITION 19 PRELAUNCH ACTIVITIES | 11/17:40 | 03:00 PM | 19:00 |
| 186 | RMS/OBSS LATE INSPECTION | 11/17:40 | 03:00 PM | 19:00 |
| 188 | MISSION STATUS BRIEFING | 11/19:40 | 05:00 PM | 21:00 |
| 189 | OBSS BERTH IN DISCOVERY'S PAYLOAD BAY | 11/21:55 | 07:15 PM | 23:15 |
| 191 | CREW CHOICE DOWNLINK OPPORTUNITY | 11/23:00 | 08:20 PM | 00:20 |
| 191 | DISCOVERY CREW SLEEP BEGINS | 12/02:00 | 11:20 PM | 03:20 |
| 192 | FLIGHT DAY 13 HIGHLIGHTS | 12/02:40 | 12:00 AM | 04:00 |
| TUESDAY, MARCH 24 FD 14/FD 15 | | | | |
| 197 | HD FLIGHT DAY 13 CREW HIGHLIGHTS | 12/09:40 | 07:00 AM | 11:00 |
| 197 | DISCOVERY CREW WAKE UP (FD 14) | 12/10:00 | 07:20 AM | 11:20 |
| 199 | CABIN STOWAGE BEGINS | 12/13:15 | 10:35 AM | 14:35 |
| 200 | FCS CHECKOUT | 12/14:30 | 11:50 AM | 15:50 |
| 200 | EXPEDITION 19 SOYUZ TMA-14 ROLLOUT | 12/14:40 | 12:00 PM | 16:00 |

| ORBIT | EVENT | MET | EDT | GMT |
|---|---|---|---|---|
| 201 | RCS HOT-FIRE TEST | 12/15:40 | 01:00 PM | 17:00 |
| 202 | U.S. PAO EVENT | 12/17:35 | 02:55 PM | 18:55 |
| 202 | CREW DEORBIT PREPARATION BRIEFING | 12/17:55 | 03:15 PM | 19:15 |
| 203 | MISSION STATUS/POST-MMT BRIEFING | 12/19:40 | 05:00 PM | 21:00 |
| 204 | MAGNUS' RECUMBENT SEAT SET UP | 12/21:00 | 06:20 PM | 22:20 |
| 205 | KU-BAND ANTENNA STOWAGE | 12/23:25 | 08:45 PM | 00:45 |
| 207 | DISCOVERY CREW SLEEP BEGINS | 13/02:00 | 11:20 PM | 03:20 |
| 208 | FLIGHT DAY 14 HIGHLIGHTS | 13/02:40 | 12:00 AM | 04:00 |
| WEDNESDAY, MARCH 25 FD 152 | | | | |
| 12 | DISCOVERY CREW WAKE UP (FD 15) | 13/10:00 | 07:20 AM | 11:20 |
| 214 | DEORBIT PREPARATIONS BEGIN | 13/13:05 | 10:25 AM | 14:25 |
| 215 | PAYLOAD BAY DOOR CLOSING | 13/14:24 | 11:44 AM | 15:44 |
| 216 | EXPEDITION 19 PRELAUNCH BRIEFING REPLAY | 13/14:40 | 12:00 PM | 16:00 |
| 217 | DEORBIT BURN | 13/17:04 | 02:24 PM | 18:24 |
| 218 | MILA C-BAND RADAR ACQUISITION | 13/17:54 | 03:14 PM | 19:14 |
| 218 | KSC LANDING | 13/18:07 | 03:27 PM | 19:27 |

# 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[3]

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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[3] 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.

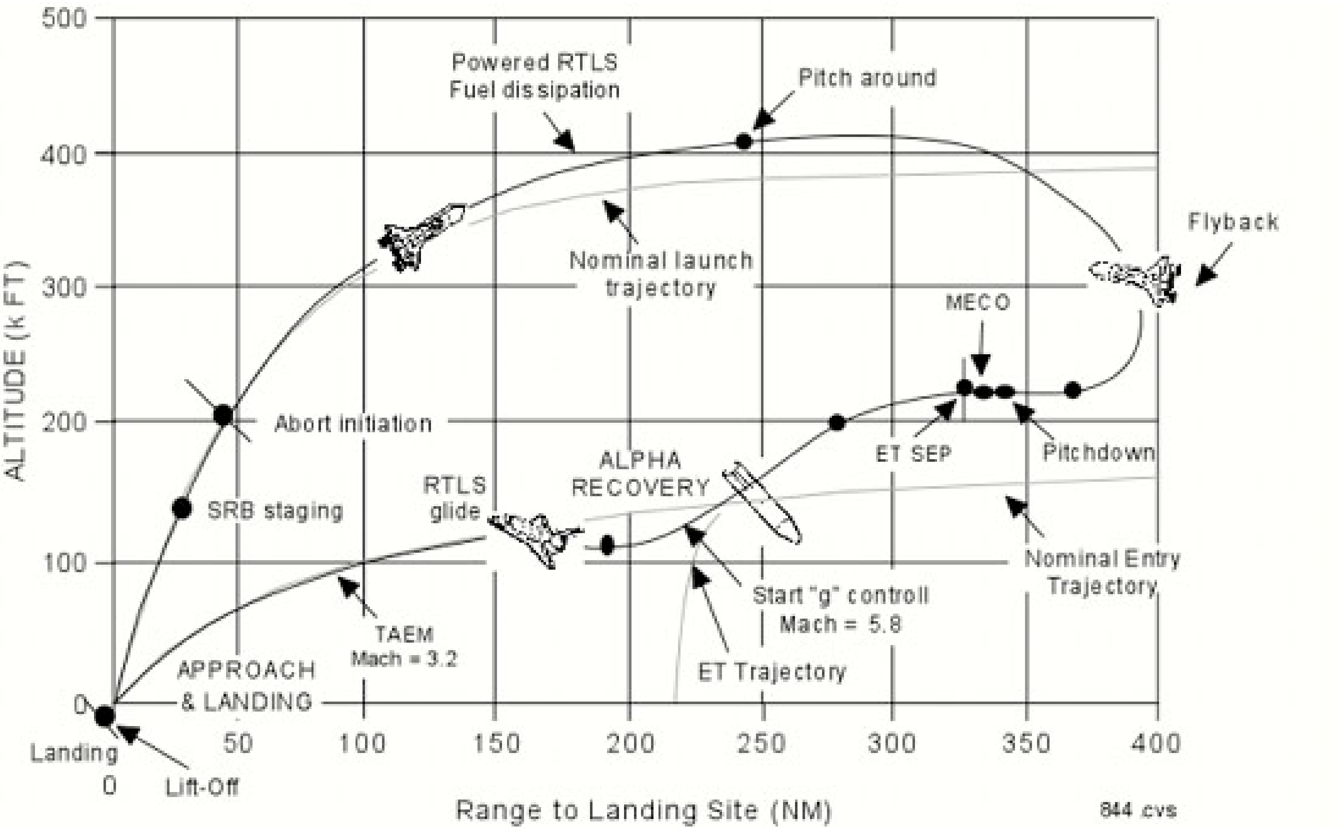
If the problem is a system failure that jeopardizes the vehicle, the fastest abort mode that results in the earliest vehicle landing is chosen. RTLS and TAL are the quickest options (35 minutes), whereas an AOA requires approximately 90 minutes. Which of these is selected depends on the time of the failure 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)[4] 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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[4] 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)[5] 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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[5] 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[6]

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

## STS-51L: Challenger

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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[6] 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.*

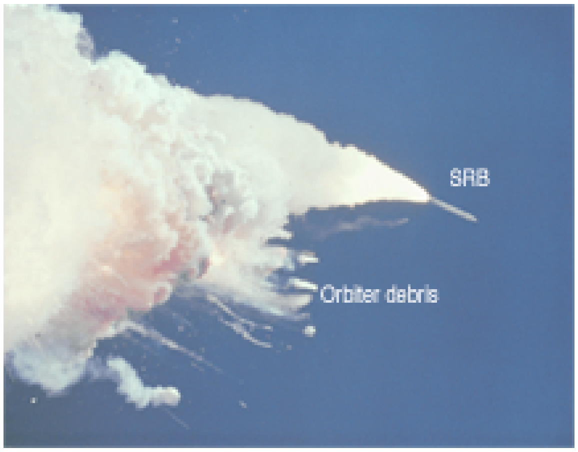
Unlike the shuttle Columbia during its first flights at the dawn of the shuttle era, Challenger was not equipped with ejection seats or other ways for the crew to get out of the spacecraft. McAuliffe's parents, Edward and Grace Corrigan, watching from the VIP site three miles from the launch pad, hugged 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.

* * *

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:

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

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|---|---|
| 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."

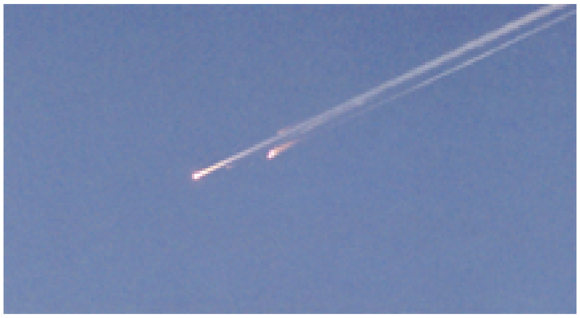
*Challenger's crew departs the Kennedy Space Center*

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

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.

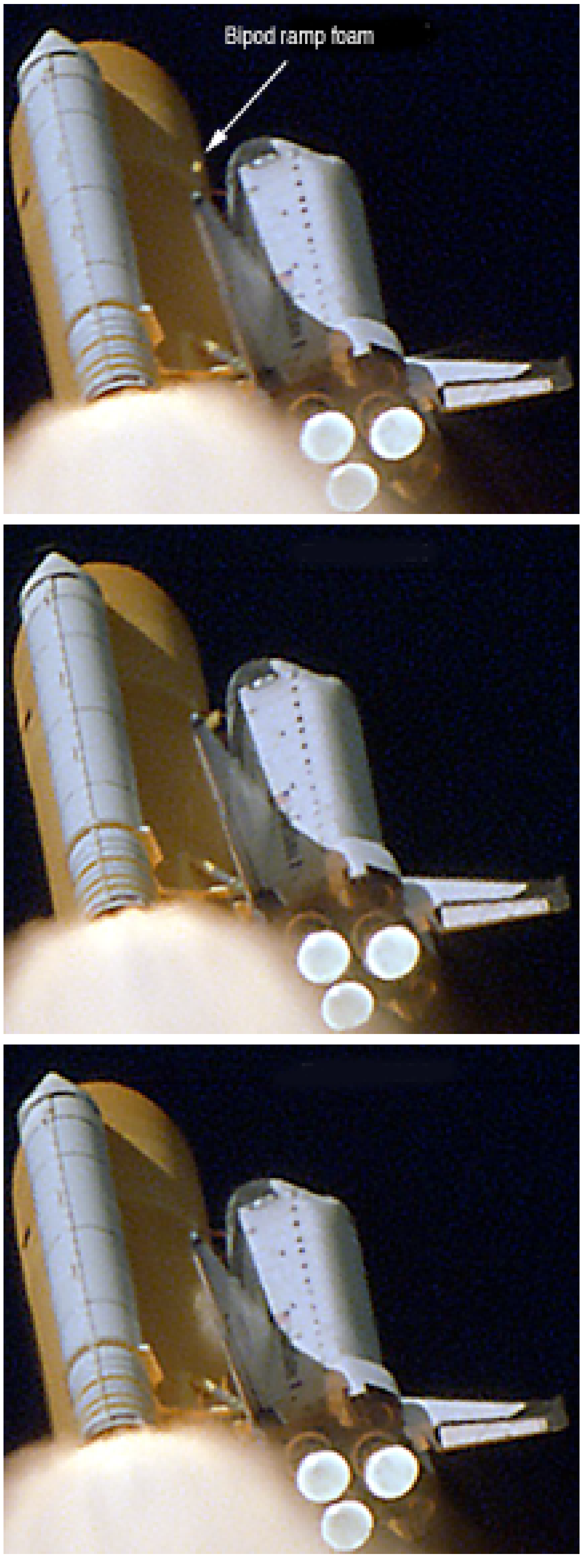
"Today was a very stark reminder this is a very risky endevour, pushing back the frontiers in outer space. Unfortunately, people have a tendency to look at it as something that is more or less routine. I can assure you, it is not.

"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."

❏ ❏ ❏

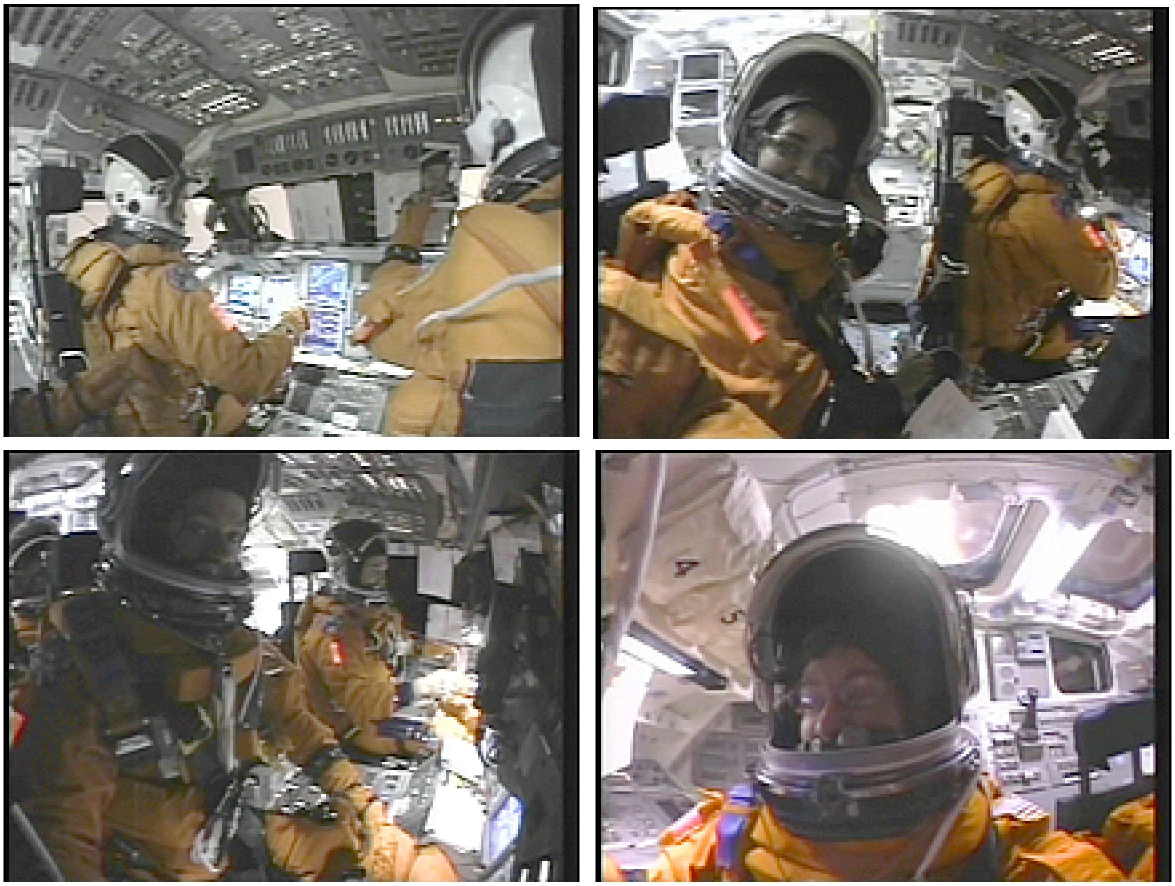
In the days, weeks and months ahead, an investigation of the disaster revealed echoes of Challenger: a long history of foam insulation problems that represented an unrecognized risk; bureaucratic inertia; slipshod internal communications and ineffective management at the top levels of NASA. The Columbia 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.

"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."

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

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

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## The Fate of Columbia's Crew

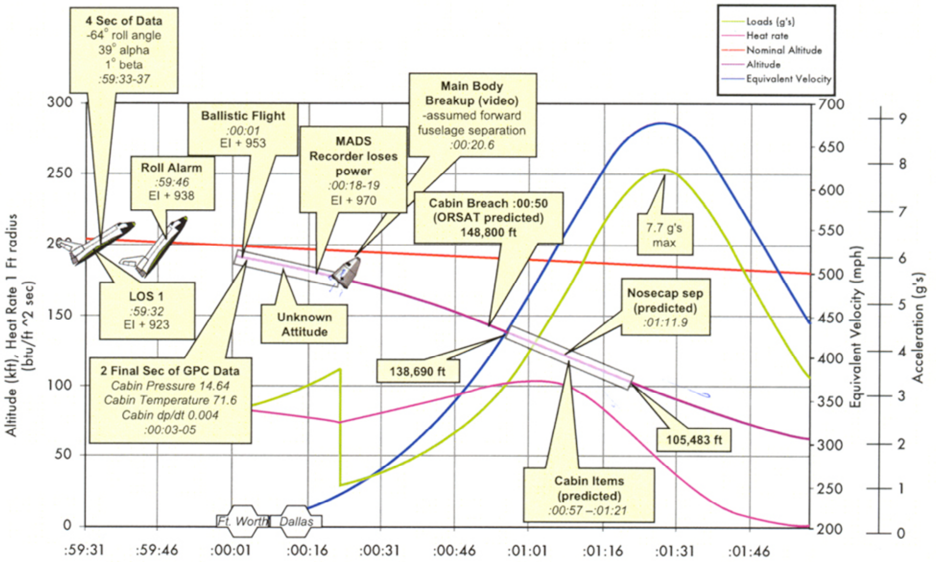
At the CAIB's request, NASA formed a Crew Survivability Working Group to determine, if possible, the cause of crew death. Here is what the group concluded (taken from page 77 of the Columbia Accident Investigation Report):

### 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